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SIXTH FRAMEWORK PROGRAMME

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Instrument: **SSA**

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Final Scientific Report

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1 Introduction – the ADAGIO project

ADAGIO contributes to the overall objective as formulated in Area 8.1 in its call (Policy-orientated research - Scientific Support to Policies) *„to support the formulation and implementation of Community policies, by providing scientific contributions to policies that are targeted precisely on needs (‘demand-driven’), coherent across the various Community policy areas, and sensitive to changes in policies as they take place*“ by **Upscaling from regional (and farm) to national level and large regions** (i.e. Central and Eastern Europe**,** Mediterranean area**)** identifying the general risks and evaluating their adaptation measures in a regional context etc. The ADAGIO partner countries of the different regions are presented in Fig. 1.
Therefore this report considers different spatial scales such as regional aspects and problems and integrates national assessments. It contains the relevant results from all the national reports, but focusing also on the common regional issues. The regional results are particularly addressed to decisions makers at the regional level, able to conduct the final ADAGIO recommendations on how to mitigate the climate-change negative effects.
Several past results from European regional studies are available such as from the European Environmental Agency (EEA) which released reports regarding vulnerability, climate change impacts and adaptation to climate change in Europe (EEA, 2004, 2005, 2007a,b, 2009). The report points out that these climate-change effects are expected to be negative in the agriculture of Southern and some parts of Eastern Europe, while positive in Northern Europe. Besides, according to the Report, climate temperature rise and changing precipitation patterns are expected to exacerbate the already acute water shortage problem in southern and south-eastern regions. Several recommendations for adaptation options for facing increasing water scarcity are adressed as well.
ADAGIO completes this picture by its applied methods, especially by the integrated bottom-up approach of **integrating decision-makers feedback** on the regional and farm level using e.g. questionnaires, interviews or discussions. Beside on the review past scientific results and results from scientific regional ADAGIO study assessments, the following results are based also on these applied methods. It is shown below that in some aspects the general results of large scale studies are modified by considering regional problems or the regional conditions of agroecosystems.

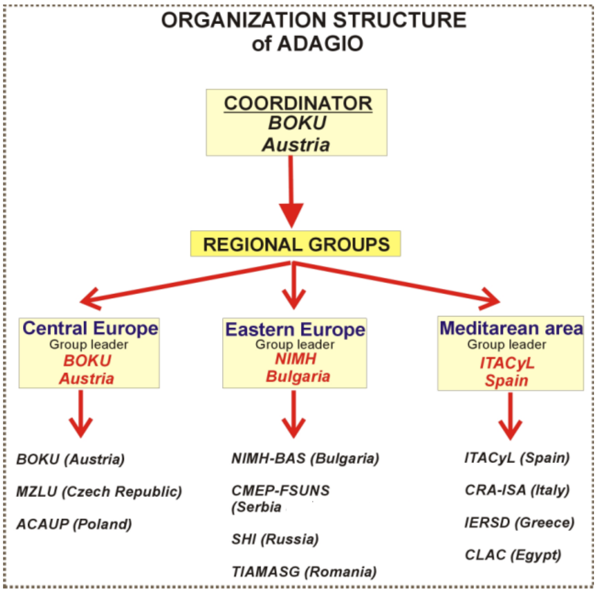

Fig. 1: ADAGIO partner countries and their regional division

2 Climate Change impacts and recommendations on adaptation measures in agriculture – The European level

(Josef Eitzinger and Angel Utset)

General situation of agricultural production conditions in Europe

In the EU(27) the number of agricultural holdings totals about 14.5 million. These farms manage 172 million hectares, or 61%, thereof are arable land. 69% of the holdings in the EU(27) cultivate less than 5 ha. As already mentioned there is a wide range of variation of agricultural structural parameters between the EU countries, which have to be considered in the assessment of regional vulnerability and adaptive capacity. For example, there is a wide range of mean farm size (Fig.1), land use (Fig.2) and farm types (Fig.3ab). Main differences can be observed between western and eastern (former soviet union) countries in the number of different farm types per country and only partly by mean farm size. These structural variations overlap with climtic regions of Europe (Fig. 4) which combination strongly influence production conditions. Fig. 4 also shows the location of the regions where the ADAGIO study assessments are carried out.

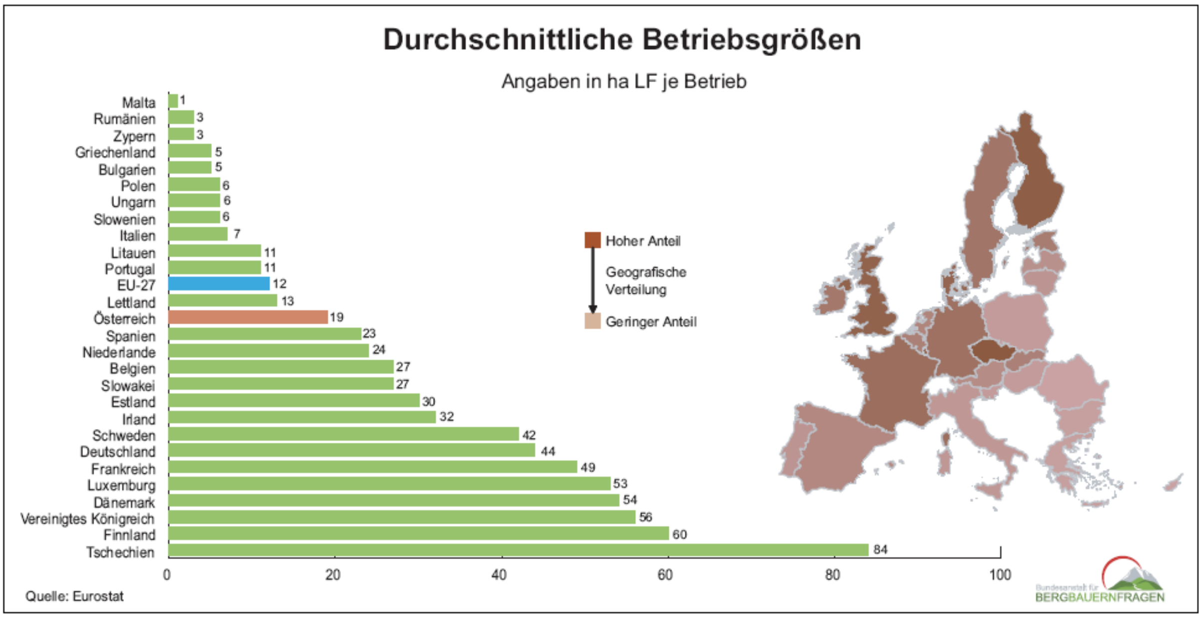

Fig.1: Mean farm size of European countries (in ha UAA), Source : Eurostat

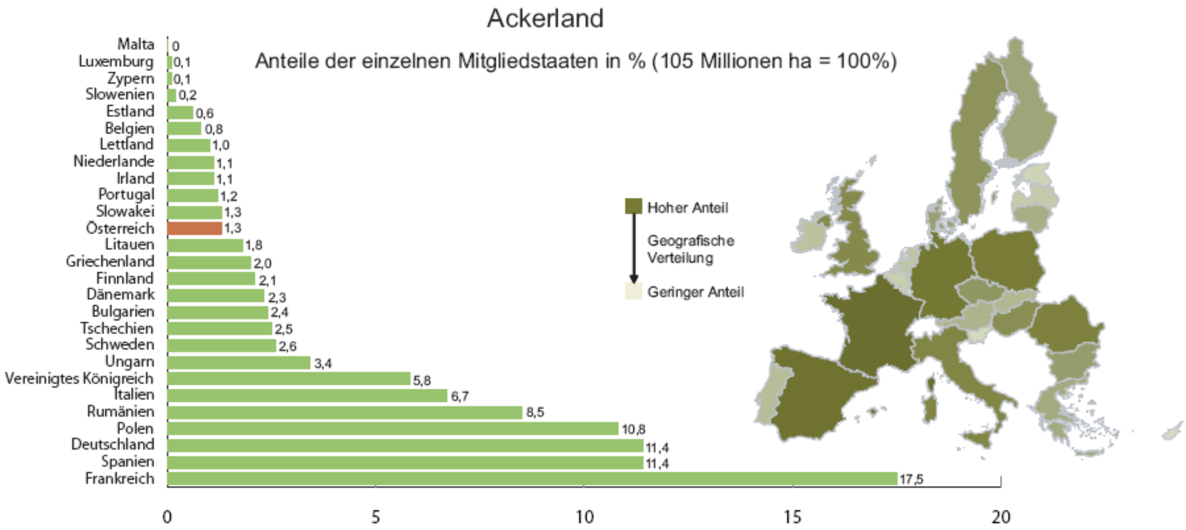

Fig.2: Relative contribution of EU countries to total arable land area in Eu (105 mio ha), Source : Eurostat

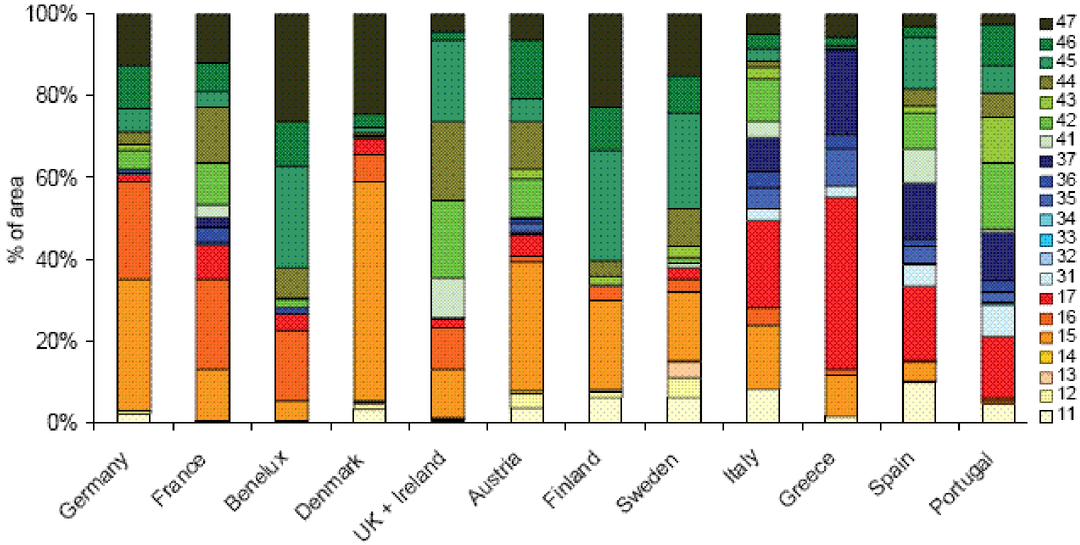

Figure 7.2 (in colour on p.185). The distribution of farm types in different countries in the EU15. Farm type classes are labelled in Table 7.2 and 7.3.

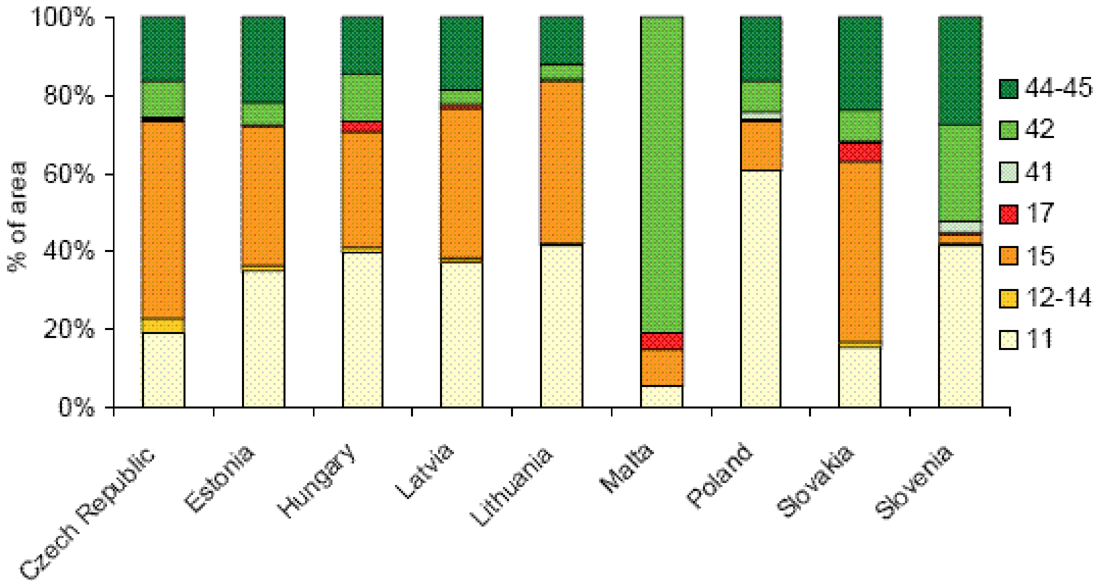

Figure 7.3 (in colour on p.185). The distribution of farm types in different countries in the New Member States. Farm types are not distinguished as much as in the EU15, but they are assumed to be similar to farm types labelled in Table 7.2 and 7.3.

Fig. 3ab : Farm types of European western countries according to Reidsma (2007), (for definition see Table 1 in Appendix 1)

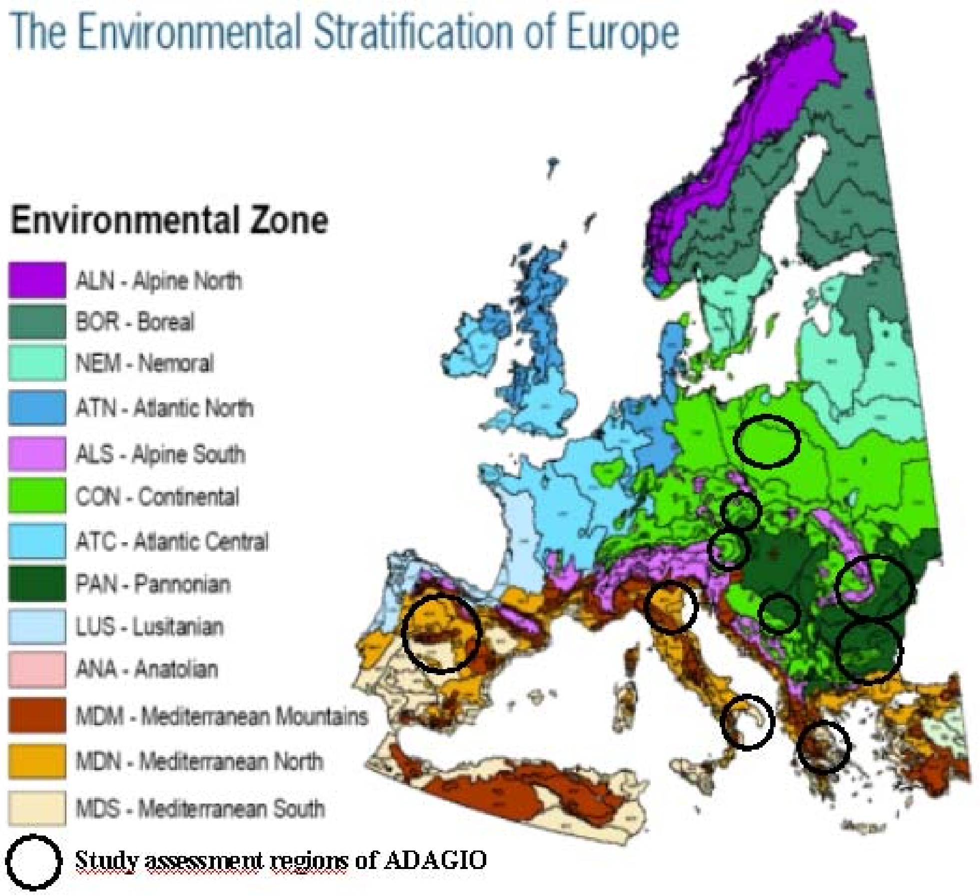

Fig. 4 : Environmental zones in Europe (Metzger et al., 2005) and location of study assessment regions of ADAGIO (without Russia and Egypt)

ADAGIO recommendations and results for the European level:

ADAGIO results focus on several issues highlighted in the EU White Paper on Climate Change Adaptation (EC, 2009). Especially, ADAGIO recommendations point out how to integrate Climate Change adaptation into Common Agricultural Policy (CAP) and the Rural Development Programs.

Besides, the bottom-up approach followed in ADAGIO showed that there is not a correspondence between farmer opinions regarding Climate Change adaptation and the published results, based on simulations. ADAGIO surveys and contacts revealed farmer resistances on introducing some simple Climate Change adaptation measures recommended by scientists (as shifting seeding dates). According to the ADAGIO surveys results, farmers are not aware very often about the already identified Climate Change impacts. For instance, only mainly farmers with rainfed crops are worried about water scarcity, although droughts could bring irrigation limitations.

ADAGIO revealed significant differences in agricultural production conditions within Europe including natural production resources, production risks and limitations as well as socio-economic conditions. Based on these facts following rules are strongly recommended for an effective development of adaptation options at the policy level:

• There is no single indicator which can fully describe all aspects of climate change impacts or vulnerabilities of agricultural production in order to develop meaningful or effective adaptation options at the local level.

• A set of indicators has to be used to fully describe all potential production risks and limitations at the local and regional level and its potential shifts under climate change sceanrios. An example for the European level is given for growing conditions (mean temperature and water demand of crops) in Fig. 5 and Fig. 6. **In Appendix B several further critical indicators for climate based production factors and their potential shifts under climate scenarios are shown for the European scale.** Such as set of indicators could be used to trigger European policies such as the CAP in order to reflect better regional problems and needs.

• For developing of recommendations for the farmers level as well as policies which are adressed to the management of agroecosystem resources by the local users - additional to a set of indicators - regional aspects and feedback from local experts and stakeholders have to be considered in order to ensure effectiveness of recommended measures or rules by law (bottom-up approach).

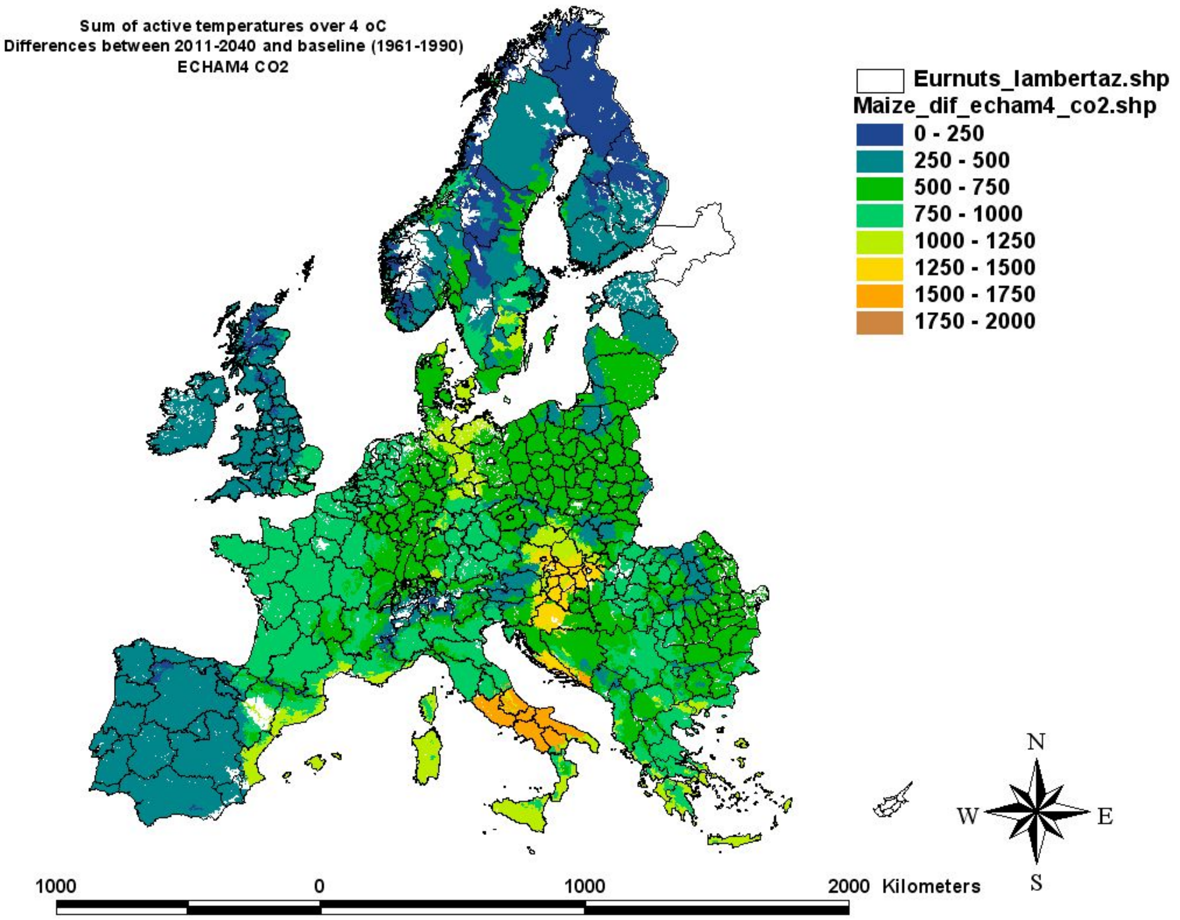

Fig. 5. Difference of the Sum of active temperatures over 4°C between 2011-2040 ECHAM4 CO2 and baseline (1961-1990), (Simota, 2009a, see Appendix B)

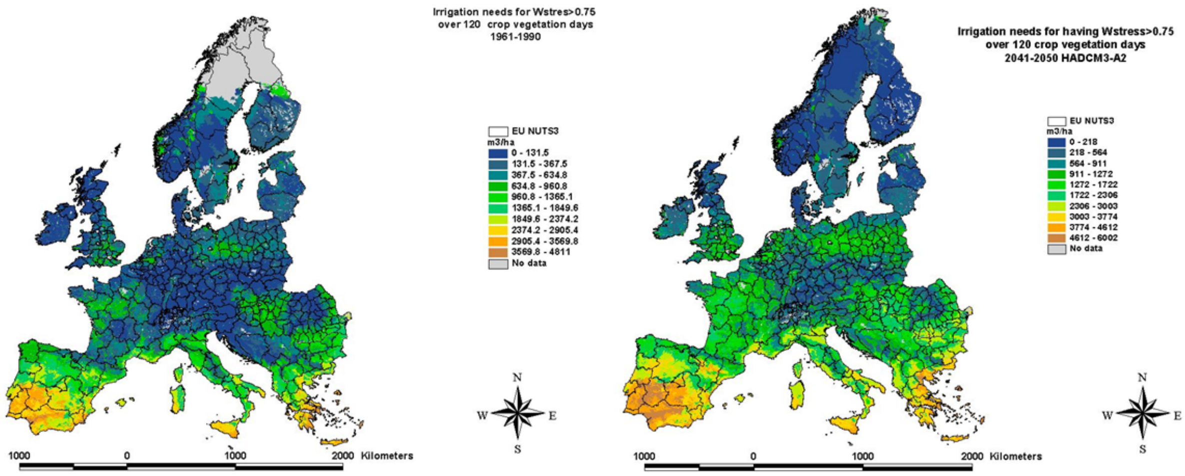

Figure 6. Irrigation needs ($m^3 ha^{-1}$) for having water stress not less than 0.75 (1: no water stress) considering 120 days crop vegetation period for baseline 1961-1990 and climate change scenario for 2041-2050 (HADCM3-A2) (Simota, 2009b)

According to the ADAGIO results from the different case study regions (Fig.4) covering different climatic, agroecological and socio-economic conditions in Europe as well as from other sources of information (literature survey, expert Know-How and questionnaires for farmers) some general conclusions can be drawn for the European level.

Main vulnerabilities and climate change impacts in agriculture in Europe under the climate sceanrios during the next decades:

• The spatial shift of agroecological production zones in Europe due to the warming trend and changes in seasonal precipitation will change local production opportunities, risks and limitations significantly but depending on the local production systems and conditions (with various potential positive or negative implications). For example, a change to higher yielding, or later ripening crops or cultivars will be possible if ample water supply is given. Cropping regions of wine, maize, soybean or sunflower could be significantly extended under the current climate scenarios in Europe.

• In general in Europe water resources for agriculture are decreasing and expected further to be decreased under climate scenarios, especially in the Mediterranean area. The regional vulnerabilities for the summer period however seem partially (flat lands and sandy soils) to be higher in the Central and South-Eastern European regions due to the much lower level of current adaptation to water scarcity in agricultural production. Partially (South-Eastern Europe) the low level of adaptation in this respect is also based on weak socio-economic conditions or agricultural (irrigation) infrastructure.

• In many more humid regions up to a certain annual precipitation (about 800mm) where land use is dominated by permanent managed grassland, vulnerability due to increasing summer droughts is given by decreasing biomass production potentials of grassland. This could trigger significant land use changes to arable farming (as an adaptaion measure), but with negative impacts on soil conditions and mitigation.

• For summer crops and permanent crops in many European regions incresing risk from heat and drought is expected, which leads to increasing spatial as well as interannual yield variability of crops. Also in animal husbandry various negative impacts such as heat stress or increasing hygienical problems are expected under climate change scenarios in the coming decades.

• Some production systems (permanent cropping and orchards or cash crops) are regionally vulnerable due to increasing weather extremes such as hail, heavy rain, local storms.

• In the Mediterranean region soil water resources for winter crops may decrease and potentially reduce agricultural water resources for the summer period (increasingly supplemental irrigation will be necessary also for winter crops).

• In general higher risks from pests (thermophile insects and others) and partially diseases in all Europe. This is based on large spatial shifts into regions which are not adapted yet to manage the relevant pest risk/disease and the unknown dynamics and interactions due to this shifts.

• In many regions increasing vulnerability of agricultural production resources is given due to soil erosion, based on the combination of regional increasing trend of heavy precipitation, increasing winter precipitation in form of rains, and expected trend of land use changes from grassland to arable farming.

• Significant shifts in crop timing will also change timing of field operations and farm management.

Main recommended adaptation options at the European policy level for the next decades:

• In all Europe a focus should be drawn to increase water use efficiency in agriculture. This includes to support or rule measures at different levels such as improving irrigation infrastructure, to effective manage water distribution and water costs for agriculture, to support or ruling water saving soil cultivation / mulching techniques, to support measures for reducing evapotranspitration potentials due to wind reduction (hedgerows and wind breaks), to improve irrigation scheduling, to adapt cropping patterns and crop rotations, to improve and protect soil functions.

• CAP good practices and environmental measures must comprise water-saving options in irrigation systems. Besides, Water Framework directive (WFD) and CAP must be integrated regarding efficient use of water in agriculture.

• EU research instruments and Rural Development Programs should promote local bottom-up assessments of Climate-Change impacts in agriculture, based on the existing EU research results. Those assessments must identify the most reliable adaptation measures to be introduced, taking in account stakeholders and farmer opinions, as well as scientific results.

• Due to the shifts of agroecological zones significant changes in agricultural land use can be expected. Policy actions are therefore recommended to monitor and rule impacts on landscape structures and functions in order to avoid negative impacts on sustainability of agricultural production, on mitigation, and on other key sectors such as water resources, tourism.

• Policy should foster and support monitoring activities and operational warning and forecasting systems of high spatial resolution for several environmental conditions such as drought, regional water resources, extreme weather (and impacts), pest and diseases pressures and risks and others.

This would help to set effective measures in time in order to prevent or mitigate significant costs in case of extreme events.

• Insurance support might be an absolute need in the near future, but it is some time unaffordable for many agricultural holdings. Therefore, impact assessments are required to define the eventual loses due to Climate Change and the insurance needs. EU and Member States policies should promote and fund affordable insurance services, keeping the insurance companies profits whilst protecting farmers against extreme events consequences. On the other hand some risks such as drought could be not insurable further in many regions, without governmantal support or alternative financial support. Insurance can be also an effective instrument to force adaptation measures at the farm level by appropriate rules for insurance fees.

• In general regional production and marketing and farm and crop diversity at the farm and regional level can significantly limit the production risks and demand on global markets as well as increase regional food security. Such initiatives should be supported from the policy level (e.g. organic farming).

• Know-How on climate change impacts, related risks and potential adaptation measures should be transferred more effectively to the user level. Although EU-supported Farm Advisory System is an excellent way to transfer such know-how, Advisory Services are usually not prepared to conduct those transfer activities. University extension services, Consultancies and public-private partnerships could support Advisory Services to introduce local Climate- Change adaptation measures. EU research instruments, as well as Rural Development Programs, should promote and finance such transfer activities, enlarging the Farm Advisory System capabilities.

• Several information measures such as adapted plans for teaching (in schools), training for experts, etc. which should be initiated and supported from the policy level. This should also include the general public in order to increase the acceptance for related problems and measures in agriculture. At the same time feedback from the user level should be considered at the expert and scientific as well as policy level in order to trigger measures for a successful and effective implementation.

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3 Climate Change impacts and recommendations on adaptation measures in agriculture – The European ADAGIO regions

3.1 Mediterranean region

(Domenico Ventrella, Italy)

This report summarizes the results of the studies of Mediterranean partners within the framework of ADAGIO Project.

In the table 1 the titles of the abstracts included in their final reports that summarize the activity carried out in this 30-month period.

Table M1: Abstracts of all national case studies carried out during the ADAGIO project

Egypt	*Vulnerability and adaptation Assessment of agriculture sector in the Nile Delta Region* (M. A. Medany and S. M. Attaher) In the vulnerability assessment, the survey questionnaire covered (i) the main specifications of the questioned farmer and the agriculture systems, (ii) the current risks facing agriculture production, in terms of natural, human, management and political risks, and (iii) the current view of the farmers about the impacts of climate change on agriculture.
Greece	*CORINE 1990 - 2000 Land Cover Changes for Greece* (Dimos P. Anastasiou) *Mapping coastal low altitude areas of Greece (below 5 meters), their watersheds and river segments* (Dimos P. Anastasiou) *Spatial Intra Specific Biodiversity Indices* (Dimos P. Anastasiou) Twelve case studies based on ECHAM5 A1B RACMO2 current and future conditions about: Spatial De Martonne Aridity Index, Spatial Ombrothermic Index, Spatial Length of Growing Period, Net Primary Productivity/Temperature, Net Primary Productivity/Precipitation, Stardex Indicators, Number of days with Mean Daily Temperature Below 0 during (Dimos P. Anastasiou) Farmer and Expert Interviews and Questionnaire Survey (Dimos P. Anastasiou)
Italy	*Soil water balance of a winter crop cultivated in Southern Italy as influenced by future climate* (D. Ventrella, L. Giglio, M. Castellini) *Vulnerability to temperature and precipitation of durum wheat in Southern Italy* (D. Ventrella. D. Vitale) *Vulnerability and agronomical adaptation to climate change regarding soil water balances and productivity of some crops in Southern Italy* (D. Ventrella. L. Giglio, M. Castellini, R. Lopez) *Strategies of agronomical adaptation for tomato and winter wheat cultivated in a Mediterranean environment* (D. Ventrella, M. Rinaldi, M. Charfeddine, S. Ruggieri, P. Garofalo, L. Giglio)

The vulnerabilities are considered as point of departure in order to individuate the optimal strategies of adaptation to climate change. For the Mediterranean Region they are summarized in Table 2.

Table M2: Main limitations, observed trends, socio-economic conditions and identified vulnerabilities for the Mediterranean Region

Dominating Agroecosystem	**Geographical region**	**Main limitations**	**Observed trends**	**Socio-economic conditions and problems**	**Main identified vulnerabilities to climate change**
Grasslands	Northern (NI) and Southern (SI) Italy	Topography (hilly), soil erosion, small farm size	Structural change to bigger farms, change to ecological farming; irrigation as normal practice (alfalfa in NI)	Weak economic conditions of small farms; rural depopulation (hilly zones)	Grassland drought; reduction of summer yield (NI); water availability for irrigation (NI)
Field crops	Greece: Central East (CE) Peloponeese (P) Egypt: Northern Delta (ND), Midle Delta (MD) and Southern Delta (SD) Italy (NI and SI)	Seasonal water shortage, high intensity and frequency of cold and heat waves Land loss due to sea level rise (SLR:ND), soil and water degradation, crop yield reduction, crop quality reduction (Egypt) Lowering of watertable (Italy, Greece) Salinization of coastal area (SI) Availability and cost of water resources (Italy and Greece) Increasing cost of cultivation (fuel and chemicals)	Greece: increase of cultivated surface, change of seeding dates, change of the traditional varieties with imported foreign ones in the past (Tobacco), reduced chemical input due to increased cost. Egypt: light to medium soil. Increasing soil salinity, medium to small land ownership, high water table. Italy: substitution of soft wheat by winter wheat, Normal irrigation for maize (NI).	Greece: low prices compared to the past, possibly reduced supply at the future, Foreign varieties cover the vast majority of the cultivated area-no alternative variety or crop is cultivated (Tobacco), unemployment of youth Egypt: poor irrigation system and drainage systems, switching from conventional agriculture to aquaculture, agric. policy conflicts Italy: intensive crop rotation (one-year rotation or multi-cropping), uncertainties for crop choice.	Shortening of crop cycle with consequent crop yield and quality reduction, increase of evapotranspirative demand of the atmosphere and irrigation water requirement (spring crops), increment or new risk of pest and diseases, spring late freezing, damages by heat waves on yield and quality. Soil degradation. Land loss due to SLR (Egypt)
Vegetables crops	Idem	Seasonal water shortage Availability and cost of water resources (for spring/summer crops); Salinization of coastal areas (SI) Financial support and investments, poor extension service,	Drip irrigation for tomato (NI), increment of high quality production, structural change to bigger farm (SI), ongoing irrigation improvement (Egypt), high intensity of pest and diseases,	Italy and Greece: variability of annual income, high economical investment. Immigration from foreign Egypt: poor irrigation and drainage systems, agric. policy conflicts, immigration from rural to urban, high population density.	Shortening of crop cycle; Increment or new risk of pest and diseases; damages by heat waves on yield and quality (summer crops) Soil degradation, crop yield reduction, crop quality reduction, pests and disease, high intensity and frequency of

		markets availability			cold and heat waves.
Tree crops	Idem	Availability and cost of water resources; lowering of soil water table depth, salinization of coastal areas (SI) Land loss due to SLR (ND), soil and water degradation, crop yield reduction, crop quality reduction, pests and disease, seasonal water shortage, high intensity and frequency of cold and heat waves, sand storms. Global product prices, irrigation water availability	Egypt: medium to small areas of vegetables, large to small land ownership, medium to high soil salinity level, ongoing irrigation improvement Greece: increase of location based certification , increase of biological cultivations, increase of local processing activities Italy: Increment of high quality production; modernization of irrigation method (low pressure); structural change to bigger farms	Italy: high work load and labour cost; variability of annual income Greece: new regulations and changes in management (CAP) Initial inputs costs and maintenance for the years until production. Egypt: poor irrigation and drainage systems, agric. policy conflicts, immigration from rural to urban high population density.	Water availability for irrigation; shortening of phenological phases; spring late freezing; damages by heat waves on yield and quality Land loss due to SLR (ND), soil and water degradation, crop yield reduction, crop quality reduction, pests and disease, seasonal water shortage, high intensity and frequency of cold and heat waves, sand storms (Egypt).

Socio-economic differences between countries of Mediterranean Region

Italy

The agriculture productivity is concentrated in Northern Italy (more than 45%) while in the Central part is about 14%. The percentage is 37% for Southern Italy where the predominant cultivation includes herbaceous and tree crops. In the last 25 years the Southern Italy have confirmed the specialization for the cultivation of cereals, fruit, citrus, horticultural products, etc.

Considering the total irrigated area, the 64% is in the North against the 28% for the Southern part where the farmers often use water from private wells even if the watertable is deep.

With particular reference to the Southern part most of the rainfall is concentrated in the winter season. This with the high or very high evaporative demand of the atmosphere is the reason because the irrigation, at the present, is a fundamental and essential agronomic practice in order to obtain sustainable yield for spring and summer crops. More than 70% of available water resources is used as irrigation. The most widespread irrigation method is the sprinkler irrigation for the 40%, applied above all in the Northern regions for crops as maize, alfalfa, sugar beet, soybean forage crops. The localized and drip irrigation methods are concentrated in Southern regions (Puglia, Sicilia and Campania) for horticultural and tree crops. The most important irrigated crops are: maize, forage crops, horticultural crops and tree crops. The citrus trees are present exclusively in the South. Substantial is the area cultivated with sugar beet and soybean. The horticultural crops are very important for the agricultural economy. Considering the tree crops, the vineyard is largely located in Puglia (Southern Italy) e Veneto (Northern Italy). The Emilia Romagna is important for apple, pear and peach trees.

The employment in agriculture shows a constant decreasing trend. This negative trend is particular evident for the autonomous farmer (-3% per year). In general, the principal weaknesses for the Italian agriculture are constituted by high average age of the farmers, small dimension of the farms and insufficient organization and cooperation between enterprises.

Finally, the percentage of woman employment decreased from 51% in 1993 to 42% in 2003.

In the climate change context, particularly large yield decreases are expected for spring-sown crops (maize, sunflower and soybeans) . For autumn-sown crops the impact is more geographically variable. Tubiello et al. (2000) found that, tacking in account the positive effect of increased CO_2 and without adaptation of management and genotype, in Emilia Romagna the wheat and maize yield could decrease by 5-15%, soybean and barley yields by more than 20% and sorghum yields by more than 50%. In Puglia wheat yields are expected to decrease by 30-50%, sorghum yields by 10-30%. No productive changes were reported for sunflower.

For the tree crop the temperature increase could expand the suitable area for plant requiring high temperature as grapewine, cytrus and olive. Bindi and Moriondo (2007) forecast an expansion of olive cultivation towards the areas in the Northern part. The same can be forecasted for the cultivation of durum wheat and for most vegetable species like lettuce, fennel and cabbage, in winter and spring cultivation, and melon. Such an increase in yield variability could have negative effects on the quality of products (fruit wine et.) and, at the same time, could determine a higher economic risk for growers.

Egypt

Nile Delta region is one of the highly vulnerable regions in the world to sea level rise (SLR). Therefore, SLR was on the top list of the key vulnerabilities in Northern Delta region. Agriculture sector in Egypt is projected to experience a severe impact. Even with 1 m SLR, approximately 12.5% of the Egypt's agricultural extent would be impacted, this percentage reaches 35% with a 5m SLR.

Soil degradation due to losses of fertility, salinization and water table increase are the most important weaknesses for Egypt agriculture. The farmers believe that soil salinization and losing soil fertility will have a serious impacts over crop-yields production in the future. Soil degradation

is attributed to the high reliance on poor irrigation systems, poor drainage systems, the high extensive cultivation system, unsustainable agriculture management. The farmers from Northern Delta sub-region believe that they will have a serious problems with soil degradation more than Middle and Southern Delta farmers. The problem is attributed to soil properties, sea-water intrusion, low water quality, poor fertilization management, and drainage problems.
About 63% of the total questioned farmers believed that pests and daises hazards become more critical in the last decades. The framers in the three sub regions indicated Aphids and Therpis as the most serious pests become more critical. Whereas, Dodder and Broomrape were the most important weeds become critical in the last decades. Cold and heat waves were addressed as environmental risks have a strong effect threaten the agroecosystems in the three regions of the delta. Whereas, they identified sand storms as an environmental risk has a strong effect threaten fruit production agroecosystems in southern delta region, and it may cause a crop losing by 10 to 70%.
The accelerated population increase in Egypt is increasing the pressures on natural resources and food production system. The reduction in agriculture land due to urbanization is one of the critical sources of vulnerability of agriculture sector. This reduction in arable land area is coupled with the reduction on the average trend of land ownership area. Regarding to the current statistics about 70% of the land ownerships in Northern and Southern Delta region are less than 2 hectare per owner. Under this situation, the integrated and sustainable management is not applicable and/or economically fitful. On the other hand, the agriculture sector is facing a general serious reduction in agriculture labour force, especially in expert labour required in orchards agroecosystems. The labour force reduction is very serious in Middle Delta sub-region. The questioned farmers attributed this reduction to the increase in the education levels in the rural community, the emergence for new economical activities in Delta region such as petrochemical companies that present better income than agriculture activities, and the immigration of young people from rural to urban.

<u>Greece</u>

The Greece partner reports that the Xerothermic plants, adapted to Mediterranean environment plants and crops, such as olives, vines and cereals, have a better adaptation capability than cotton or maize. High quality wines and olive products, are produced in Greek islands under very dry conditions, sometimes in marginal soils, and two of their most common diseases are associated with humidity. On the other hand, maize, cotton, may need additional irrigation water resources. Rice, has been already facing a cultivation area decrease, due to the shortage on water required for flooding and in specific geographical areas, emerging soil salinity. Sea level rise, in combination with groundwater wells for irrigation, may increase the probabilities for soil and water salinity. However, farmers do cope with these extremes so far and adapt their practices to them, and this decision depends heavily on the economic farm outcome.
Reduction of population in mountains and rural areas is a trend with a lot of country and European resources dedicated to it, directly or indirectly (Ex. Common Agricultural Policy and Subsidies). However, urbanzation and emigration is not a new trend for Greece, but occurs since the 1950's and even earlier in some cases: if agricultural primary sector profitability decreases due to climate change, areas with smaller farm size and no alternative income sources than agriculture may face population movements.
Flatland agricultural areas close to major road networks and urban centers, where agricultural farm size is 5 ha or generally larger than mountain and hilly farm sizes, show a trend which could be applicable for the future; part time farmers have more suitable conditions, since a shift in agriculture (ex. from cotton to gardening products) for a part time income is evidently more possible than for rural citizens who are based only to primary sector income. Low farm size, and the need for change, is also a major vulnerability which influences profitability and it is an issue of

governmental and organizational studies and actions. High profit crops, such as tabacco and cotton, show a decrease or huge reduction lately (as in Table 2): the economic dependency of whole farming communities to these crops, creates the need for alternative crops with similar net profit levels, or the creation of local alternative sources of income.

Gaps, need for research, knowledge still underdeveloped for the countries of Mediterranean Region

For the Italian conditions, but also for the characteristic conditions of Greece, we can aspect: (1) a larger development and recourse of irrigation with localized methods (microsprinkler and drip irrigation), (2) an increase of supplemental irrigation for normally rainfed crop (winter wheat or sugar beet with autumn sowing), (3) major destination of water resources for crops with highest economical profit, (4) overuse of groundwater (private wells) for the more extensive crops.
In this context, the most important challenge for the irrigated agriculture will be to save water and to increase the Water Use Efficiency. One of the reasons to increase the WUE is linked to economical aspects because the competition with the other productive and/or social sector will determine an increase of water price.
Few studies are available in scientific literature about the effects of the practices of conservative, no- or minimum-tillage on vegetables annual crops and it is questionable if the simulation models are adequate to describe the effects of tillage on soil fertility and crop productivity. At the same time, this option is considered of lesser importance for grasslands while there are interesting practices for tree crops finalized to conserve soil water (tillages in inter-rows, controlled grassing, etc.)
About 68% of the total questioned farmers in Delta region of Egypt believe that the crop yield experienced some reduction in the last 10 years due to unfavourable climate conditions. The farmers in Northern Delta sub region indicated the most reductions in vegetables and orchards agroecosystems. About 98% of the total sample in Delta region believe that the projected increase in temperature due to climate change will have a serious impact on crops production, in terms of crop-yields reduction, increase in crop-water requirements, intensifying best hazards, crop-yields quality reduction, intensifying salinity problem, changing sowing and harvesting dates, and increase in fertilizers requirements.
The high reliance in low efficient surface irrigation systems, limits the opportunities of improving on-farm irrigation management applications. When poor irrigation management coupled with water shortage and low water quality, produce high vulnerable situation to the increase in crop-water requirements. This situation become more critical in Northern and middle Delta sub-regions, due to the increased salinity problems that require special irrigation management.
The following point can be considered common for the Mediterranean area:

- studies concerning the optimization of irrigation with saline water (effects on plant yield and soil structure);
- current irrigation and drainage systems (from engineering point of view but also from modelling purposes with physically based model);
- improvements of crop tolerance to drought conditions and heat waves;
- increase of efficiency of methods for irrigation scheduling including the advanced technologies based on remote sensing;
- using of wastewater opportunely depurated (opportunities and warnings for each cropping systems);
- effects of the practices of conservative, no- or minimum-tillage on vegetables annual crops and improvement of modelling to describe the effects of tillage on soil fertility and crop productivity.

Tools used for the assessments of the Mediterranean Region

The Italian partner carried out pilot assessments using climatic data coming from statistical and dynamical downscaling as input data in crop/soil simulation models. In particular he used the following models:

SWAP (Soil Water Atmosphere Plant)t, a physically based model with: (1) simple option for simulating the soil/plant water balance of Scarola and Watermelon, (2) detailed approach (WOFOST) to simulate the crop grwoth of Sorghum;

DSSAT (Decision Support System for Agrotechnology Transfer) to simulate two important crops for Capitanata area in the Norther part of Puglia Region (Southern Italy): winter wheat and tomato. For these crops (C3 plants) the option for taking in account the effect of CO2 on plant productivity was activated.

On other important tool was the bibliographic research and judgements of experts.

The Egypt partner focused his work s survey with a bottom-up research methodology based on traditional knowledge compatible with sustainable development requirements.

Medany et al. (2007) concluded that designing adaptation strategy for agriculture sector should consider the simple and low cost adaptation measures that may be inspired from traditional knowledge, and meet local conditions and compatible with sustainable development requirements. The goal of WP3 activities is to conduct a multi-criteria adaptation assessment in the Delta Region, through conducting a community-based assessment. This assessment was conducted through focusing in three emerging issues of; (i) the acceptable options of adaptations at farmers' level, (ii) insurance and financial systems of adaptation, and (iii) the adaptation for land loss in North Delta due to SLR.

The proposed adaptation measures under the assessment were based on the main key points affecting the vulnerability of the agriculture system under the projected climatic changes of identified in WP2 assessment. The community-based pilot assessment is performed using a pre-set questionnaire. The surveys were conducted in 18 pilot locations in Delta region. While, Nile Delta region was classified into three sub-regions of northern, middle and southern Delta sub-regions. The survey covered 160 samples in northern Delta, 142 samples in middle Delta, and 77 samples in southern Delta, by overall samples of 379.

The Greek partner based the studies on regional Climate Model Agroclimatic Index analysis, in a spatial resolution suitable for regional and case studies and local assessments, based on the ECHAM 5 A1B Racmo 2 Scenario from the ENSEMBLES Project. The periods of analysis were 1971-1990, 2031-2050 and 2071-2090, and also for daily data 1961-1990, 2021-2050 and 2071-2100. Map series and tables produced presented local vulnerabilities even at the smallest administrative unit level (ex. LAU2) according also to the CORINE 2000 Classification of Level 3. In addition, direct interaction with farmers was pursued, and small scale field assessments were applied too.

Adaptation strategies for the Mediterranean Region

The Table 3 summarizes the feasible and recommended adaptation options.

Table M3: Observed trends, recommended adaptation options, uncertainties and mitigation effects.

Dominating Agroecosystem	**Geographical region**	**Observed trends in adaptations to climate change**	**Recommended feasible adaptation options to climate change**	**Identified limitations for adaptation options to climate change**	**Uncertainties, cost/benefits, risks (including economic risks), opportunities of adaptation options**	**Mitigation effects (assessment)**
Grasslands	Northern (NI) and Southern (SI) Italy	Farm: earlier cutting dates; irrigation as normal practice (alfalfa) Regional-National: Structural change to bigger farms, change to ecological farming.	More extensive production, Earlier cutting dates Scheduled irrigation Fertilization Alternative fodder crops	Farmers income Water availability Topography (hilly) Soil erosion Small farm size	Milk price Change to fodder crops increases flexibility; Higher costs for machinery Highly sensitivity to milk price	positive: less manures produced (lower N2O emissions) negative: if grassland is changed to arable land
Field crops	Greece: Central East (CE) Peloponeese (P) Egypt: Northern Delta (ND), Midle Delta (MD) and Southern Delta (SD) Italy (NI and SI)	Farm: changing sowing dates, increasing irrigation requirements, modifying plant protection programs, Gypsum and compost, to avoid SLR impacts on soil (ND). Substitution of soft wheat by winter wheat (NI). Normal irrigation for maize (NI) Reduction of sugar beet cultivation (SI) Regional: improving irrigation and drainage systems	Farm: changing sowing dates increasing irrigation requirements, modifying plant protection programs, changing fertilization requirements Change from summer to winter crop (cereals) Irrigation scheduling; Conservation soil water; Regional: improve the current irrigation and drainage systems Switch cropping activates to aquaculture (ND) Changing cultivars and crops	Availability and cost of water resources (for spring/summer crops) Salinization of coastal areas (SI) Small farm size Marketing constrains. Technology limitations (E) Financial resources Environmental hazards Scientific knowledge limitations (genetic improvement) Marketing constrains.	Not necessarily sowing date optimization increases production expenses; increase of productive stability. No control for farmers on prices products Increase the flexibility to face temperature and water requirements increase. Changing sowing dates could be not efficient to face SLR (ND) and soil degradation problems. The required knowledge may be not ready or available.	Positive effects on C sequestration are expected by minimum or conservative tillage benefits in terms of N_2O emission are questionable. Reduction of N_2O are expected with optimized fertilization

		and switching to aquaculture (ND), establishing farmers' adaptation cooperative-fund (Egypt). Changing cultivars and crops.	Adaptation tax on crops prices (ND) Using urban water (SI); Precision agriculture (I); Remote sensing (I)	Food security constrains	The environmental impacts of aquaculture are highly uncertain (ND). The cost of breeding cultivars could be very high. Market constrains have higher effect in controlling crop pattern than environmental pressures.	
Vegetables crops	Idem	Farm: changing sowing dates, increasing irrigation requirements Farm-Region: Increment of localized irrigation (NI); increment of high quality production (SI); structural change to bigger farms (SI). Regional: Enhancement of water distribution, and control; drainage system (ND) governmental plan for adaptation finance (ND) National (E): Changing cultivars-changing crop pattern. Reduction of area	Farm: changing sowing/transplanting time, crop and variety choice, optimal irrigation scheduling and fertirrigation, conservation of soil water, modifying plant protection programs, changing fertilization requirements Drip, LEPA and ULDI irrigation (NI) Regional: New varieties; Enhancement irrigation network and scheduling Precision agriculture Remote sensing Saline irrigation water (SI) Establishing adaptation tax on crops prices (E).	Marketing constrains, Availability and cost of water resources (for spring/summer crops) Salinization of coastal areas Small farm size Market price fluctuations Economic resources availability Scientific knowledge limitations Lack of public organization; Food security constrains	Not necessarily sowing date optimization increases production expenses; increase of productive stability. No control for farmers on prices products Increase the flexibility to face temperature and water requirements increase. Changing sowing dates could be not efficient to face SLR (ND) and soil degradation problems. The required knowledge may be not ready or available. Northern Delta have a wider opportunities for marketing with less transforming cost, The cost of breeding cultivars could be very high. Market constrains have higher effect in controlling crop pattern than environmental pressures.	Reduction of N_2O are expected with optimized fertilization and precision agriculture

		due to water resources availability decrease (G)				
Tree crops	Idem	Farm – Reg: Increment of high quality production Modernization of irrigation method (low pressure); Structural change to bigger farms. Increasing irrigation requirements Continues supply by extra amounts agricultural gypsum and compost, to avoid SLR impacts on soil (E) Reg.-Nation. (E): improve the current irrigation & drainage systems, governmental plan for adaptation finance. Changing cultivars	Farm: Irrigation scheduling and fertirrigation Controlled grassing modifying plant protection programs: Irrigation system change Farm – Regional: New varieties Enhancement irrigation network and scheduling; Precision agriculture Remote sensing Using urban water Adaptation tax on crops prices (E)	Availability and cost of water resources Lowering of soil water table depth Salinization of coastal areas (SI) Economic resources availability Lack of public organization Scientific knowledge limitations Food security constrains	Increase of productive stability Uncontrolled import of products Increase the flexibility to face temperature and water requirements increase. The required knowledge may be not ready or available. No control for farmers on prices products The cost of breeding cultivars could be very high. Market constrains have higher effect in controlling crop pattern than environmental pressures.	Growing grass in orchards is positive for protection and soil fertility Reduction of N_2O are expected with optimized fertilization

The “Optimization of sowing/transplanting time (advancing for spring crops – delaying for winter crops) and the “Selecting varieties and/or species among those available at present” are the most feasible and fast adaptation options to reduce the negative effects of climate change. But the factor that characterize the work of Mediterranean partners is the proposed adaptation strategy concerning the irrigation and in general the water requirements of the cropping systems cultivated in the Mediterranean area. The optimization of amount and time of irrigation and/or other water management practices is the main way to increase the water use efficiency at farm/regional level. The adoption at farming/regional scale of new technologies to schedule the irrigation, and of advanced procedures based on remote sensing information, and structural enhancement at regional/farming scale for using urban depurated water are the proposed strategies of adaptation at regional level. For the particular situation based on sea level rise, in Egypt the analyses recommended “switch cropping activates to aquaculture” as adaptation measures that could be applied at regional level in Northern Delta region with good impacts on the national food security, but inducing new environmental pressure on the natural resources on the region.

For the Mediterranean agriculture the options feasible in short term can be synthesized in the following points:

Table M3: schematic overview of the adaptation options for Mediterranean region

Adaptation options that are feasible in short term	**Adaptation options that are feasible in midterm and where further testing is needed**
Optimization of sowing/transplanting time (advancing for spring crops – delaying for winter crops); cropping activities; Selecting varieties and/or species among those available at present with more appropriate thermal time and vernalisation requirements and/or with increased resistance to heat waves and drought; Optimization of amount and time of irrigation and/or other water management practices as drainage; Optimization of fertiliser rates to maintain grain or fruit quality; Applying the available technologies to conserve soil water (No tillage, minimum tillage); Using water resources of low quality (saline water) Improve the effectiveness of pest, disease and weed management practices	Constitution (with traditional or innovative method), evaluation and introduction of new variety; Structural enhancement of irrigation efficiency and changes in farming systems Adoption at farming/regional scale of new technologies to schedule the irrigation for obtaining high values of water productivity; Adoption of advanced procedures based on remote sensing information in order to optimize the use of water resources at regional scale Structural enhancement at regional/farming scale for using urban depurated water
Particular adaptatin strategies for Egypt	
Improvements of current irrigation and drainage system	Switch cropping activates to aquaculture
	Environmental controlled production techniques

In general one of the most important effect of climate change is to increase the evaporative demand of the atmosphere. Consequently, an increase of irrigation requirement is expected for the next decades of this century. However, this effect is counterbalanced by the shortening oh cycle length forecasted for the plants (the majority) characterized by determinate cycle. Therefore the studies indicated light increases of irrigation and in several case also reduction at seasonal scale. **Advancing the sowing time**, the risk is to have higher irrigation

requirements with low values of water use efficiency. Fortunately, this trend was confirmed but at the same time, the irrigation variations are not so significant to be limited its convenience allowing water use efficiency comparable to those of the past.
In conclusion, this adaptation measure is feasible for all the evaluated erbaceous cropping systems with advanced sowing/transplanting time for spring crops and deleted sowing for winter crops like winter wheat.

Changes in cultivar is the other easy option of adaptation of climate change. The criteria to take in consideration would be based on: more appropriate thermal time and vernalisation requirements; increased resistance to heat waves; increased resistance to drought.
A pilot assessment about Sorghum was considered for the first point in which the parameter "life span" of leaves was used as sensitive parameter in order to emulate the response of several cultivars at different length of biological and cropping cycle. As expected cultivars with higher thermal time requirement and consequently with longer cycle, represent an adaptation measure in order to reduce the negative impact of climate change for crops a determinate cycle and spring sowing or transplanting.
Changes in specie has to be established with the same criteria of changing cultivar. This option was considered in grassland changing to annual fodder crops. In cropping systems based on cereals and industrial crops with a reduction of availability of irrigation an increasing cultivation of winter wheat or other winter cereals can be expected. In Northern Italy there is a substitution of soft winter wheat by durum winter wheat and this tendency could increase in the future. In the vegetable rotations, above all in the Southern Italy, a shift toward winter vegetables (lettuce, fennel, cabbage) is expected as well.

In an agricultural context characterized by increasing demand of evaporation of the atmosphere and competition with the other sectors, reducing of availability of eater resources, the **optimization of water** is the most important factor to reduce the negative impact of climate change establishing when, how much and how to irrigate. To optimize amount and time means to reduce the water losses by deep percolation and soil evaporation giving the water at right moment avoiding water stress to the plant and drainage. The available methods are: evapotranspirometric method, monitoring the water status of soil and plant with tensiometers, FDR and TDR technology, deficit irrigation system, partial root drying .
The localized irrigation method, as drip or microsplinker irrigation, is very common in Southern Italy for tree crops (vineyards, citrus and partially olive) and vegetable crop (tomato, watermelon, lettuce, cabbage, etc.). In Northern Italy the situation is different with several methods like sprinkler, flood or furrows irrigation extensively still used. Other interesting methods are: low energy precision irrigation (LEPA), the Ultra Low Drip Irrigation (ULDI) with 0.1-0.2 $l\ h^{-1}$, irrigation with photovoltaic energy, sub-irrigation.

Because the potential productivity of northern zones is in general expected to be increased due to longer vegetation, for Northern Italy but also in Southern Italy if advanced sowing time are applied, it is appropriate to expect changes in **fertilization** schemes in annual crops and perennial systems, as grassland and trees in particular vineyards. The fertirrigation is also an important opportunity.

The **tillage practices,** with particular reference to minimum or no-tillage**,** have important effects that can increase the soil water conservation and protect the soil against soil erosion by water and wind. Adoption of conservative tillage are expected to be useful, above all, for cropping systems based on cereals with particular reference for winter wheat and maize in Northern and Southern Italy.

Other options to reduce the water losses include: the soil mulching whit synthetic or, preferably, vegetal material as crop residues of the previous cultivation

Where there is a limited availability of water of good quality for irrigation, the **saline waters** represent an important resource. This is typical in several areas of Southern Italy with particular reference to coast area of Adriatic and Jonical sea. In general this water comes from not very deep groundwater of unconfined or perched types and it can represent the only resource of water. In other cases, the famers generally use the water from the irrigation network and the water from the wells when the first is not available.

There are expected changes in **crop protection** (pest, diseases and weeds) needed for every crop. The economic benefit of monitoring and protection is different in function of many factors. It's quite low for grasslands. In case of cropping systems based on cereals the protection optimization is more important and it becomes strategically very fundamental for tree and vegetables crops like vineyards (in Southern Italy), apple and pear (Northern Italy) and tomato and other vegetables crop for which many treatments in general are carried out.

<u>Adaptation options in midterm</u>
The constitution with traditional or innovative methods, the next evaluation and introduction of **new varieties** can introduce in the available genotypes improved traits concerning appropriate thermal time and vernalisation requirements, increased resistance to heat waves and drought, but also increased resistance to new or expected dangerous pest, diseases and weeds, improved productivity or yield stability.

The **structural enhancement of irrigation efficiency** is an important factor for Italy. In general in many areas improvements of canalization system are required in order to reduce the relevant water losses that in several places can be 40-50%.
The **changes in farming systems** concern the noted and expected tendency of substitution of food production by energy production considering that several crops are suitable for different type of biofuels and a northward expansion of these crops.
For the tree crop the temperature increase could expand the suitable area for plant requiring high temperature as grapewine, cytrus and olive forecasting an expansion of olive cultivation towards the areas in the Northern part. The same can be forecasted for the cultivation of durum wheat in substitution of soft winter wheat in Northern Italy and for most vegetable species like lettuce, fennel and cabbage, in winter and spring cultivation, and melon.

Significant increases of water use efficiency can be obtained adopting on at farming/regional scale of **new technologies** to schedule the irrigation. **Remote sensing** information should be applied in order to improve the land cover classification (very important for irrigation planning), the assimilation of leaf area index (LAI) and shallow soil water contents and the estimation, with the last three points very useful to support the components estimate of soil/crop water balance and to schedule the irrigation at watershed scale with daily temporal resolution.

The last point regarding the adaptation measures of long term regards the structural enhancement at regional scale in order to use the **depurated urban water**. This is an important question that needs of a legislative support because the current Italian law is very restrictive for depurating this type of water with thresholds values very low and requiring high costs to depurate these waters.

For the particular context of Egypt, compared to Italy and Greece, the feasible options in short term can be synthesized in the following points:
More than 70% of the total sample considered that "**changing cultivars**" and "**changing crop pattern**" is the most important adaptation measure for agriculture systems in Nile Delta region could be applied at the national level. Whereas, "**increasing irrigation requirements**" and "**changing sowing dates**" came in the next level of adaptation priorities, and both adaptation measures could be applied at farm level. Improve the **current irrigation** and **drainage systems** are addressed as an efficient adaptation measures at regional level of implementation.
The primary results of the evaluation analysis recommended changing sowing dates as an adaptation measure at the farm level could increase the flexibility of the farming system to face temperature and water requirements increase due to climate change. Whereas, changing sowing dates could be not efficient to face SLR in Northern Delta and soil degradation problems. Moreover, it may limit by the marketing windows dates, which may not match the new harvesting dates, especially for cash crops.
The evaluation analyses recommended "**switch cropping activates to aquaculture**" as adaptation measures could be applied at regional level in Northern Delta region. This measure could imply good impacts on the national food security, while it may induce new environmental pressure on the natural resources on the region. Moreover it remarked be a high degree of uncertainty in terms of farmers acceptance for carrier change, the capacity of fishing industry, and the availability of financial resources.
Using **environmental controlled production techniques** for orchards production is one of the recommendations of the evaluation analysis that could be applied in the three sub-regions of the Delta. This measure will require high financial investments and technology level, which may led to a general increase in the total price of fruits. But, it may increase the flexibility of the production system to face temperature and water requirements increase.
On other important option of adaptation is to **Establish climate insurance and adaptation self financial systems** with the objective of establishing insurance and financial systems to overcome the unfavorable climate conditions impacts over agriculture production, and/ or sustain the required resources for adaptation of the agriculture sector. This tax may help in accelerating the adaptation implementation by ensuring the required adaptation fund. On the other hand, the consumers may refuse it because it will increase the prices of the agricultural products, and the required fund for adaptation may exceed this level.
Table M4 shows the results of the second section of the adaptation pilot assessment of the farmers' perception for the actions to face land loss due to SLR and salinity buildup in Northern Delta. The results reflect that more than 60% of the farmers summarized the SLR impacts as salinity buildup, and they believe that the soil maintenance techniques could handle the problem.

Table M4: Farmers perception for the actions to face land loss due to SLR and salinity buildup in Northern Delta

Adaptation measure	% of the sample
Gradual increase in cultivating salinity tolerant crops.	64%
Adding soil layers to land in order to increase its elevation.	43%
Gradual decrease in the current cultivating area to obtain a higher level of crop management with a constant level of production cost.	9%
Continues supply by extra amounts agricultural gypsum and compost, to improve soil characteristics.	69%
Establish a new drainage system in field, equipped with a suction pumping unit, to remove the excessive water table and control it in a constant level.	29%
Switch cropping activates to aquaculture	5%
Leave the current cultivated land, and move to other land located away from the sea.	2%
Leave the agri-business and find other carrier.	1%

The evaluation analyses recommended gradual switching of the current old land by reclaimed land in Upper Egypt, in order to face SLR impacts on the agricultural systems in Northern Delta. Although the implementation of this measure could be limited by many biophysical and socio-economical limitations and uncertainties, it may sustain the national agriculture production at the secure level of production.

3.2 Central European region

(Josef Eitzinger, Austria)

Key aspects of climate change impacts and main vulnerabilities in agriculture:

The central European region covers a wide range of climates ranging from cool and humid (e.g. alpine region) to warm an semiarid/humid (mostly lowland areas) of the transition of continental type of climate to atlantic and to mediterranean type of climate. The ADAGIO countries in that region, Poland, Czech Republic, Austria can be considered as represenative for that region. This region also covers a wide and distinctive difference in farm structure and socio-economic conditions, mostly caused by the different historical socio-economic and political developments of the western (Austria) and eastern (Poland, Czech Republic) countries. Potential vulnerabilities to climate change as well as adaptation options of the relevant agroecosystems are affected by both conditions.

Although the Central European region is more humid compared to the Mediterranean region, summer drought and water scarcity for crops (in combination with heat waves) is named in all countries as the main danger for agricultural production under climate scenarios, except in some mountainous and alpine regions. This assessment is of course based on the current regional production systems, mainly not adapted yet to severe drought conditions (which is reverse compared to the mediterranean area of already drought adapted production systems).

In all ADAGIO countries of Central Europe main arable crop production regions are already effected by increasing drought conditions and water shortage during the summer period, leading to increased demand of water for irrigation for irrigated crops.

Grasslands (in combination with dairy farming) in regions below app. 700mm precipitation are most vulnerable to the warming trend in Central Europe, which comprise relatively large regions in Central Europe. Regions where a change to crop production or other alternatives is difficult due to terrain or soil conditions, will be probaly the worst affected areas in agriculture in Central Europe. However, there are big regional differences, caused not only by topographical effects on annual precipitation but also by soil conditions regarding soil water storage capacity.

Production of orchards and vineyards will be probably mostly negatively affected by changed pest and disease occurrence in Central Europe, according to experts and farmers opinion. However, in some cases a change in frost danger or hail are named as well.

Other climatic impacts and observed trends mostly named in this region are:

- increasing spatial and interannual yield variability due to extreme weather (mainly summer droughts and heat waves)
- annual rainfed summer crops with high water demand such as sugar beet are already disappearing in some regions by climatic reasons (where irrigation systems or water is not available or economic)
- potential of increasing soil erosion in vinyards and crop farming in hilly terrain due to regional increasing trend of heavy and winter precipitation
- change of pest and disease occurrence; pests are generally considered by farmers as the second important danger beside of drought (especially several thermophile insects are affected)
- shortening of the cropping cycle, effecting field work timing

- in some regions potentially more frost damages are expected in years with early start of growing season or warm phases during late winter period, especially for apples, cherries, apricose.

Tab. X: Regional characteristics of Central European Agricultural Vulnerability (focused on ADAGIO countries Austria, Poland, Czech Republic)

Domina-ting Agro-ecosystem	**Main limitations**	**Observed trends**	**Socio-economic conditions and problems**	**Main identified vulnerabilities to climate change**
Arable regions; Crops (rainfed)	Soils : light soils and low available water (regionally, especially Poland); Climate : Precipitation (except near alpine regions); farm structural changes (all countries), CAP reform influences	Introducing of conservation tillage, promoting added values and agro-industry through ecological farming or niche production (esp. Austria), advertising regional products (Austria), change of farm size structure (esp. Austria, Poland); bioenergy production alternatives using crops not always sustainable;	Small farms (crops and animal production) often not continued by next generation and/or increasing part time work in agriculture. Prevailing traditional production techniques at smaller farms (esp. Poland) and very mall farm sizes (Poland, Austria)	Shortening of crop cycle. Increasing spatial and interannual yield variablities due to drying trend in almost all the region, especially for rainfed summer crops; changed pest and disease risks (esp. insects); increasing soil erosion risk due to increase of heavy precipitation in hilly terrains.
Grassland dominated regions	Terrain: alpine grassland regions; Precipitation in some regions	Increasing number of farms with biomass or bioenergy production (esp. Austria); long term increasing yield potential under climate change only in near alpine or cool/humid regions; decreasing number of dairy farms	Alpine (grassland dairy) farms often not continued by next generation and/or increasing part time work in agricultur. High workload and low income of dairy farming. Prevailing traditional production techniques at smaller farms (esp. Poland)	Drought : all regions on the border line to arable dominated areas; Damages by summer heat waves : all regions (also alpine), more risk from pests (earthworm).
Vineyards, orchards	CAP and Wine Market reform influences, frost risk, pests and diseases risks	Structural change to bigger farms, Strong agronomic control by Origin-certification (terrain), linking with tourism and increasing self marketing and export orientation. New wine growing areas in the long term can be explored.	Small farms : often not continued by next generation and/or increasing part time work (all countries)	Earlier harvests and fastening of phenology will alter timing of field work and production methods; change of vine quality such as increasing sweetness (short term) and cultivars (long term); danger of new pests; increasing irrigation needs for young plants. Locally increasing risks for frost damages especially for orchards (apple, apricose, cherries); increasing soil erosion risk.

<u>Key aspects in adaptation options in agriculture in Central Europe:</u>

In all ADAGIO countries of Central Europe all main arable **crop production** regions are affected by increasing drought conditions and water shortage during the summer period, which leads to several recommended adaptation options regarding the protection and efficient use of the agricultural and soil water resources.

Grasslands (in combination with dairy farming) in regions below app. 800mm precipitation were shown as most vulnerable to the warming trend in Central Europe, which comprise relatively large regions in Central Europe. Because of the fact and that grassland production is much less flexible for adaptation options at different levels due to several reasons, it is considered as the most critical sector and most emphasis has to be paid for feasible adaptation options. For example, for regions where a change to crop production or other alternatives by changing land use is difficult due to terrain or soil conditions, there are only few potential adaptation options possible for farming.
On the other hand a challenge is given in regions where permanent grasslands could be used for arable farming in order to compensate decreasing grassland yields. This may have negative impacts on soil erosion potential, landscape functions or greenhous gas mitigation

Perennial cropping systems such as orchards and vineyards will be probably mostly effected by changed pest and disease occurrence in Central Europe, which leads to the conclusion that adaptation measures should focus on this topic. Also adaptation options to avoid soil erosion and to improve crop management is a critical frequently reported issue for perennial crops.

Adaptation options mostly recommended in the Central European region are :

<u>Short term:</u>
- Soil water conservation techniques (mulching, reduced and minumum tillage)
- Change to heat and drought tolerant cultivars
- Change cultivars and crops according temperature demands
- Change sowing date and shift timing of field works
- Adaptation in crop rotation (e.g. more winter crops)
- Ensure frost protection methods (and for hail in some regions)
- Effective Insurance system (ideally supported by government)
- Adapted animal stables, ensuring power generation, increasing hygienic measures

<u>Medium term:</u>
- Improve, introduce monitoring and operational warning/forecasting systems for pest and diseases as well as extreme weather impacts (such as drought)
- Improve or establish irrigation infrastructure
- Breeding of adapted cultivars (esp. for higher water use efficiency and heat stress)
- Crop diversification (farm and regional scale)
- Increasing storage capacities (fodder)
- Changing land use and/or production system (e.g. cereals to maize, grassland or annual crops to vineyards, grassland or crop prduction to energy biomass production)
- Landscape structure improvements to reduce evapotranspiration (lowering wind speed, in some flat semi-arid regions by hedgerows or windbreaks)
- To ensure higher market price stability for agric. products (improves planning of adaptation options) by using appropriate tools (not only political measures); eg. ecological farming; terroir characteristics for wine quality aspects

Mostly named limitations of adaptation options in Central Europe, related to socio-economic conditions :

- structural changes are mainly driven by economic reasons rather than by climatic driven reasons (strong decrease of income per work unit (esp. Poland), too small farm sizes (Austria, Poland), complex terrain and high production costs (Austria), too low income at small farms (esp. related to family business) leads to abadoning small farms (Austria, Poland) or reduction of agricultural used land (Poland).

- farmers of small farms are less educated in agricultural production in general (often part time depending on other incomes) leading to a decreasing success or interest in farming.

- adaptive capacity of small farms seems to be better in well developed countries with better infrastructure (or well established local market) (such as in Austria, where already many small farms could successfully change to ecological production or alternatives/niche). Eastern countries are much less flexible in that sense, probably also by the missing political support, low financial resources, not well developed infrastructures, fewer possibilities of additional incomes beside agriculture at the same location.

Main other limitations:

- bad existing or destroyed infrastructure (esp. irrigation systems) and less financial resources for improvements
- to less water available in the region for additional irrigation (partly an infrastructure problem; e.g. regions in Czech Republic and Poland)
- too high costs of certain adaptation options
- terrain and soil restrictions
- no market (or still no) and market price uncertainties leads to uncertainties in success of esp. mid term adaptation options (e.g. change of land use or production system)
- labour and time pressures

A detailed regional analysis is shown in Table X (below).

Table 1. Common regional characteristics of main feasible adaptation options of the Central European most vulnerable regions (focused on ADAGIO countries Austria, Poland, Czech Republic)

Dominating Agroecosystem	**Geographical region**	**National name of regions**	**Agroecosystem, related to common agroclimatic etc. indicators**	**Observed trends in adaptations to climate change (distinguish between farm level, regional level, national level)**	**Recommended feasible adaptation options to climate change**	**Identified limitations for adaptation options to climate change**	**Uncertainties, cost/benefits, risks (including economic risks), opportunities of adaptation options**	**Mitigation effects (assessment)**
Crop farming dominated by cereals in dry/warm areas	Austria, Czech Republic, Poland	Znojmo, Břeclav, Upper Austria and Lower Austria	Maize growing production region (agroecological zone)	Structural change to bigger farms in small scaled farm regions. Focus on more drought and heat resistant crops e.g. soybean (in more humid regions), sunflower; irrigation consideration; shift in timing of field operations;	Alternative crops (e.g. soybean);	strongly market price related	Need for new markets; higher vulnerability to management errors	Positive: better use of the production potential per unit of energy
					Change of field operation timing	Time pressure on the availability of machinery at the right time.	More uneven spread of machinery use (less efficient)	
					Improvement of irrigation infrastructure, systems and methods	Underfunded infrastructure and limited water sources (CZ, Poland); inefficient irrigation systems and methods applied (Austria)	High demand for capital (governmental financial support) and depended on local water resources (CZ, Poland)	

					Minimum tillage, mulching Drought resistant cultivars Improved pest/disease monitoring	Not suitable for all soils, high machinery costs Only limited benefit (but still attractive for farmers as it requires no other change of behavior); Costs, investments; in Poland and CZ mostly support driven	Tillage techniques have only limited ability to improve water balance Only unconvincing evidence of suitable cultivars Still less used among farmers, cost effective measure	Possitive: lower need for fossil fuels; positive: less energy input and fossil energy use
Grassland farming in regions with limiting precipitatio n	Austria, Czech Republic	N-Austria, Eastern Austria; Czech Highland s	grassland and potatoes growing region (agroecological zone)	Farm level: Structural change to bigger farms, intensification and specializations; combination with bioenergy (biogas) production as additional income source; change to ecological production	alternative fodder crop production (e.g. silomaize, cereals) introduce perennial crops according to climatic conditions (orchards, vinyards, wood biomass) increase farm size and grass production area (to compensate lower area productivity) change from dairy to sheep farming (extensivication) change from dairy to pork production (intensification)	terrain (slopes) soil conditions, high investments in new infrastructure higher costs (machinery, energy) investments necessary, market availability investments, terrain, soil conditions	higher productivity possible; potential negative or positive effects on landscape functions (attractivity) forced by ongoing structural changes higher flexibilty to climatic extremes) lower work load	negative, if grassland changed to arable land (THG emissions and

					(based on introduced maize production)			soil erosion based carbon losses)
				Regional level	adapt stables (against heat stress) and increase fodder storage capacity	inverstments necessary,	high costs	
				National level	Regional Water conservation measures and water storage systems Strengthen market price stability of milk price Support drought insurance/monitoring for grassland production systems	e.g. protecting groundwater resources	Allows better planning/lowering risks for adaptation options without change of farming system costs	
Perennial crops in current production regions (orchards, vineyards)	Austria, Czech Republic		maize and wine growing regions (agroecological zone)	Farm level: changing wine cultivars, white to red wine varieties; change to ecological production (Austria); introduction of mulching systems; improved marketing (Austria): quality defintions by terroir descriptions (enhancing local identification)	Change of cultivars, change from white to red wine varieties Using mulching systems, protection against soil erosion adapted fertilization regime to drought conditions (optimizing N-fertilization, potassium) adapted crop management	medium term measure adaptation in fertilization regime needed (timing, amount) additional effects on quality aspects (wine) several measures (e.g. leaf management)	low investments low investments low investments low investments	positive: more effective use of fetilizers

					(vineyards)			
					shift of phenology and timing of harvest and crop management measures	autonomous adaptation; potential multiple effects on quality aspects	potential higher harvest costs, and labour costs (e.g. night time harvests)	
					Improving pest and disease management and monitoring/warning	new pest/diseases needs continuous adaptation		less use of chemicals
					change to ecological farming	multiple positive effects (see above)		positive: less fossil energy use, improved soil carbon storage
					Introducing/improvin g irrigation opportunities	investments needed, regional water resources limitation		
				Farm/regional	protection against weather extremes: drought, heat, hail and late frost damage	invest in relevant facilities and/or crop insurance		

3.3 Eastern Europe
(Vesselin Alexandrov, Bulgaria)

The ADAGIO countries representing Eastern Europe involve Bulgaria, Serbia, Romania and Russia. The above countries are characterized by various climatic conditions from continental climate in the European part of Russia to mild climate in South Bulgaria which is very near to the Mediterranean region. In all ADAGIO countries of Eastern Europe the most arable **crop production** regions are affected by increasing frequency, intensity, occurrence and duration of extreme weather events such as droughts, floods, soil slides, forest fires, etc.

The table below is trying to describe the major limitations, observed trends, socioeconomic conditions and problems as well as vulnerabilities because of climate change. Of course there are some differences between the considered countries but some common features can be noted as well:

- farmers' age is increasing. It seems the agriculture can not attract young population, especially in East Europe. Not only the young people migrate in the cities or even in West European countries. Although Bulgaria and Romania already belong to the EU many people from the countryside are moving, for example in Spain
- small farm size is another main limitation. Fortunately there is a trend in the considered countries (except Russia where the trend is opposite) to aggregation of the small farms.
- Weak economic conditions. It is a common feature for the countries in East Europe. This has a negative effect on agricultural production in this region. As a result there are:
- Lack of real education for farmers
- Low labor costs
- Low price of agricultural products which affects the farmers income

It seems that all considered countries are faced by climate change impacts and there are vulnerabilities as a result of:

- extreme weather events such as drought, dry winds, wet spells, intensive precipitation, frosts, heat and cold waves
- soil erosion and salinisation
- decrease of crop growth and development because of higher air temperatures
- occurrence of new pest and diseases

Hence, adaptation options are needed in Eastern European agriculture under the current and expected climate variability and change conditions. This will be summarized as a main issue during the next ADAGIO activities.

Tab. 1: Regional characteristics of Vulnerability in Eastern European Agriculture (focused on ADAGIO countries Bulgaria, Romania, Russia, Serbia)

Country	Dominating Agroecosystem	Main limitations	Observed trends	Socio-economic conditions and problems	Main identified vulnerabilities to climate change
Bulgaria	Crop farming, Vine farming, Orchard farming	higher farmer's age, inappropriate rural infrastructure; lack of modern irrigation systems and other machines, high cost of water; small farm size; Topography	Slow change to bigger farms, Expectation of EU subsidies; foreign investments	Weak economic conditions, cheap labour cost, low efficiency and productivity	Higher yield variability due to an increase in the frequency of climate extremes, pests and diseases occurrence; crop growth shortening
Romania	Crop farming	higher farmer's age, Water stress during the crop development, cold waves during winter time, small farm size	No significant changes in land use; Slow change to bigger farms; land abandonment	Weak economic conditions, cheap labour cost, no education; low level of farmer's knowledge related to CAP	Drought , wind erosion heat waves, frost due to decrease of snow cover. Shortening of crop cycle. New pests and diseases
Russia	Grassland, Crop farming	waterlogging, bush area returning frosts on soil; Bogginess, Raviness, erosion, scour of the top fertile soil, wet spells; ice crust; Soil degradation, gully formation, returning frosts on soil, high air temperatures; storm rains, low water supply; Low soil moisture content, desertification, storm rains, dry winds, soil salinization, low water supply	Structural change from large collective farms to small ones, distracting of drainage systems Crop rotation, Fertilization; Enlarging in areas under cash crops	Weak economic conditions of small farms, low agricultural product price, young generation migration	New diseases, returning frosts on soil, Drought, dry winds, wet periods, water erosion, New pests and diseases

Serbia	Orchard farming , Crop farming/	small farm size, No irrigation or limited irrigation, Topography	Change from crop to fruit production; Farm size expansion Increasing numbers of organic farmers; Joining farmers to association - Development of cattle breeding	Weak economic conditions of small farms, limitted storage capacities, placement problem; Unstable agro economic policy. Without clear development strategy; No strategy of agro industry and cattle breeding development; Weak financial potential of people. Chaotic market of vegetables	Large amplitude of daily temperature during vegetation period, frequency and intensity of spring frost, amount and distribution of precipitation during vegetation period, hail, temperature fluctuations during winter period, high summer temperatures and drought; Weather storms

Agriculture in the Eastern European region is still in the transition of the market economy as a result of social and political changes during the last 20 years. So the potential adaptation measures of the respective agroecosystems, considered in WP3., are influenced by the specific climate and.socio-economic conditions

Dominating Agroecosystems in the project European countries, considering at work package 3 are:

- Cereals
- Orchards
- Vegetables
- Grapes/vine yards

Observed trends in adaptations to climate change (distinguish between farm level, regional level, national level):

- Farm: Shift of timetable for tillage operations
- farm: succession croppi ng
- farm: improving crop rotation system including alternative crops
- farm: application of early spring- and autumnal irrigation, adjusting dozes of fertilizers
- Earlier sowing, harvesting
- Greater percentage of early cultivars in sowing
- National: use of drought tolerant cultivars
- National: bare fallowing
- Decrease land under wheat and increase land under barley and triticale
- Increase farmers interest for climatic changes
- Enhance farmers interest for expert advices
- Greater involvement of experts and advisory services
- Regional: increase acreage for winter cereals (wheat, barley)
- Regional: including silage maize + barley into crop rotation system

- Regional: soil gipsuming, stubble – mulch tillage, use of manures, additional phosphorous fertilization
- Regional: increase acreage for winter cereals (wheat, barley) and spring barley
- regional: introducing grass arable rotation
- Aggregation of small farms into larger ones
- Reducing areas with sunflower due to water shortages vs. Increasing areas ith winter oilseed rape
- Restarting irrigation systems
- Structure Increase plant density per unit area
- Quicker adjustment of big farms to adaptation measures
- Enhance farmers interest for expert advices
- maintaining heat and water regime in optimum, control for surface runoff
- Increase farmers interest for climatic changes
- Rapid construction and application of irrigation systems
- Introduction of new plant cultivars
- Improvement of technical discipline
- Application of modern pesticides

Recommended feasible adaptation options to climate change

- Aggregation of small farms in medium and large ones
- Change timings of field operations
- Introducing minimum tillage
- more effective application of thetechniques for protection grape vine against early autumn and later spring frosts,
- Forest wind belts
- improving protective belt systems in the crop areas (for improving snow cover management) improving snow arresting tree belts
- effective snow hedge application
- slope terrasing
- Optimal soil cultivation time
- Optimal sowing time
- effective application of wind break belts, afforestation of sands
- improving practice for water erosion protection improving practice for water accumulation into soil
- Judicious use of NPK fertilizers
- Maintenance of good plant health
- Incorporatio n of plant residues into the soil
- Optimal plant density per area unit
- Dry resistant cultivars (>2020s)
- earlier ripening cultivars
- more productive cultivars
- Good water management
- Irrigation changes
- Rationale use of irrigation (pumping water uphill not more than 30 m height)
- improving bench border irrigation
- Irrigation on sandy soils
- Local irrigation systems

- improving basin check irrigation, fertilizer irrigation, channel irrigation
- Increasing percentage of winter crops
- wide use of grasses varieties in crop rotation system, including alfalfa, effective use of wind –break belts
- improving ravine and bully afforestation for soil erosion protection
- Use of plant rotation (example: maize sown after cereals)
- Plant residues incorporation with nitrogen application
- Decrease of plant density per unit area in dry plant growing systems
- Optimal time and quality of seedbed preparation and sowing slope terracing introduction of new hybrids
- introducing cultivars responded to fertilizers, effective application of basin irrigation in costal zone
- introducing cultivars more resistant to droughts
- Farms (current climate): Adoptation of Integrated Fruits Production
- Regional (current climate): hail nets
- enhancement of organic contents in soils
- Alternative, earlier species and table cultivars
- Maintaining good health of plants

Identified limitations for adaptation options to climate change

- topographical limitations, forest-clad relief,
- farmer behaviour,
- Farmers income: Unreliable incomes
- High costs
- legislation bareers;
- Unfavorablebank credits
- Non existence of subventions for plant production
- Unsure cereal market
- Undeveloped market
- Haotic market coditions
- Unfinished privatization of food industry
- Non existence of national adaptation strategy
- Great number of farms is out of advisory service programs
- Old machinery
- Insufficient number of special machinery
- Field elevation over irrigation water source (Danube)
- Sandy soils
- Heavy vertic soils
- forest-clad relief, bogginess, low soil fertility, soil acidification
- ravine/gully systems in topography; water erosion; dry winds; droughts
- dry winds, floods, mudflow
- extra-wetted soils
- low soil fertility,
- soil acidification
- solonetz –like soils dust storms, floods, mudflow
- Undeveloped refining industry
- Great number of small farms, pulverised production

- Insufficient production of manure

Uncertainties, cost/benefits, risks (including economic risks)

- grape insect pest and diseases harmfulness
- increasing harmfulness of potatoes diseases
- increasing distribution of insect pests, diseases and weeds, new insect pest acclimatization
- higher costs for machinery; farmer incomes
- change to other crops increases flexibility;
- Suggested measures of adaptation do not increase production expenses Application of these measures would increase production stability
- Farmers do not have influence on prices of input or output
- Crisis in animal production is also a problem
- High yield variability from year to year
- Higher costs of irrigation up to becoming non profitable from an economic point of
- view
- High sensitivity to market prices
- decreasing frost killing risk; intensified harmfulness of such winter insect pest as chinch bug
- intensify of dry winds and droughts intensified harmfulness of frit fly
- Crisis in animal production decreases local corn prices
- Great variation of incomeprices increases economical risks
- Corn is more often devastated by summer drought or hail intensified harmfulness of corn bug floods
- increasing rotting -out risk
- increasing wetting -and rotting out, lodging, pest, diseases and weeds
- intensifying rice diseases
- Less costs for plant protection, nutrition, added value
- Benefits only in case of optimal application date
- Reduced production risks, more maschinery needed
- Higher fruits prices
- change to fodder crops increases flexibility;
- Uncertain placement of agricultural products on market (cabbage, potato)
- Uncontrolled import of vegetable
- High farmer dependence from trade sector
- Training of farmers for using minimum tillage

Table 2 : regional characteristics of adaptation options of the Eastern European vulnerable regions (focused on ADAGIO countries Bulgaria, Serbia, Romania, Russia

Dominating Agroecosystem (as given in Del. 3-5 report)	**Geographical region**	**Nationa l name of region**	**Agroecosystem, related to common agroclimatic etc. indicators**	**Observed trends in adaptations to climate change (distinguish between farm level, regional level, national level)**	**Recommended feasible adaptation options to climate change**	**Identified limitations for adaptation options to climate change**	**Uncertainties, cost/benefits, risks (including economic risks), opportunities of adaptation options**	**Mitigation effects (assessment)**
Grape/ Vine farming	South of European part of Russia	Northern Caucasus		maintaining heat and water regime in optimum, control for surface runoff	more effective application of the techniques for protection grape against early autumn and later spring		grape insect pest and diseases harmfulness	enlarging grape planted areas towards elevations
	Northwestern Bulgaria (NUTS2)	Severozapadna Bulgaria	Climatic water balance; precipitation sums; GDD	No trend is observed	Dry resistant cultivars (>2020s) Drip irrigation	topographical limitations, farmer behaviour, legislation bareers;	higher costs for machinery; farmer incomes	na
	Northern Bulgaria (NUTS2)	Severna Bulgaria	Climatic water balance; precipitation sums; GDD	Earlier sowing, harvesting	Dry resistant cultivars (>2020s) Irrigation changes	topographical limitations, farmer behaviour, legislation bareers	change to other crops increases flexibility; higher costs for machinery; farmer incomes	na
Crop farming Dominated by **cereals**	Northern Vojvodina	Northern Backa, Nortern Banat		Decrease land under wheat and increase land under barley and triticale Increase farmers interest for climatic changes Enhance farmers interest for	Optimal soil cultivation time Optimal sowing time Optimal plant density per area unit Judicious use of NPK fertilizers Maintenance of	Farmers income Unfavorable bank credits Non existence of subventions for plant production Unsure cereal market Unfinished	Suggested measures of adaptation do not increase production expenses Application of these measures would increase production stability Farmers do not have influence on	Adaptation measures should improve soil fertility Judicious fertilizing of cereals will decrease soil, water and food pollution

				expert advices Insufficie nt help by government Greater involvement of experts and advisory services	good plant health Incorporatio n of plant residues into the soil	privatization of food industry Non existence of national adaptation strategy Great number of farms is out of advisory service programs Old machinery	prices of input or output Association of farmers is very slow Crisis in animal production is also a problem	
	Northeastern Bulgaria (NUTS2)	Severoiztochna Bulgaria	Climatic water balance; precipitation sums; GDD	Earlier sowing, harvesting	Dry resistant cultivars (>2020s) Irrigation changes	topographical limitations, farmer behaviour, legislation bareers	change to other crops increases flexibility; higher costs for machinery; farmer incomes	na
	Romania SouthWest -Oltenia	Dolj	ESAI • fragile2-fragile31961-1990 •fragile32041-2050 Growing Period Days • 80-200d1961-1990 • 100-250d2041-2050 BGI Aridity Index • 30-751961-1990 • 50-1002041-2050 Rainfall/PET • 0.843	Farm: Shift of timetable for tillage operations Region: increase acreage for winter cereals (wheat, barley)	Change timings of field operations Introducing minimum tillage Irrigation on sandy soils Changing cultivar structure	Field elevation over irrigation water source (Danube) Sandy soils	Higher cost of machinery High yield variability from year to year Higher costs of irrigation up to becoming non profitable from an economic point of view Training of farmers for using minimum tillage	Negative: If crop rotations restricts to 1-2 crops If forest and wind belts are changed in arable increasing wind erosion Positive: Minimum tillage prevent soil compaction and increase carbon sequestratiuon in soils
	Romania SouthWest -Oltenia	Olt	ESAI • fragile1-fragile21961-1990 • fragile3-critical22041-2050 Growing Period Days	No significant trends	Change timings of field operations Introducing minimum tillage Increasing percentage of winter crops	Topographical limitations Heavy vertic soils	Higher cost of machinery High yield variability from year to year Training of farmers for using minimum tillage High sensitivity to market prices	Negative: If crop rotations restricts to 1-2 crops If oileed crops area is more than 25% Positive: Minimum tillage prevent soil compaction and increase carbon

			• 60-200d1961-1990 • 100-250d2041-2050 BGI Aridity Index • <501961-1990 • 50-1002041-2050 Rainfall/PET • plain: 0.87 hills:0.94					sequestratiuon in soils
	Romania South – Muntenia	Teleorman	ESAI • fragile1-fragile21961-1990 • fragile32041-2050 Growing Period Days • 80-250d1961-1990 • 100-250d2041-2050 BGI Aridity Index • <501961-1990 • 50-1002041-2050 Rainfall/PET • 0.85	Farm: Shift of timetable for tillage operations Region: increase acreage for winter cereals (wheat, barley) and spring barley	Change timings of field operations Introducing minimum tillage Local irrigation systems Changing cultivar structure Aggregation of small farms in medium and large ones	-	Higher cost of machinery High yield variability from year to year Higher costs of irrigation Training of farmers for using minimum tillage system High sensitivity to market prices	Negative: If crop rotations restricts to 1-2 crops If oileed crops area is more than 25% Positive: Minimum tillage prevent soil compaction and increase carbon sequestratiuon in soils
	Romania West – Banat	Timis	ESAI • fragile2-critical21961 - 1990 • fragile3-critical22041 - 2050 Growing Period Days	Farm: Shift of timetable for tillage operations; Several farms introducing minimum tillage Region: increase acreage for winter cereals (wheat, barley) and spring	Change timings of field operations Introducing minimum tillage Change of cultivar structure	-	Higher cost of machinery High yield variability from year to year Training of farmers for using minimum tillage system	Negative: The falling down of groundwater level Increasing the nitrate pollution of grounwater due to increasing livestock Positive: Positive: Minimum tillage prevent soil

			• 80-200d1961-1990 • 80-150d2041-2050 BGI Aridity Index • <501961-1990 • <502041-2050 Rainfall/PET • 0.922	barley				compaction and increase carbon sequestratiuon in soils
Crop farming dominated by cereal and oilseed	Romania South – Muntenia	Calarasi	ESAI • fragile2-critical21961 - 1990 • fragile3-critical32041 - 2050 Growing Period Days • 120-250d1961-1990 • 150-300d2041-2050 BGI Aridity Index • 50-751961-1990 • 50-752041-2050 Rainfall/PET • 0.77	Farm: Shift of timetable for tillage operations; Aggregation of small farms into larger ones Region: increase acreage for winter cereals (wheat, barley) and spring barley Reducing areas with sunflower due to water shortages vs. Increasing areas ith winter oilseed rape Restarting irrigation systems	Change timings of field operations Introducing minimum tillage Rationale use of irrigation (pumping water uphill not more than 30 m height) Increaseing percentage of winter crops	Field elevation over irrigation water source (Danube)	Higher cost of machinery High yield variability from year to year Higher costs of irrigation up to becoming non profitable from an economic point of view Training of farmers for using minimum tillage system	Negative: If crop rotations restricts to 1-2 crops If oileed crops area is more than 25% Positive: Minimum tillage prevent soil compaction and increase carbon sequestratiuon in soils
	Romania South – Muntenia	Ialomita	ESAI •fragile21961-1990 •fragile22041-2050 Growing Period Days • 200-250d1961-1990 • 250-	Farm: Shift of timetable for tillage operations; Aggregation of small farms into larger ones Region: increase acreage for winter cereals	Change timings of field operations Introducing minimum tillage Rationale use of irrigation (pumping water uphill	Field elevation over irrigation water source (Danube)	Higher cost of machinery High yield variability from year to year Higher costs of irrigation up to becoming non profitable from an	Negative: If crop rotations restricts to 1-2 crops If oileed crops area is more than 25% Positive: Minimum tillage prevent soil compaction and increase carbon

			300d2041-2050 BGI Aridity Index • 30-751961-1990 • 50-752041-2050 Rainfall/PET • 0.754	(wheat, barley) and spring barley Reducing areas with sunflower due to water shortages vs. Increasing areas with winter rape	not more than 30 m height) Introducing minimum tillage		economic point of view Training of farmers for using minimum tillage system	sequestratiuon in soils
	Romania SouthEast – Dobrogea	Constanta	ESAI • fragile2-fragile31961-1990 • fragile2-fragile32041-2050 Growing Period Days • 120-150d1961-1990 • 80-150d2041-2050 BGI Aridity Index • 50-1001961-1990 • 50-1002041-2050 Rainfall/PET • 0.664	Farm: Shift of timetable for tillage operations; Introducing minimum tillage Region: increase acreage for winter cereals (wheat, barley) Reducing areas with sunflower due to water shortages vs. Increasing areas with rape and soya	Change timings of field operations Introducing minimum tillage Change of cultivar structure Forest wind belts Rationale irrigation	Field elevation over irrigation water source (Danube)	Higher cost of machinery High yield variability from year to year Higher costs of irrigation up to becoming non profitable from an economic point of view Training of farmers for using minimum tillage system	Negative: If crop rotations restricts to 1-2 crops If oileed crops area is more than 25% Positive: Minimum tillage prevent soil compaction and increase carbon sequestratiuon in soils
Winter **wheat**	Chernozem zone	Chernozem Centre and Middle Volga Region	HTC (Hydrotermal coefficient by Selianinov) Indexes by Shashko, Procerov	farm: succession croppi ng Regional: including silage maize + barley into crop rotation system National: bare fallowing	improving protective belt systems in the plain areas (for improving snow cover management) improving snow arresting tree belts	ravine/gully systems in topography; water erosion; dry winds; droughts	decreasing frost killing risk; intensified harmfulness of such winter insect pest as chinch bug	adjusting nitrogenous additional fertilizing; improving tillage practice to suppress winter pest population into soil improving biological methods for crop protection
Winter wheat	SouthEast of European part of	Lower Volga& Southern	HTC, Indexes by Shashko, Procerov	farm: fall tillage regional: manures applying, improving	effective snow hedge application	solonetz-like soils, solonetz formation, sands	reducing frost killing risk	optimizing snow hedge dimension and interspaced as well

	Russia	Pre-Ural Region		crop rotation system by introduction of alfalfa				configuration improving irrigation systems
Hard Winter wheat	South of Europea n part of Russia	Northern Caucasus	HTC, Indexes by Shashko, Procerov	farm: application of early spring- and autumnal irrigation, adjusting dozes of fertilizers Regional: bare- and legume fallowing, soil gipsuming	wide use of grasses varieties in crop rotation system, including alfalfa, effective use of wind –break belts	solonetz –like soils and sands, mountains droughts ,dry winds, dust storms, floods, mudflow	droughts	drought tolerant cultivars
Wheat durum	SouthEast Europea n part of Russia	Lower Volga & Southern Pre-Ural Region	HTC, Indexes by Shashko, Procerov	farm: soil loosing in autumn, in-deep tillage, sub-surface plowing, Regional: soil gipsuming, stubble – mulch tillage, use of manures, additional phosphorous fertilization	effective application of wind break belts, afforestation of sands	solonetz-like soils, solonetz formation, sands	droughts, dry winds, dust storms	regulation the height and width of belts, belts configuration, spreading generic composition
Spring wheat	Central Russia	Non-Chernoze m Centre &Volga-Viatka Region	HTC, Indexes by Shashko, Procerov	farm: improving crop rotation system including alternative crops regional: introducing grass arable rotation and meadow grass rotation	improving practice for water erosion protection improving practice for water accumulation into soil	compacted soils, spring drought	reducing frost killing risk	adjusting dozes of fertilizer and timing of farm operations
Winter **barley**	South of Europea n part of Russia	Northern Caucasus	HTC, Indexes by Shashko, Procerov	improving fall tillage and deep plowing, introducing in crop rotation system sunflower	improving bench border irrigation	solonetz –like soils and sands, mountains droughts ,dry winds, dust storms, floods, mudflow	reducing frost killing risk, mudflow	enlarging planted areas introducing new cultivars towards elevations

Spring barley and spring wheat	Chernozem zone	Chernozem Centre &Middle Volga Region	HTC, Indexes by Shashko, Procerov	farm: conservation tillage; soil rolling in the dry spring Regional: earlier sowing dates National: use of drought tolerant cultivars	improving ravine and bully afforestation for soil erosion protection	ravine/gully systems in topography water erosion dry winds droughts	intensify of dry winds and droughts intensified harmfulness of frit fly	use of more drought tolerant cultivars improving biological and chemical methods for crop protection increasing manures efficiency
Crop farming dominated by **maize**	Southern Vojvodina	Southern Backa and Srem		Greater percentage of early cultivars in sowing structure Increase plant density per unit area Quicker adjustment of big farms to adaptation measures Enhance farmers interest for expert advices Insufficient help by government	Use of plant rotation (example: maize sown after cereals) Plant residues incorporation with nitrogen application Decrease of plant density per unit area in dry plant growing systems Judicious use of NPK fertilizers Optimal time and quality of seedbed preparation and sowing	Farmers income Non existence of subventions for plant production Still great density of weeds on arable land Old machinery reduces soil cultivation quality Scarce information of the farmers	Crisis in animal production decreases local corn prices Great variation of income prices increases economical risks Corn is more often devastated by summer drought or hail	More frequent interrow cultivation expedite organic matter mineralization, so there is need for incorporating organic matter under corn Use of corn for ethanol production will change growing technology Farmers cooperation is at very low level Burning of organic matter (increasing CO_2 concentration)
Maize for silage and grain	Chernozem zone	Chernozem Centre &Middle Volga Region	HTC, Indexes by Shashko, Procerov	farm: water conservation tillage Regional: water management afforestation National: more productive cultivars	slope terracing introduction of new hybrids	ravine/gully systems in topography water erosion dry winds droughts	intensified harmfulness of corn bug	adjusting doses of fertilizers
Maize for grain	South of Europea n part of	Northern Caucasus	HTC, Indexes by Shashko, Procerov	deep plowing, application of dozes of fertilizers in	introducing cultivars responded to fertilizers, effective	dry winds, floods, mudflow	floods	introducing new more productive cultivars and hybrids, optimizing

	Russia			optimum, use of perennial grasses in crop rotation systems	application of basin irrigation in costal zone			sprinker irrigation in summer season
Winter **rye**	Central Russia	Non-Chernozem Centre& Volga-Viatka Reg.	HTC, Indexes by Shashko, Procerov	intensification of surface runoff, deep drainage	introducing cultivars more resistant to rots	extra-wetted soils	increasing rotting -out risk	application of entomophages against Agriotes lieatus and Phyelotreta vittuka
	NW Russia	North-West Russia	HTC, Indexes by Shashko, Procerov	farm: improving crop rotation system by introducing perennial grasses, increasing fertilization including manure application Regional: soil liming, different kind of drainage	change in timing of farm operation, adjusting dozes of fertilizers and liming	forest-clad relief, bogginess, low soil fertility, soil acidification	increasing wetting -and rotting out, lodging, pest, diseases and weeds	rye cultivars more resistant to snow mold, application of entomophages
Rice	South of Europea n part of Russia	Northern Caucasus	HTC	rice system cultivation in optimum, adjusting dozes of fertilizers, irrigation rates and timing	improving basin check irrigation, fertilizer irrigation, channel irrigation	solonetz –like soils dust storms, floods, mudflow	intensifying rice diseases	computerized irrigation
Orchard farming	Southwestern Bulgaria (NUTS2)	Jugozapadna Bulgaria	Climatic water balance; precipitation sums; GDD	No trend is observed	Dry resistant cultivars (>2020s) Drip irrigation	topographical limitations, farmer behaviour, legislation bareers	higher costs for machinery; farmer incomes	na

	Southeastern Bulgaria (NUTS2)	Jugoiztochna Bulgaria	Climatic water balance; precipitation sums; GDD	Earlier sowing, harvesting	Dry resistant cultivars (>2020s) Irrigation changes	topographical limitations, farmer behaviour, legislation bareers	change to fodder crops increases flexibility; higher costs for machinery; farmer incomes	na
	Fruška gora	Fruškogorski rejon		farm: regional: plans for regional irrigation system national: more anti-hail nets covers (shade benefits)	Farms (current climate): Adoptation of Integrated Fruits Production Regional (current climate): hail nets	High introducing costs High costs	Less costs for plant protection, nutrition, added value Reduced production risks, more maschinery needed	Negative: / Positive: Enviromental benefits, less water used Negative: / Positive:/
	Bela Crkva	Belocrkvanski rejon		farm: regional: more anti-hail nets covers (shade benefits) national: more anti-hail nets covers (shade benefits)	Farms (current climate): Adoptation of Integrated Fruits Production Regional (current climate): hail nets	High introducing costs High costs	Less costs for plant protection, nutrition, added value Reduced production risks, more maschinery needed	Negative: / Positive: Enviromental benefits, less water used Negative: / Positive:/

	Subotica	Subotick o-horgoški rejon		farm: regional: bare soil system in orchards, moving orchards to less light soils national: more anti-hail nets covers (shade benefits)	Farms (current climate): Adoptation of Integrated Fruits Production Farms (>2008): enhancement of organic contents in soils Regional (current climate): hail nets	High introducing costs Manure needed High costs	Less costs for plant protection, nutrition, added value Benefits only in case of optimal application date Reduced production risks, more maschinery needed	Negative: / Positive: Enviromental benefits, less water used Negative: higher N2O emissions Positive: More stable sand light soils Negative: / Positive:/
	Arilje	Arilje		farm: regional: no response to climatic changes national :	Farms (current climate and beyond): Alternative, earlier species and table cultivars	Undeveloped market	Higher fruits proces	Negative: More intensive cultivation Positive:
Crop farming Dominate d by **vegetables**	Southern Bulgaria (NUTS2)	Jujna Bulgaria	Climatic water balance; precipitation sums; GDD	Earlier sowing, harvesting	Dry resistant cultivars (>2020s) Irrigation changes	topographical limitations, farmer behaviour, legislation bareers	change to fodder crops increases flexibility; higher costs for machinery; farmer incomes	na

	Southern Vojvodina	Southern Backa, Southern Banat		Increase farmers interest for climatic changes Rapid construction and application of irrigation systems Introduction of new plant cultivars Improvement of technical discipline Application of modern pesticides	Introduction of alternative species in the production Greater use of organic fertilizers Judicious use of NPK fertilizers (Nitrogen control) Maintaining good health of plants Good water management	Unreliable incomes Undeveloped refining industry Haotic market coditions Great number of small farms, pulverised production Insufficient number of special machinery Insufficient production of manure	Uncertain placement of agricultural products on market (cabbage, potato) Uncontrolled import of vegetable High farmer dependence from trade sector	Vegetable production is the most intensive production with highest accumulation and financial effects Raised temperatures and irrigation will enhance quality of many vegetable products (tomato, pepper, onion, etc.)
Potatoes	Central Russia	Non-Chernozem Centre Volga-Viatka Region	HTC, Indexes by Shashko, Procerov	use of responded to fertilization cultivars	earlier ripening cultivars	extra-wetted soils	increasing harmfulness of potatoes diseases	cultivars resistant to Erwinia phytophthora Beg and Phytophtora infestanse
	NW Russia	North-West Russia	HTC, Indexes by Shashko, Procerov	improving resistantability of potatoes cultivars to intensifying potatoe diseases	more productive cultivars	forest-clad relief, bogginess, low soil fertility, soil acidification	increasing distribution of insect pests, diseases and weeds, new insect pest acclimatization	more resistant cultivars, application of introduced and aboriginal entomophages

Overall assessment on feasibility of recommended adaptation options.

Based on the observed trends in agroclimatic conditions and crop management practice including results from farmer's questionnaires as well as climate scenarios and expert assessments, the following aspects for feasibility of recommended adaptation options are summarized:

1. There is a number of adaptation options which are considered as low cost and may be implemented within a short-term period: for example, adjustments in timing of farm operations, adapted tillage practice and biological methods for crop protection. Last option is of exclusive importance under climate change. Under the corrected application of these options, they do not damage the environment. Besides, these options may be applied in different agroecological regions.
2. Considerably low cost and short-term are such options as snow rolling, snow piling and snow plowing for regulation of soil climate during cold season. However, they have specific application by regions, and also they are environmentally-friendly options.
3. Adjustments in recommended use of fertilizers may be considered as short- term adaptation options. They are applied to different agroecological conditions. However, under climate change the efficiency of fertilizers may be significantly changed. Meanwhile, incorrect fertilizer application may lead to environmental pollutions, especially watersheds. Moreover, application of several kinds of fertilizers may increase the GHG emission into the atmosphere. At the same time, increasing in costs of fertilizers resuts in adverse effects on volumes of farm production.
4. Adjustments in soil liming and soil gypsuming standards (medium-term adaptation options), obviously influence beneficially the soil fertility and additional yields under climate change.
5. Improvement of crop rotation systems is a long-term adaptation option. This option requires considerable money investments in to seeds, machinery and equipment and human labor. However, the efficiency of this option are expected to be high under climate change in terms of agroecosystems productivity.
6. Application of protective belts and agroforestry as well as windbreaks is rather high cost, because requires transplants and care of plants. However, this option is very effective for application in semiarid regions. At the same time, applying adaptation measure such as snow hedges is low cost.
7. Agricultural land use planning and crop selection are long-term adaptation options, which may be considered as adaptation strategies. They are widely used and require great money investments. Under climate change these options are of exclusive importance.
8. Effective water use in agriculture requires money investments, especially for construction (or modernization) of irrigation systems. However, separate irrigation methods may prove low cost and effective enough.
9. It appears that agricultural insurance development will results in raising the efficiency of farmer's labor in Russia.
10. Application of more ecologically-pure agricultural techniques are increasingly wide implemented in Russia (e.g., application of vermicompost as a manure fertilizer).
11. irrigation
12. minimum tillage
13. changing the cultivar structure
14. Adoptation of Integrated Fruits cultivation
15. Anti- hail nets covers

16. Optimum date and sowing density
17. Changes in soil tillage and in the system of application of NPK nutrients
18. Prevention of fruit damages caused by late spring frost
19. Prevention of sunburns
20. Prevention of trunk injuries caused by extremely low winter temperatures
21. More reliable and accessible weather forecast before or during growing season

4 Climate Change impacts and recommendations on adaptation measures in agriculture – ADAGIO partner countries

4.1 Austria

4.1.1 Abstracts of national case studies carried out during the ADAGIO project

Case study 1 :

Crop adaptation strategies to a possible impact of climate change in north-eastern Austria

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Abstract

Climatic changes in the near future will have an essential influence on current agricultural cropping systems in arid and semi-arid regions. The main objective of this study was to determine the vulnerability and adaptation of major agricultural crops in north-eastern Austria under a changing climate.

The DSSAT model was applied to winter wheat and spring barley of the Marchfeld region, one of the main field crop production areas in Austria, to assess potential yield under different climate scenarios. The scenarios were carried out with ECHAM5, HadCM3 and NCAR PCM global circulation models (GCMs) for present conditions (reference period 1961-1990) and 2035's, based on SRES-A1B emission scenarios. Yield model simulations were simulated for all defined scenarios (climate, management, crop) and different soil classes.

Climate change forces a delay of the sowing date for winter wheat of maximal 16 days in October; whereas for spring barley it allows an earlier sowing date in March (up to 15 days). A warming will decrease the crop-growing duration and a decrease of potential yield of the selected crops can be expected until 2035. Especially on sandy and shallow soils high yield reductions can be notified. Spring barley shows to be more sensitive to climate change as winter wheat with higher yield decrements. Simultaneously, the interannual yield variability of both crops will increase, leading to a higher economic risk for farmers. A replacement of ploughing by minimum tillage and direct drilling would lead to an increase of mean yield for winter wheat (up to 5 % in comparison with ploughed soil) and for spring barely (up to 6 %) in 2035. This effect is mainly a result of improved water supply for the crops and a decrease of unproductive water losses. Compared to current conditions, an optimal irrigation for winter wheat would require between -3 and 33 mm per year (area-weighted average) and for spring barley between 18 and 49 mm per year more water in respect to today.

Case study 2 :

Adaptation options and consequences for vulnerable grassland production areas in Austria (case study region Bucklige Welt, eastern Austria)

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Abstract

Austrian permanent grasslands systems are an important part of Austrian agriculture and comprise 22% of Austrian landuse, often located in alpine regions ehere arable farming is not suitable. Therefore this type of land use contributes significantly to touristc acceptance of landscape functions. The case study region is located eastern of the alps, where grassland production is close to climatological limits and a large gradient of precipitaion ans soil conditions will impact grassland productivity as well as site specific adaptation options significantly.

The hilly region of Lower Austria and Styria at the eastern end of the Austrian Alps, see Fig.1, shows a historical grown, typical land use. Within big areas of coniferous and mixed forests, and farmlands in an elevation range from 300 to 1100 m above mean sea level big areas are used as meadows and pastures. Increasing temperatures and variations in the amount of precipitation during the vegetation period showed a high risk for drought events during the last 2 decades in this region. This case study investigates the regional vulnerability of grasslands due to drought events considering the temperature and precipitation conditions during the vegetation period April to August, the available soil water capacity, terrain slope and aspect. The evaluation shows critical areas and discusses the adaptation possibility to dedicate meadows and pastures to farmland.

. It shows, that from the total area of grassland 37,534 ha already 2,134 ha are critical under present climate conditions. From this critical area 832 ha have a slope > 8 %, which means, that these areas cannot be used as farmland as adaptation method. In future the drought threatened area will increase about 50 % up to 3,017 ha, 1,256 ha of them with a slope above 8 %. Considering the temperature and precipitation conditions during vegetation period the region south-east of Hartberg seems to be most vulnerable, see **Fehler! Verweisquelle konnte nicht gefunden werden.**. However, the slopes are predominant below 8 % as well as the soil water capacity conditions are very good, see **Fehler! Verweisquelle konnte nicht gefunden werden.**. This means, that the potential for the adaptation method – a change from Grassland to farmland – seems to be possible.

Fig.1: Location of the case study region

Case study 3 :

Response of farmers on climate change impact and adaptation options (questionnaire)

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Abstract

In total 72 questionnaires have been handed in, mostly from lower (43) or upper (21) Austria, 5 from Burgenland, and each with one from Carinthia, Styria and Vienna. The farms are distributed over 29 political districts. Most farms are sized 5 to 200 ha, with a peak between 20 and 50 ha. The percentage of irrigated land is shown in question 19. 54 percent of all farms are operated organically.

About 30% each focus on grassland and animal husbandry, agriculture with or without animal husbandry. 18% focus on forestry, the rest is dispersed among viniculture, orchards, vegetables, special cultures and other as biogas and areas of nature conservation.

The predominant soil is middle soil (43%) followed by light soil (31%) and heavy soil (12%).

The predominant terrain on the farms in even (37%) followed by hilly (32%) and a small percentage of steep terrain (4%).

Key Results:

According to the information available to them at the moment, most farmers expect some impacts of the climate change in their region on agricultural production (36%). 29% expect major impacts and only a small minority (6%) expect only slight impacts. Not a single respondent expects no impact at all.

In the face of a possible climate change nearly half (45%) would start with immediate adaptation. 20% would reinforce research, experiments and analysis of adaptation methods and 14% would take other action. 4% would take no action at all.

About a third state that pests (28%) or plant disease (27%) have been a problem for their farm sometimes. 20% often had problems with pests, 5% with plant diseases. 11% never had problems with pests and 15% never had to fight with plant disease.

About half of the respondents (54%) made additional observations on their farm/in the nature in the last years which were caused by altered atmospheric conditions or climate change (e.g. increased soil erosion caused by heavy precipitation).

Persistent snow cover was most damaging to winter barley, winter wheat and rye. The cultures most strongly affected by drought were grassland, summer barley and winter wheat. High temperatures mostly harmed grassland, forest, winter wheat and legumes. Thunderstorms mainly damaged forests. Pests and plant disease caused most damage in forests, legumes, winter wheat and orchards.

Under present conditions 50% would change the soil cultivation because of the expected climate change. 48% would try a new cultivar, 40% would change date in sowing and 37% try new species. 26% would change their pest and disease control, 13% would change fertilization and 13% try other adaptive action. 11% would introduce, enlarge or improve their irrigation and 11% think about abandoning agriculture.

4.1.2 Regional vulnerabilities and reasons

For the detailed regional descriptions see the Tables 1.1 and 1.2 in the Appendix.

1.2.1 Summary description of the most significant identified vulnerabilities of the regions/agroecosystems in Austria

In **Austria,** there are big regional differences within short distances in the type of agricultural production systems (mainly permanent grassland and dairy production, arable crop production and orchard and wine farming) due to the topographical impact of the Alps on regional climate, especially in precipitation and temperature. These facts are also the reason why regional vulnerabilties in agriculture vary in a wide range within Austria. In recent studies it was shown that the more humid and cool alpine regions dominated by permanent grassland would increase their production potential, while the warmer and dryer regions, dominated by arable crop production would face more drought and heat stress during summer, having mostly negative impacts on production potential of summer crops. In this aspect not only the interannual variablitiy of crop yields are expected to increase but also the differences between soils with high and low soil water storage capacity (increasing regional crop yield variability). Grassland dominated regions which currently are close to the climatic limit regarding precipitation and grassland water balance will face signcant increase of production risk due to increasing drought and heat frequency. Regarding other weather extremes, Austrian agriculture is affected in the past years by increasing number of heavy thunderstorms, hail and extreme precipitations. Due to the topographical impact of the alps seveal hot spots of thunderstorm activity are indentified which are in the hilly regions close to the alps (prealpine regions). In several regions the potential damages or production risk in agriculture could therefore increase by more intensive thunderstorms or rainfall (although not yet indicated by climate scenarios). Especially soil erosion could increase significantly through these extremes which needs special consideration in order to maintain long term soil productivity (based on soil functions and fertility). An overview of the most vulnerable regions is shown in Fig. 1.1.

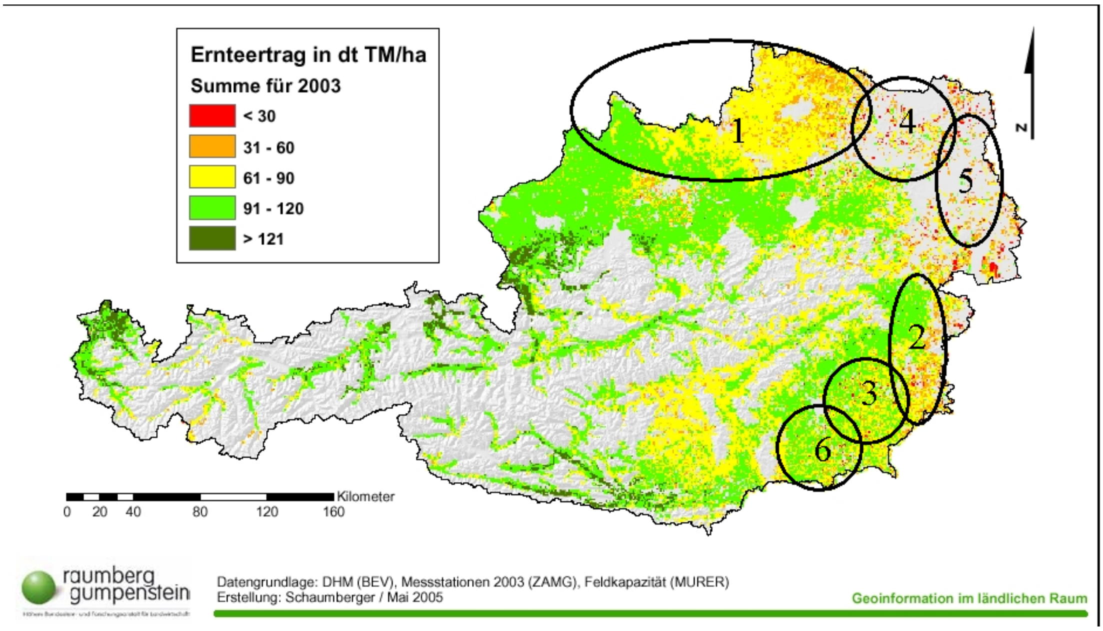

Fig. 1.1. Location of main vulnerable agroecosystem regions in Austria as identified by ADAGIO (shown on a map with simulated drought damages in Austrian grasslands in the drought year of 2003). For numbers refer to Table 1.1

Detailed regional aspects on identified main vulnerable agroecosystems in Austria can be described as follows:

• Several studies report under climate scenarios increasing temperatures and increasing heat waves for the main agricultural production areas in Austria, which leads to a further drying trend and increasing risks for summer droughts.

• There is a severe shift of temperature zones or agroecological zones under climate scenarios, where all Austrian regions will be affected. The increase of mean temperatures will accelerate phenological development of plants and increase the length of the vegetation period of about 8-10 days per decade. This will affect production potential of different crops in a different way depending on the climatic region. For example, there will be an increase of production potential in the more humid and cool grassland regions, whereas without adaptation in arable regions with water limitation a decrease of crop production potential can be expected especially for summer crops. Also frost damage potential could increase for orchards due to earlier growing periods in spring.

• Especially summer crops will suffer due to increasing dry conditions (in combination with heat stress) in the main arable regions of Austria. Water demand for crops will increase especially due to higher evaporation rates, leading also to higher water demand for irrigated crops (vegetables, maize, potatoes, sugar beet) and/or increasing costs for production. For specific alternatives, depending on high biomass production such as bioenergy crops, this could be an increasing problem for the future. This will especially be important for the most vulnerable ADAGIO regions 1,2, 4 and 5 (Fig.1.1).

• There will be more field work days during summer, however, there is also a shift of timing of field work together with phenological shifts. Especially harvest conditions could be improved but field work in spring would be more difficult in some cases because of expected higher soil wetness in early spring due du higher precipitation during the winter/spring period.

• The direct CO2 effect compensates partly negative indirect climate change effect on crops (e.g. faster crop development), leading to slight increase of mean yields for winter cereals till the 2050s if sowing dates are adapted. However, for summer crops increasing drougth stress and slightly decreasing yield can be expected as shown for the study region 5 (Fig.1.1) Marchfeld. The results also indicate that spatial (due to variation of soil water storage capacity) and internnual crop yield varibility will increase. A further increase of temperatures would lead to decreasing yields without further adaptation measures.

• Increasing mean temperatures lead to an increasing frequency of heat waves. This can trigger other stresses such as from tropospheric ozone or UV-radiation, which were already reported for that regions.

• A future increase of weather extremes (except higher frequency of drought and heat, partly heavy precipitation) is still speculative in many regions of Austria, and statistically not confirmed yet. However, if extreme events such as hail, storm frequency or heavy precipitations will increase it would have a high damage potential for crop production (e.g. hail, soil erosion, storm damages).

• Increasing mean temperatures will change niches for pests and diseases and weeds. There are reported several past trends of increasing activity and spatial distribution of pests such as for the European corn borer (Maize) and others. There are already also observed new weeds, which are not considered yet as a main problem however.

• Small and large scale regional differences in production potential are clearly increasing due to the impact of local soil water storage capacity and available water reserves. Sites with low water reserves or sandy soils will loose production potential or increase production risk.

• Grassland dominated regions near a critical limit of summer water balance would suffer by the ongoing drying trend significantly by a reduction of grassland production potential, with severe effects on bovine and dairy production. Especially regions in northern and eastern Austria were identified as most vulnerable due to their climatic water balance under the climatic scenarios, soil conditions and terrain (represented by th ADAGIO regions 1 and 2 in Fig. 1.1). Fig. 1.2 shows an assessment of an agroclimatic model on the increasing risk for grassland production by increasing negative summer water balance under climatic scenarios. It is shown that relatively large areas are affected, although many of them are mixed grassland and crop production areas. Another risk by warming for all grassland regions are increasing damages by pests (especially earthworm) and heat stress damages. Long term effects are changes in grassland composition leading potentially to decreasing fodder quality.

• In animal production heat sensitive animals such as pigs and poultries will suffer from more heat stress, leading to lower production or death. Especially in stables, depending on cooling systems and power availability the risk will increase during heat waves, where also power security can be reduced. Higher production costs may result from rising interannual crop yield variability and costs for higher fodder storage capacity.

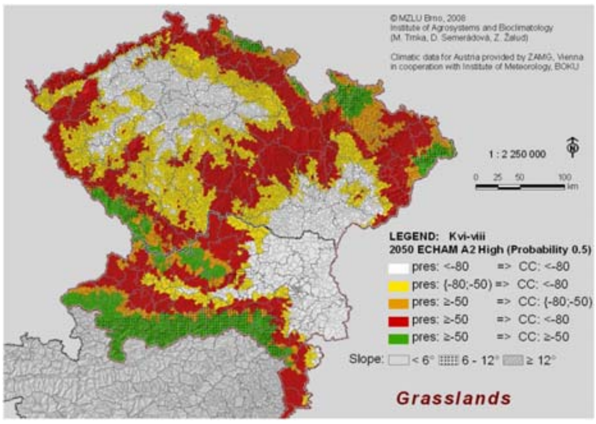

Fig. 1.2. Increasing risk of grassland production in Austrian and Czech Republic grassland dominated areas by increasing dry summer conditions (red color represent areas which are not anymore suitable for grassland production according to current conditions under the ECHAM scenario for the 2050s).

• For permanent crops such as vineyards and orchards (main vulnerable regions in Austria are regions 3 and 4 in Fig. 1.1) only expert assessments are available on regional vulnerabilities. In general experts expect an increasing risk from pests (especially thermophile insects) and diseases, by accelerated developing cycles or the fast spreading of new climatic sensitive pests or diseases. Also increasing soil erosion will be a problem in some hilly regions if heavy precipitation events may increase (whereas the uncertainty of regional models is still high).

Increasing risk of frost damages for orchards especially during flowering can be expected according to agroclimatic models, especially due to earlier growing seasons. In the long term shifts in cultivars are expected driven from local changing wine quality paramters (from white to red wine cultivars, or new wine growing regions).

4.1.3 Feasible and recommended adaptation options

For the detailed regional descriptions see the Table 1.3 in the Appendix.

4.1.3.1. National Overview of the identified most feasible adaptation options of the regions/agroecosystems in Austria

Austria covers a wide range of climates ranging from cool and humid (e.g. alpine region) to warm and semiarid/humid (mostly lowland areas) of the transition of continental type to atlantic and to mediterranean type of climate. Potential adaptation options of the relevant agroecosystems are affected by these conditions significantly, beyond the structural problems of dominating small farm sizes in Austria.

All main arable **crop production** regions are affected by increasing drought conditions and water shortage during the summer period, which leads to several recommended adaptation options regarding the protection and efficient use of the agricultural water resources.

Agricultural grasslands (in combination with dairy farming) in regions below approximately 800 mm annual precipitation were shown as most vulnerable to the warming trend, which comprise relatively large regions, especially north, south and east of the Alps. Because of the fact that grassland production systems are much less flexible than arable farming systems regarding to a change in production techniques it is considered as the most critical sector and emphasis has to be paid on developing feasible adaptation options. For example, for regions, where a change to crop production or other alternatives by changing land use is difficult due to terrain or soil conditions, there are only few potential adaptation options possible for farming alternatives.

Perennial cropping systems, such as orchards and vineyards, will be probably mostly affected by changed pest and disease occurrence, which leads to the conclusion that adaptation measures should focus on this topic. Also adaptation options to avoid soil erosion and to improve crop management are a critical frequently reported issue for perennial crops.

Adaptation options to climate change mostly recommended in Austria are:

In the short term:

- Soil water conservation techniques (mulching, reduced and minimum tillage)
- Improving irrigation scheduling (e.g. by using agrometeorological stations)
- Change to heat tolerant cultivars
- Change cultivars and crops according temperature demands
- Change sowing date and shift timing of field works
- Improving and introducing monitoring systems for pest and diseases
- Adaptation in crop rotation (e.g. more winter crops)
- Ensure frost protection methods (and for hail in some regions)
- Effective insurance system including grasslands (ideally supported by government)
- Adapting animal stables for heat waves, ensuring power generation and increasing hygienic measures for farm food production (e.g. milk production)

In the midterm:

- Improving or establishing irrigation infrastructure and regional water resource management
- Breeding of adapted cultivars (e.g. for higher water use efficiency and heat stress)
- Increasing crop diversification (farm and regional scale)
- Increasing storage capacities (fodder storage)
- Change of production system (e.g. cereals to maize, grassland to vineyards, grassland or crops to energy biomass production)
- Landscape structure improvements for reducing evapotranspiration (by lowering the wind speed, in some flat semi-arid regions)
- To ensure higher market price stability for agricultural products (which significantly can improve sustainable planning and implementation of adaptation options) by using appropriate tools (e.g. political measures, ecological farming, establishing regional food production and local markets, develop marketing concepts, such as "terroir" characteristics for wine quality aspects).

Mostly named limitations of adaptation options, related to socio-economic conditions are structural changes, which are mainly driven by economic reasons rather than by climatic ones. Among these are too small farm sizes or complex terrain limitations and high production costs . Too low income at small farms (esp. related to family business) leads to abandoning small farms or reduction of agricultural used land. Farmers of small farms are often also less educated in agricultural production (often part time depending on other incomes) leading to a decreasing success or interest in farming.
The adaptive capacity of small farms seems to be better in well developed regions, where already many small farms could successfully change to ecological production or alternatives and niches.

Other limitations are too high costs of certain adaptation options, terrain and soil restrictions, no (or still no) market for the specific product. Market price uncertainties lead to increasing risks for sustainable implementation of adaptation measures; especially those which are related to investments (e.g. change of land use or production system). In several cases labour and time pressures are also limiting the implementation of adaptation options (such as a change to ecological farming in Austria).

4.1.3.2 Selected most important and feasible adaptation options at the farm level in Austria (detailed)

4.1.3.2.1. Improving water use efficiency in crop irrigation scheduling and methods

Time of implementation: 3-10 years
Application level: farmers, policy level

In Austria irrigation is applied in specific for summer crops (vegetables, mais, sugar beet, potato, etc.) especially in the north-western part with intensive crop production. Prevailing irrigation methods concern sprinkler irrigation, and water resources used mostly from groundwater, which mainly were still ample during the past decades. There are no charged costs for groundwater pumping and water rights are traditionally fixed (numer of wells), so costs for irrigation are energy, irrigation system and labour. Especially irrigation scheduling is oriented to available labour, but not directed to optimized water demand of crops, so water demand for irrigation is relatively high with low water use efficiency. No specific methods such as deficit irrigation are applied widely. For adaptation directed to a better water use efficiency in crop irrigation, sprinkler irrigation is recommended where applicable (esp.

orchards). Also timing of sprinkler irrigation could be better planned in order to minimize unproductive water losses (e.g. irrigation during night instead during daytime with more wind). Further, supporting scheduling techniques such as agrometeorological weather stations for estimating crop water stress should be introduced widely. However, the main hamper to introduce water saving methods are that costs-return are too low for the single farmer, which is probably difficult as long as there are no higher water costs. A long term planning and measures at the policy level should be introduced in order to be able to manage water distibution and availability for upcoming heavy droughts in the future, where water resources could be limited significantly for agriculture in some regions in Austria.

4.1.3.2.2. Adaptation of soil cultivation by using soil water conservation techniques

Time of implementation: 1-5 years
Application level: farmers

Primary soil cultivation of arable land is dominated by plouhing in Austria. Especially in the dry regions (e.g. north-east of Austria) during the past decades during droughts at ploughed soils drought occured faster with negative effects on crop yield. There is a trend in Austria to direct drilling and reduced soil cultivation, mainly caused by saving of costs (energy) for soil cultivation. Also soil surface mulching is increasingly applied, especially in organic farming. However, there is still a big potential to limit open soil surfaces and unproductive water losses, especially for the second half of the year (after harvest of the main crops). Innovative techniques such as adapted crop rotations and the use of intermediate crops with low water consumption are recommended, but should be applied using the Know How of local experience.

4.1.3.2.3. Adaptation of landscape structure for optimization of local climatic conditions by indroducing hedgerows

Time of implementation: 5-20 years
Application level: farmers, policy level

Hedgerows can have multiple effectes of local climatic conditions, which can improve growing conditions of neighbouring crops significantly, especially in dry and windy regions (by reduction of potential evapotranspiration, enhancing humidity and the water storage potantial of a landscape). In Austria, hedgerows were introduced especially as windbreaks in the north-eastern part of Austria during the 1960s in order to mitigate soil wind erosion. However, during the past decades the function of reduced unproductive evaporation became more important and visible due to the agrometeorological drying trend in that region. For this effect, however, the current windbreaks do have to large distances, so that there is a potential to adapt by introducing new hedgerows. Hedegrows however, will change the landscape picture and also need area, which is lost for crop production. However, the positve effects can outrange the areal loss during the next decades as reported from studies. Moreover, intelligent solutions could have a potential such as using productive and tall energy crops as hedgerows and others. In that field especially the policies such support such landscape adaptations, although local evaluation of the multiple effects and social acceptance is strongly needed.

4.1.3.2.4. To limit risk of interannual variation of fodder production in dairy/grassland farming (mix of measures)
Time of implementation: 1-15 years
Application level: farmers, policy level

Due to the expected increase of summer drought in large grassland regions in Austria a decline of the average yield potential and increase of interannual yield variabiltiy is expected in regions around or below 800mm of precipiatation. Especially regions with soils of low water storage capacity are effected, such as the highlands nord of the Danube, or regions in the eastern part of Austria. Recommended adaptation options to minimize the risk of decreasing fodder production for dairy farming concern several measures. The most important option is the change to arable fodder production, where soil and terrain allows. This measure, however, should be minimized due to the effect of decreasing soil carbon stocks with negative consequences for soil structure and mitigation. Several fodder crops such as legumes or cereals could be a good alternative, but care should be taken by a replication with maize production. However, as in many grassland regions the yield potential especially for maize strongly could increase due to the warming trend, the policy level should introduce measures to limit that trend with negative consequences for sustainable production (especially due to soil erosion and negative effects on soil organic carbon and soil structure).
Other recommended actions are, where economically feasible, a more extensive production or increasing of available area per unit of animal. A change to organic farming would help in this context significantly. Other measures contain the increase of fodder storage capacity in order to bridge temporal yield losses from permanent grassland. All these adapataion options have to be evaluated in detail be regional experts in order to meet the variable spatial natural and socio-economic conditions.

4.1.3.2.5 To introduce soil erosion protection measures in hilly terrain (mix of measures)
Time of implementation: 1-5 years
Application level: farmers

Mean soil erosion could increase under climate scenarios, as obvious from the trend during the past decades of regional increasing heavy precipitation, due to warmer winters and increasing duration and amount of winter rains in many Austrian arable regions. Here practically all regions in Austria are affected, but especially those in hilly terrain, where measures against soil erosion should increasingly implemented in order to avoid long term negative effects on the soil production potential and soil fertility. Measures should in general minimize (spatially and temporally) open soil surfaces during all the year. These include a closed crop rotation and different types of mulching. Further the soil structure should be stabilized or improved by organic input (e.g. legume crops), avoiding soil compaction or too intensive soil cultivation (plough). Finally, landscape structures such as hedgerows and strips of uncultivated soil horizontal to the vertical slopes can help significantly to brake soil erosion and avoid fertil soil losses. In orchards and vineyards mulches should protect soils, especially in hilly terrain as mostly vineyard strips are parallel to vertical slopes. Soil cultivation should be done in the horizontal where the terrain allows (contour soil cultivation or terrasses).
Most measures in order to avoid soil erosion can be implemented relatively easily and are cost effective and are strongly economic in the long term due to avoiding irreversible losses of soil production potential.

4.1.4 Scientific basis of ADAGIO results

4.1.4.1 List of all literature used for national ADAGIO purposes, analysis etc. (national and international)

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4.1.5 List of scientific ADAGIO publications

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4.1.5.1 List of not yet published (manuscript status) scientific ADAGIO related publications (national or international).

See under 4.5.2. and 5.5.2

4.1.5.2 List of published or not yet published (manuscript status) ADAGIO results specific designed for national farmers or stakeholders

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Eitzinger, J., Thaler, S., Kubu, G., Rischbeck, P., Formayer, H. (2008): Potentielle Auswirkungen und Anpassungsmaßnahmen der Landwirtschaft an den Klimawandel im Nordosten Östereichs (Weinviertel-Marchfeld region); (Potential impacts and adaptation options to climate change in agriculture in north-eastern Austria) In: Auswirkungen des Klimawandels in Niederösterreich (NÖ-Klimastudie 2007). Amt der Niederösterreichischen Landesregierung, 356.

Eitzinger, J., Kersebaum, K. C., Formayer, H. (2009): Landwirtschaft im Klimawandel - Auswirkungen und Anpassungsstrategien für die Land- und Forstwirtschaft in Mitteleuropa. (Agriculture and Climate Change – Impacts and adaptation strategies for agriculture and forestry in Central Europe). http://de.agrimedia.com, 320, Agrimedia, D-29459 Clenze, Deutschland; ISBN: 978-3-86037-378-1, 320pp.

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Eitzinger, J., Thaler, S., Kubu, G., Trnka, M., Alexandrov, V. (2009): Der Klimawandel, seine absehbaren Folgen für die Landwirtschaft in Oberösterreich und Anpassungsstrategien. (Climate Change and consequences for agriculture in Upper Austria, and recommended adaptation options). Amt der OÖ Landesregierung, 60

Eitzinger, J., Heilig, M. (2009): Klima und Witterung - ein komplexes Thema. In: Weidenweber, Ch. (Hrsg.), Klimawandel - Nutzen und Risiko für den Hausgarten; (Climate Change – chance and risk for the house garden) Reihe: Gartenzeit Spezial, 120; av-Buch, Wien; ISBN 978-3-7040-2355-1

Klik, A.; Eitzinger, J.; Liebhard, P. (2009): Welche Anpassungen der derzeitigen Erosionschutzmaßnahmen sind unter den Bedingungen des Klimawandels zu empfehlen?. (Which adaptations of soil erosion protection measures can be recommended unter conditions of climate change?) StartClim2008, 40

4.1.5.3 Other national public relation activities (e.g. lectures, farmer meetings, articles in newspapers), use the updated table below, for ALL ADAGIO period

Listed in the Thematic Group 4 report

4.2 Spain

4.2.1 Abstracts of national case studies carried out during the ADAGIO project

Case study 1 :

Evaluating crop management options in the Spanish cereal production under climate change conditions (Questionnare for stakeholders)

Angel Utset
ITACyL, Valladolid, Spain

Abstract
A survey was applied to Castilla y Leon farmers in the framework of ADAGIO. The survey was designed to know directly from farmers the following items:

1. Knowledge level regarding Climate Change from both, global and local point of views
2. Already-observed Climate risks on local agricultural production.
3. Agricultural risks of the expected Climate Change for Castilla y Leon
4. Willingness to adopt the already-identified Climate-Change adaptation measures.
5. European, National and regional regulations that could encourage or limit the adoption of Climate-Change adaptation options.

The Castilla y Leon Union of Cooperatives (URCACyL) was used as platform for farmer contacts. The URCACyL journal reaches to more than 40 000 subscribed farmers in Castilla y León. The survey was answered by about 0.1% of the URCACyL farmers, which represents similar sample size than other successful studies and the participants in similar environmental initiatives.

As average, half of the farm areas in the consulted sample are dedicated to rainfed wheat and barley. Moreover, irrigated barley and wheat meant about 10% of the average land use of the farms. Vineyards meant, as average, 20% of the farmer answers. Similar percents represent irrigated crops as alfalfa, potato, vegetables, maize and sugarbeet. The 65% of the consulted farmers were from 35 to 60 years old. The 17% were younger and 13% older than 60. Furthermore, 56% of the consulted farmers have bachelor educational level, or higher.

Our results indicate that educated and young farmers are the most worried people about Climate Change consequences in Castilla y Leon agriculture. Furthermore, even though the percent of vineyards and irrigated crops is small, compared to the total regional land use, a large percent of irrigated and vineyard farms are concerned about climate risks.

The farmers were asked about the Climate Change effects in their farms. A 39% percent of them think there will be “Strong” effects. Same percent considers there will be “Considerable” effects. The 22% of the farmers expects “Some” effects. None of the consulted farmers think that Climate Change will bring “no effect” to Castilla y Leon agriculture.

The increment of pests and diseases is the worse climate risk identified by the regional farmers. Moreover, a large percent of the Castilla y Leon farmers are willing to change their pests and diseases management, according to Climate change conditions. Hence, pest and diseases risks must be considered in a primary place while starting a Climate-Change adaptation process in the regional agriculture. However, the importance of this issue in the farmer responses could be related to the current invasion of *Microtus arvalis* to the Castilla y Leon fields, connected to the uncommon conditions of the 2006-2007 winter, rather than to a global perception of this climate risk.

Droughts and less precipitation are important constraints to present and future agriculture, according to Castilla y Leon farmers. Nevertheless, it is perceived as a climate risk mainly in

rainfed crops, as barley and wheat. Farmers do not consider changes in irrigation as a practical Climate Change adaptation option. However, irrigated agriculture in the region could be very vulnerable to Climate Change, as has been pointed out in many papers. Therefore, an important effort must be made to prepare farmers dealing with irrigated crops on this potential risk, since they are not aware about it yet.
Besides water issues, Castilla y León farmers consider that temperature rising and heat waves are present climate risks that might be higher in the future. However, they are more willing to introduce new varieties, able to cope with Climate Change risks, than to change land use or seeding and harvest dates. This could be due to practical issues, but contradicts previous assessments that indicated those simple management changes as the most suitable Climate-Change adaptation options. Consequently, a participatory process aimed to introduce Climate-change adaptation options in Castilla y Leon agriculture must take in account current varieties and the potential breeding tasks, instead of only simple management changes.

4.2.2 Regional vulnerabilities and reasons

For the detailed regional descriptions see the Tables 2.1 and 2.2 in the Appendix.

4.2.2.1 Summary description of the most significant identified vulnerabilities of the regions/agroecosystems in Spain

As pointed out already, most of the Spanish agricultural decisions, from the governmental point of view, rely on the regional administrations (Autonomic communities) rather than on the central government. However, some other competences, as water use control, rely on the central administration at Madrid. There have been some changes recently, due to the reforms of several Autonomic Communities Statutes, which makes more complex to lie with the agricultural regulations at the country level. Therefore, we have focused on Castilla y León, the biggest Spanish Autonomic Community rather than on the whole Spain. Castilla y León comprises 94 000 km^2 and it is the most important Spanish producers of cereals, maize, potatoes and several other crops. Furthermore, we have focused on crop agriculture mainly.
Accordingly, taking into account the main crops in Castilla y Leon, the Table 1 has been reduced.
According to the Papadakis agroclimatic classification, most of the Castilla y Leon area corresponds to Mediterranean Template, combining cold winters with dry hot summers. Crop season is constrained to the summer months, due to regular freezes between October and March. Only 16% of total rainfall corresponds to the summer agricultural period. Hence, water availability is a serious constraint for summer crops.
About 9% of the Castilla y Leon population lives from agriculture. This percent is higher than the national and almost three times the European mean. Population density in Castilla y Leon is three times lower than the Spanish mean and five times lower than the European mean. Rural population density is half of the regional mean. Despite of the low population and the climatic constraints; the Castilla y Leon crop production means 40% barley, 32% wheat, 57% sugarbeet, 38% maize and 30% potatoes of Spanish total. Besides, Castilla y Leon comprises 27% of Spanish pastures and the second most famous Spanish wine production.
Climate Change effects will posses new constraints on Castilla y Leon agriculture, as have been estimated from several assessments. Increment in the irrigation requirements and less available water could be expected. Besides, cereal cropping might be damaged by heat and water stresses in the spring, as well as vernalisation changes due to temperature increments in the winter. Moreover, high temperatures could significantly reduce wine quality. The existing assessments provide also several short term adaptation options for agriculture as changing harvest and seeding dates, as well as land use. However, those up-bottom assessments are not

enough to implement such options within the farmer's community. Therefore, a bottom-up approach has been followed, assuming that Climate Change adaptation-measures can be effectively taken only by combining physical vulnerability assessments with social issues.
The current policies regarding Climate Change and agriculture, as the CAP and others, must be divulgated adequately within the farmer community. Besides, demonstration activities dealing with the possibilities of RDF and other specific subventions, as bioenergetic crops, must be conducted in order to inform farmers about them. Demonstration activities aimed to the implementation of conservation tillage and new water-saving irrigation practices, related to RDF subventions, would be well received by Castilla y Leon farmers.
A relative large percent of farmers would quit their land if the climate risks increment in the future. They are mainly aged people, but some young people agree also to abandon the farm. This disappointing answer is related to the Castilla y Leon depopulation, particularly in the countryside. It means that any action aimed to introduce Climate-Change adaptation option in the regional agriculture must deal with the actual social issues, through a participative process. Such process must drive hope to farmers regarding the future of the Castilla y Leon agriculture, instead of creating alarm or fears.

4.2.3 Feasible and recommended adaptation options in Spain

Summary
We have identified several discrepancies between the available up-bottom assessments of Climate Change impacts on Castilla y León agriculture and what the farmers think about it. This could be a serious limitation to introduce potential CC adaptation options. Furthermore, farmers have pointed out their particular interests regarding CC adaptation options. Therefore, information and particularly demonstration activities must be carried out, in a participative way, in order to bring the results of CC vulnerability assessments to the farmers practice. The obtained result will point out which are the target areas where such information-demonstration activities should be carried out. The "users" of this result will be the regional authorities (i.e. Junta de Castilla y León), as well as farmer' organizations as URCACyL. On the other hand, despite of its regional character, several regularities could be found with other Mediterranean or European regions.
Climate change would bring higher temperatures and fewer precipitations to Spain. Therefore, water-use planning is a very important issue at the national and regional levels. The result provides estimations of crop water requirements for three periods of the century, considering several GCM and emission scenarios; as well as potential CO_2 effect on reducing crop transpiration. The analysis is specifically focused on current irrigation designs. The Spanish irrigation modernisation involves a large investment to be amortized in more than 50 years. Current irrigation designs do not take in account the potential ETo changes due to CC. The result towards on this issue, hence it could be used as a guideline in future irrigation designs.

4.2.4 List of references

4.2.4.1 List of <u>scientific</u> ADAGIO publications (which include ADAGIO results). It means: ADAGIO related results which were published <u>during</u> the AGAIO project.

Utset, A., Del Rio, B. 2008. La agricultura de Castilla y León frente al cambio climático: un proceso participativo de adaptación. Innovación y Tecnología Agroalimentaria, 3:18-35.

Utset, A., Del Rio, B., Eitzinger, J. 2009. ¿Están preparados los regadíos modernizados para enfrentar el reto del Cambio Climático en España?. Proceedings of the XXVII Congress of Spanish Association of Irrigation and Drainage (AERYD), 59-60

4.3 Bulgaria

4.3.1 Abstracts of national case studies carried out during the ADAGIO project

<u>Case study 1:</u>

Adaptation in agriculture (focused on irrigation) – a survey

Vesselin Alexandrov, Sevda Vrachovska, Avram Avramov, Elissaveta Trapcheva, Valentina Stamenova

Abstract

Measures for improving irrigation under climate changes:

- improvement of management, use and protection of water resources in irrigated agriculture;
- improving the efficiency of the management and use of the existing irrigation facilities and elaboration of the technological and technical facilities for irrigation;
- use of rational and economically sound irrigation regimes for the irrigated crops and elaboration of the technologies for cultivation of crops in the conditions of droughts and water deficit.

Measures for improve management, use and protection of water resources in irrigated agriculture:

- establishing the impact of climate changes and drought on the quantity and quality of water resources used in irrigated agriculture;
- assessing the needs of water for irrigation of agricultural crops under climate changes and preparing long term projections for the required water resources to be used in agriculture
- Work is going on in various institutions
- Numerical experiments to determine the optimal dates and water quantity for irrigation of the maize for various climate scenarios are carried out in NIMH, using computer system for agrotechnological decision taking DSSAT. The calculations are taken in regard to biophysical and economic analysis of the final yield and the received profit from the maize
- During limited precipitation in summer, irrigation facilities must be used, oriented towards design and operation of irrigation facilities, which use water resources in an economical way and have very low water transportation losses during irrigation.
- Gravitee feed irrigation and flooding of beds and rice fields should be used as a last resort, only when proven to be effective.
- Main and distribution canals of old irrigation systems must be coated to bring to minimum losses from filtration. Permanent canals in irrigation systems must be afforested on sufferance strips to utilize filtered water and to cover them aiming at the reduction of the physical evaporation from water surface in the canals

Adaptation measures to improve management efficiency and use of existing irrigation systems and elaboration of technological and technical means for irrigation:

- To prepare up-to-date strategy and new program for the rehabilitation and restructuring of irrigation management and improving the efficiency of use of the existing irrigation infrastructure;
- To change legislation and regulation in the irrigation sector taking into consideration the altered agricultural conditions, the experience from the reforms carried out so far and to ask for free use of the technologically established hydromeliorative infrastructure and service facilities on the territory of the associations;
- To implement proper educational and training programs with emphasis on major issues on the involvement of users of water and the general public on drought problems;
- Preparation of information materials for water users on the benefits and good practices of agricultural crop irrigation.

Adaptation measures for use of rational and economically viable irrigation regimes:

- Determining the vulnerability of agricultural crops under climate changes, long term droughts and water deficit in the major agroclimatic regions in the country, respectively their impact on the quantity and quality of the yield from them;
- Reassessment of the water and irrigation norms and legislative provisions of irrigation, new zoning for the irrigated crops in the country;
- Development and application of optimized irrigation regimes for the major agricultural crops for various agroclimatic regions in the country;
- Research on the effect from irrigation and sustainability of yields under various water saving methods and irrigation technologies;
- Creation and application of mineral fertilization systems and integrated weed fight during cultivation of agricultural crops under irrigation conditions;
- Application of proper moisture preserving technologies and techniques for soil treatment in irrigated lands;
- Adaptation and introduction in practice of information and advisory system for irrigation necessity forecast and defining the parameters of the irrigation regime for the irrigated crops;
- Technology changes for irrigated crop cultivation in various agroclimatic regions under water shortage conditions;
- Use of new cultivars and hybrids that adapt better to water deficit.

Case study 2:

Questionnaire on adaptation options

Vesselin Alexandrov, Sevda Vrachovska, Avram Avramov, Elissaveta Trapcheva, Valentina Stamenova

Abstract

The following questions were included:
1. Is there climate change in Bulgaria during the last years?
2. Do you think that more extreme natural phenomena as droughts, storms, intense precipitations, floods, landslides, forest fires, etc. are being watched in Bulgaria in the last years?

4. Are you convinced that the Bulgarian agriculture should be adapted to the contemporary meteorologic conditions (with increased tendency to extreme situations) as well as to the expected climatic conditions in the country during the 21st century (warming and summer precipitation reductions)?
5. Do you have impression what information is needed to analyze and offer measures for adaptation of the Bulgarian agriculture to climate change?
6. Please mark the correct (according to you) answers and try to comment the following adaptation measures of agriculture under climate change in Bulgaria:
6.1. new zoning of agroclimatic resources:
6.2. raising the upper limit of agricultural production from 800 to 1000 m a.s.l. due to warming also in the high elevations:
6.3. developing land management practices to adapt to changes in soil properties:
6.4 restoring natural features such as hedgerows to help reduce erosion:
6.5. adopt measures to reduce the impacts of extreme precipitation events:
6.6. introduce measures to secure safety of livestock during extreme flooding events:
6.7. changes in technology for yield harvesting, transportation and conservation under summer drought conditions:
6.8. transfer of technologies from relevant climatic zones:
6.9. introduction of new crops that adapted to higher temperatures:
6.10. develop breeds or change to breeds adapted to changed conditions, especially drought and heat resistant varieties:
6.11. changes in sowing dates:
6.12. increase in irrigation area and or water volume:
6.13. introduction of new management techniques e.g. requiring less water:
6.14. adopt water re-use technology:
6.15. changes in fertilizer use:
6.16. develop farming practices that minimize susceptibility to new pests and diseases:
6.17. maximizing effectiveness of labor and machinery:
7. Do you think that some of the above-mentioned adaptation measures would cause the necessity for monitoring of environmental changes, e.g. changes in biodiversity?
8. Is it necessary to develop an information system (e.g. by engaging internet, media, lectures, courses, etc.) related to climate variability and change and their impact on agriculture?
9. Who should provide funds in order to apply adaptation measures of agriculture under climate change in Bulgaria?

Major findings are:

• Targeted studies are needed

Studies carried out are related to farming systems that reduce the risk of soil erosion. Partial measures are taken occasionally. The problem requires a complex multi-disciplinary approach to solving it. Most of the measures are considered or planned in the country, but for economic reasons do not apply. If it is considered that some areas are vulnerable, probably monitoring should be used. The majority do not have info on a new zoning of agroclimatic resources, but assume it is extremely necessary. Modern mapping options will make this information more accessible and usable.

It must be taken into account both the soil and climatic conditions before making a recommendation. In some cases, soil characteristics will be limitation to such a measure

In our practice of irrigation is in desperate condition because of lack of consistent policy in this regard over the last 20 years.

Research in the country and abroad are on the level of practical implementation methods for increasing efficiency in irrigation, reducing water losses. And discussed in detail in

publications, including dissertations and international scientific journals and popular magazines. In general practice most commonly observed in most irrigation vandal way
• There are technologies developed for re-use of wastewater for irrigation
• There is a possibility to implement models for fertilization, consistent with agrochemical characteristics of soil and crop requirements; at a research stage of the Institute of Soil Science, etc.
•Information support system to provide daily information to farmers on evapotranspiration reference for precise irrigation system adapted to the technology of irrigation, soil properties, etc. Will increasingly pose problems related to additional payments in agriculture and due to unfavorable weather conditions. Must have available information on agro-environmental resources and indicators of adverse climatic events, the impact on agriculture and possible adaptation measures.
•It is necessary to conduct regular discussions between politicians and a society of scientists as well as technocrats, because the researchers have the knowledge to developed specific measures to adapt agriculture to climate change.The state is willing to implement adaptation measures in agriculture, as it involves not only the development of this sector in the country, but also the protection of nature as a whole, because the risk of desertification.

Case study 3:

A strategy evaluation of irrigation management of maize crop under climate change in Bulgaria

Vesselin Alexandrov, Sevda Vrachovska, Avram Avramov, Elissaveta Trapcheva, Valentina Stamenova

Abstract
Adaptation to a changing climate will occur in several forms, including for example technical innovations, changes in agricultural land areas, and changes in use of irrigation.
The greatest part of the national maize production is concentrated in the areas with elevation below 800 m. Besides, the most of global circulation models (GCMs) are with smoothed orographic features. That is why, 21 experimental crop variety stations in Bulgaria with elevation below 800 m were selected for the simulation study. Meteorological and agrometeorological data from the above-mentioned stations were gathered from 1971 to 1995. The 30-year baseline climate data were based in this study on the period 1961-1990, recommended by the World Meteorological Organization (WMO). Several climate change scenarios were created by changing observed data from the current climate (1961-1990) according to doubled CO_2 simulations of 7 GCMs. The 1xCO_2 CCC and GFDL R-30 models simulate relatively well current precipitation throughout the period from November to April. According to the GCMs used in the study annual temperatures in Bulgaria are predicted to rise between 2.9°(HCGS) and 5.8°C (UK89) under an effective doubling of CO_2 (2xCO_2). In general, precipitation is expected to increase during the winter and to decrease during the warm half-year (CCC, GISS, GFDL R-30, OSU). The 2xCO_2 UK89 and HCGS models even project minor increasing only in November and July and October, respectively
The altered temperature and precipitation databases corresponding to each of the climate change scenarios were used to run the CERES GENERIC 3.0 simulation model of maize. Crop management, technology, and distribution of cultivated land were assumed to be constant.
Agricultural production is very sensitive to change and variation in weather conditions during the regular growing season. All the developmental processes, starting as early as the

germination process immediately after planting, and as late as the ripening process during physiological maturity, are affected and controlled by temperature. All scenarios projected a shorter vegetative (sowing-silking) and reproductive (silking-full maturity) growing season of maize (Fig. 3a). These changes were driven by the temperature increases of the scenarios. Simulated grain maize yield decreases in Bulgaria were caused primarily by warming and precipitation deficit during the growing season of this crop. Maize grain yield was more vulnerable under the CCC, GFDL and especially UK89 scenarios: yield reductions were near 30 % and 50-60 %, respectively. Under the GISS, OSU and HCGS scenarios, losses were projected to be bellow 20 %. In comparison with the rest GCMs outputs for Bulgaria the 2xCO_2 GISS scenario did not have as great of a negative effect on yields. This is because the GISS model simulated increases of rainfall during the vegetative period of maize. The GISS, OSU and HCGS scenarios also had the lowest warming in this part of the year. Some changes were observed when the direct effect of increased CO_2 had been assumed in the study. In this case the reduction of maize grain yield decreased. The reason of these changed results was the influence of increased levels of CO_2 acting as a fertilizer.

The DSSAT Seasonal Analysis program was run in order to determine the most appropriate timing and water amount of irrigation applications under the expected climate change during the growing season of maize. Both biophysical and economic analyses were done. The strategic analysis, was done in respect to the simulated value of harvest maize yield and net return. The tested treatments of the irrigated numerical experiment assumed maize growth and development under rainfed conditions, different date(s) and water amount of irrigation (Table 1).

Table 1. Description of the treatments examined in Kojnare.

Treat-ment	Dates of irrigation	Water applied [mm]
1	rainfed	-
2	8.VIII	40
3	29.VI	40
4	29.VI, 14.VII	80
5	29.VI, 14.VII, 8.VIII	120
6	29.VI, 14.VII, 8.VIII	240

In a similar way, the economic analysis of the Seasonal Analysis computer program calculates means, standard deviations, maxima and minima of the economic returns, and plots these as box plots, cumulative function plots, or mean-variance diagrams. Formal strategy evaluation of all treatments is carried out using mean-Gini stochastic dominance (Tsuji et al., 1994). In contrast to the biophysical analysis returns per hectare of the 6th treatment are lower than returns of the 4th and 5th treatments due to more water being applied. By running the "Strategy Analysis" option of the Seasonal Analysis program, the mean-Gini dominant treatment of the irrigated experiment can be calculated, in terms of the costs and prices used to analyze it. Actually, the dominant treatment was the 5th treatment - 40 mm water applied per every day (total 3 days) of irrigation.

4.3.2 Regional vulnerabilities and reasons

<u>For the detailed regional descriptions see the Tables 3.1 and 3.2 in the Appendix.</u>

4.3.2.1 Summary description of the most significant identified vulnerabilities of the regions/agroecosystems in Bulgaria

In the last decade, natural severe meteorological events occurred worldwide, raising the decision-makers' awareness of these recurring dangers. Over the 20th century, southeastern Europe experienced a drought warming at a level, that is higher than the global average. Projected climate would exacerbate water shortage and quality problems in many water scarce areas in the region. Heat waves in the summer as well as intense precipitation events will become more frequent throughout Europe. Due to envisaged climate change scenarios risk of drought is likely to increase in central and southern Europe. In recent years, drought conditions have endangered water resources in southeastern Europe and adversely affected the livelihood of many people.

In the last few decades it became more and more evident that in all countries in the Balkan sub-region and in the surrounding countries as well drought has a major impact on any forms and areas of life and economy, on the whole society and on the environment, too. Drought is the natural phenomenon probably most damaging to agriculture - which is the first economic domain and the most severely affected - yet eventually everyone feels the impact. Declining productivity affects rural and national environment and economy.

The climate in Bulgaria is temperate Continental-Mediterranean. Due to the geographical situation and the varied landscape, the contrasts in the climate are distinct among regions. The climate is with four distinctive seasons and varies with altitude and location. The Black Sea coast features a milder winter as opposed to the harsher winter conditions in the central north plains. Bulgaria has five climatic zones - Moderate Continental, Intermediate, Continental-Mediterranean, Maritime and Mountainous. The main factor distinguishing the first three zones is the latitude, the terrain for the mountainous and the Black Sea for the maritime. The air humidity is between 66 and 85% in the different regions of the country. There is a stable snow cover during the winter of about 20-200 cm. The Thracian Plain and the north-eastern coastal area suffer from low rainfalls. The total annual quantity of precipitation measured at the 40 monitoring meteorological stations vary from 455 to 93 mm, which is 60% to 137% of the norm. The mean values in 1999 was 619 mm, which is 98.84% of the annual norm, by about 4.3% lower than the value for 1998, and by 6.4% lower than the value for 1997. The tendencies over the last years are: almost ubiquitous reduction of precipitation, especially in the mountain areas of the country; total annual quantities of precipitation in northeast Bulgaria, Black Sea coast, Upper Thrace Low-down, southwest Bulgaria, Vratza-Pleven and Sofia regions are lower; no change in the established annual rate of non-precipitation days. The average wind speed is 1.2 m/s (1.3 m/s in winter time), while prevailing winds are west or northeast. The Balkan Mountains are the southern boundary of the area in which continental air masses circulate freely. The Rhodope Mountains mark the northern limits of domination by Mediterranean weather systems. The area between, which includes the Thracian Plain, is influenced by a combination of the two systems, with the continental predominating. Average precipitation in Bulgaria is about 630 mm per year. Dobrudja in the northeast, the Black Sea coastal area, and parts of the Thracian Plain usually receive less than 500 mm. The remainder of the Thracian Plain and the Danubian Plateau get less than the country average; the Thracian Plain is often subject to summer droughts. Higher elevations, which receive the most rainfall in the country, may average over 2,540 mm per year. The coastal climate is moderated by the Black Sea, but strong winds and violent local storms are frequent during the winter. Winters along the Danube River are bitterly cold, while sheltered

valleys opening to the south along the Greek and Turkish borders may be as mild as areas along the Mediterranean or Aegean coasts.
In the last few years the tendency is towards warmer and drier climate. 1998 had warm and dry winter, hot dry summer, cool dry spring, and cold and very rainy fall. These abrupt deviations from the normal climatic conditions reflect increased climate instability. Thus, the temperature amplitude recorded a maximum for the last decade. Significant are the amplitudes of the other climatic characteristics as well. 2000 was the warmest year in 30-year period, while the rainfalls were 60% less compared to standard values.

Drought is a natural, recurrent feature of the climate of Bulgaria. There are two main tendencies: growing air temperature, and decreasing precipitation amount. As a result soil drought during the second half of the twentieth century have increased its frequency and intensity. Many drought episodes occurred especially during the last decade of the previous century. Soil drought conditions were registered also during the first years of the 21st century. All this comes to the conclusion that soil drought conditions were, are and will be observed in Bulgaria. It is necessary to point out, that climate change scenarios for the country project more drought events during the current century. That is why, monitoring, drought conditions in Bulgaria are important issue that must be considered by scientists, decision makers, policymakers and the whole society.

Soil erosion in Bulgaria is another vulnerable climate related factor for agriculture in the country Soil diversity in Bulgaria is enormous. Soils have different characteristics, fertility and vulnerability to climate change. The temperature rise will increase the water deficit in soils with low precipitation rates that are prone to droughts. The most serious impacts will be observed for soils with light mechanical content and bad water characteristics and partly for heavy clay soils. About 30% of the soils in Bulgaria are prone to wind erosion.

The climate and weather risk in each NUTS3 regions in the country were generalized by the National Civil Protection
A survey shows that during the climate change in Bulgaria in the 21st century, most vulnerable will be: a) spring agricultural crops, due to the expected precipitation deficit during the warm half-year; b) crops cultivated on infertile soils; c) crops on non-irrigated areas; d) arable lands in south-east Bulgaria where even during the present climate, precipitation quantities are insufficient for normal growth, vegetation and productivity of agricultural crops.

4.3.3 Feasible and recommended adaptation options

For the detailed regional descriptions see the Table 3.3 in the Appendix.

4.3.3.1. National Overview of the identified most feasible adaptation options of the regions/agroecosystems in Bulgaria

Agriculture in Bulgaria

- The agriculture is one of the most important sectors of the Bulgarian economy. Much of the Bulgarian population is involved in it.
- The sector forms a relatively small share of the GDP.
- Cultivated agricultural land covers 48% of the total territory of the country.
- Agriculture is still in a crisis at present.
- Most of the farms are small and do not have at their disposal significant financial means. Various European funds are not enough efficiently used.
- The government must invest to get out quickly of the crisis in this important structural sector of the Bulgarian economy.

4.3.3.2 Selected most important and feasible adaptation options at the farm level in Bulgaria (detailed)

4.3.3.2.1 Changes in irrigation

It was already mentioned adaptation in agriculture to a changing climate will occur in several forms, including for example technical innovations, changes in agricultural land areas, and changes in use of irrigation. As the climate warms there will likely be shifts toward greater use of irrigation systems to grow crops in Bulgaria. It is considered that available soil moisture for maize crop cultivation in the country is insufficient for normal crop growth even under current climate. Many farming technologies, such as efficient irrigation systems, provide opportunities to reduce direct dependence on natural factors such as precipitation and runoff. Improvements allow greater flexibility by reducing water consumption without reducing crop yields. The use of more efficient irrigation systems can be expected due to the need for tighter water management practices in order to counter increased demand. Water losses through seepage and evaporation in canal and flood irrigation systems can be minimized by lining the canals with cement or switching to pipe irrigation systems. The significantly higher costs of production related to irrigation systems will most likely result in shifts to less water demanding uses in areas where there are higher rates of moisture loss. Using more groundwater for crop irrigation is also a perspective way. First of all, however, the irrigation systems available till 1990s should be restored in the country.

4.3.3.2.2 Changes in sowing dates

The sowing dates of crops in Bulgaria would shift under the GCM climate change scenarios in order to reduce the yield loss caused by an increase in temperature. The selection of an earlier sowing date for maize will probably be the appropriate response to an increase in temperature. This change in planting date will allow the crop to develop during a period of the year with cooler temperatures, thereby increasing the growth duration, especially the grain filling period. The simulation results show that the sowing date of maize in experimental station Carev brod (Northeast Bulgaria) should occur at least 2 weeks earlier in the 2080s under the ECHAM4 scenario, relative to the current climate conditions. It should be noted, however, that although changes in sowing date are a non-cost decision that can be taken at the farm-level, a large shift in sowing dates probably would interfere with the agrotechnological management and other crops, grown during the remainder of the year.

4.3.3.2.3 Changes in crop cultivars and varieties

Crop diversification allows farmers to cope with climate variation from year to year. This type of adaptation will likely occur at the farm system level. Switching from monocultures, which are more vulnerable to climate change, pest and diseases to more diversified agricultural production systems will also help farmers in coping with changing climatic conditions. Seed banks that maintain a variety of seed types provide an opportunity for farmers to diversify to counter the threat of climate change or to develop a profitable specialization. Another option for adaptation is to use different hybrids and cultivars. There is an opportunity for cultivation of more productive, later or earlier-maturing, disease- and pest-tolerant hybrids and cultivars. Switching from maize hybrids with a long to a short or very short growing season projected an additional decrease of final yield under an eventual warming in Bulgaria. However, using hybrids with a medium growing season, would be beneficial for maize productivity. The expected thermal and humid conditions in Bulgaria will permit to vary the assortment of many fruit and vegetable crops. Grape and fig production is expected to increase in the future. The climate in South Bulgaria is influenced by the Mediterranean. Warming may cause natural northward shift of some agricultural crops and trees grown in the upper areas of neighboring countries such as Greece and Turkey. Technological innovations, including the development of new crop hybrids and cultivars that may be bred to better match the changing climate, are considered as a promising adaptation strategy. However, the cost of these innovations is still unclear.

4.3.3.2.4 New crop zoning

The greatest part of the national wheat and maize production under the current climate is concentrated in the areas with elevation below 800 m. New zoning of crop cereal production in agricultural land areas with elevation below 1000 m due to expected warming can be proposed. In this case, the agricultural land area for cultivation of cereal crops will increase approximately by 50, 000 ha.

4.3.4 Scientific basis of ADAGIO results

4.3.4.1 List of all literature used for national ADAGIO purposes, analysis etc. (national and international)

Intergovernmental Panel on Climate Change (IPCC), 2001. Climate Change 2001: The Scientific Basis. Contribution of Working Group I to the Third Assessment Report of the Intergovernmental Panel on Climate Change [Houghton, J.T.,Y. Ding, D.J. Griggs, M. Noguer, P.J. van der Linden, X. Dai, K. Maskell, and C.A. Johnson (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

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Koleva Ek., V.Alexandrov, 2008. Drought in the Bulgarian low regions during the 20th century. *Theoretical and Applied Climatology* 92(1-2): 113-120.

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Александров, В., 2006. Влияние изменений климата на экосистемы Балканского полуострова и Центральной Европы. *Метеорология и гидрология* 9: 88-98.

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4.3.5 Dissemination activities during ADAGIO (during all project lifetime)

4.3.5.1 List of <u>scientific</u> ADAGIO publications (which include ADAGIO results). It means: ADAGIO related results which were published <u>during</u> the AGAIO project.

Aksoy, H, N.E. Unal, V. Alexandrov, S. Dakova and J.Y. Yoon, 2008. Hydrometeorological analysis of northwestern Turkey with links to climate change. International Journal of Climatology 28(8): 1047 – 1060

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Eitzinger, J., G Kubu, V. Alexandrov, A.Utset, D.T.Mihailovic, B.Lalic, M. Trnka, Z.Zalud, D.Semeradova,D. Ventrella, D. Anastasiou, M. Medany, S. Altaher, J. Olejnik, J. Leśny, N. Nemeshko, M.Nikolaev, C.Simota, G.Cojocaru, 2008. Vulnerabilities and adaptation options of European agriculture – recent results from the ADAGIO project. Proceedings of the Conference “Global Environmental Change – Challenges to Science and Society in Southwestern Europe” CD version

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Orlandini S, Nejedlik P, Eitzinger J, Alexandrov V, Toulios L, Calanca P, Trnka M, Olesen JE. 2008 Impacts of climate change and variability on European agriculture: results of inventory analysis in COST 734 countries.Ann N Y Acad Sci. 1146:338-353.

Petkova N., E. Koleva, V. Alexandrov, 2008, Winter Climate Variability at Danube Plane, North Bulgaria, XXIV th Conference of the Danubian Countries, 2-4 June, Bled Slovenia.

Petkova N., V. Alexandrov, E. Koleva, 2008, Snow Cover Variability in North Bulgaria, 2008, Global Environmental Change: Challenges to Science and Society in Southeastern Europe, International conference,19-21 May, Sofia,.

Tzenkova-Bratoeva, A., J. Ivancheva, V. Alexandrov, 2008. Bioclimatic Conditions in Bulgarian Black Seaside in the 21th Centur. Proceedings of the Conference “Global Environmental Change – Challenges to Science and Society in Southwestern Europe” CD version.

4.3.5.2 List of not yet published (manuscript status) scientific ADAGIO related publications (national or international).

No pending publications

4.3.5.3 List of published or not yet published (manuscript status) ADAGIO results specific designed for national farmers or stakeholders, which are more than common articles in newspapers (e.g. books, brochures, reports which can serve as a permanent source of information).

Alexandrov, V., 2009. Climate change, vulnerability and Adaptation

Andreev, V., V.Alexandrov, Ek.Bachvarova, 2009. Atmosphere and related risks

4.3.5.4 Other national public relation activities (e.g. lectures, farmer meetings, articles in newspapers), use the updated table below, for ALL ADAGIO period

Listed in the Thematic Group 4 report

4.4 Serbia

4.4.1 Abstracts of national case studies carried out during the ADAGIO project

Case study 1:

Improvement of Serbian crop production using new modelling tools

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Abstract
The basic task of this pilot assessment was to illustrate the usefulness of the available climate and crop-growth simulation tools into Serbian agricultural research and practice. Started as AGRIDEMA ("Introducing tools for agricultural decision-making under climate change conditions by connecting users and tool providers"; FP6-2003-Global-2-003944) pilot project related to calibration and validation of weather generators and crop models for local agroecological conditions and crop varieties (Lalic, 2006; Lalic et al., 2006; Lalic et al., 2007), this study is continued as a part of ADAGIO ("Adaptation of agriculture in European regions at environmental risk under climate change"; FP6 – ADAGIO – Proj. No SSPE-CT-2006-044210) project with main goal to assess effects of climate change on crop and fruit production and protection. Using statistical parameters of observed weather series and ECHAM4 model outputs for different integration periods (ECHAM4 25 – 2025; ECHAM4 50 – 2050; ECHAM4 00 – 2100) for Novi Sad region, Met&Roll weather generator synthesised weather series of daily maximum and minimum temperature, solar radiation and precipitation amounts for present and changed climate conditions.
In order to assess plant response to changed climate conditions crop model SIRIUS was run using observed weather data and generated weather series for 2001-2024 simulation period.
All GCMs scenarios used in this study projected shorter vegetation period for winter wheat in Novi Sad region. The emergence appearance was simulated for 294-306 d, while observed values are 297-310 d and during the period considered, grain mass exerts trend of decrease while, in case of grain yield, variability is more emphasised characteristic. This behaviour was caused primarily by projected temperature variation and precipitation decrease during crop-growing season without direct CO_2 increase included.

Case study 2:

Vulnerability and adaptation of agricultural production in Vojvodina region to climate changes

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Abstract
A short overview on past and current climatic situation in Vojvodina region, its vulnerability and adaptation of agricultural production on climate change impact is presented. As a Partner 4 in the project, this ADAGIO group is responsible to suggest the measures of adaptation on

the basis of the "observed" indicators about climate change in the selected regions with an intensive agricultural production and to lead the thematic ADAGIO group "Adaptation on occurrence of pests and diseases determined by climate change".
In this pilot assessment special attention was devoted to climate change effects in Vojvodina region during 1949-1999 period on annual temperature and precipitation trends obtained by a simple trend analysis.
On the basis of the questionnaire conducted during 2007. in 13 agricultural extension services with 199 experts interviewed we reached some reliable conclusions. They were based on a remarkable number of evidences related to climate change impact, in Vojvodina region, on plant pests and diseases appearance, fruit production and crop management.
Regarding the effects of climate change in plant protection field we detected the permanent occurrence (in the ten last years) the following diseases:

1) **Powdery mildew of cereals** - dry and warm springs and dry summers with temoprary showers provide favorite conditions for development of powdery mildew;
2) **Fusarium head blight** - dry and warm springs and dry sumers with temoprary showers are, for plants stress conditions, providing ideal environmental conditions for Fusarium head blight development on cereals;
3) **Cercospora leaf spot** – hot summer with frequent appereance of long periods with the spring night temperatures reaching or exceeding 15 ^{o}C, are ideal conditions for development of cercospora leaf spot on sugar beet;
4) **Sunflower blight** - a frequent occurrence of very dry and warm springs provided no conditions for development of sunflower blight;
5**) Potato and tomato Alternaria spot leaf diseases** - increased trend of occurrence of spots on potato and tomato plants is typical for Alernaria leaf spot that, except the leaf, also attacking other parts of plant (stalk and fruits) during hot summer

Case study 3:

Uncertainties in SVAT schemes as a source of problems in ReGCM simulation

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Abstract
Climate change has become a "Grand Challenge" modelling problem nowadays. As a researcher Michael Wehner from Scientific Computing Group, NERSC stated, the path for the future is relatively clear and only more sophisticated physical parameterizations can lead to a better simulation of the real system.
The examples of regional climate modelling using ECHAM4 climate model outputs for Northern Serbia region (Vojvodina) for annual air temperature and evaporation trends are calculated. Simulations are done also for annual and summer air temperature, annual precipitation, evaporation and water deficit.
Deviation between simulated and observed values for historical run for period 1961-1990 is common behaviour for all climate models. Obviously, further efforts should be focused on elimination of physical causes of deviations observed.
As a possible source of problem, uncertainties in definition of vegetation parameters in land-surface modelling part of regional model has been analysed. We presented impact of error introduced in estimation of vegetation cover for 2% and 5 % comparing with real value, on calculated amount of evaporation.

Case study 4:

Calculation of agrometeorological indices for Novi Sad region using different GCM scenarios

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Abstract

For data assimilation and critical analysis the daily maximum and minimum temperatures, precipitation and solar radiation at Novi Sad (Rimski Šančevi) weather station were analysed for 1957-1998 observation period. Climate change scenario representativeness was tested using 36 different GCM scenarios for Novi Sad (Serbia) region. The synthetic series of daily maximum and minimum temperatures, solar radiation and precipitation amounts were generated for Novi Sad (Rimski Šančevi) using MRWG for 1990-2025 periods. Climate scenarios are assimilated from seven climate models (CSIRO (A), CGCM2 (C), ECHAM4 (E), GFDL (G), HadCM3 (H), CCSR/NIES (J), NCAR-PCM (N)) integrated over three different integration periods (2025, 2050 and 2100) and with three CO2 scenarios (SRES-B1 (lo), SRES-A2 (hi), ME (mi)). It means that 63 different scenarios have been used in order to access the best possible scenario for Novi Sad region.

Using generated weather series for present and changed climate conditions, agrometeorological indices are calculated for all available scenarios. In order to make quantitative and qualitative assessment of obtained results, relative deviation of agrometeorological indices for each year during the 1990-2025 period has been calculated in respect to average value for 1957-1998 period. Results obtained using observed data and for, so called, “optimistic” (SRES-B1) and “pessimistic” (SRES-A2) scenario using 7 different GCM outputs and for 2025 integration period are presented.

Length of growing season - number of days between last spring and first autumn frost. According to all considered scenarios increase in length of growing season has been expected.

Potential evapotranspiration from vegetated surface (Wto) – was calculated using Turc’s formula, G - solar radiation, t-mean monthly temperature). According to all considered scenarios increase in potential evapotranspiration has been expected.

Cumulative rainfall (H) – was calculated as a monthly sum of precipitation. According to all considered scenarios significant variation of cumulative rainfall during vegetation period will be the main characteristic of next decades.

Crop drying day (c1, c2) – was calculated as a number of days with total daily precipitation bellow 5 mm (c1), i.e. 10 mm (c2)**.** According to all considered scenarios significant variation of cumulative rainfall during vegetation period will be the main characteristic of next decades.

Photothermal unit (PTU) and heat unit (TU) – were calculated taking into account daily temperature (T_d), threshold temperature (T_c) (10 ^{o}C in this case) and day length. Expected increase in PTU and TU is up to 20% according to SRES-B1, while in case of SRES-A2 it can exceed 35% of average value for 1957-1998 period.

Precipitation deficit (H-WTo) - was calculated as a difference between precipitation and potential evapotranspiration. Mainly dry vegetation periods with precipitation deficit between 50 and 100% will be main characteristic of next few decades. However, moderate or even wet years are possible but not common behaviour of future climate in Novi Sad region.

Hidrothermic coefficient (HTK) – was calculated using monthly amount of precipitation (H) and accumulated temperatures above 10 ^{o}C (TU). This parameter has been used in order

to describe soil wetness during vegetation period. For each month from April to September, values of HTK were calculated.

Case study 5:

Agrometeorological conditions in Vojvodina: past, present and future tense

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Abstract
Past, present and future (according to scenarios) values and trends of agrometeorological indices in Vojvodina (Northern Serbia) region are presented**.** Data assimilation and critical analysis are obtained for 1958-2005 observation period. Assimilation of GCM outputs from three climate scenarios (HadCM3, ECHAM5, NCAR-PCM) and SRES-A2 GHG emission scenario was done for three integration periods (2045, 2085) + standardised scenario. After calibration and validation of Met&Roll WG, average annual and vegetation period relative error of maximum (rTmax), minimum (rTmin) and daily temperature above ^{o}C (rTd0) monthly sums during vegetation period averaged over 1990-2005 validation period are calculated.
As a representative set of agrometeorological indices, for Vojvodina region, following variables and parameters were calculated: sum of temperatures above 0^{o}C, cumulative rainfall, potential evapotranspiration, crop drying days, precipitation deficit, photothermal unit, heat unit and length of growing season. Values of indices were calculated for six selected places in Vojvodina region (Banatski Karlovac, Kikinda, Zrenjanin, Novi Sad, Subotica, Sombor) using observed data and climate model outputs. In order to determine CC impact on agrometeorological indices, calculations of their values and appropriate trends for selected places during a vegetation period were performed.

- **sum of temperatures** above 0^{o}C – significant difference in trends between south-eastern and western-to-central part of Vojvodina in 1981-2006 period is less emphasized during the 1996-2006 decade. According HADCM3 the most vulnerable region will be south-eastern part of Vojvodina while, according to ECHAM5 and NCAR-PCM models, expected temperature sums in the future will be on present level.
- **cumulative rainfall** – in contrast to relatively uniform trend distribution during 1981-2006 period, a remarkable difference in cumulative rainfall distribution trend between northern and southern part of Vojvodina can be noticed. On the other hand, HADCM3, ECHAM5 and NCAR-PCM models suppose relatively uniform trend distribution with slightly exerted negative trend in south-eastern part of Vojvodina
- **potential evapotranspiration** – significant increase of potential evapotranspiration during vegetation period, starting on year 1980 is still actual. According to all models this trend will be kept in whole Vojvodina region during next three decades. During the 1986-2006 period extremely high trend of evapotranspiration was characteristic of south-eastern part of Vojvodina while, during the last decade this trend is rather uniform over the whole region.
- **crop drying days** (c1 and c2) – enormous number of days with less than 5 mm of precipitation during vegetation period reached on year 2000. (175 days) will be kept, according to scenarios, with possible small decrease during upcoming decades. In contrast to 1996-2006 period, when the most vulnerable region was south-eastern part of Vojvodina, in the future one can expect, less or more, similar trend of crop drying days in the whole region.

- **precipitation deficit** – calculated as a difference between precipitation and potential evapotranspiration (H-Wto), was negative during the whole period of interest indicating potentially arid conditions.

Case study 6:

Climate change impact and adaptation measures related to fruit production

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Abstract

Contemporary and intensive fruits production is greatly dependant on environmental conditions. If environmental conditions are not optimal, even the best cultivar with highest level of agro and pomo techniques will not show god production results. Considering this but also the fact that fruit species are perennial crops it is of high importance to diminish any environmental risks. The most important climatic parameters for fruits growth and development are: light, temperature, precipitation, hail occurrence and wind.

In agroecological conditions of Serbia limiting factors that are of significant influence on yield and quality decline are: low winter temperatures, late spring frosts, sudden temperature changes during winter, hail, high summer temperatures, , lack of precipitation and water logging.

In last ten years the most important factors that caused yield variations are low winter temperatures causing bud damages and late spring frosts causing blossom and fruits damages. It has also been noticed that in few last years sudden winter temperatures changes occur. Regarding the rest of environmental factors one of the most influencing is lack of water during vegetation period and period of buds formation (with most of fruits species this is July and August) but also water logging due to high precipitation rate in a short period. This is particularly the case with heavy soils where water tight horizon was formed at the depth of 40-50 cm.

Proposal of measures in fruitgrowing for lessening climatic chages effects:

- general management of growing policy in order to introduce tolerant cultivars and to avoid growing sensible fruits in regions with significant environmental risks;
- advantage should be given to cultivars that have been locally selected, or have been introduced long time ago because they are suppose to be more adapted to environmental conditions. It is also of great importance for fruit trees to enter dormancy well prepared as this is assurance they will stand low winter temperatures;
- installation of anti frost sprinklers;
- summer pruning, which induce formation of lateral branches;
- in order to lower the frost risks 4-6 cultivars with different blooming time should be grown. The best combination is to grow early and late flowering cultivars;
- the only effective protection against hail is anti hail nets;
- the state and local governments should substitute anti hail nets as it has been done in other European countries.;
- considering climatic changes, in contemporary fruitgrowing it is necessary to select those fruits species and cultivars that can give best results in local agroecological conditions, to put anti hail nets over orchards where necessary, to set up irrigation and anti frost sprinklers as a must in most of fruits growing regions in Serbia.

Case study 7:

Climate change impact and adaptation measures related to small grain disseasses

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Abstract
It is evident that certain climatic changes have been taking place in recent years. Global warming is one of them. The climatic changes have been affecting agriculture the most, especially when it comes to the occurrence of plant diseases and pests. The risk of disease and pest damages to agricultural crops has increased significantly as a result of climatic changes.
The present report will use personal observation and surveys of growers to describe and analyze the occurrence of diseases in some field and vegetable crops in the Serbian province of Vojvodina in recent years.
The project includes analysis of the severity of diseases caused by parasitic fungi in wheat, sunflower, sugar beet, potato and tomato (listed below), followed by suggestion of appropriate adaptation measures for each group of cultivars.

Small grains
In wheat, significant outbreaks of the following diseases have been observed:
Powdery mildew (*Blumeria /Erysiphe/ graminis)*
Rusts of small grains (*Puccinia* spp.)
Leaf and glume blotches (Septoria spp.). *Septoria tritici,* perfect stage *Mycosphaerella graminicola; Septoria nodorum* perfect stage *Leptosphaeria nodorum* etc.).
Tan spot of wheat (*Pyrenophora tritici-repentis*).
Barley scald (*Rhynchosporium secalis*).
***Fusarium* spp. /*F. graminearum,* perfect stage *Gibberella zeae; F.moniliforme,* perfect stage *G.fujikuroi,* etc.**
Nonparasitic spots.

Sunflower
In sunflower, climatic changes, especially the increase of growing season temperatures, have increased the severity of some diseases and the damage they cause. These diseases are:
Black leaf spot (*Phoma macdonaldi,* perfect stage *Leptosphaeria lindquistii*)
Brown stem canker (*Phomopsis helianthi,* perfect stage *Diaporthe helianthi*)
Brown spot (*Alternaria helianthi*)
Powdery mildew (*Erisiphae cichoracearum*)
Rust (*Puccinia helianthi*)
Charcoal rot (*Macrophomina phaseolina)*

Sugar beet
Cercospora leaf spot (*Cercospora beticola*)
Powdery mildew (*Erysiphe betae*)

Tomato and potato
Early blight of tomato and potato (*Alternaria solani*)

Case study 8:

Possible effects of the global climate change on crop production and adaptation measures

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Abstract

Increased temperature sum and reduced rainfall during growing season (April-October) are bound to cause a number of changes of other climatic (weather) parameters, in the first place an increase in potential evapotranspiration and decreases in soil humidity and rainfall sum. It will primarily affect the duration of growing season. The production of spring crops (soybean, sunflower, corn, sugarbeet, potato, etc.) will obviously start earlier. Spring crops will be planted earlier, in late winter or early spring. Accordingly, the planting of winter crops (rapeseed, barley, rye, triticale, etc.) will be possible or will have to be moved to October - November, in order to make the crops reach timely the stage of growth and development optimum for overwintering. Additionally, temperature increase during growing season does not automatically exclude the occurrence of low temperatures in winter, i.e., while plants are dormant. Consequently, winterhardiness of winter crops remains as a point of scientific interest.

Increased temperature during growing season affects positively the intensity of physiological processes in plants. Simultaneously, the duration of these processes becomes shorter. Since intensity cannot compensate for duration, the volume of organic matter production, i.e., yield, will inevitably be reduced. Furthermore, plants will produce more stress-causing free radicals. As it cannot be foreseen which part of the season will be most affected by stress-causing changes, it is necessary to prepare a list of possible preventive measures and make it available to farmers.

General adaptation measures involve changes in planting structure (crop rotation, choice of crops and cultivars, etc.), changes in soil tillage (primary and pre-sowing) and in the system of application of NPK nutrients. Main purposes of soil tillage are creation of conditions favorable for maximum accumulation of moisture outside of growing season and its efficient use during growing season. If the climate change goes in the direction of increased evapotranspiration and reduced rainfall during growing season, adaptation of the current fertilization systems is indispensable. Emphasis will be placed on primary fertilization (pre-plowing application of NPK nutrients) at the expense of top dressing. Foliar dressing will gain in importance. Use of NPK nutrients will increase because the rate of their utilization will be reduced.

Urgent local adaptation measures . A more reliable weather forecast before or during growing season will enable farmers and the extension service staff to take appropriate measures. In some cases, these measures will be preventive, such as determining the planting rate on the basis of available soil moisture, success in the control of diseases, pests or weeds, nitrogen dose used for top dressing, etc. Production technologies of other field crops should be adapted in similar fashion. Intervenient crop care measures (rolling, crust breaking, additional pollination of open-pollinated plants, etc.) will be more frequent, in response to critical events or conditions. Extension service will play an important role, but it will have to cooperate closely with local research centers.

Irrigation systems. Construction and maintenance of irrigation facilities require considerable investments. These investments, however, may be quickly returned through increased food production. Irrigated production too requires adaptations in production technology aimed at

reduction of roduction costs. Here it should not be overlooked that the amounts of quality irrigation water are limited.

4.4.2 Regional vulnerabilities and reasons

For the detailed regional descriptions see the Tables 4.1 and 4.2 in the Appendix.

4.4.2.1 Summary description of the most significant identified vulnerabilities of the regions/agroecosystems in Serbia

Limiting ecological conditions in Serbia that influence yield and quality of fruits are: low winter temperatures, late spring frosts, hail, temperature fluctuations during winter period, high summer temperatures and drought. As it was presented in our Pilot Assessment studies aaccording to all considered modelling scenarios, in next decades following climatic effects can be expected:

- increase in length of growing season;
- increase in potential evapotranspiration;
- significant variation of cumulative rainfall during vegetation period;
- mainly dry vegetation periods with precipitation deficit between 50 and 100%. However, moderate or even wet years are possible but not common behavior of future climate in Novi Sad region.

Therefore, main identified climatic vulnerabilities which should be expected are: drought during spring and summer, decreasing winter precipitation, weather storms. Also, regarding the effects of climate change in plant protection field we detected the permanent occurrence (in the ten last years) of the following diseases:

- **Powdery mildew of cereals** - dry and warm springs and dry summers with temoprary showers provide favorite conditions for development of powdery mildew;
- **Fusarium head blight** - dry and warm springs and dry sumers with temoprary showers are, for plants stress conditions, providing ideal environmental conditions for Fusarium head blight development on cereals;
- **Cercospora leaf spot** – hot summer with frequent appereance of long periods with the spring night temperatures reaching or exceeding 15 ^{o}C, are ideal conditions for development of cercospora leaf spot on sugar beet;
- **Sunflower blight** - a frequent occurrence of very dry and warm springs provided no conditions for development of sunflower blight;
- **Potato and tomato Alternaria spot leaf** diseases - increased trend of occurrence of spots on potato and tomato plants is typical for Alernaria leaf spot that, except the leaf, also attacking other parts of plant (stalk and fruits) during hot summer

Additionally, in several recent years outbreaks of following plant diseases were observed in the Serbian province of Vojvodina:
In wheat, significant outbreaks of the following diseases have been observed: **Powdery mildew** (*Blumeria /Erysiphe/ graminis);* **Rusts of small grains** (*Puccinia* spp.); **Leaf and glume blotches (Septoria spp.); Tan spot of wheat** (*Pyrenophora tritici-repentis*); **Barley scald** (*Rhynchosporium secalis*); ***Fusarium* spp. /*F. graminearum,* perfect stage *Gibberella zeae; F.moniliforme,* perfect stage *G.fujikuroi,* etc; Nonparasitic spots.**
In sunflower, climatic changes, especially the increase of growing season temperatures, have increased the severity of some diseases and the damage they cause. These diseases are: **Black**

leaf spot (*Phoma macdonaldi,* perfect stage *Leptosphaeria lindquistii*); **Brown stem canker** (*Phomopsis helianthi,* perfect stage *Diaporthe helianthi*); **Brown spot** (*Alternaria helianthi*); **Powdery mildew** (*Erisiphae cichoracearum*); **Rust** (*Puccinia helianthi*); **Charcoal rot** (*Macrophomina phaseolina)*.
In sugar beet outbreakes of following diseases have been observed: **Cercospora leaf spot** (*Cercospora beticola*); **Powdery mildew** (*Erysiphe betae*)
In Tomato and potato outbreak of **Early blight of tomato and potato** (*Alternaria solani*) is observed.

Regarding crop production in the Vojvodina province, following vulnerabilities were observed:

Soil potential. The biggest problems are a high level of weediness with perennial weeds and compaction of the subsoil. This is a result of inadequate soil cultivation and unstable planting profile.

Irrigation. According to statistics, only 3% of the land is irrigated. Water used for irrigation is controlled but not in all places. Irrigation systems are constructed slowly.

Land use. The soil is not being used up to its potential and land use is often in conflict with good agricultural practice. Not enough crop rotation is used. There is not enough livestock and not enough barnyard manure and other organic fertilizers are incorporated. The level of investment is therefore low. Lack of economic power and government subsidies limits agricultural investments. Organic farming does exist but not up to the potential and interest expressed by farmers.

Sensitivity to climatic changes. The whole territory of Serbia is often struck by thunderstorms with hail. Hail protection exists but does not always work so damages occur. Droughts occur frequently in summer months (July, August). Lately, droughts have been occurring during the October-February period. Lack of winter precipitation threatens the production of winter cereals, maize, sugar beet, rapeseed, etc. Wheat and barley yields are reduced by drought as well as increased temperatures in June. High temperatures in July (over 35°C) reduce pollination in maize and soybean. Increased temperatures in the month of March speed up vegetation so late frosts damage the fruits, sugar beet, etc. Lack of winter precipitation combined with summer droughts decreases the production of all crop species.

Finally, given current economical and social factors in Serbia important constraints in applying appropriate adaptation measures are:

Economical:

- high introducing costs;
- unfavorable bank credits;
- undeveloped market;
- old machinery which reduces soil cultivation quality;

Legal and institutional:

- farmers do not have influence on prices of input or output;
- non existence of subventions for plant production;
- high farmer dependence from trade sector;
- uncontrolled import of vegetables;
- unfinished privatization of food industry;

Policy and planning

- non existence of national adaptation strategy;
- great number of farms is out of advisory service programs;

- association of farmers is very slow;

From the list can be easily seen that there is a great number of steps that could be performed in order to improve agricultural adaptation measures to climate changes, which are beyond current economical problems in Serbia.

4.4.3 Feasible and recommended adaptation options

For the detailed regional descriptions see the Table 4.3 in the Appendix.

4.4.3.1. National Overview of the identified most feasible adaptation options of the regions/agroecosystems in Serbia

Limiting factors that influence yield and quality of growing plants in Serbia can be divided into ecological conditions and socio-economic aspects. Ecological conditions which most significantly interfere with production are: low winter temperatures, late spring frosts, hail, temperature fluctuations during winter period, high summer temperatures and drought. Each of these factors demand specifically designed set of protective measures in order to prevent or diminish possible damages (listed below as points 2.1 – 2.7). Since variety of harmful factors is very large, succesfull implementation of all needed protective measures will demand significant time and resources (financial and organizational). However, this interfere with the second group of mentioned limiting factors in Serbia – socio-economic ones. Both, organizational and financial situation needs improvement. On the organizational side following factors are most prominent: (i) farmers are burdened by the small size of their farms; (ii) the existing agricultural cooperatives are not fulfilling the needs of the farmers; (iii) the establishment of new, modern cooperatives is going on slowly because of a lack of a clear strategy of agricultural development; (iv) agricultural legislation is lacking too; (v) the process of transition has not been completed yet in the field of agriculture so agriculture is bearing the brunt of the social burden; (vi) agricultural products are being sold through a well developed trade network, which the farmers themselves have no influence on; (vii) great number of farms is out of advisory service program. On the financial side, following problems should be emphasized: (i) farmers income are still wery low; (ii) unfavorable bank credits; (iii) non existence of subventions for plant production. Additionally, despite the fact that 80% of the soil has good characteristics, Serbia suffers from lacking of efficient irrigation system, which results in inadequate soil cultivation and unstable planting profile
Therefore, situation in Serbia is such that there is a lot of room for further improvements: starting from local, farm-level adaptation options, to large national-level restructuring of almost the whole field of agricultural production, which is out of scope of this project. However, if needed restructuring is performed with awareness to the problem of climate changes, process of implementation of concrete adaptation options suggested in this document can be much more efficient.

4.4.3.2 Selected most important and feasible adaptation options at the farm level in Serbia (detailed)

4.4.3.2.1 Adoptation of Integrated Fruits cultivation

Time needed for implementation: 1-10 years
Application level: farm

Analysis and reasoning

Integrated production concentrates not only on chemical plant protection, but also on the cultivation measures as a whole. When planting new orchards, the orchardist should choose for each location the fruit cultivar which because of its natural qualities offers the best chance for regular crops and good quality. In choosing new varieties, preference should be given to those which do not require post-harvest treatment for long-term storage. The planting distance should be measured in a way that the chosen combination of variety and rootstock has enough room to grow without using severe pruning or synthetic plant growth regulators. Covering the area under the trees with tree bark keeps the ground damp, suppresses grass growth and reduces erosion, and is thus to be considered favorable. Through irrigation, natural precipitation is complemented to reach the minimum needs of the fruit trees. The application of irrigation should correspond to the actual requirements (use tensiometer or other instruments of measurement). The amount of water should depend upon the deficiency of precipitation as well as on the acqueousity (field capacity) and the profundity of the ground. The entire cultivation program should be aimed at maintaining the trees' natural resistance against diseases and pests so that no additional spraying is necessary. The goal of fertilization in integrated cultivation is to contain the nutrients in the soil within the optimal parameters and to achieve this as far as possible through natural cycles. Soil analysis is the most important basis for the fertilizer dosage of phosphate, potassium, magnesium, boron and other nutrients.

As it can be seen from above description and having in mind some of observed trends in climate change in Serbia (mainly dry vegetation periods, increase in potential evapotranspiration, increase in length of growing season) this approach offers integration of several important adaptation measures which should ensure minimization of harmful environmental factors. Despite high introducing costs, on a longer time scale it will decrease costs for plant protection and nutrition.

4.4.3.2.2 Anti- hail nets covers

Time needed for implementation : 1-5 years
Application level: farm

Analysis and reasoning

The whole territory of Serbia is often struck by thunderstorms with hail. Hail protection exists but does not always work so damages occur. Since hail is one of the most important climatic parameters which could interfere with fruits growth and development, and since simulation results indicate increased frequency of extreme weather conditions and storms, the state and local governments should substitute anti hail nets as it has been done in other European countries. Despite high initial costs and more machinery needed, application of this adaptation option would greatly reduce production risks.

4.4.3.2.3 Optimum date and sowing density

Time needed for implementation : 1-5 years
Application level: farm

Analysis and reasoning

Optimum planting date determined on the basis of long-term trials allow better rooting (root development) of individual plants. This will allow better utilization of soil, including the nutrients in the soil. This is especially important since it is observed that in Serbia the soil is not being used up to its potential and land use is often in conflict with good agricultural practice. Additionally, according to all considered simulation scenarios increase in length of growing season has been expected. Therefore, it is necessary to improve planting precision and quality in order to reduce risks of observed sudden temperature changes during winter as well as of low relative humidity in vegetation period. Optimum planting date should be moved from early to mid- or late October. This is necessary in order to prevent excessive plant development before winter which would jeopardize their cold tolerance. Winter cereals should reach the stage of tillering before the beginning of winter. Emphasis is placed on adequate development of the root system before the quiescence period. Planting density should be reduced in accordance with the available acreage. From the present 500-600 viable seeds/m^2, the number of seeds should be reduced to 350-400, in dependence of cultivar. With barley, the number of seeds/m^2 should be reduced to 150-250, taking into account the tillering potential. The level of investment is low and the proposed adaptation measures reduce production costs (wheat seeding rate is reduced by about 20%) while seed savings will bring direct financial benefits. At the level of the region of Vojvodina, the benefits will be 300.000 ha x 25 €/ha.

4.4.3.2.4 Changes in soil tillage and in the system of application of NPK nutrients

Time needed for implementation : 5-10 years
Application level: farm

Analysis and reasoning

General adaptation measures involve also changes in soil tillage (primary and pre-sowing) and in the system of application of NPK nutrients. Main purposes of soil tillage are creation of conditions favorable for maximum accumulation of moisture outside of growing season and its efficient use during growing season. If the climate change goes in the direction of increased evapotranspiration and reduced rainfall during growing season, adaptation of the current fertilization systems is indispensable. Emphasis will be placed on primary fertilization (pre-plowing application of NPK nutrients) at the expense of top dressing. More precisely: (i) entire amounts of P_2O_5 and K_2O should be applied before primary tillage (fertilization for 2-3-year reserve is also an option, depending on potential soil fertility); (ii) a half or two thirds of nitrogen, or about 60 to 90 kg/ha, will be applied before primary tillage; (iii) the remaining nitrogen will be top dressed around the end of the dormant period; exact date of application will be determined on the basis of precise analyses of mobile N in the soil, aiming at optimum regulation of crop stand and the formation of foliage. Additionally, foliar dressing will gain in importance. It will exact extra expenditures at the beginning of production, which may imply a necessity to take bank loans. Use of NPK nutrients will increase because the rate of their utilization will be reduced.

4.4.3.2.5 Prevention of fruit damages caused by late spring frost

Time needed for implementation : 5-10 years
Application level: farm

Late spring frosts in Serbia cause significant damages in majority of fruit species. Moreover, according to various model outputs increased frequency and intensity of late spring frosts should be expected in future. Annual yield fluctuations occur as a result of frost damages of flowers, young fruitlets, especially in peach, apricot and plum. In order to prevent or diminish possible damages, integrated set of measures should be specially designed. Following are core measures:

- plantations with hail protection irrigation systems (antifrost system) – especially useful in apricot plantations;
- summer pruning of apricot (by summer pruning new growth is induced. Buds on such branches are flowering 3-5 days later compared to other fruiting branches, so they are less susceptible to frost damages. It is very important to combine 4-6 cultivars with different flowering dates in order to prevent frost risk in spring);
- usage of agrotextile and low tunnels as frost protection – especially useful for protection of strawberry plantations;
- appropriate chemical treatment

4.4.3.2.6 Prevention of sunburns

Time needed for implementation : 5-10 years
Application level: farm

During vegetation, high temperatures and insolation may cause negative effects as sunburns on fruits, leaves, bark, trunk and branches. Since occurrence of extreme weather conditions is to be expected in Serbia in forthcoming years, including periods of very high temperatures, appropriate measures should be implemented, including:

- hail nets - the only reliable way to protect crops is to build hail net construction. New apple plantations in Vojvodina are established with hail protection nets which also prevent sunburns of fruits, leaves and branches;
- careful cultivar selection can prevent severe damages;
- rows orientation in plantations - rows should be orientated south - north direction.

4.4.3.2.7 Prevention of trunk injuries caused by extremely low winter temperatures

Time needed for implementation : 5-10 years
Application level: farm

Low winter temperatures are unfavourable specially for *Prunus* species (peach and apricot) which are less tolerant. The only way to prevent damages is selection of frost resistant cultivars, growing in temperate climate conditions, and preparation of fruits to winter rest.

4.4.3.2.8 More reliable and accessible weather forecast before or during growing season

Time needed for implementation : 1-5 years
Application level: national

Analysis and reasoning

A more reliable weather forecast before or during growing season will enable farmers and the extension service staff to take appropriate measures. In some cases, these measures will be preventive, such as determining the planting rate on the basis of available soil moisture, success in the control of diseases, pests or weeds, nitrogen dose used for top dressing, etc. Considering continuous rise in computational power and consequent development of models for numerical weather predictions, increase in accuracy of weather predictions can be expected for both: middle-term (up to 7 days) and long term (up to 20 days) predictions. Availability of these data can significantly increase efficiency of agricultural production in segments which are most vulnerable to climate change, such as:

- reliable prediction of extremely low winter temperatures as well as of spring frosts, will create opportunity for preparation and application of protective measures few days in advance;
- reliable weather prediction can be used as an input to SWAT model which should enable prediction of soil moisture and consequent optimal usage of water capacities;
- reliable weather prediction can be used as an input to CROP and Nitrogen-Balance models which should enable optimal usage of fertilizers;
- reliable weather prediction can be used as an input to Pest and disease models which should enable optimal protection of plants from pests and diseases.

4.4.4 Scientific basis of ADAGIO results

4.4.4.1 List of all literature used for national ADAGIO purposes, analysis etc. (national and international)

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4.4.5 Dissemination activities during ADAGIO (during all project lifetime)

4.4.5.1 List of scientific ADAGIO publications (which include ADAGIO results). It means: ADAGIO related results which were published during the AGAIO project.

Lalić, B., Panković, L., Mihailović, D.T., Malešević, M., Arsenić, I., 2007: Modeli biljne proizvodnje i njihova upotreba u prognozi dinamike vegetacije (Crop models and its use in vegetation dynamic forecasting), *A Periodical of Scientific Research on Field and Vegetable Crops,* 44, No. 1, 317-325.

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Eitzinger,J., G. Kubu, V. Alexandrov, A.Utset, D.T. Mihailovic, B. Lalic, M. Trnka, Z. Zalud, D. Semeradova, D. Ventrella, D. P. Anastasiou, M. Medany, S. Altaher, J. Olejnik, J. Lesny, N. Nemeshko, M. Nikolaev , C. Simota, G. Cojocaru, 2008: Adaptation of vulnerable regional agricultural systems in Europe to climate change – results from the ADAGIO project. *8th Annual Meeting of the EMS / 7th ECAC* (Amsterdam, The Netherlands, 28 September- 3 October 2008). *Abstracts*, **Vol. 5**: EMS2008-A-00066.

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Lalic, B., D.T. Mihailovic, M. Malesevic, 2009: Introduction of crop modelling tools into Serbian crop production: Calibration and validation of models. In: *Support Water-Management Decision-Making Under Climate Change Conditions*. (Eds. Angel Utset Suastegui). Nova Science Publishers, Inc., New York. (In Press) ISBN: 978-1-60692-033-6.

Mihailovic, D.T. and B. Lalic, 2009: Land-air parameterisation scheme (LAPS): A toll for use in agrometeorological modelling. In: *Support Water-Management Decision-Making Under Climate Change*

Conditions. (Eds. Angel Utset Suastegui). Nova Science Publishers, Inc., New York. (In Press) ISBN: 978-1-60692-033-6

4.4.5.2 List of not yet published (manuscript status) scientific ADAGIO related publications (national or international).

B.Lalic, D.T. Mihailovic and M.Dubrovsky: Introduction of crop modelling tools into a Serbian crop production: Climate change impact assessment on yield and growth dynamic, (**Journal of Agricultural Science)**

R.Jevtić, B.Lalić, D.T.Mihailović, J. Eitzinger, V. Alexandrov, D. Ventrella, M. Trnka, D.P. Anastasiou, M. Medany, J. Olejnik, M. Nikolaev: Adaptation to Diseases, Pests and Weeds Caused by Climatic Changes and Evaluation of Associated Risks in European Regions –Results from the Adagio Project, (**submitted**)

D.T.Mihailović, B.Lalić, R.Jevtić, Z. Keserović, Ž. Petrović, S. Jasnić: Climate Change Impacts and Adaptation Options in Serbia – Results from the ADAGIO Project

B. Lalic, D.T. Mihailovic, J. Eitzinger, G. Jacimovic: Assessment of Possible Relation Between Trends in Agroclimatic Indices and Crop Model Outputs

A. Firanj, B.Lalic, D.T. Mihailovic :Calibration And Validation Of Dssat Model For Serbian Agroecological Conditions

B. Lalic and D.T. Mihailovic: Assessment of climate change impact on phenology dynamic in Vojvodina region

D.T. Mihailovic, B. Lalic, R.Jevtic, J. Eitzinger, M. Medani, et al. : Climate change impact on plant diseases in Central Europe and Mediterranean Region **(Climate Research)**

4.4.5.3 List of published or not yet published (manuscript status) ADAGIO results specific designed for national farmers or stakeholders, which are more than common articles in newspapers (e.g. books, brochures, reports which can serve as a permanent source of information).

1. Proceeding of the Workshop on Modelling and Measuring Aspects of some Environmental Issues, Novi Sad, Serbia

Brochure of the Center for Meteorology and Environmental Predictions

2. The Republic of Serbia National Sustainable Development Strategy/Action Plan for Strategy implementation, period 2009-2017:

a. The Republic of Serbia **NATIONAL PROGRAMME FOR INTEGRATION WITH THE EUROPEAN UNION (NPI)**:http://www.seio.sr.gov.yu/code/navigate.asp?Id=76

b. The Republic of Serbia NATIONAL SUSTAINABLE DEVELOPMENT STRATEGY; **http://www.un.org/esa/agenda21/natlinfo/countr/serbia/nsds_serbia.pdf**

c. MINISTERIAL DECLARATION *"Building Bridges to the Future"* by Ministers of the region of the United Nations Economic Commission for Europe (UNECE); Doc. ECE/BELGRADE.CONF/2007/8;

d. Belgrade initiative: Enhancing the regional SEE cooperation in the field of Climate Change – Climate Change framework action plan for the SEE region, and the establishment of a sub-regional, virtual climate change related centre for research and systematic observation, education, training, public awareness, and capacity building;

e. South East European Climate Change Framework Action Plan For Adaptation - Executive Summary and Action Plan
http://www.rec.org/REC/Programs/REREP/docs/11th_meeting/executivesummary.pdf

4.4.5.4 Other national public relation activities (e.g. lectures, farmer meetings, articles in newspapers), use the updated table below, for ALL ADAGIO period

Listed in the Thematic Group 4 report

4.5 Czech Republic

4.5.1 Abstracts of national case studies carried out during the ADAGIO project

Case study 1 :

Expected Changes in Agroclimatic Conditions in Central Europe

Miroslav Trnka[1], Josef Eitzinger[2], Daniela Semerádová[1,3], Petr Hlavinka[1], Jan Balek[1], Martin Dubrovský[1, 3], Gerhard Kubu[2], Petr Štěpánek[4], Sabina Thaler[2], Zdeněk Žalud[1,3]

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[4] Czech Hydrometeorological Institute, Department of Meteorology and Climatology, Brno, Czech Republic

Abstract

During the past few decades, the basic assumption of agroclimatic zoning, i.e., that agroclimatic conditions remain stable in the long-term, has been shattered by ongoing climate change. The first aim of this study was to develop a tool that would allow for effective analysis of various agroclimatic indicators and their dynamics under climate change conditions (Table 1) for a particular region. The results of this effort were summarized in the *AgriClim* software package, which provides users with a wide range of parameters essential for the evaluation of climate-related stress factors in agricultural crop production. The software was then tested over an area of 114,000 km^2 in Central Europe. We have found that by 2020, the combination of increased air temperature and changes in the amount and distribution of precipitation will lead to a prolonged growing season and significant shifts in the agroclimatic zones in Central Europe; in particular, the areas that are currently most productive will be reduced and replaced by warmer but drier conditions in the same time the higher elevations will most likely experience improvement in their agroclimatic conditions. This positive effect might be short-lived, as by 2050, even these areas might experience much drier conditions than observed currently. Farmers will be able to take advantage of an earlier start to the growing season, at least in the lowland areas, as the proportion of days suitable for sowing increases. As all of these changes might occur within less than four decades, these issues could pose serious adaptation challenges for farmers and governmental policies. The rate of change might be so rapid that the concept of static agroclimatic zoning itself might lose relevance due to perpetual change.

Table 1: Assume CO_2 concentration and change in mean global temperature as the key inputs for construction of time-specific climate change scenarios using the pattern-scaling technique. The values are based on the MAGICC v.4.1 model, and the temperature changes are with respect to 1975.

Emission scenario	Year			
	2020		2050	
	CO_2 (ppm)	Temperature change (°C)	CO_2 (ppm)	Temperature change (°C)
SRES - A2 High	418.0	0.64	535.9	1.79
SRES – B1 Low	413.6	0.35	490.4	0.76

Note: Results in extenso have been published in Plant, Soil and Environment (2009) and Climate Change (2009) papers (part 1.5.1.).

Case study 2 :

Is The Rainfed Agriculture In Central Europe At Risk? - Using A Novel Methodology To Produce High Resolution And Regionally Relevant Support For Decision Makers

M. Trnka[1,2], M. Dubrovský[1,2], P. Štěpánek[3], J. Eitzinger[4], Semerádová [1,2], P. Hlavinka[1], J. Balek[1], Z. Žalud[1,2], P. Skalák[3], A. Farda[3]
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Abstract
Growth and development of field crops are connected to the environment via a combination of linear and non-linear responses and are strongly affected by the weather and climate conditions. Extreme weather events that are a natural cause of climate variability such as drought, frosts or heat waves can also have severe consequences for crops. In the same time timing of the key field operations (i.e. sowing and harvest) depends the weather conditions influencing yield quantity and quality in each given season.The first aim of the study was to develop a methodology that would enable a sophisticated and flexible analysis of various agroclimatic indicators. The results of this effort were summarized into the AgriClim software package that provides range of agroclimatic indicators including: **i)** duration of growing season and of the vegetation summer, **ii)** number days suitable for sowing and harvesting; **iii)** accumulated water deficits during key parts of growing season (April-June); **iv)** number of growing degree days without significant water stress **v)** snow cover presence/absence during days with Tmin < -5°C and -15°C and duration of snow cover and **vi)** probability of serious frost damage to winter field crops.
The AgriClim was then within domain of the regional climate model ALADIN that covers the area of whole Central Europe between latitudes 45° and 51.5° N and longitudes 8° and 27° E including at least partly of Austria, Czech Republic, Germany, Hungary, Poland, Romania, Slovakia, Switzerland and Ukraine. The ALADIN model was run in 10 km resolution over the whole domain and the final maps were interpolated to 1 km resolution using digital terrain model (Fig. 1)).

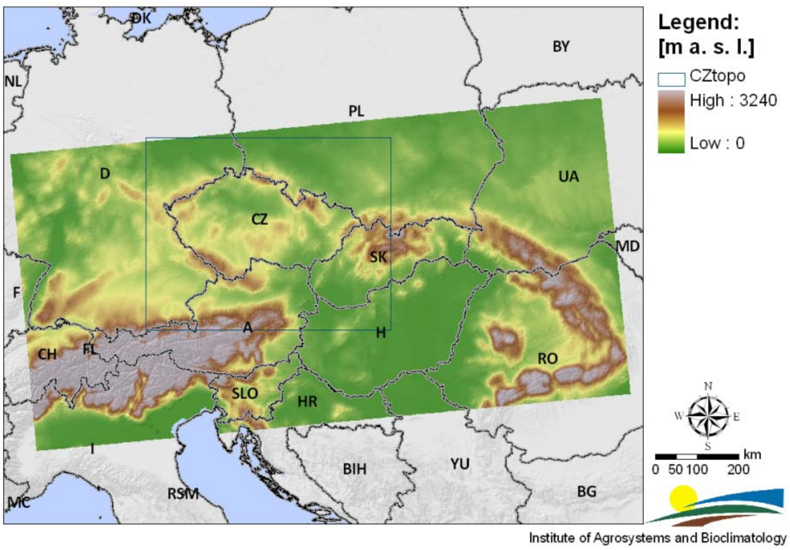

Fig. 1. Domain of ALADIN RCM model with representation of altitude in 10x10 km resolution.

The control run used observed boundary conditions (ERA40) and covered the period 1961-2000 with 1961-1990 period being used as a baseline to train a weather generator. Then a parameters of weather generator were perturbed based on the outputs of representative set of Global Circulation Models (including HadCM, NCAR-PCM and ECHAM) for various levels of climate system sensitivity and emission scenarios. This novel procedure significantly improves the reliability of RCM based projections combining RCM resolution while accounting for GCM related uncertainties. The selected agroclimatic indices were then calculated for each of over 10 000 grid points. The soil properties that were required for indices **ii – iv** were derived from the FAO 1:1000 000 soil map. The outputs of the control run were compared with 1 km resolution AgriClim runs for the Czech Republic. The results indicate that : **i)** between 2021-2050 the combination of increased air temperature and changes in the amount and distribution of precipitation will lead to prolongation of growing season and significant shifts in the agroclimatic zones affecting e.g. potential for vine production. The extent of the presently most productive areas will be reduced and replaced by warmer but drier conditions, which are less suitable for rainfed farming. **ii)** While the trends of the changes expected in lowlands are mostly negative according to the production potential of rainfed crops, the higher elevations will most likely experience improvement of their agroclimatic conditions. **iii)** Diary oriented agriculture (based on permanent grassland) at higher altitudes could suffer through an increased evapotranspiration demand combined with the decrease of precipitation leading to the intolerable water deficits. **iv)** The areas that are already warm and relatively dry we will experiencing 20-year drought intensity three times as frequently and water deficits that have not been encountered before. **v)** Farmers will most likely be able to take advantage of earlier start of growing season at least in the lowland areas as the proportion of days suitable for sowing will increase.

The methodology used enabled to cover large territory with high level of detail accounting for various sources of uncertainty and surpases in our opinion presently available study in several aspects. The findings are crucial for tailoring the right adaption responses to the expected changes.

Note: Results in extenso have been published during final Adagio workshop (Vienna, June, 2009) have been submitted to special issue of Journal of Agriculture Sciences (part 1.5.1.).

<u>Case study 3 :</u>

Assessing Differences In The Farm Level Vulnerability Of The Cereal Production In The Central Europe – Consequences, Uncertainties And Adaptation Options

M. Trnka[1], J. Eitzinger[2], S. Thaler[2], P. Hlavinka[1], D. Semeradová[1], M. Dubrovsky[1,3], Z. Žalud[1], G. Kubu[2], H. Formayer[2]

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Abstract

It is obvious that production stability and quality would be influenced under changed climatic conditions and that these changes will differ between regions and farms. However the magnitude of the change in crop production (both positive and negative) is not fully known due to the large differences between individual global circulation models (GCM) and SRES scenarios. In order to assess trends and magnitude of crop yields (and other production characteristics of two selected crops) we applied dynamic crop models CERES-Barley and CERES-Wheat. Both models were evaluated using data from 17 (7) experimental sites with 230 (87) experimental years as well as compared with statistical yield levels at the NUTS4 level. The extensive experimental database was also used to verify whether the model correctly simulates differences in crop growth processes caused by varying farming techniques, climatic and soil conditions. In order to carry out spatial analysis, the model was run for all combinations of 125 weather stations using 400 soil pits using special software package: Marwin. The results were then interpolated into a 1x1 km grid matrix using ArcInfo GIS software and only grids covered by arable land were analyzed further. The selection of the model crops made possible to distinguish between climate change impact on the winter and summer crops. The resolution used in the study allowed to evaluate changes on the scale of large farm units (NUTS 4) for which the models were also validated and thus assess their vulnerability to the climate changes.

In order to estimate the uncertainty in the future cereal production at this spatial scale number of GCMs provided for the Fourth Assessment Report (4AR) was used, namely ECHAM, HadCM and NCAR-PCM. The GCM based projections were based on the three SRES scenarios (i.e. A2, A1B and B1) taking into account three levels of climate system sensitivity (CS). The scenario values were used to set up boundary parameters of the future climate over the Czech Republic and part of Austria (including CO_2 levels required as an input for the crop model). In the next step synthetic weather series of 99 years were generated for each of 125 weather stations and centered for time periods centered on years 2020, 2030, 2040, 2050 and 2100. In order to estimate future yields more realistically both long-term trends in grain production yields between 1918-2005 (accredited to technological advance) and effects of simple adaptation strategies were taken into account. The latter included optimization of fertilization and sowing dates, changing basic parameters of the cultivar and finally measures to increase soil water accumulation during winter that precede to sowing.

The range of uncertainty caused by the different projections within the set of used GCM is relatively large and is most pronounced in case of A2 SRES scenario in combination with the high climate system sensitivity. In general yields are expected to increase across most productive areas in the target regions especially when positive CO2 effect as estimated by CERES model is included. However so called indirect effect of climate change (i.e. change of climate conditions without considering fertilization effect of CO2) is mostly negative especially due to increased water stress and reduced duration of growing season. Overall uncertainty of the future crop productivity is rather high (larger than 20% between individual GCM for 2050) and becomes even higher in case of spring cereals (compared to winter cereals). The results suggest that the effect of GCM driven boundary conditions are dominant on the national level, whereas the future regional and farm level productivity is significantly influenced by relatively subtle differences in the abiotic conditions (e.g. present climate or soil conditions). However the effect of uncertainty within the available set of GCM-SRES-CS on the future national production levels is one order higher than then the effect of sub-regional differences.

Note: Results in extenso have been published during final Adagio workshop (Vienna, June, 2009) have been submitted to special issue of Journal of Agriculture Sciences (part 1.5.1.).

Case study 4 :

Estimating Climate Change Impact On Occurrence Of Selected Species In High Resolution – A Novel Approach

E. Kocmánková[1], M. Trnka[1,2], J. Eitzinger[3], M. Dubrovský[1,2], P. Štěpánek[4], Semerádová [1,2], J. Balek[1], D. P. Skalák[4], A. Farda[4], J. Juroch[5], Z. Žalud[1]

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Abstract

Climate conditions exert significant influence over the population dynamic, life cycle duration, infestation pressure and the overall occurrence of majority of agricultural pests and diseases. Particularly in the case of those pest species whose development is directly linked with the climate conditions the shift of their climatic niche or their infestation capability is to be expected under the changing climate. The presented study is focused on the most important potato pest i.e Colorado potato beetle (*Leptinotarsa decemlineata*, Say 1824) (CPB) and most important pest of grain maize i.e. European corn borer (*Ostrinia nubilalis*, Hübner 1796) (ECB). Estimates of potential distribution of both pest species for the present as well as expected climate conditions are based on the dynamical model CLIMEX. The major innovation introduced by the study comes not only with its resolution, area covered but in particular from the methodology point of view as advantages of Regional Circulation Models as the primary source of weather data (as key inputs for the pest models) are combined with approach employing weather generator.

The CLIMEX model was at first validated with observed data of European corn borer and Colorado potato beetle observed occurrences and then applied within domain of the regional climate model ALADIN that covers the area of whole Central Europe between latitudes 45° and 51.5° N and longitudes 8° and 27° E including at least partly of Austria, Czech Republic, Germany, Hungary, Poland, Romania, Slovakia, Switzerland and Ukraine. The ALADIN model was run in 10 km resolution over the whole domain and the final maps were interpolated to 1 km resolution using digital terrain model. The control run used observed boundary conditions (ERA40) and covered the period 1961-2000 with 1961-1990 period being used as a baseline to train a weather generator. Then parameters of weather generator were perturbed based on the outputs of representative set of Global Circulation Models (including HadCM, NCAR-PCM, ECHAM and ARPEGE) for various levels of climate system sensitivity and emission scenarios. The results of the present (1961-1990)

As the result of CLIMEX simulations there is the Ecoclimatic index (EI) which constitutes the overall climate favorability for species long-term survival. Models of pests' potential geographical distribution in current climate describe the pests' occurrence including the number of generations based on the calculations of degree-days. In the conditions of longer vegetative season in expected climate pest likely will be able to complete the additive generations per season. As the results of our study indicate according to HADCM A2 2050 the number of ECB's generations is likely to increase on the average of 1.2 (range of 0.1-4.3). In the case of CPB the average of the generations increase is 1.7 (range 0.1 – 6.1). Except the increase of generation number there is expected the shift of pest's occurrence area to higher altitudes which means the significant danger for recently unoccupied areas. Contemporaneously there is registered the significant disproportion in the regional responses

of pests' to changed climate which is represented by the higher increase of EI values (and number of generations) coupled with increasing altitude. These facts support the risk of endangering of agro ecosystems of middle Europe by increasing losses caused by these harmful organisms.

The novel procedure in the study significantly improves the ability of RCM based projections to represent uncertainty ranges by combining RCM resolution, weather generator and outputs of multiple GCMs. The methodology used enabled to cover large territory with high level of detail accounting for various sources of uncertainty and surpasses in our opinion presently available study in several aspects. The findings are crucial for tailoring the right adaption responses to the expected changes.

Note: Results in extenso have been published during final Adagio workshop (Vienna, June, 2009) and will be submitted to special issue of Journal of Agriculture Sciences and as an invited paper to the Climate Dynamics journal (part 1.5.1.).

4.5.2 Regional vulnerabilities and reasons

For the detailed regional descriptions see the Tables 5.1 and 5.2 in the Appendix A.

4.5.2.1 Summary description of the most significant identified vulnerabilities of the regions/agroecosystems in Czech Republic

The first aim of the ADAGIO study was to develop a methodology and, subsequently, a tool that would enable easy and flexible analysis of various agroclimatic indicators and their dynamics under climate change conditions for the selected region of the Czech Republic and Austria. The results of this effort were summarized in the *AgriClim* software package, which provides users with a wide range of parameters essential for the evaluation of climate-related stress factors (e.g., frost damage, snow presence, drought) in agricultural crop production, as well as indicators enabling agroclimatic classification of sites or regions. Although the methodology is aimed primarily at conditions of rainfed field crop production, it could be adapted within a specific region for all types of agricultural and forestry systems. To demonstrate the possibilities offered by *AgriClim,* we investigated the expected changes in agroclimatic zones and stress factors across the Czech Republic and parts of Austria. Our work complements the studies that have been performed so far in this area, as previous studies focused primarily on either particular crops (e.g., winter wheat, spring barley or maize) or single indicators like reference evapotranspiration. We compared the baseline agroclimatic conditions of the region to those expected in the near future (around 2020) and around the middle of the 21st century, assuming the realization of two SRES scenarios (A2 and B1). This allowed us to reach more general conclusions than those made in impact studies based on crop models and, thanks to the selected range of indicators, to cover most of the key climate factors limiting crop production. We have drawn several conclusions from this research. First, we expect that by 2020, the combination of increased air temperature and changes in the amount and distribution of precipitation will lead to a prolongation of the growing season and significant shifts in the agroclimatic zones. The current most productive areas will be reduced and replaced by warmer but drier conditions, which are less suitable for rainfed farming. Second, while trends in the changes expected in lowlands are mostly negative according to the production potential of rainfed crops, higher elevations will most likely experience improvement in their agroclimatic conditions. However, this positive effect might be a relatively short-lived situation, since by 2050 (at least if SRES A2 is realized), even these areas might experience much drier conditions than nowadays. Third, dairy-oriented agriculture (based on permanent grassland) at higher altitudes could suffer through an increased evapotranspiration demand combined with a decrease in precipitation, leading to the intolerable water deficits. Fourth, areas that are already warm and relatively dry (e.g., the southeast) will experience droughts with a 20-year return probability three times more frequently than under baseline conditions. At the same time, there is a risk of water deficits becoming relatively frequent in places where they have not been encountered before. Fifth, farmers will most likely be able to take advantage of an earlier start to the growing season (at least in lowland areas), as the proportion of days suitable for sowing will increase. Sixth, the proportion of days suitable for harvesting should increase during July-September with a decrease in interseasonal variability. However, harvesting conditions in June will remain relatively unfavorable, which might pose problems for the harvest of early maturing crops (e.g., winter barley and winter rape) with increasing interseasonal variability. Seventh, all these changes might occur within less than four decades. Most areas will transition through the conditions of at least two agroclimatic zones from the applied scheme, which will pose serious adaptation challenges for farmers and governmental policymakers. The rate of change might be so high that the concept of static agroclimatic zoning itself might lose its relevance due to perpetual change. Finally, overall, the negative impacts on field crop production will probably be more significant in the Czech Republic than in Austria for several reasons, including the very limited water resources available for irrigation and the larger field sizes in the Czech Republic. On the other hand, the decreasing suitability of permanent grassland production is likely to become a serious problem in some drier parts of Austria due to complex terrain that limits adaptive capacity.

4.5.3 Feasible and recommended adaptation options

<u>For the detailed regional descriptions see the Table 5.3 in the Appendix.</u>

4.5.3.1. National Overview of the identified most feasible adaptation options of the regions/agroecosystems in Czech Republic

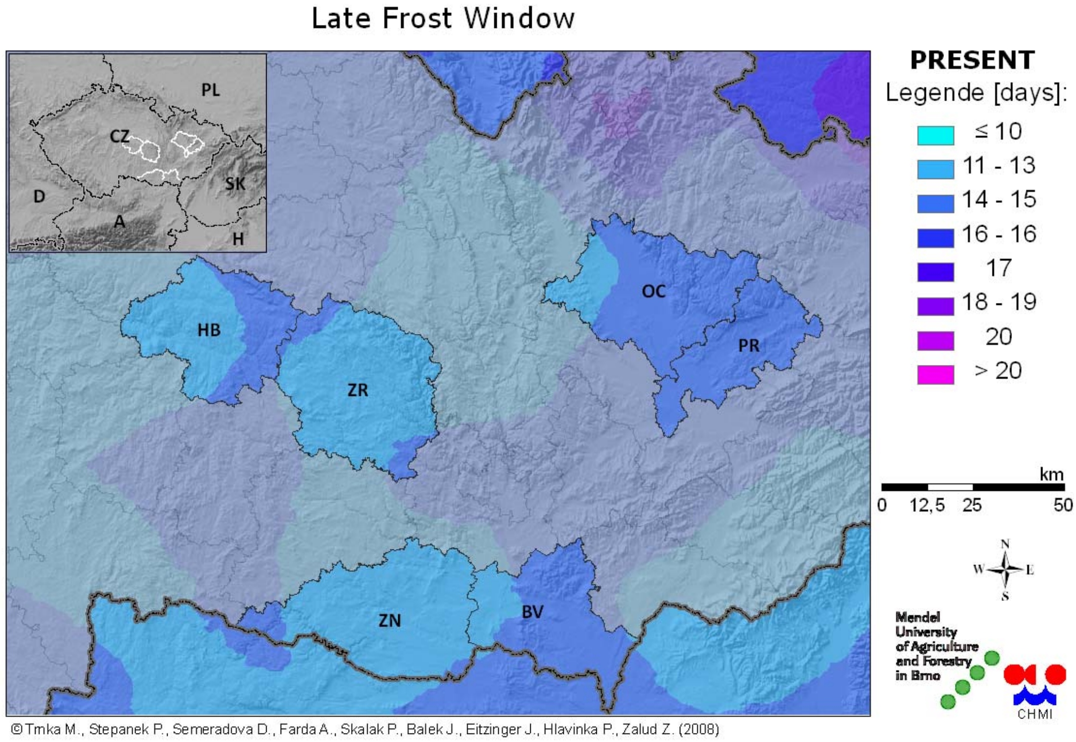
The prolongation of the growing season will be accompanied by a regression of the latest dates of frost during spring. In the case of both low and high frequency events, the highest regression of the last spring frost is expected under the HadCM scenario. The frost-free period in the spring might be up to 20 days longer than under the baseline conditions by 2050. Interestingly, the shifts are higher for low-frequency events in cold locations and for high frequency events in the lowlands. The differences between individual scenarios are considerable, but in all cases show qualitatively the same trend. Based on the shifts of the period with a frost return probability of 20 years it could be concluded that by 2050, the late spring frosts are more likely to occur during a period of intensive growth, when the mean air temperature is above 10°C. The shift of the growing season toward the beginning of the year means that there is a higher risk of radiation frosts during the longer nights. The risk is higher at lowland sites, where the growing season should, by 2050; start in the second half of March, which means a night prolongation of almost two hours at the 49th parallel however also Region 1 at least according to ALADIN RCM based projections seems to be more vulnerable. Higher winter temperatures will result in a shortening of the period between the first and last day with snow cover. The change is more pronounced toward the end of winter and occurs more at lowland sites (i.e., the Regions 1 and 2 that are presently dominated by grain maize and sugar-beet production). The mean length of snow period in these sites will decrease from the present two months to one month from mid-December to mid-January. The number of days with snow cover will be reduced by 16 to 22 days by 2020 and by up to 43 days by 2050, assuming the A2 SRES emission scenario. Under the B1 emission scenario, the changes will be more subtle. A decrease in the number of snow days is closely connected to the prolongation of the growing season, but might also lead to a higher probability of winter crop damage due to low temperatures as crops are less frequently protected by snow against extremely low temperatures. However, the results of our analyses suggest, the chance of frost damage due to missing snow cover should decrease considerably in the lowlands (Regions 1 and 2), although it does not diminish entirely. On the other hand, at higher altitudes, where snow cover is presently sufficient to prevent frost damage almost entirely, this type of risk will increase (Region 3). The devastating effect of frost damage on winter crops without snow cover was clearly seen in late December of 2002, when 21% of the total winter crop acreage (or 300,000 ha) in the Czech Republic was destroyed in a single night.

4.5.3.2 Selected most important and feasible adaptation options at the farm level in Czech Republic (detailed)

4.5.3.2.1 Adaptation of farm production practices

During WP3 an expert and literature survey as well as model experiments that allowed assessment of adaptation option under the climate change in Czech Republic was completed and resulted in a list of selected adaptation options (change of sowing date, change of fertilization scheme, change of cultivars, soil water saving tillage and change of the crop) with the quantification of the effect of these measures under the changed climate that were obtained through means of process based crop modeling focusing on the three case study regions.

Czech Republic as a whole is dominated by the large fields with low diversity of farms and production (see activity reports). The overall arable area is one of the highest in EU especially in the main production basins (Morava and Elbe river) where land-use is dominated by almost homogeneous croplands with low biodiversity, open terrain and very larger fields (some over 50 ha) with a single crop usually of the same cultivar. The farm size is extremely high compared to Austria with relatively small diversity of major cash crops. In the same time in the past ten years several major extreme events caused large-scale loses to cereals leading to increasing concern of farmers. These events included droughts in 2001, 2003 and 2004; heavy frost damage during 2002/2003 winter and damage from long snow cover (2006) as well as large scale losses during summer storms (2008). Altogether farmers in most of the regions are becoming very responsive to the studies assessing adaptation options. For example farmers in regions with frequent drought problems (south-east) are aware of increasing water scarcity and already taking measures for improving water use efficiency of cropping systems mostly by reduced soil cultivation and using of mulching, as well as crop rotation options (reduction of drought intolerant summer crops in dry regions such as sugar beets or peas). There is also increasing political pressure to



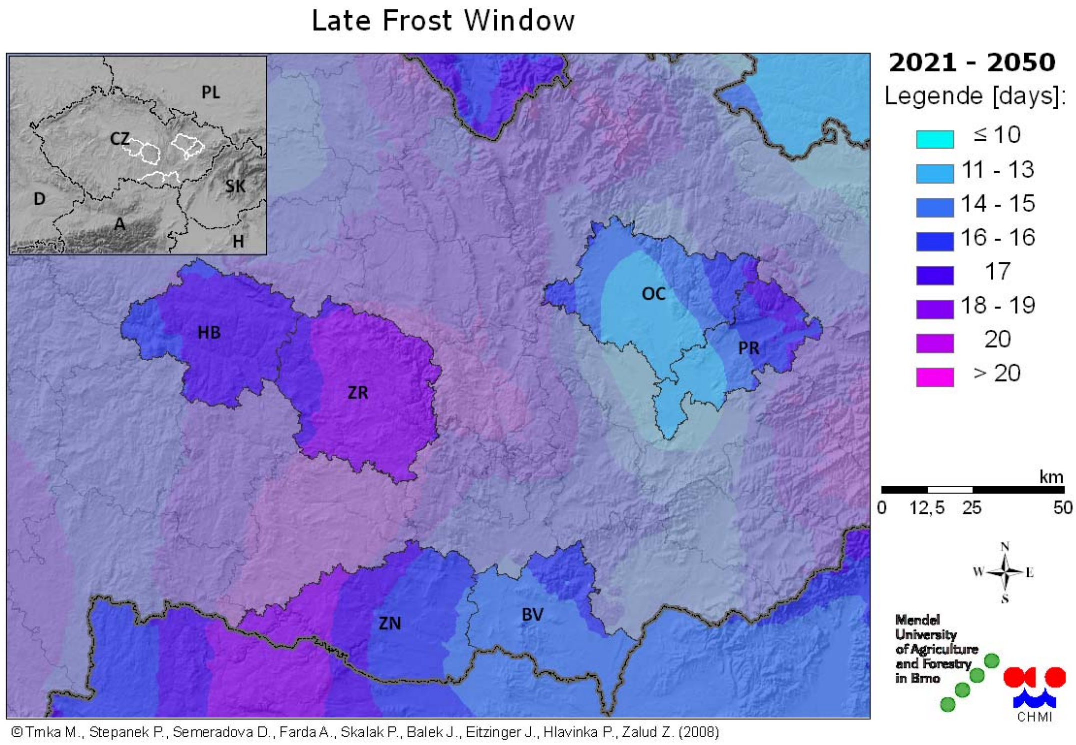
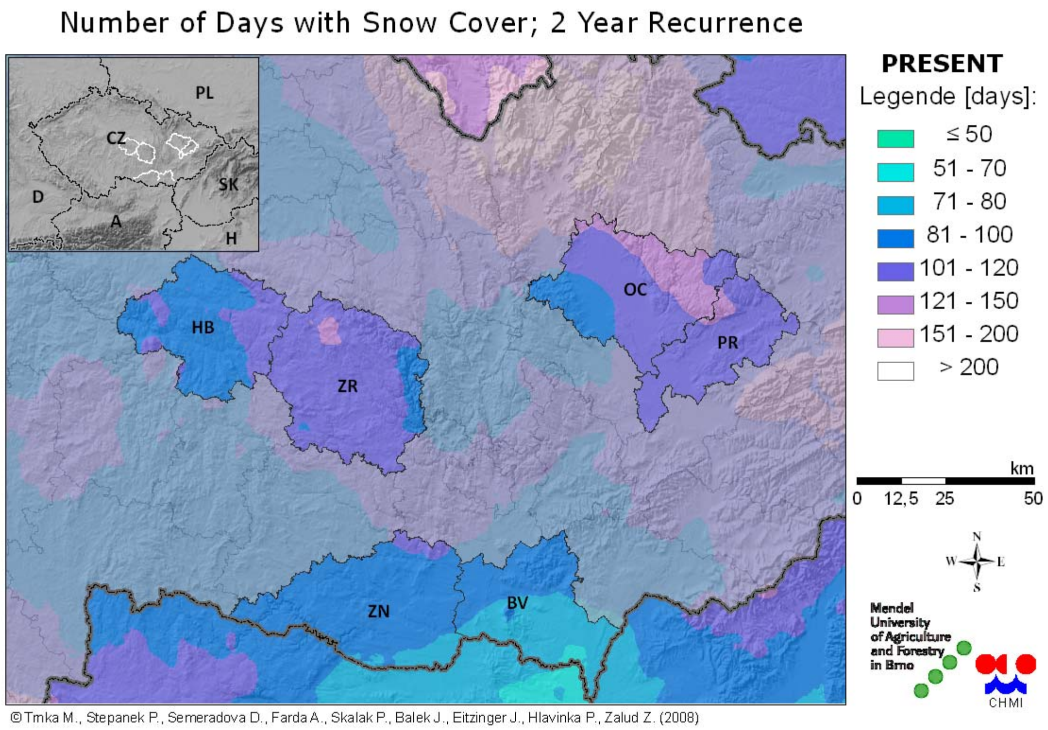


Fig.11. Difference between last frost date (in days) with 2 and 20 year return period for present conditions and those expected by 2021-2050.

classify regions with progressing drying to LFA although they do not fulfill the criteria set by European Commission. This indicate one of the major risk for the future climate as farmers remain in reactive (rather than proactive) mode and seek state aid instead of private activity.
On the seasonal level, a mean shift of sowing and harvesting dates is already observed, as a

direct reaction to spring weather conditions. For some crops, especially maize, it is observed a change to later ripening cultivars over the past decades. The harvesting windows are getting shorter creating large pressure on the companies in the agri-service business. For grassland regions drought related problems and lower yield stability is becoming problem in some areas where the precipitation is limiting factor.



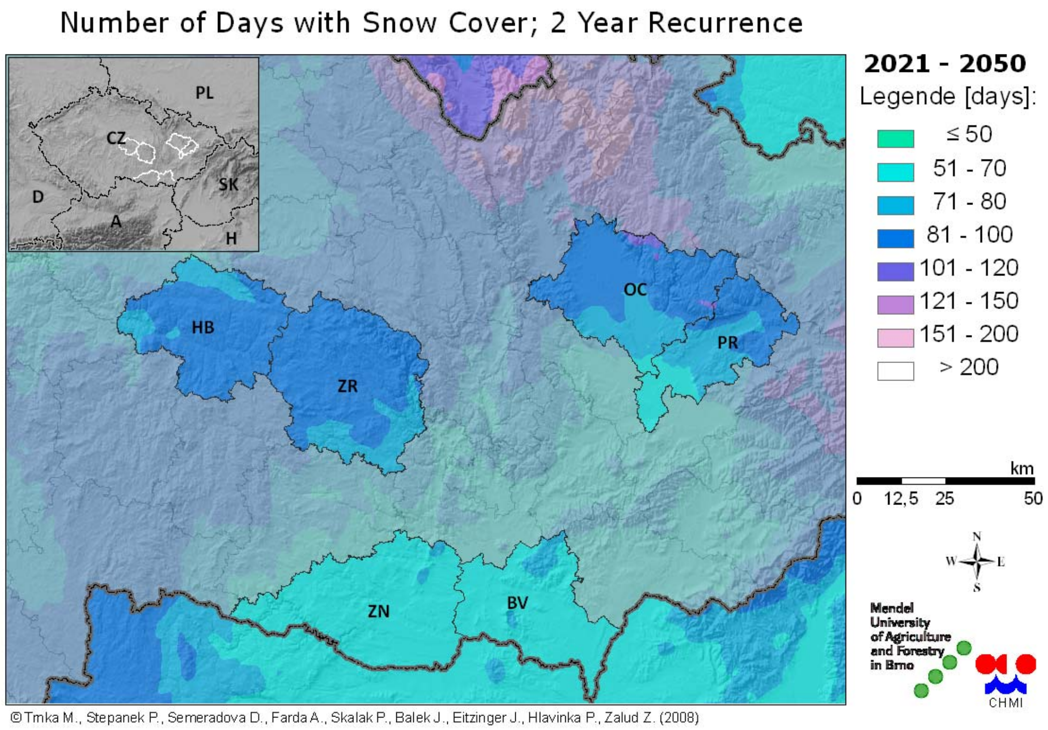


Fig.12. Number of snow days with 2year return period for present conditions and those expected by 2021-2050.

Adaptation options that are feasible in short term

Annual crops :
• shifting of sowing dates
• permanent organic mulching cover agains water losses and/or soil erosion
• reduced soil cultivation,
• changes in crop rotation for an improved crop water use efficiency (e.g. more winter crops, drought and heat tolerant cultivars)
• change to later ripening cultivars or new crops (e.g. maize, soybean, sunflower)
Permanent crops (vineyards, orchards) :
• permanent mulching covers agains water losses and soil erosion
• change of cultivars (vine)
• introducing irrigation systems
• adaptation of vineyard maintainance measures (pruning, fertilizing, etc.)
Permanent grasslands :
• change of cutting regime to more extensive
• adapted fertilizing
• alternative or additional fodder production by crops

The crop model analyses provided us with estimates of feasibility of the short term adaptation options especially in the case of field crops. We noted that reduced soil cultivation and introduction of winter cultivars brought significantly higher yields especially in the areas with soils with high water holding capacities. The potential of cultivars with higher water use efficiency and later ripening was also explored and gain of 50-150 kg/ha/day of increased grain filling period was indicated. However the last two adaptation options are now only theoretical as there are no such cultivars available on the market. The most obvious and already practiced adaptation is thus shift to winter crops combined with shift of sowing dates. Our results indicate that the fall sowing window (September – November) will have more suitable sowing days than under present conditions which is the first condition for realization of this adaptation strategy. The shift of optimum sowing date was estimated for range of scenarios with the results for high climate sensitivity and A2-SRES scenario for 2050 is presented at Figure 13.

Adaptation options that are feasible in midterm and where further testing is needed (or where investment will be required)

Annual crops :
• extension of irrigation
• crop rotation changes to more winter crops (investigation of multiple effects needed)
Permanent crops (vineyards, orchards) :
• change in crop management, fertilizing and crop protection methods
• new production regions should be evaluated
Permanent grasslands :
• testing irrigation options
• change of grassland composition to more drought tolerant cultivars and plants
• change of fertilization methods (more effective application methods of manures, manure treatments)
• evaluating alternative regional production options better adapted to increasing summer droughts

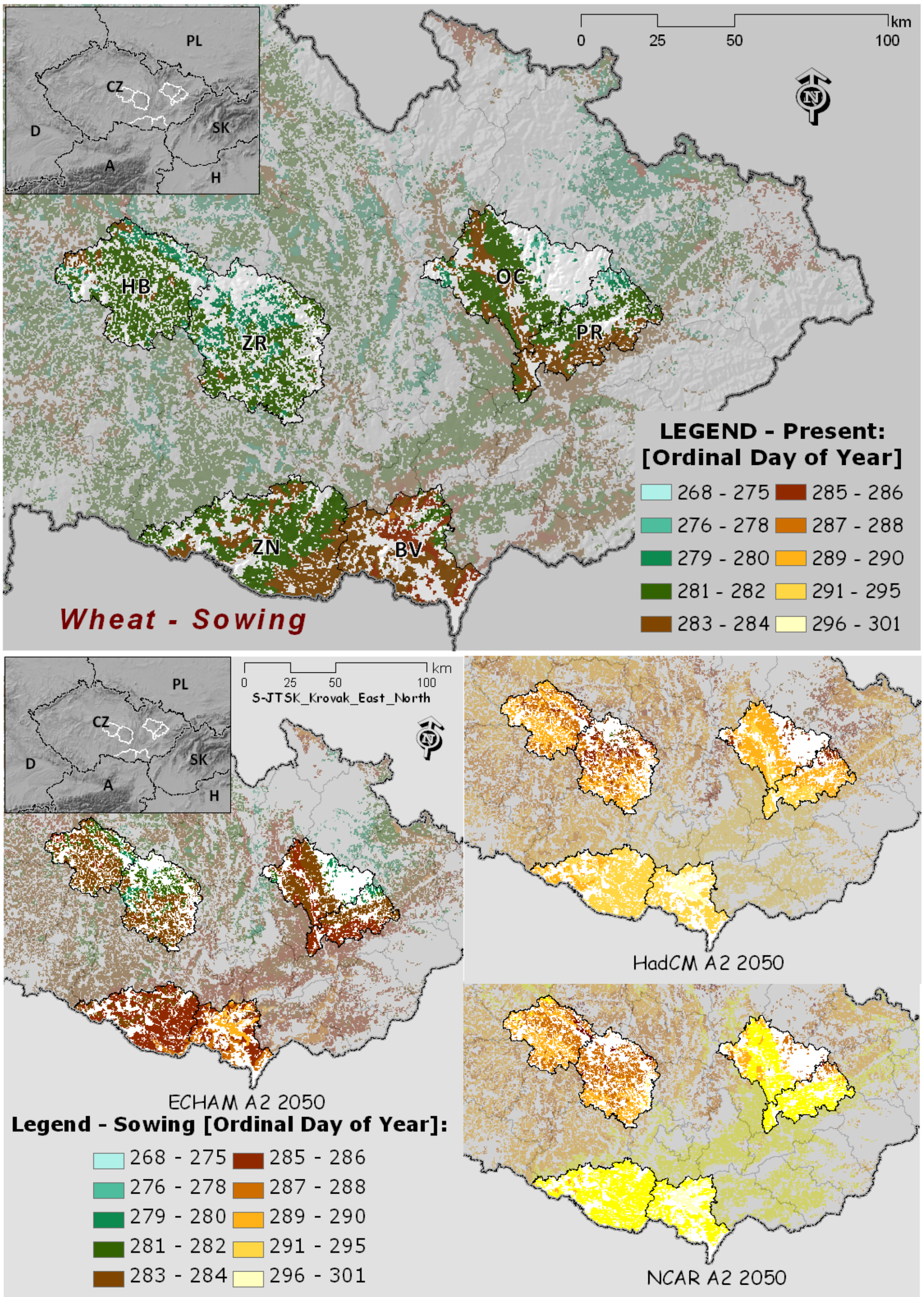
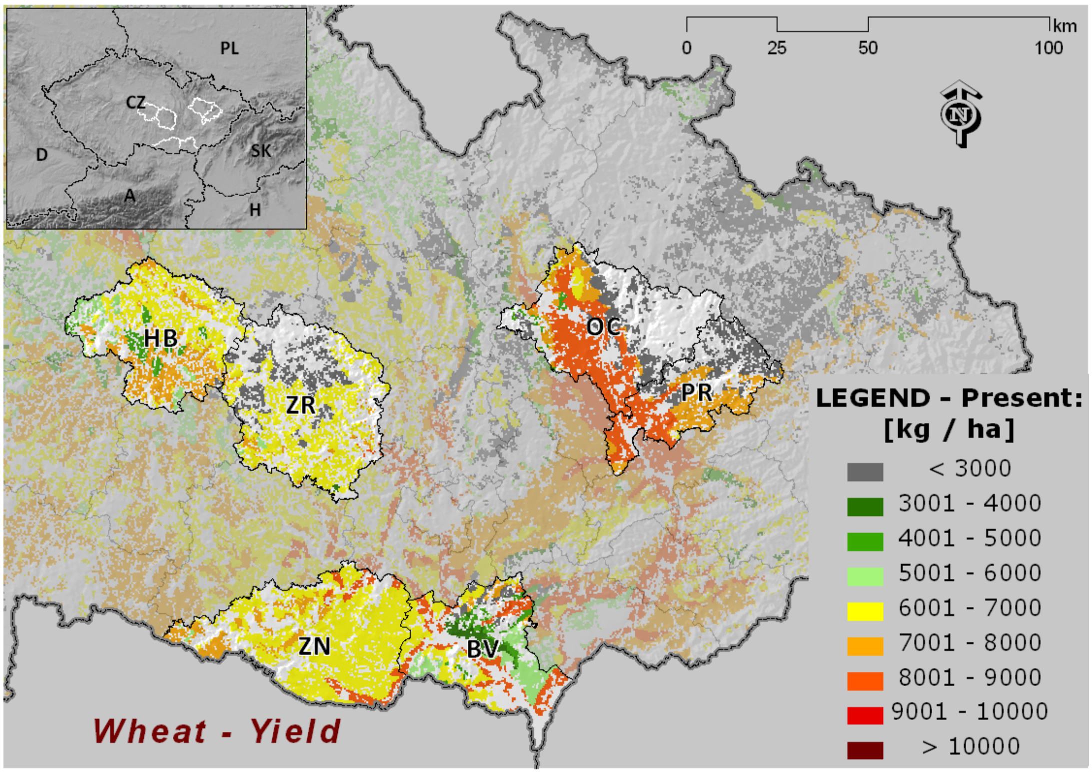


Fig.13. Expected shift of sowing days in three case study regions for winter wheat by 2050.

There are large benefits to be expected when shifting from spring to winter cropping that is widely practiced in the most of the country anyway. In some commodities (e.g. barley) intensive experiments and breeding programs are ongoing to prouduce winter type cultivars with sufficient malting qualities to substitute for spring malting barley cultivars. The expected changes in winter wheat yields (that are mostly positive across all three case study regions) seems to support this strategy (Fig. 14). However these positive outcomes will be possible only if the positive effect of increased carbon dioxide concentration built in the CERES crop models is indeed realized. Some studies suggest that the positive effect of CO_2 is largely exaggerated. When we account for this uncertainty the analysis shows that even application of short-term adaptation strategies (change of sowing days and fertilizer applications) will not be sufficient to prevent yield losses (Fig 15 and Fig. 16). In this case the most productive Region 2 will be the hardest hit however the higher elevations with still sufficient water reserves will benefit from changed conditions considerably (Region 3). To offset negative yields the irrigation should be considered however this is not likely to be an economically viable solution. It remains to be seen if the expected yield lossess could be mitigated by crop breeding and soil moisture saving procedures.



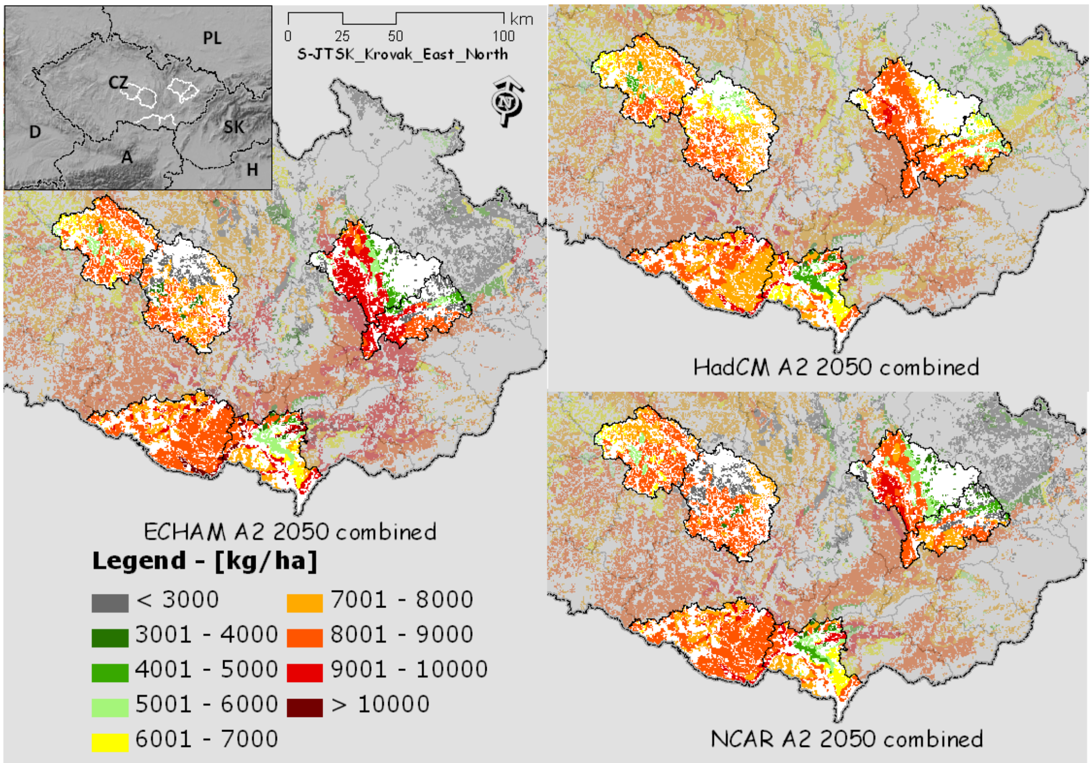
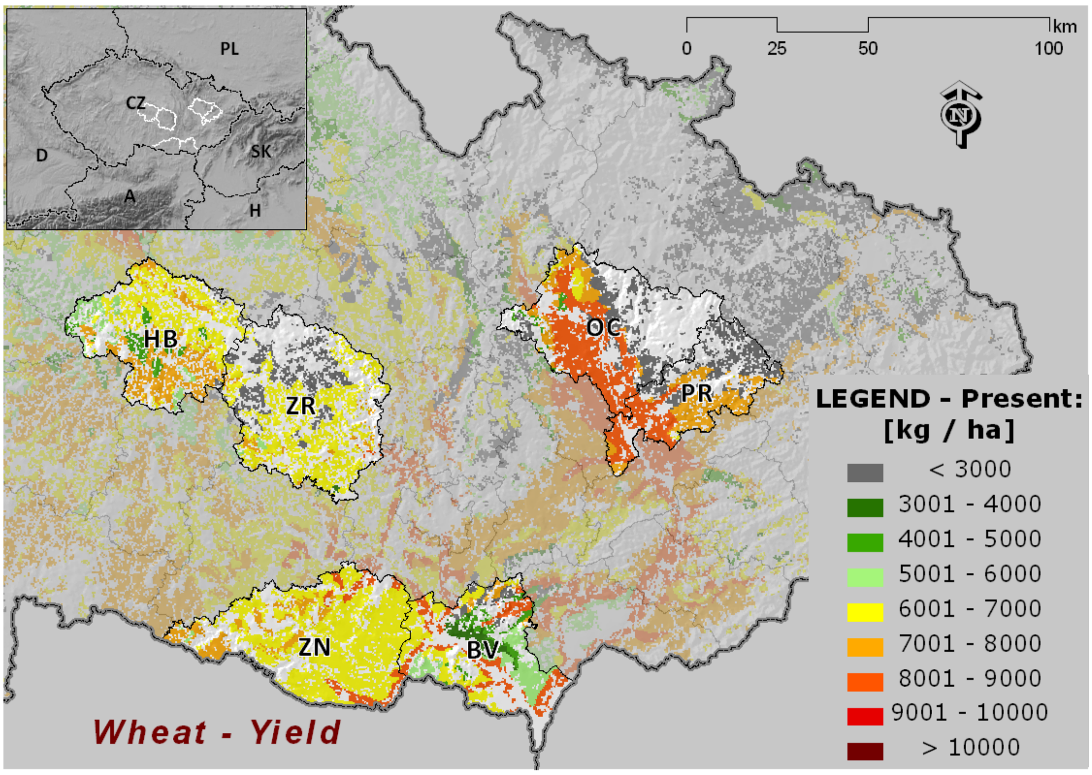


Fig.14. Present (upper) and expected (lower) yield levels in the three case study regions. The expected yield levels include the positive effect of CO_2 and also adaptation on the side of farmers (optimalization of sowing dates and fertilizations dates).



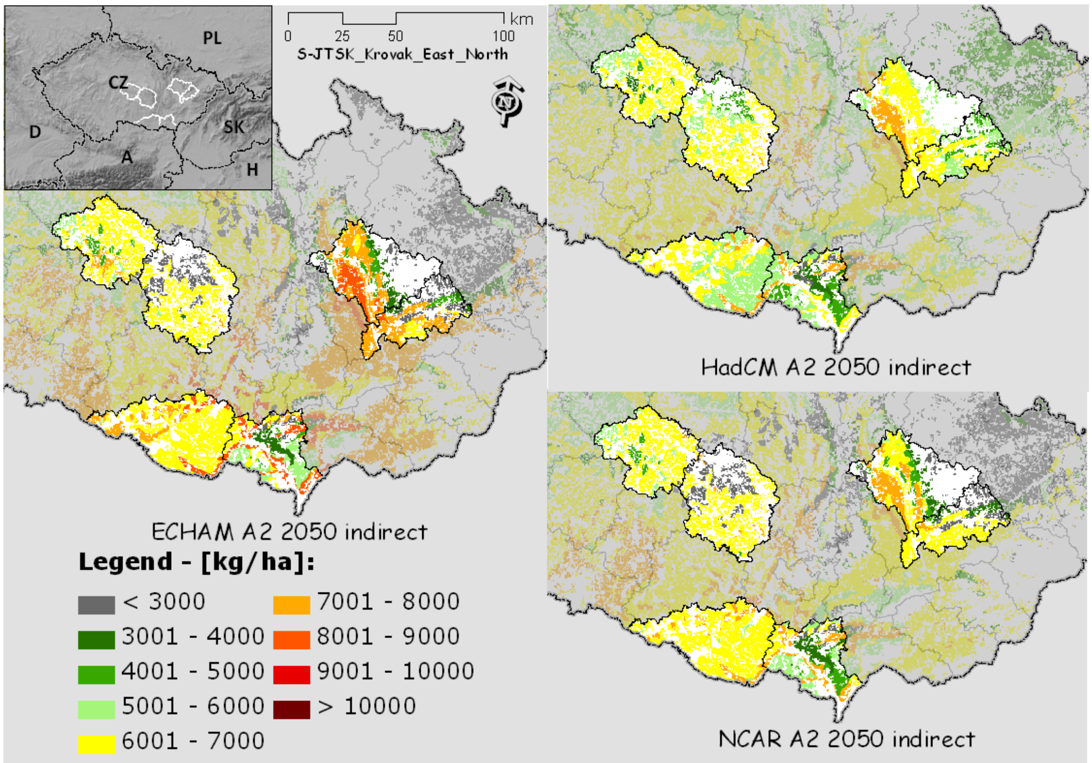


Fig.15. Present (upper) and expected (lower) yield levels in the three case study regions. The expected yield levels do not include the positive effect of CO_2 and are just result of the changed weather patterns and adaptation measures.

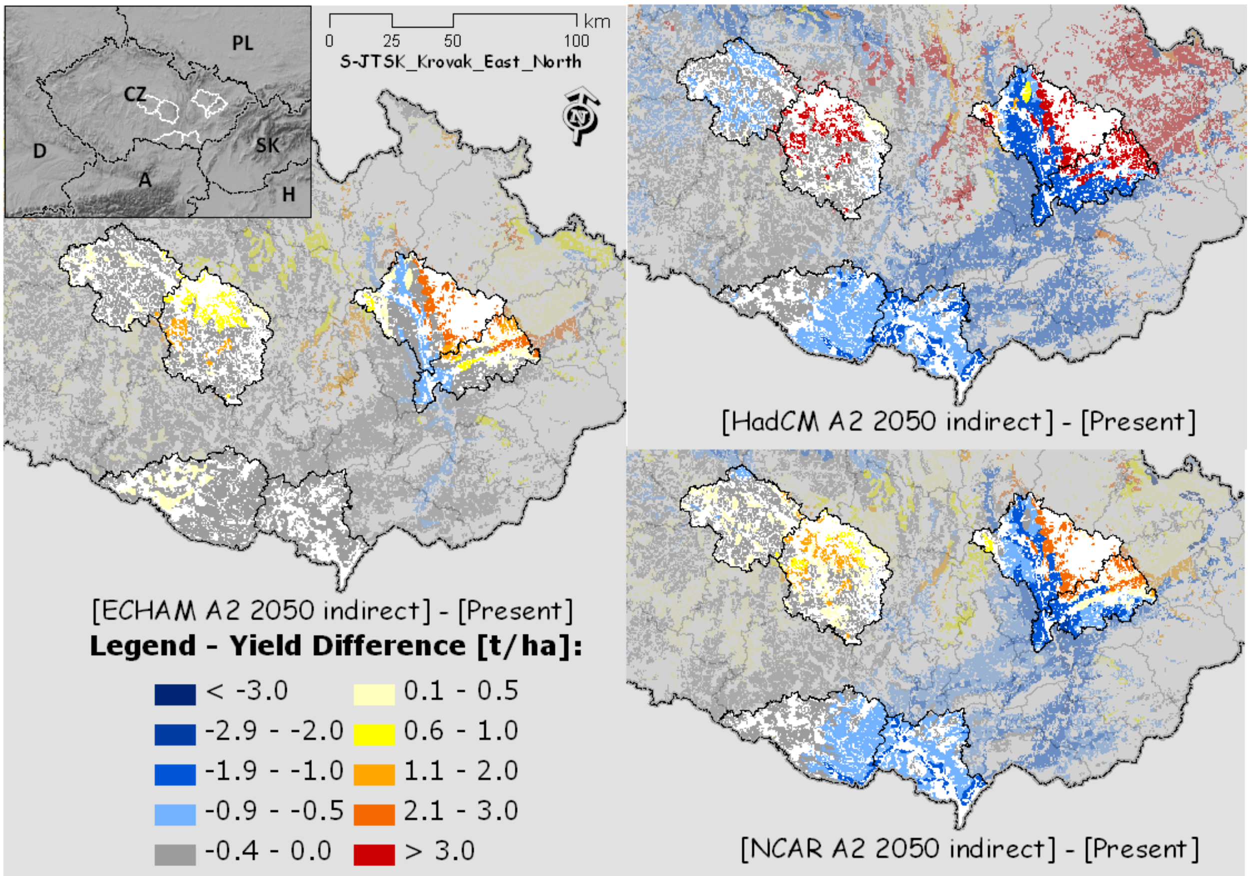


Fig.16. As in Fig. 15 but visualized as the difference in yields between expected levels and the present.

It should be noted that farmers and farm organization seem to remain in the reactive (rather than proactive) mode and seek the state aid rather than long-term planning and risk management. There is also confusion about the state agricultural policy that is caught between pressures of farm companies focused on the intensive agriculture, ecological farms, calls for sustainability and production of biomass- and bio-energy. As a result the priorities of the state agriculture policy changes quite often and the subsidies are probably not always spend most efficiently. Most of the crop production is marked driven and based on short term market conditions only (could be illustrated on sharp increases of oil seed rape in 1990´s; of poppy seed after 2005 and winter wheat in 2008). These responses do not consider how the production potential of various crops may change under climate scenarios. This could be a problem in the future in the semi-arid production regions, because of the high water demand of high yielding crops such as used for biomass production.
Adaptation measures of farm production practices could not be avoided but is mostly viewed as response to the seasonal variability rather than to the reported trends. Unlike in Austria farmers are not able to compensate seasonal losses by insurance and are becoming even more vulnerable.

4.5.3.2.2 Adaptation to climate-related pest and disease risks

The farmers and extension experts consider diseases and pests as first signs of regional impacts of climate change. However only in a few cases (mostly insects) a warming trend can be related to e.g. the spatial distribution of pests such as the european corn borer or Colorado potato beetle. Farmers adaptation to changing pest and diseases has been so far limited to

currently applied protection methods, which are more related to „reaction“ than adaptation. However there has been sharp increase in acceptance of GM crops and grain maize in particular. One of the most cited adaptation measure would be a development of a national system for regional monitoring of crop and pest occurrence and advance warning systems.
Results obtained based on the project specific case studies were published in peer reviewed journals (4 papers) and in the bulletin of the Czech Phytopathological Society (1 overview paper). In the same time two interviews (one in national newspaper and one in famer magazine) were given by the team members as well as 6 lectures (January-April 2008) to over 300 farmers in total. Close collaboration is maintained with the Czech Agricultural Chamber and farmers in selected "case study" regions.
Based on the research results and questionnaires the possible adaptation of the Czech farmers could be summarized as follows:

Adaptation options that are feasible in short-term

Annual crops :
- adapting crop rotations
- keeping minimum distances to fields of similar crops (reduction of pest transfer)
- field based pest and disease monitoring (by observations and/or agromet weather stations)
- using methods biological methods (e.g. parasitic wasps in case of European Corn Borer)
- using resistant crops and cultivars (and GM cultivars or hybrids)

Permanent crops (vineyards, orchards, hops plantations) :
- field based pest and disease monitoring (by observations and/or agromet weather stations)
- using antagonists

Adaptation options that are feasible in midterm and where further testing is needed (or where investment will be required)

Annual crops:
- change to resistant and GM crops
- increasing crop diversity (farm and regional) however this is in conflict with productive requirements
- operational, regional pest and disease monitoring
- evaluating or testing new antagonists and more research into the pest life cycles

Permanent crops (vineyards, hops plantations) :
- changing production regions and technology of cultivation
- operational, regional pest and disease monitoring

Animal production:
- ensuring stock capacity for fodder
- adapted stable buildings and abandonment of old (enclosed) stables to avoid heat stress
- improving hygienic conditions around animals

4.5.3.2.3 Adaptation strategies by changing land-use and crop selection

The options for a change in land use and crop selection in the Czech Republic was considered on a regional and national level. Czech Republic as a whole is dominated by the large fields with low diversity of farms and production. The farm structure in the country and composition of the crops follows climate conditions quite closely and is expressed also in the form of the agroclimatic zonation. The eventual climate change will mean very significant

shifts of agroclimatic zones and will inevitably force change of the landuse compared to the present conditions. Especially the grassland areas are particularly threaten due to the low precipitation even under the present climate (Fig. 17). As this figure shows the grassland production might become impossible in next few decades regardless of the scenario used. Under the present conditions Region 3 in particular has the largest area of grassland areas (and associated diary and cattle production).
So far (based on the questionnaire analysis) farmers (especially in the high land regions) have switched to crops they could not grow before (e.g. grain maize or sunflower). In the same time farmers in the Region 1 are finding very difficult to maintain sustainable production of field crops without irrigation. However the availability of irrigation of field crops is very limited because of economical and water availability reasons. At some sites biomass production by perennial trees is significantly changing land-use and could be viewed as an alternative to grasslands in the endangered areas. So far we have observed regional changes in crops because of increasing water problems (in lowlands) and improving agroclimatic conditions (in highlands) however these changes are also driven by economical factors as well.

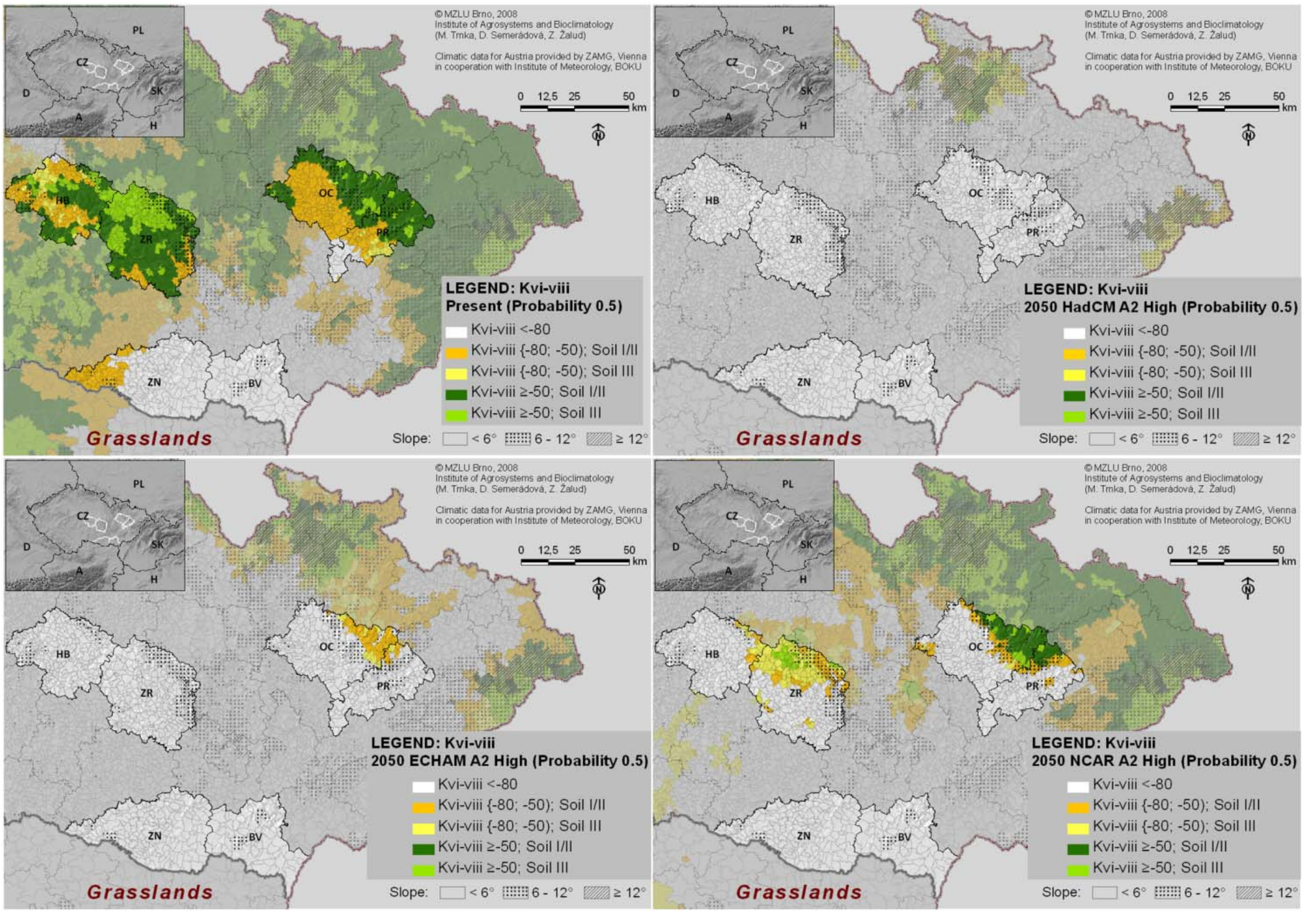


Figure 17. Areas suitable (green) and conditionally suitable (yellow) for the grassland production under present and 2050 climate conditions in three case study regions.

<u>Adaptation options that are feasible in short term</u>

Annual crops :

• change from summer to winter crops

- using crops/cultivars with higher temperature requirements and water use efficiency

Permanent crops (vineyards, orchards, hops) :

- using multiple cropping

Permanent grasslands :

- transfer of grassland to arable land or to poplar/willow/aspen plantations

Adaptation options that are feasible in midterm and where further testing is needed

Annual crops :

- **irrigation (in most extreme cases and only in some areas)**
- eventually introducing agro-forestry systems (wind protection, improving microclimatic conditions) as seen in Austria

Permanent crops (vineyards, orchards) :

- irigation
- new production regions (based on climate shifts)

Permanent grasslands :

- change to different production
- change from intensive to extensive production
- change to wood based bioenergy production

4.5.4 Scientific basis of ADAGIO results

4.5.4.1 List of all literature used for national ADAGIO purposes, analysis etc. (national and international)

See under AUSTRIA

4.5.5 Dissemination activities during ADAGIO (during all project lifetime)

4.5.5.1 List of scientific ADAGIO publications (which include ADAGIO results). It means: ADAGIO related results which were published during the AGAIO project.

Trnka M., Eitzinger J., Kapler P., Dubrovský M., Semerádová D., Žalud Z., Formayer H., 2007. Effect of Estimated Daily Global Solar Radiation Data on the Results of Crop Growth Models, Effect of Estimated Daily Global Solar Radiation Data on the Results of Crop Growth Models. *Sensors*. 2007. Vol. 2007, no 7, pages 2330--2362. ISSN 1424-822.

Trnka M., Eitzinger J., Hlavinka P., Dubrovský M., Semerádová D., Štěpánek P., Thaler S., Žalud Z., Možný M., Formayer H.: Climate-driven changes of production regions in Central Europe *Plant Soil Environ*., 55 (2009): 257-266

Trnka M., Eitzinger J., Semerádová D. Hlavinka P, Balek J., Dubrovský M., Kubu G., Štěpánek P, Thaler S., Žalud Z., 2009., Expected Changes in Agroclimatic Conditions in Central Europe, *Climatic Change* (accepted in print)

Schaumberger A., Trnka M., Eitzigner J., Formayer H., Bartelme N., 2007, Agrometeorological monitoring of Austrian grassland using GIS based modelling, European Geosciences Union, Vienna, EGU2007-A-10449 AS1.13-1MO3P-0066

P. Hlavinka (1), M. Trnka (1), M. Dubrovský (2), D. Semerádová (1), Z. Žalud (1), M. Možný (3); P. Rischbeck (4), 2007, Relationship between Agricultural Drought and Yields of Selected Crops at Regional Scale within the Czech Republic , 7th EMS annual meeting, El Escorial 1-4. October, EMS2007-A-00400;

M. Trnka (1), M. Dubrovský (2), P. Hlavinka (1), D. Semerádová (1), Z. Žalud (1), V. Horáková (3), 2007, Projection of Uncertainties of the Climate Change Scenarios into the Cereal Production Estimates - Central Europe as a Case Study 7th EMS annual meeting, El Escorial 1-4. October, EMS2007-A-00389

Trnka, Miroslav -- Dubrovský, Martin -- Hlavinka, Petr -- Semerádová, Daniela -- Štěpánek, Petr -- Eitzinger, Josef -- Formayer, Herbert -- Žalud, Zdeněk, Crop yields and agroclimatic conditions in central Europe between 2020 and 2050. In Symposium on Climate Change and Variability; Agro Meteorological Monitoring and Coping Strategies for Agriculture, Oscarsborg, Norway, June 3-6, Book of abstracts, FOKUS Bioforsk. 8. vyd. 2008, s. 69. ISBN 978-82-17-00374-8.

Trnka, Miroslav -- Dubrovský, Martin -- Hlavinka, Petr -- Semerádová, Daniela -- Štěpánek, Petr -- Eitzinger, Josef -- Formayer, Herbert -- Žalud, Zdeněk, Projection of Uncertainties of the Climate Change Scenarios into the Estimates of Future Agrometeorological Conditions and Crop Yields. Geophysical Research Abstracts. [online]. 2008. URL: http://European Geosciences Union,Vienna, 13,; 18 April 2008.

Trnka, Miroslav -- Olesen, Joergen -- Eitzinger, Josef -- Štěpánek, Petr -- Brázdil, Rudolf -- Dobrovolný, Petr -- Dubrovský, Martin -- Žalud, Zdeněk, Recent Trends in Agroclimatic Characteristics and Consequences for Adaptation Options in Cereal Production -- Adaption in Agriculture, but to what?. EMS Annual Meeting Abstracts. [online]. 2008. URL: http://8th EMS / 7th ECAC Annual Meeting, 29 September - 03 October 2008, Amsterdam.

Semerádová, D. -- Trnka, M. -- Žalud, Z. -- Dubrovský, M. Dopady změny klimatu na výnos pšenice ozimé na okresní úrovni -- prostorová analýza pro Českou republiku (Impact of climate change on yields of winter wheat on the district level – spatial analysis for the Czech Republic). [CD-ROM]. In In XVI. posterový deň s medzinárodnou účasťou "Transport vody, chemikálií a energie v systéme poda-rastlina-atmosféra". 11 s

Semerádová, D. -- Trnka, M. -- Dubrovský, M. -- Žalud, Z. Prostorová analýza dopadů změny klimatu na výnos pšenice ozimé. (Spatial analysis of the climate change impacts) [CD-ROM]. In Bioklimatologické aspekty hodnocení procesů v krajině. ISBN 978-80-86690-55-1.

4.5.5.2 List of not yet published (manuscript status) <u>scientific</u> ADAGIO related publications (national or international).

M. Trnka, J. Eitzinger, M. Dubrovsky, P. Štěpánek, Semerádová, P. Hlavinka, J. Balek, Z. Žalud, P. Skalák, A. Farda, Formayer H., 2010 Is The Rainfed Agriculture In Central Europe At Risk? - Using A Novel Methodology To Produce High Resolution And Regionally Relevant Support For Decision Makers, Journal of Agriculture Science, (submitted manuscript)

M. Trnka, J. Eitzinger, S. Thaler, P. Hlavinka, D. Semeradová, M. Dubrovsky, Z. Žalud, G. Kubu, H. Formayer, 2010 Assessing Differences In The Farm Level Vulnerability Of The Cereal Production In The Central Europe – Consequences, Uncertainties And Adaptation Options, Journal of Agriculture Science, (submitted manuscript)

E. Kocmánková, M. Trnka , J. Eitzinger, M. Dubrovský, P. Štěpánek, Semerádová, J. Balek, P. Skalák, A. Farda, J. Juroch, Z. Žalud 2010- Estimatingclimate change impact on occurrence of selected species in high resolution – a novel approach, Journal of Agriculture Science (submitted manuscript)
E. Kocmánková, M. Trnka, Z. Žalud, D. Semerádová, M. Dubrovský, J. Juroch, J. Eitzinger, M. Možný (2010): Estimating climate change impact on the occurrence of selected pests in the Central European region (invited manuscript – will be submited by Sep. 30)

4.5.5.3 List of published or not yet published (manuscript status) ADAGIO results specific designed for national farmers or stakeholders, which are more than common articles in newspapers (e.g. books, brochures, reports which can serve as a permanent source of information).

Lošák, T. -- Hlušek, J. -- Žalud, Z. -- Trnka, M. -- Semerádová, D. -- Dubrovský, M. Zásady správné výživy a hnojení kukuřice v měnících se klimatických podmínkách. In Kukuřice v praxi 2008. MZLU v Brně: MZLU v Brně a KWS Osiva, s.r.o., 2008, s. 23--34. ISBN 978-80-7375-135-7.

Žalud, Z., Trnka, M., Semerádová, D., Dubrovský, M., Změna klimatu a její dopady na růst a vývoj polních plodin- In Czech (Climate Change and Its Impacts on the Production of Field Crops). Agromagazín. 2007, roč. 8, č. 3, s. 7-10.

4.5.5.4 Other <u>national</u> public relation activities (e.g. lectures, farmer meetings, articles in newspapers), use the updated table below, for ALL ADAGIO period

Listed in the Thematic Group 4 report

4.6 Italy

4.6.1 Abstracts of national case studies carried out during the ADAGIO project

Case study 1 :

Soil water balance of a winter crop cultivated in Southern Italy as influenced by future climate

D. Ventrella, L. Giglio, M. Castellini

Abstract

An efficient management of the water resources is considered very important for Italy and in particular for Southern areas characterized by a typical Mediterranean climate in order to improve the economical and environmental sustainability of the agricultural activity. In this plot assessment we applied SWAP (Soil-Water-Atmosphere-Plant) model to optimize the management for scarola, cultivated in winter period in a farm located in the Metapontino Area in the Jonical costal zone of Southern Italy.

SWAP, with the simple growth module, was parameterized by using crop and soil data set collected in a private farm situated in the coastal area of the Puglia region in Southern Italy (lat. 40° 28' 48.40" N and long. 16° 47' 37.97" E) with sandy-loam soil and characterized by intensive winter cultivation of scarola (Cichorium endivia var. latifolium Hegi cv Growers Giant). The climatic data were obtained with a dynamical downscaling utilizing the HadCM3 General Circulation Models coupled with the HadRM3P Regional Climate Model , developed by the Hadley Centre, UK., in order to obtain a final spatial resolution of 0.44° latitude by 0.44° longitude. In order to simulate climate change, two emission scenarios (A2 and B2) were a selected among those proposed by the Special Report on Emissions Scenarios (IPCC 2000), to have a wide and representative range of changes in temperature patterns.

The climatic daily data of the scenarios A2 and B2 (from 2071 to 2100) and reference period (REF, from 1961 to 1990) were utilized for SWAP applications with unique inizializations. For each scenarios we compared three transplanting dates (October 1st; October 15th and October 30th with the second one representing the typical date) submitted to noirrigation (NI) and full-irrigation (FI) as typical for fertirrigation scheduling. For each run we considered these output at temporal scale of cultivation period: cycle length (CL), rain (R), potential evapotranspiration (ETp) and drainage (D). We have also considered the ratio between actual and potential transpiration (RT) and irrigation depth (ID) for NI and FI treatments, respectively.

The comparison among the three climatic scenarios shows higher monthly averages of maximum temperatures for A2 and B2 than the REF scenario with differences up to 7 °C in the summer period. Significant reductions of annual rainfall are detected under A2 and B2 (-17 and -24%, respectively) particularly during the spring and summer months. Under A2 the winter precipitations compensate partially the summer drought.

The first important results is the reduction of the crop cycle (-17 and -35% under B2 and A2, respectively). According with this reduction R and ETp (-30% for A2) are predicted to decrease. Without irrigation the analysis indicates a lower RT fraction (-12 and -7%) corresponding to higher water stresses for lettuce cultivation. The irrigation water requirement (ID) is forecast to increase under B2 (+ 6%) and to decrease under A2 (-15%). The higher rainfall concentration in the winter period under A2 explains the larger water losses under A2. With advanced transplant and regardless of IPCC scenarios, a significant cycle reduction is expected by 20% in average that determines a decrease of irrigation requirement of the same

order of magnitude. At the contrary with a delayed transplanting date, the crop cycle and consequently the irrigation depth is expected to increase above all under A2 scenario.
In conclusion these findings show a significant evidence that the changes of climate would can have on the winter lettuce cultivation in Southern Italy. The expected warming can be expected to shorten the cultivation period with consequent reduction of rainfall, potential evapotranspiration and irrigation. The transplanting time is found to be an useful agronomic practice in order to decrease the irrigation requirement of lettuce. Compared to normal time of transplanting, an advanced date of 15 days is expected to save water by 20% in average.

Case study 2 :

Vulnerability to temperature and precipitation of durum wheat in Southern Italy

D. Ventrella. D. Vitale

Abstract
Despite advances in technology and the widespread prevalence of irrigation, the agricultural production and quality of harvested crops remains highly dependent on weather. According to a paper of Lobell et al. (2005) regarding the agriculture in California, the goals of this activity were twofold: (1) to provide a quantitative understanding of past relationships between crop production of durum wheat and climate of Southern Italy; and (2) to evaluate the net impact of climate on observed yield trends over the study period.
We have analized a data-set for a period of 30 years including the annual yield and the flowering time of 9 cultivars of winter wheat cultivated in the plain of Foggia (Puglia Region) at the "CRA-Centro di Ricerca di Cerealicoltura". The variability of productive and phonological data were related to a daily climatic data set. In particular the following steps were carried out: (i) preliminary analisys (quality control , homogenization and gap filling, test to evaluate presence of trend), (ii) relationship between flowering time and precipitation and cumulated daily temperatures with three different threshold; (iii) relationship of flowering time and yield with monthly data of temperature (minimum and maximum) and precipitation.
The most important results can be synthesized in the following points:
1. A significant positive trend of temperature in spring and summer is resulted. Regarding the maximum temperatures the same result was obtained also in autumn. Moreover we found a significant trends of monthly precipitations: positive in January and September and negative in October.
2. Significant correlations resulted among the temperatures (minimum and maximum) and precipitation at monthly scale.
3. The length of vegetative period resulted positively correlated with cumulated temperature above 0° and negatively correlated with temperatures above 5 and 10°C.
4. The relationship of flowering time (Y) and yield (Y) with monthly data of temperature (X, minimum and maximum) and precipitation (X) was examined by means of regression analysis based on the following equation relating the response variable Y (flowering time or yield) with the three most significant climatic variables (X_1, X_2 and X_3):

$$Y_t = aX_{1,J,t} + bX^2_{1,J,t} + cX_{2,J,t} + dX^2_{2,J,t} + eX_{3,J,t} + fX^2_{3,J,t}$$

The length of vegetative period appeared most dependent on maximum temperature of November (+), Maximum Temperature of March (-) and Rainfall in March (for *Creso, Duilio and Simeto cultivars*).

Concerning the regression on yield of winter wheat the most important climatic parameters were: the precipitation in April, the minimum temperatures in March, the minimum temperatures and precipitation in November.

Case study 3 :

Vulnerability and agronomical adaptation to climate change regarding soil water balances and productivity of some crops in Southern Italy

D. Ventrella. L. Giglio, M. Castellini, R. Lopez

Abstract
Adopting the same procedures of previous pilot assessment about climatic data and regional soil data, we have extended the analysis to other important crops for Jonical coast of Southern Italy with spring-summer cycle of cultivation: sorghum and water melon.
The Sorghum is an interesting crop for animal feeding for the climatic conditions of Southern Italy. This pilot assessment was carried out using SWAP model previously calibrated and validated. In average at present condition, the cycle length is about 100 days with limited availability of natural water resources by rain e with the necessity to apply the normal irrigation scheduling to fulfill the transpiration requirement. Adopting the same climatic data set of the previous pilot assessment, we carried out an analysis concerning the future periods (2070-2100) under conditions of IPCC scenarios of B2 and A2, considering 4 sowing times: the normal sowing time of 01/may and three advanced times of 20/Apr, 10/Apr, 30/Mar and 20/Mar.
Without adaptation the cycle length decreases by 20% in both the scenarios. This reduction determines a consistent decrease of rainfall at seasonal scale and little variations on transpiration (potential and actual). Because of reduction of LAI, the tendency of soil evaporation is to increase while the irrigation requirement increases by 15%.
The impact of climate change on sorghum productivity, on biomass an yield, is high with reductions that exceed the levels of 40% and 50% for B2 and A2 respectively. The yield decrement depends essentially by the shortening of reproductive phase when the assimilates accumulate in the grains.
The adaptation strategy of advancing the sowing time can be considered as positive because it is possible to reduce the negative impact of climate change on sorghum productivity. In particular it is evident that a ten-day advance period decreases the biomass and yield losses by 10% under B2 scenario allowing a productive reduction of about 10% (starting from -40%) with the most advanced time sowing compared to the past situation.
Under A2 scenario the relationship "advancing time period/productivity" is about the same with the minimum losses of 20% that can be obtained with the most advanced sowing time.
The advancing of sowing time has important effects on the component of water balance and in general it tends to decrease the reductions and to restore the parameter values of past situation. This is particular evident for cycle length, plant transpiration and soil evaporation.
The effect is less emphasized for rain and deep percolation. Finally, we have very low variations on irrigation depth under scenario B2 while in the other scenario the advancing the sowing has no effect time up to 20 days, while the most advanced time allows to restore the irrigation depth of reference situation.
For water melon, without adaptation the cycle length decreases by 20% in both the scenarios. Like the Sorghum, this reduction determines a consistent decrease of rainfall at seasonal scale (-60%) and less variations on transpiration (-10%). In this case we have also a reduction in evaporation flux (-25%). Under A2 the reductions are: -70%, -10% and -30% for rainfall,

transpiration and evaporation respectively. Similar reduction of deep percolation are expected for B2 and A2. Also in this case, advancing of sowing time has important effects on the components of water balance and in general it tends to decrease the reductions and to restore the parameter values of past situation. For cycle length and irrigation depth there is also a little increment with the most advanced sowing time under B2. In the other cases, advancing the sowing time by 20 days determines reductions, compared to the past, less than 5% for actual transpiration and evaporation and irrigation. Drainage and rainfall result the less sensitive component to this adaptation strategy.

Case study 4 :

Strategies of agronomical adaptation for tomato and winter wheat cultivated in a Mediterranean environment

D. Ventrella, M. Rinaldi, M. Charfeddine, S. Ruggieri, P. Garofalo, L. Giglio

Abstract

The crop model used in this pilot assessment is embedded in the Decision Support System for Agro-technology Transfer (DSSAT) software application. Crop growth is based on CROPGRO, a generic crop growth model that was originally developed for legumes and adapted to other crops including tomato. The data sets used for model calibration and evaluation were derived from a field experiment carried out at the experimental farm of the "Agricultural Research Council – Research unit for cropping systems in dry environments" in Foggia (418270 latitude N, 158040 longitude E) in Southern Italy. The area (about 400,000 ha) is mainly cultivated with durum wheat which is grown in a 3–4 years rotation with tomato or sugar beet. The soil is a silty-clay vertisol of alluvial origin (1.20 m depth) and is classified as a fine, termic, Typic Chromoxerert (according to USDA Soil Taxonomy) with 24.9 % sand, 39.7 % silt and 35.4% clay. Rainfall is unevenly distributed throughout the year, mostly concentrated in the winter months with a long-term yearly average of 550 mm. Long-term seasonal (28 April–28 September) potential evapotranspiration (ETo) and rainfall of processing tomato amount to 484 and 178 mm, respectively.

In this application of DSSAT, we have considered a normal transplanting time as reference – April 20th – compared to April 10th (advanced) and April 30th (delayed).

Moreover for every simulation the option to take in account the effect of CO_2 air concentration on plant productivity was activated.

The reference values of tomato cultivation obtained in the past simulation indicate the predominance of reproductive period compared to the vegetative one (111 vs 40 days). The productivity levels of about 5 t ha^{-1} are obtainable with 568 mm of evapotranspiration, 540 mm of irrigation and about 14 irrigation events. The WUE is about 0.9 kg m^{-3} while the irrigation efficiency equal to 0.9 kg m^{-3} . The advanced transplanting determines a reduction of vegetative and reproductive period (about -20% and -5%, respectively). In this case, the positive effect of high level of CO_2 allows a significant increase of biomass production (more than 20%) and a less consistent increase of yield (10% for B2 and 5% for A2), with a consequent reduction of harvest index. The delayed transplanting for this spring/summer crop determines a larger reduction of crop cycle (-40%) that has a negative effect on yield above all under A2. Moreover the LAI max is expected to dramatically increase. Significant increases are reported also for ETP and irrigation (depth and number) above all under A2 with negative consequences on WUE and irrigation efficiency.

For winter wheat simulation by using DSSAT, we have considered a normal sowing time as reference – November 26th – compared to October 27th (advanced) and December 26th

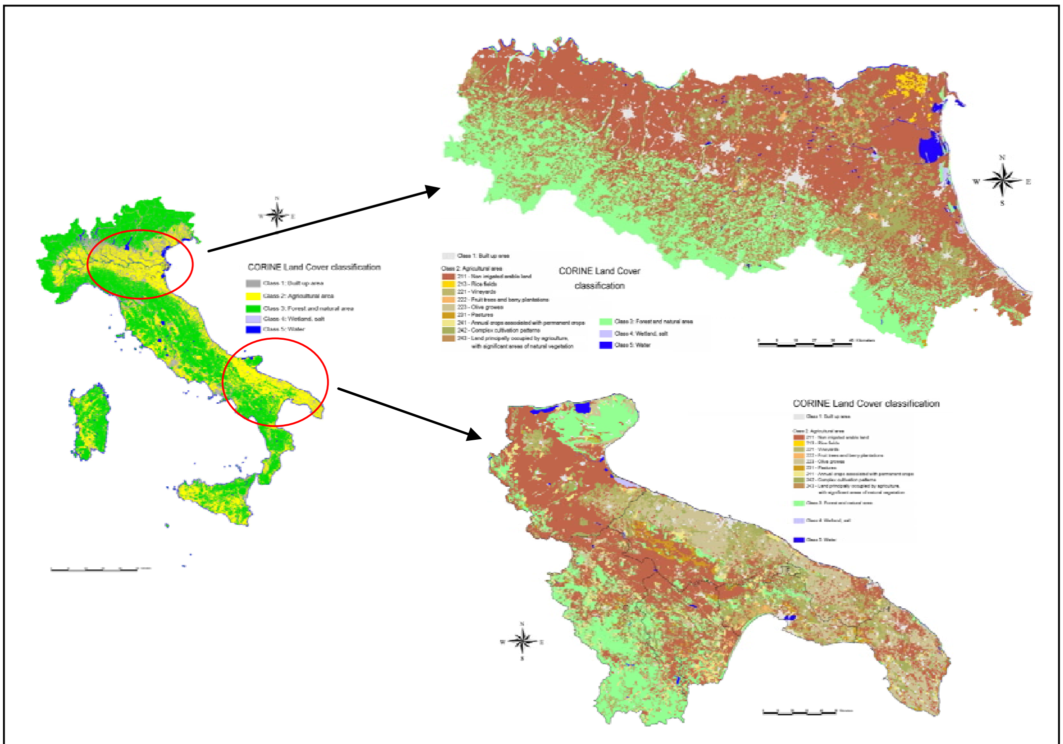
(delayed). For every simulation the option to take in account the effect of CO_2 air concentration on plant productivity was activated.
The reference values obtained in the past with normal sowing time indicate an ETp of about 540 mm with the ETa (actual evapotranspiration) equal to 300 mm. The average yield is about 4 t ha^{-1} with 10 t ha^{-1} of biomass. The advanced sowing time determines a shortening of crop cycle above all for the vegetative period and under scenario A2. Compared to the past and normal sowing time, in the future with advanced sowing all the parameter of plant/soil water balance are expected to decrease with variations most accentuated under A2. The yield reduction are 15% in B2 and 25% in A2. Regarding the delayed sowing time there is a more significant reduction of crop cycle length (20% for vegetative period and 15% for reproductive period) compared to advanced sowing. But, the shift of wheat cultivation in a warmer period allows interesting increases for yield (15 and 10% for B2 and A2) and biomass (less than 5%).

4.6.2 Regional vulnerabilities and reasons

<u>For the detailed regional descriptions see the Tables 6.1 and 6.2 in the Appendix.</u>

4.6.2.1 Summary description of the most significant identified vulnerabilities of the regions/agroecosystems in Italy

In Italian regions and with particular reference to the Southern part most of the rainfall is concentrated in the winter season. This with the high or very high evaporative demand of the atmosphere is the reason because the irrigation, at the present, is a fundamental and essential agronomic practice in order to obtain sustainable yield for spring and summer crops. More than 70% of available water resources is used as irrigation. The most widespread irrigation method is the sprinkler irrigation for the 40%, applied above all in the Northern regions for crops as maize, alfalfa, sugar beet, soybean forage crops. The flood irrigation is utilized for rice crop in the northern regions (above all Piemonte). The localized and drip irrigation methods are concentrated in Southern regions (Puglia, Sicilia and Campania). It is reserved to horticultural and tree crops with large interrow with the wetted soil concentrated near the



The two Italian regions : Emilia Romagna (top) and Puglia - Basilicata(bottom) regions (From Corine 2000).

drippers allowing an efficient plant uptake and minimizing losses by soil evaporation. The most important irrigated crops are: maize, forage crops, horticultural crops and tree crops. The citrus trees are present exclusively in the South. Substantial is the area cultivated with sugar beet and soybean. The horticultural crops are very important for the agricultural economy. They are present everywhere but the most important regions are the Emilia-Romagna in the North and the Puglia region in South. The most important species are tomato, melon and water-melon. Also important in Southern Italy are several autumn/winter crop as lettuce, fennel and cabbage for which supplemental irrigation is in general applied. Considering the tree crops, the vineyard is largely located in Puglia (Southern Italy) e Veneto (Northern Italy). The Emilia Romagna is important for apple, pear and peach trees.

In the framework of climate change we aspect: (1) a larger development and recourse of irrigation with localized methods (microsprinkler and drip irrigation), (2) an increase of supplemental irrigation for normally rainfed crop (winter wheat or sugar beet with autumn sowing), (3) major destination of water resources for crops with highest economical profit, (4) overuse of groundwater (private wells) for the more extensive crops. In this context, the most important challenge for the irrigated agriculture will be to save water and to increase the Water Use Efficiency. One of the reasons to increase the WUE is linked to economical aspects because the competition with the other productive and/or social sector will determine an increase of water price. At the moment in Italy in several but important regions the method of payment of the water it is per hectare and this is one of the first reasons for an excessive water use. In Basilicata region the price is about 150 Euro ha^{-1}. We expect that for the future the payment method for these regions will be per cubic meters of water effectively used.

In Sardegna ("Consorzio di Bonifica della Nurra") the prices for irrigation water is 0.03 Euro m^{-3}. In Capitanata (Puglia), during years characterized by water scarcity, the water price was 0.09 Euro m^{-3} and 0.52 Euro m^{-3} when the water use was above 430 m^3 ha^{-1}.

The agriculture productivity is concentrated in Northern Italy (more than 45%) while in the Center is about 14%. The percentage is 37% for Southern Italy where the predominant cultivation includes herbaceous and tree crops while livestock farming is concentrated in the North. In the last 25 years the Southern Italy have confirmed the specialization for the cultivation of cereals, fruit, citrus, horticultural products, etc.

Considering the total production, the North has shown an higher economic growth since 1992 compared to South and Centre. The trend of Southern Italy is more fluctuant because of higher climatic variability. The economical growth in the agricultural sector has characterized mostly the northern part while for the areas in Central and Southern part the growth rates were significantly lower.

Analyzing the agriculture production, the trends since 1980 were not particularly positive for cereals, forage crops and animal breeding. At the contrary the trends for horticultural and fruit products were more positive. Good export was realized in the wine and grapevine sector.

Considering the total irrigated area, the 64% is in the North against the 28% for the Southern part. This higher concentration of irrigated lands in the Northern part is due to the lager availability of water resources. In Southern Italy the farmers often use water from private wells even if the watertable is deep. If we compare the irrigated area with the irrigable area we note that more than 60% was effectively irrigated with little difference between North and South. There is a higher number of irrigated farm in the South with the average size of farm of 6.8 ha in the North against 2 ha in South.

The employment in agriculture shows a constant decreasing trend. This negative trend is particular evident for the autonomous farmer (-3% per year). For the dependent worker it was a reversal tendency during the 2000-2002 periods. However after these years it was a very negative decrease in the 2003 (-6%) partially compensated in the next year (+2.6%)

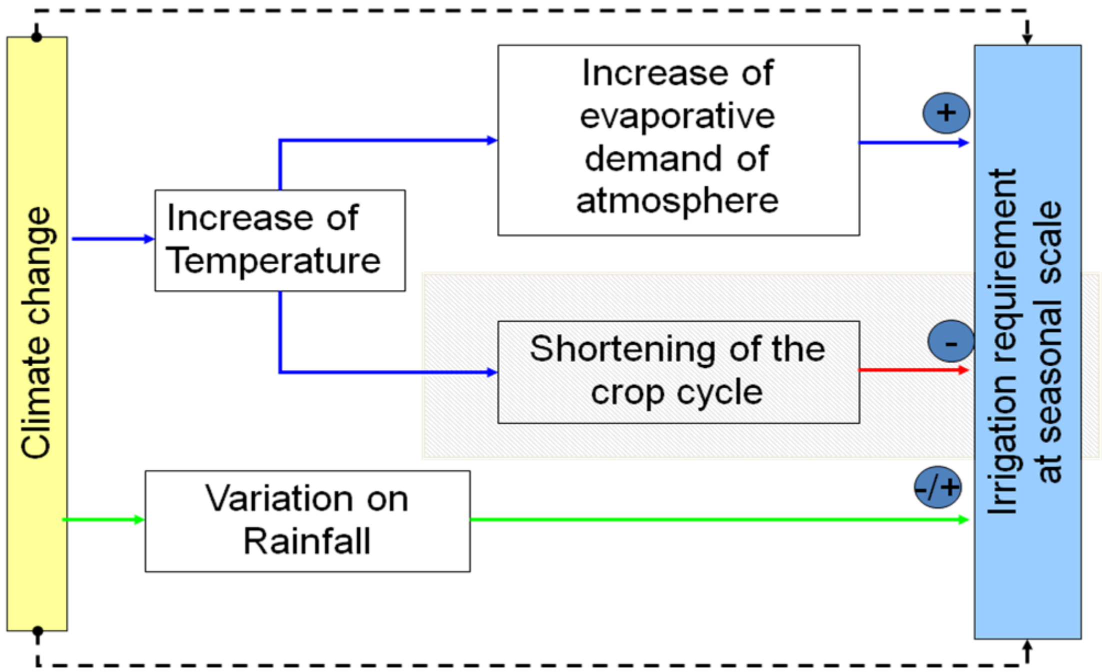
In general, the principal weaknesses for the Italian agriculture are constituted by high average age of the farmers, small dimension of the farms and insufficient organization and cooperation between enterprises.

Finally, the percentage of woman employment decreased from 51% in 1993 to 42% in 2003.

The current predictions for the Italian territory of this century are for an increase of temperature, emission and concentration of CO_2. Concerning the rainfall there is a great uncertainty. Brunetti et al (2006) studied the Italian climate variability for the last 200 years. After individuating three and six regions on temperature and rainfall basis, respectively, they (the Alpine regions, Po plain and the Peninsular Plain), they observed a quite uniform temperature trend with an increment of 1°C per century all over Italy on a yearly basis with no significant differences for the different regions or for the different seasons. Precipitation trend analysis showed a decreasing tendency. But the decreases are very low and rarely significant. Considering the average all over Italy, there is a 5% decrease per century in the annual precipitation amount, mainly due to the spring season (−9% per century)

The current prediction of General Climate Model downscaled with statistical or dynamical methods for the end of this century forecast a reduction of summer precipitations in Southern Italy and little changes for the Northern Italy with a little increase for the winter rains. Concerning the temperature, they forecast an increase quite uniform among the regions up to 5-6°C in Southern Italy in the summer months.

Current levels of CO_2 limit CO_2 assimilation in C3 crops, and increasing CO_2 concentrations up to about 800–1000 ppm stimulate photosynthesis. In non-limiting conditions a yield stimulation for C3 crops with a doubling of CO_2 has been estimated at 30% but under more realistic conditions the estimates are significantly lower : 12% for grasses, 10-15% of grain yield for wheat and rice. According to Bindi and Houden (2004) the herbaceous crop can be gathered in two groups in functions of the type of phonological cycle: determinate crops and indeterminates crops. For the crops with determinate cycle, the most greater part of cultivated species, the duration to maturity depends on temperature and in many cases on the daylength. An increase of temperature could shorten the cycle and determine a decrease of yield but also a reduction of irrigation requirement at seasonal scale. The contrary will happen for the crops



with undeterminate cycle, like carrots, if the irrigation water availability will increase.

Particularly large yield decreases are expected for spring-sown crops (maize, sunflower and soybeans) . For autumn-sown crops the impact is more geographically variable. Tubiello et al.

(2000) found that, tacking in account the positive effect of increased C22 and without adaptation of management and genotype, in Emilia Romagna the wheat and maize yield could decrease by 5-15%, soybean and barley yields by more than 20% and sorghum yields by more than 50%. In Puglia wheat yields are expected to decrease by 30-50%, sorghum yields by 10-30%. No productive changes were reported for sunflower.
For the tree crop the temperature increase could expand the suitable area for plant requiring high temperature as grapewine, cytrus and olive. Bindi and Moriondo (2007) forecast an expansion of olive cultivation towards the areas in the Northern part. The same can be forecasted for the cultivation of durum wheat and for most vegetable species like lettuce, fennel and cabbage, in winter and spring cultivation, and melon.
For perennial crops, however, in the current production areas the yield variability (fruit production and quality) is expected to increase under global change than at present.
Such an increase in yield variability could have negative effects on the quality f products (fruit wine et.) and, at the same time, could determine a higher economic risk for growers.
Olive is a typical Mediterranean specie particularly sensitive to low temperature and water shortage, thus both the northern and southern limits of cultivation are conditioned by the climate.
Early flowering determined by higher temperatures in winter period, can expose the plants to next late freezing if low temperatures occur. In the last ten-year period above all in Northern part, significant events of freezing took place with negative consequences in fruit and cereal sectors. Additionally the risk of damage to fruit trees caused by early autumn frosts is likely to decrease.
Extreme-weather events, like heat waves or sudden big storms, could easily wipe out crops on vast scales if they occur for even a few days during critical germination or flowering times. During a heat wave in the summer of 2003, temperatures in Italy, more than 6°C over their long-term mean, determined a reduction of corn yield in the rich Po up to 36%.
Intensively managed grasslands could respond positively to both the increase in CO_2 concentration and to a temperature increase, given that water supply is sufficient. At the contrary extensively managed grasslands may respond differently to climate change and increase in CO_2. Climate change is likely to modify the community structure of grasslands and consequently the quality of the forage (Olesen, 2007).

4.6.3 Feasible and recommended adaptation options in Italy

<u>For the detailed regional descriptions see the Table 6.3 in the Appendix.</u>

4.6.3.1. National Overview of the identified most feasible adaptation options of the regions/agroecosystems in Italy

Emilia Romagna: observed trends in adaptations to climate change

In Emilia Romagna and in general in the center-northern regions the water for irrigation comes primarily from rivers and canal networks. In the southern regions consistent volumes of water are accumulated in great dam that collect the winter precipitation for the next period of spring and summer. Paradoxically, in a situation of progressive diminution of precipitation, the regions of the North could suffer more than those of Southern Italy. At the same time, the farmers in Emilia Romagna are experiencing a progressive reduction of water table, an important resource for irrigation and one of the most important action is to save the water adopting more efficient irrigation systems, monitoring the soil or plant water status, cultivating specie more resistant to water stress (sunflower vs. maize) or early cultivar,

adopting adequate crop factors (Kc) to optimize the irrigation scheduling, supporting the farmer activity improving the technical assistance.
For alfalfa cultivation the summer production of forage is decreasing, whereas the irrigation is becoming an ordinary agronomical practice. Also for the grasslands in hill environment the irrigation has become important to stabilize the production and to preserve the equilibrium of species. Numerous species needs to accumulate a certain requirement in cold to go out of the dormancy. Lower winter temperatures could prevent such accumulation of cold and to provoke in the brief period a loss of the potential yield, due to a smaller flowering. A significant negative trend was found concerning the annual number of days useful to the meet the cooling requirement.

Puglia and Basilicata: observed trends in adaptations to climate change
Concerning the grapevine and the other tree crops, the increase of temperature during the summer period accelerates the phenology determining early flowering, decreasing of maturity period, increasing the risk of late freezing anticipating, missed fulfillment of cooling requirements. Temperatures higher than 34°C in June and July can determine grape burn. The higher precipitation in September can influence negatively the quality of grapes or wine and the occurrence of diseases like *Botrytis*.
For olive cultivations, conditions more favorable for several diseases determined by *Phloeotribus*, *Mycocentrospora* and *Colletotrichum*, are expected.
Considering the environmental characteristics of Puglia and Basilicata the expected warming could have, in very long period, consistent effects on soil content of organic matter, salinization of soils in the coastal area, overuse of groundwater resources, abandonment of the marginal lands, intensification of the agricultural activity in the flat areas.
Regarding the vegetable production that in these Regions is very important for the economical point of view the climate warming is expected to have a great impact on yield and product quality. For example, the consequences of very hot summer of 2007 were: heavy reduction of yield of beans, green bean, tomato, potato, melons, peppers; abandonment mof product on fields, increasing damage of *Phythophthora on potato, burn of tomato fruits, no harvest of tomato in several areas of Puglia region.*
For potato cultivation, a the detected yield reduction of 2007 was about 20%, because of scarcity of water resources. Moreover, higher temperatures have positive effects on growth of *Phthorimaea operculella with* heavy negative consequences on quality and price of the products. A hot and humid climate supports the diffusion of *Phythophthora* and *Leptinotarsa.*
For tomato, high temperatures (>32°C) determine heavy negative modifications on the cycle of lycopene, a caroteinoid pigment considered very important for human health. The refolding of the stem, by high temperature and humidity, can determine yield reduction up to 20%.

For the Italian agriculture the options feasible in short term can be synthesized in the following points:

Adaptation options that are feasible in short term
1. Optimization of sowing/transplanting time (advancing for spring crops – delaying for winter crops); cropping activities;
2. Selecting varieties and/or species among those available at present with more appropriate thermal time and vernalisation requirements and/or with increased resistance to heat waves and drought;
3. Optimization of amount and time of irrigation and/or other water management practices;
4. Optimization of fertiliser rates to maintain grain or fruit quality;

5. Applying the available technologies to conserve soil water (No tillage, minimum tillage);
6. Using water resources of low quality (saline water)
7. Improve the effectiveness of pest, disease and weed management practices

Adaptation options that are feasible in midterm and where further testing is needed (or where investment will be required)
1. Constitution (with traditional or innovative method), evaluation and introduction of new variety;
2. Structural enhancement of irrigation efficiency and changes in farming systems
3. Adoption at farming/regional scale of new technologies to schedule the irrigation for obtaining high values of water productivity;
4. Adoption of advanced procedures based on remote sensing information in order to optimize the use of water resources at regional scale
5. Structural enhancement at regional/farming scale for using urban depurated water

4.6.3.2 Selected most important and feasible adaptation options at the farm level in Italy (detailed)

Short term Adaptation options

The autonomous adaptations require, in general short periods to be applied and in general the principal goal is to optimize the production without particular investments. "Autonomous" means that it's possible to apply them with no-interaction with other sector, as policy, other productive sectors, etc. At the same time the autonomous adaptations can be applied autonomously by the farmers even if should be better if these decisions are supported by research and agricultural services.

4.6.3.2.1 Sowing or transplanting time

Time implementation: one year.
Application level: farm level

In our pilot assessment we have evaluated the optimization of sowing or transplanting time for several crops (scarola, sorghum, watermelon, tomato and winter wheat) representative of typical cropping systems based on cereals and vegetable crops. For the first group the three-year rotation based on winter wheat (ww) and tomato (t) is one of the most important in the era of Capitanata in Puglia with two year of ww that precedes the tomato cultivated for industrial purposes.

For both of two crops, sowing/transplanting optimization was effective to reduce significantly the negative effects of climate change on productivity, in particular with delayed sowing for winter wheat and advanced transplanting for tomato.
The other crops are typical for cropping systems specialized on vegetable yield. As the winter wheat also for the scarola, a crop with a winter cultivation, a delayed transplanting time allows a better response in term of utilization of water resources increasing in particular the actual transpiration and the water use efficiency calculated as ratio between this plant flux and the irrigation depth. The other crops with a cultivation during the spring and summer months showed the same type of response of tomato with the advanced times of sowing or transplanting that allow the best productive levels. With these cultivations, the irrigation requirements for Southern Italy are generally high and the availability of water resources

typically limited. For this reason the analysis has to be compared with the consequences on this topic.

In general one of the most important effect of climate change is to increase the evaporative demand of the atmosphere. Consequently, an increase of irrigation requirement is expected for the next decades of this century. However, this effect is counterbalanced by the shortening oh cycle length forecasted for the plants (the majority) characterized by determinate cycle. Therefore our studies indicated light increases of irrigation and in several case also reduction at seasonal scale. Advancing the sowing time, the risk is to have higher irrigation requirements wit low values of water use efficiency. Fortunately, we have confirmed this trend but at the same time, the irrigation variations are not so significant to be limited its convenience allowing water use efficiency comparable to those of the past.
In conclusion, this adaptation measure is feasible for all the erbaceous cropping systems that we have evaluated in this study in Southern and in Northern Italy whit the warning that it has to be evaluated for any combination of climate, crop and soil, with a particular attention in the areas (as Northern Italy) that are characterized by low temperatures during the first months of the years.

4.6.3.2.2 Changes in cultivars

Time implementation: one year.
Application level: farm level

Changes in cultivars is the other easy option of adaptation of climate change. The criteria to take in consideration would be based on:
more appropriate thermal time and vernalisation requirements;
increased resistance to heat waves;
increased resistance to drought.
Our pilot assessment about Sorghum has considered the first point in which the parameter “life span” of leaves was used as sensitive parameter in order to emulate the response of several cultivars at different length of biological and cropping cycle. As expected cultivar with higher thermal time requirement and consequently with longer cycle, represent an adaptation measure in order to reduce the negative impact of climate change for crops a determinate cycle and spring sowing or transplanting.
As the first one, also this opportunity is possible for cropping systems based on cereal or vegetable crops. Obviously, this selection is possible to apply also for trees, even if several authors suggest to choose early ripening fruit tree species or genotypes could reduce the water consumption.
Changes in specie has to be established with the same criteria of changing cultivar. In our cases, this option was considered in grassland changing to annual fodder crops. In cropping systems based on cereals and industrial crops with a reduction of availability of irrigation an increasing cultivation of winter wheat or other winter cereals can be expected. In Northern Italy there is a substitution of soft winter wheat by durum winter wheat and this tendency could increase in the future. In the vegetable rotations, above all in the Southern Italy, a shift toward winter vegetables (lettuce, fennel, cabbage) is expected as well.

4.6.3.2.3 Optimization of irrigation management
Time implementation: few years.
Application level: farm level

In an agricultural context characterized by increasing demand of evaporation of the atmosphere and competition with the other sectors, reducing of availability of eater resources, the optimization of water is the most important factor to reduce the negative impact of climate change. How it is possible to put in effect this possibility? Essentially the way is to answer to three important questions: when, how much and how to irrigate. In other words we have to determine amount and time of irrigation and to choose the irrigation system. and/or other water management practices. To optimize amount and time means to reduce the water losses by deep percolation and soil evaporation giving the water at right moment avoiding water stress to the plant and drainage. The evapotranspirometric method is one of the available methods. The others include those based on monitoring the water status of soil and plant. In general, these methods are expensive with the exception of using tensiometers that are useful tools for cultivations that require an high/medium water status with the soil matric potential close to field capacity and in any case not lower than -600/700 cm, the physical limit of these tools. Recently new instruments based on FDR technology are available and in general not so

expensive like TDR methodology. New FDR instruments that measure the soil humidity profiles are of particular interest for tree crops and suitable for the contexts that characterize the farms in Northern and Southern Italy. Finally, it is hoped that the farmers are supported by public and territorial agricultural service in order to apply these procedures.

Above all for tree crops, particularly interesting are the methods of: (1) deficit irrigation giving less water during several phenological phases that can improve the equilibrium into the plant, increase the productivity or save water; (2) partial root drying .
The localized irrigation method, as drip or microsplinker irrigation, is very common in Southern Italy for tree crops (vineyards, citrus and partially olive) and vegetable crop (tomato, watermelon, lettuce, cabbage, etc.).

In Northern Italy the situation is different with several methods like sprinkler, flood or furrows irrigation extensively still used. For the actual context and above all for the future, it is expected a larger diffusion of localized methods even if not always the farmers use less water with this method compared to traditional ones, above all when the payment method is based on hectares and not on effective consumption. Other interesting methods are: low energy precision irrigation (LEPA), the Ultra Low Drip Irrigation (ULDI) with 0.1-0.2 l h^{-1}, irrigation with photovoltaic energy, sub-irrigation.

4.6.3.2.4 Optimization of fertilization and tillage practices

Time implementation: few years.
Application level: farm level

Because the potential productivity of northern zones is in general expected to be increased due to longer vegetation, for Northern Italy but also in Southern Italy if advanced sowing time are applied, it is appropriate to expect changes in fertilization schemes in annual crops and perennial systems, as grassland and trees in particular vineyards. The drawback of this option is about the possibility to have higher risk of nutrient leaching, as in particular for nitrogen, if the fertilization is not optimized in time and amount of fertilizers distribution. The fertirrigation is also an important opportunity because with this agronomical practice there is the possibility to give the nutrients in many applications of little amount reducing the risks of soil leaching and over-accumulation in the fruits. The fertirrigation is a common practice utilized in tree and vegetable cropping system with high income.
The tillage practices have important effects that can increase the soil water conservation and protect the soil against soil erosion by water and wind. Adoption of conservative tillage are expected to be useful, above all, for cropping systems based on cereals with particular reference for winter wheat and maize in Northern and Southern Italy. Few studies are available in scientific literature about the effects of this practices (conservative, no- or minimum-tillage) on vegetables annual crops and it is questionable if the simulation models are adequate to describe the effects of tillage on soil fertility and crop productivity. At the same time, this option is considered of lesser importance fro grasslands while there are interesting practices for tree crops finalized to conserve soil water (tillages in inter-rows, controlled grassing, etc.)
Other options to reduce the water losses include: the soil mulching whit synthetic or, preferably, vegetal material as crop residues of the previous cultivation

4.6.3.2.5 Utilization of saline water and crop protection

Time implementation: few years.
Application level: farm level

Where there is a limited availability of water of good quality for irrigation, the saline waters represent an important resource. This is typical in several areas of Southern Italy with particular reference to coast area of Adriatic and Jonical sea. In general this water comes from not very deep groundwater of unconfined or perched types and it can represent the only resource of water. In other cases, the famers generally use the water from the irrigation network and the water from the wells when the first is not available. In any case the criteria and/or the options to use the saline water are:

- the saline concentration has to be consistent with the sensitivity to saline stress of the crop (sorghum, wheat, sugar beet are resistant, in general, the vegetables are sensitive) and the soil texture (clay soil are more sensitive to structure degradation effects of saline water and at the same time the water retention is high with less drainage capacity);
- it is possible to manage the saline water irrigating species more tolerant, mixing waters at different saline concentrations, giving good water in the most tolerant phase (as vegetative) and the saline water after the flowering;

- in the Mediterranean areas the precipitation are concentrated in few months of winter periods with events characterized by high intensity. These conditions are favourable to have a good drainage and solute leaching at yearly scale an consequently it is possible add no extra-water during the irrigation season. In other words the leaching requirement can be fulfil by the natural winter precipitation.
- in any case it is necessary to monitor the soil salt concentration in order to apply an artificial leaching of soil before the crop sowing, when an previously established threshold value is exceeded;
- The irrigation with saline water is a suitable practice with vegetable or industrial crop with spring/summer cycle, but is of more difficult application for tree crops.

There are expected changes in crop protection (pest, diseases and weeds) needed for every crop. The economic benefit of monitoring and protection is different in function of many factors. It's quite low for grasslands. In case of cropping systems based on cereals the protection optimization is more important and it becomes strategically very fundamental for tree and vegetables crops like vineyards (in Southern Italy), apple and pear (Northern Italy) and tomato and other vegetables crop for which many treatments in general are carried out.
Considering the expected climate change the plant protections that have to be optimized concern:

- for grapevine: grape burn and *Botrytis*.
- for olive cultivations; *Phloeotribus*, *Mycocentrospora* and *Colletotrichum*;
- for vegetables *burn* of tomato fruits, on potato *Phythophthora, Phthorimaea operculella , Leptinotarsa.*

4.6.3.2.6 Adaptation options in midterm

Time implementation: 2-3 years or more.
Application level: farm level, regional level

The Adaptation options that are feasible in mid or long term require higher investment than the autonomous ones and in several cases they need further testing or scientific investigation. Moreover, they require also significant contributions of other sectors, as research institution, industrial sector and public economic supports. For these reasons these options have to be planned at high level involving political institution at regional or national level. In several cases these options can be connected with the activity of private company.
The constitution with traditional or innovative methods, the next evaluation and introduction of **new varieties** can introduce in the available genotypes improved traits concerning appropriate thermal time and vernalisation requirements, increased resistance to heat waves and drought, but also increased resistance to new or expected dangerous pest, diseases and weeds, improved productivity or yield stability.
The **structural enhancement of irrigation efficiency** is an important factor for Italy. In general in many areas improvements of canalization system are required in order to reduce the relevant water losses that in several places can be 40-50%. With particular reference to Southern Italy the construction of new water dams are expected to collect water during the autumn/winter period. Other alternatives involve the de-salinization systems.
The **changes in farming systems** concern the noted and expected tendency of substitution of food production by energy production considering that several crops are suitable for different type of biofuels and a northward expansion of these crops.
For the tree crop the temperature increase could expand the suitable area for plant requiring high temperature as grapewine, cytrus and olive forecasting an expansion of olive cultivation towards the areas in the Northern part. The same can be forecasted for the cultivation of

durum wheat in substitution of soft winter wheat in Northern Italy and for most vegetable species like lettuce, fennel and cabbage, in winter and spring cultivation, and melon.
As indicated in the autonomous adaptation, the increase of water use efficiency can be obtained adopting on at farming/regional scale of **new technologies** to schedule the irrigation. In this cotext the seasonal forecasting service is expected to useful for industrial and vegetable crops but also for tree crops sensitive to water stress (grapevine, citrus, etc.) whilst in case of grassland and winter cereals could be less important. At the same time we could expect that this opportunity should be available in Southern and Northern Italy.
In this context advanced technology based on **remote sensing** information should be applied in order to improve the land cover classification (very important for irrigation planning), the assimilation of leaf area index (LAI) and shallow soil water contents and the estimation, with the last three points very useful to support the components estimate of soil/crop water balance and to schedule the irrigation at watershed scale with daily temporal resolution.
The last point regarding the adaptation measures of long term regards the structural enhancement at regional scale in order to use the **depurated urban water**. This is an important question that needs of a legislative support because the current Italian law is very restrictive for depurating this type of water with thresholds values very low and requiring high costs to depurate these waters. At the present using these waters is recommended with localized irrigation methods that not wet directly the commercial organs of the plant (fruits for tomato or tree crops, leaves for several vegetables). In a research carried out in lysimiters of our research this type of water uses as irrigation was investigated in comparison with groundwater for tomato and other vegetables cultivations on sandy and clay soils After three years of continuous treatments the results were to have no productive reductions and no soil profile accumulation of nitrates, chloride, pH, etc.

4.6.4 Scientific basis of ADAGIO results

4.6.4.1 List of all literature used for national ADAGIO purposes, analysis etc. (national and international)

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4.6.5 Dissemination activities during ADAGIO (during all project lifetime)

4.6.5.1 List of scientific ADAGIO publications (which include ADAGIO results). It means: ADAGIO related results which were published during the AGAIO project.

Ventrella D., Giglio L., Bindi M., Moriondo M. 2007. *Soil water balance of a winter crop cultivated in Southern Italy as influenced by future climate*. On: Farming Systems Design 2007, Int. Symposium on Methodologies on Integrated Analysis on Farm Production Systems, M. Donatelli, J. Hatfield, A. Rizzoli Eds., Catania (Italy), 10-12 September 2007, book 2 – Field-farm scale design and improvement, pag. 175-176.

Lovelli S., Perniola M., Ferrara A., Ventrella D., Bindi M. 2008. Effect of Climate Change on Water Use and Irrigation Requirements of Muskmelon and Broccoli in Southern Europe. Italian Journal of Agronomy, 3 Suppl., 723-724.

Ventrella D., Giglio L., Rinaldi M., Moriondo M., Bindi M. 2008. Vulnerability of some herbaceous crops to climate change in Southern Italy. Italian Journal of Agronomy, 3 Suppl., 789-790.

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Rinaldi M., D'Andrea L., Ruggeri S. Garofalo P. Moriondo M., Ventrella D. 2009. Influenza dei cambiamenti climatici sulla coltivazione del frumento duro [Influence of climate change on durum wheat cultivation]. Italian Journal of Agronomy, 2, 32-33.

Ventrella D., Vitale D., Troccoli A., Rinaldi M., Gallo A., Colecchia S.A. 2009. Effetti della temperatura e precipitazione sull'epoca di spigatura e resa di alcune varietà di frumento duro coltivato in Capitanata. [Effects of temperature and precipitation on flowering time and yield of some varieties of winter wheat cultivated in Capitanata area]. Italian Journal of Agronomy, 2, 60-61.

4.6.5.2 List of not yet published (manuscript status) scientific ADAGIO related publications (national or international).

Ventrella D., Rinaldi M., Charfeddine M., Ruggieri S., Giglio L., Moriondo M., Adaptation to climate change for durum wheat and tomato in Mediterranean environment: irrigation and nitrogen fertilization. Italian Journal of Agronomy (manuscript).

Ventrella D., Giglio L., Rinaldi M., Moriondo M., Bindi M. Vulnerability and adaptation of some herbaceous crops to climate change in Southern Italy: soil water balances and productivity. The Journal of Agricultural sciences (manuscript).

4.6.5.3 List of published or not yet published (manuscript status) ADAGIO results specific designed for national farmers or stakeholders, which are more than common articles in newspapers (e.g. books, brochures, reports which can serve as a permanent source of information).

Ventrella D., 2007. E*voluzione dei sistemi colturali a seguito di cambiamenti climatici*. [Evolution of cropping systems as affected by climate change]. Conference "Cambiamenti climatici e rischi geologici in Puglia", Sannicandro (Bari), 10 Novembre. Geologi e Territorio: 3/4. 95-102.

Ventrella D., 2008. Cropping systems and climate change. Proceedings of Conference "Irrigation, Salinization and desertification". pp. 6 (in press)

4.6.5.4 Other national public relation activities (e.g. lectures, farmer meetings, articles in newspapers), use the updated table below, for ALL ADAGIO period

Listed in the Thematic Group 4 report

4.7 Greece

4.7.1 Abstracts of national case studies carried out during the ADAGIO project

Introduction
Regional Climate Model Agroclimatic Index analysis was made for the total of the Country of Greece, in a spatial resolution suitable for regional and case studies and local assessments, based on the ECHAM 5 A1B Racmo 2 Scenario from the ENSEMBLES Project. The periods of analysis were 1971-1990, 2031-2050 and 2071-2090, and also for daily data 1961-1990, 2021-2050 and 2071-2100. [However, Based on the ADAGIO objectives, indicative pilot regions were selected based on the vulnerability assignment of WP2, where the southern and eastern parts of the country will be the most vulnerable, based on most GCM results. 3 regions were selected indicatively from Greece, and for those decision maker/expert interview analysis formulated the Tables 1 and 2 (Please see relevant tables as in WP2) and Table 1/WP3 (Please see relevant tables as in WP3)]. Map series and tables produced can present local vulnerabilities even at the smallest administrative unit level (ex. LAU2) according also to the CORINE 2000 Classification of Level 3. In addition, direct interaction with farmers was pursued, and small scale field assessments were applied too.

Scientific publications referring to the case studies mentioned below are:

“Climate change and rural areas: Farmer's perspectives” Dimos P. Anastasiou, Presentation & Abstract; ENSEMBLES Project, September 2008, Athens, Greece
“Methods and spatial analysis for the ADAGIO agricultural adaptation assessment in Greece” Dimos P. Anastasiou; ADAGIO Symposium Abstract Publication (& Presentation), June 2009, BOKU, Vienna, Austria.
“Methods and spatial analysis for the ADAGIO agricultural adaptation assessment in Greece” Dimos P. Anastasiou, Mike Petrakis and Christos Giannakopoulos; ADAGIO Symposium Extended Abstract Publication “Impact of Climate Change and Adaptation in Agriculture”, August 2009, BOKU, Vienna, Austria.

Case study 1 :

CORINE 1990 - 2000 Land Cover Changes for Greece

Dimos P. Anastasiou

Abstract
The CORINE Land Change 1990 and 2000 Dataset (Seamless vector database) were acquired from the European Environment Agency website registered and reprocessed to our WGS 1984 Universal Transverse Mercator spatial database (with relevant zones for Northern Hemisphere for Greece).
The majority of changes, as far as surface change size is considered, are happening within the “Forest Areas”, and the “Agricultural Areas”, followed by the artificial surfaces and the water bodies. Since the interest of the ADAGIO assessment is towards agriculture, a summary of these results is provided here, while detailed tables and maps are provided at the Annexes and the Thematic Group Report 3 (which are also posted at the Greek Partner ADAGIO website).
Location and characterization of the study region: The study region is the whole Greece at an analysis scale of the map, which for CORINE is 1:100.000. The objective is to provide a land

use/land change characterization of Greece based on widely accepted and quality checked data, such as the abovementioned CORINE dataset. More specifically for the whole area of Greece for land cover shifts over 1.000 ha (for total of Greece) from the CORINE "Agricultural Areas" we have the following figures:

CORINE 1990 Level 3 Code Name	CORINE 2000 Level 3 Code Name	Land cover Shift 1990-2000 (LEVEL 3 Codes)	Area (Ha)
Non-irrigated arable land	Road and rail networks and associated land	211-122	1031.8
Land principally occupied by agriculture, with significant areas of natural vegetation	Artificial surfaces (Level 1 Code)	243-131	1254.1
Complex cultivation patterns	Fruit trees and berry plantations	242-222	1258.49
Complex cultivation patterns	Rice fields	242-213	1264.14
Vineyards	Non-irrigated arable land	221-211	1664.72
Non-irrigated arable land	Industrial or commercial units	211-121	1782.05
Vineyards	Complex cultivation patterns	221-242	1829.36
Pastures	Non-irrigated arable land	231-211	1852.64
Non-irrigated arable land	Construction sites	211-133	2049.89
Vineyards	Olive groves	221-223	2796.41
Complex cultivation patterns	Industrial or commercial units	242-121	2870.09
Non-irrigated arable land	Rice fields	211-213	3377.88
Non-irrigated arable land	Complex cultivation patterns	211-242	3618.17
Complex cultivation patterns	Discontinuous urban fabric	242-112	4021.96
Non-irrigated arable land	Artificial surfaces (Level 1 Code)	211-131	4838.54
Permanently irrigated land	Rice fields	212-213	10012.36
Rice fields	Permanently irrigated land	213-212	10821.44
Non-irrigated arable land	Permanently irrigated land	211-212	16919.07

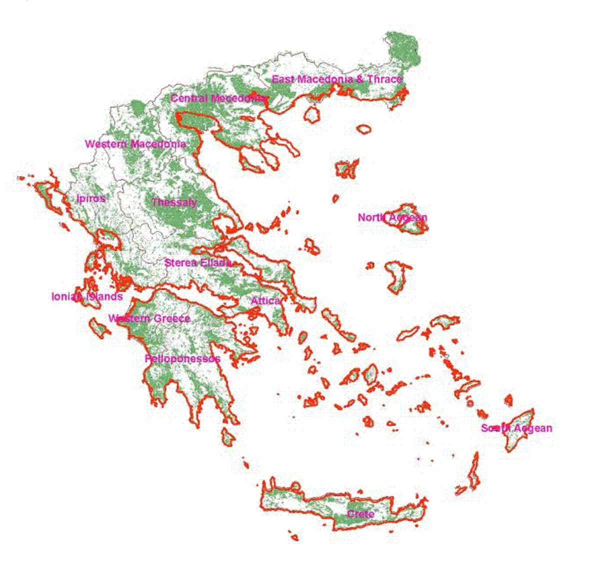
Case study 2 :

Mapping coastal low altitude areas of Greece (below 5 meters), their watersheds and river segments

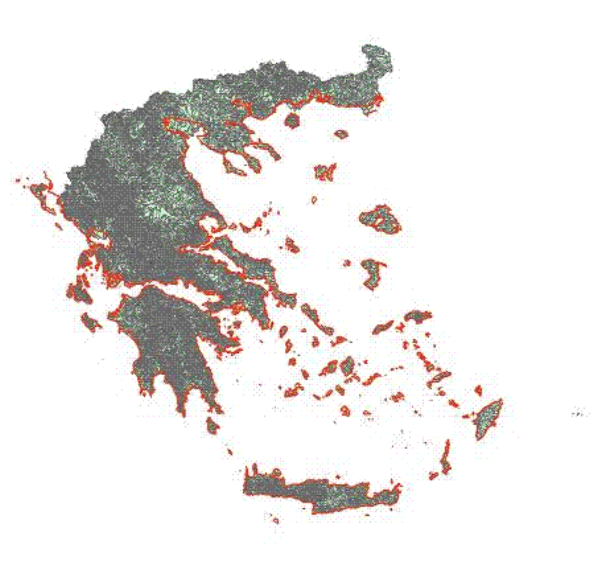
Dimos P. Anastasiou

Abstract
As almost all assessments done for Greece, this is also a mapping effort to provide to decision makers and all stakeholders in general with precise maps of the analysis. To derive this, there are several main datasets used acquired from the JRC and EEA, the European Catchments Database, the 5 meter Contour of coastal areas, and the CORINE 2000. The provided maps give a detailed overview of the areas, rivers, river segments and catchments, where the

altitude is equal to or below 5 meters. Any sea level rise, as this may be derived from future climate change scenarios, will have its impacts first on the lowest altitude areas.
Please note that, with a highest accuracy DEM and contour line, such as one of 1 meter for example, the results of the classification will be different. However, the analysis here was done with the highest resolution dataset available (5 meter contour Line).



CORINE CLC agricultural areas and the 5 meter coastal contour line.



European Catchments Database and the 5 meter coastal contour line.

Results indicate that certain areas of Northeastern and Eastern Greece, but also western Greece, have agricultural areas, and specifically “Permanently Irrigated Areas” below the 5 meter altitude contour line. So, in case of any sea level variability, the changes would be first observed to these areas with the lowest altitude, as in detail pictured at the maps above.

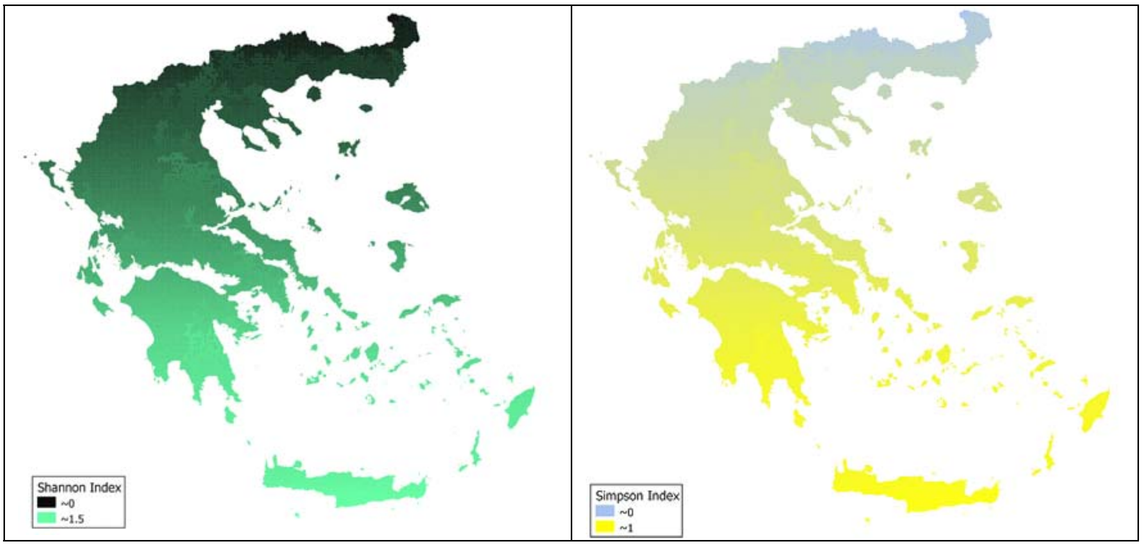
Case study 3 :

Spatial Intra Specific Biodiversity Indices

Dimos P. Anastasiou

Abstract
Biodiversity is an inherent part of the IPCC assessment reports, and usually it is not examined quantitatively as often as climatological data changes, for example. An experimental way is applied at the ADAGIO assessment for Greece, to provide a measure of landscape homogeneity, through the application of spatial intraspecific biodiversity indices. Since homogenous data availability is a major factor influencing the validity of analysis results, the CORINE Land Cover 2000 dataset (250 meter resolution) was used to derive 5 spatial indices for the total of the country of Greece. These indices refer to landscape diversity, which is related to many other environmental variables, such as the ecosystem responses to environmental stressors. For example, if a serious drought happens to a bean, cotton or wheat extended monoculture, the ecosystem responses and impacts to the crop will be more or less similar, depending on local conditions and how these affect the crop responses. If, however, the same happens to a diverse landscape, the ecosystem responses per land cover type, crop

species, and management regime can vary significantly, depending on the sensitivity of each land use to the disturbance. Therefore in certain cases landscape biodiversity is positively correlated with the ecosystem resilience to disturbances; this is why it is quantitatively analyzed here.

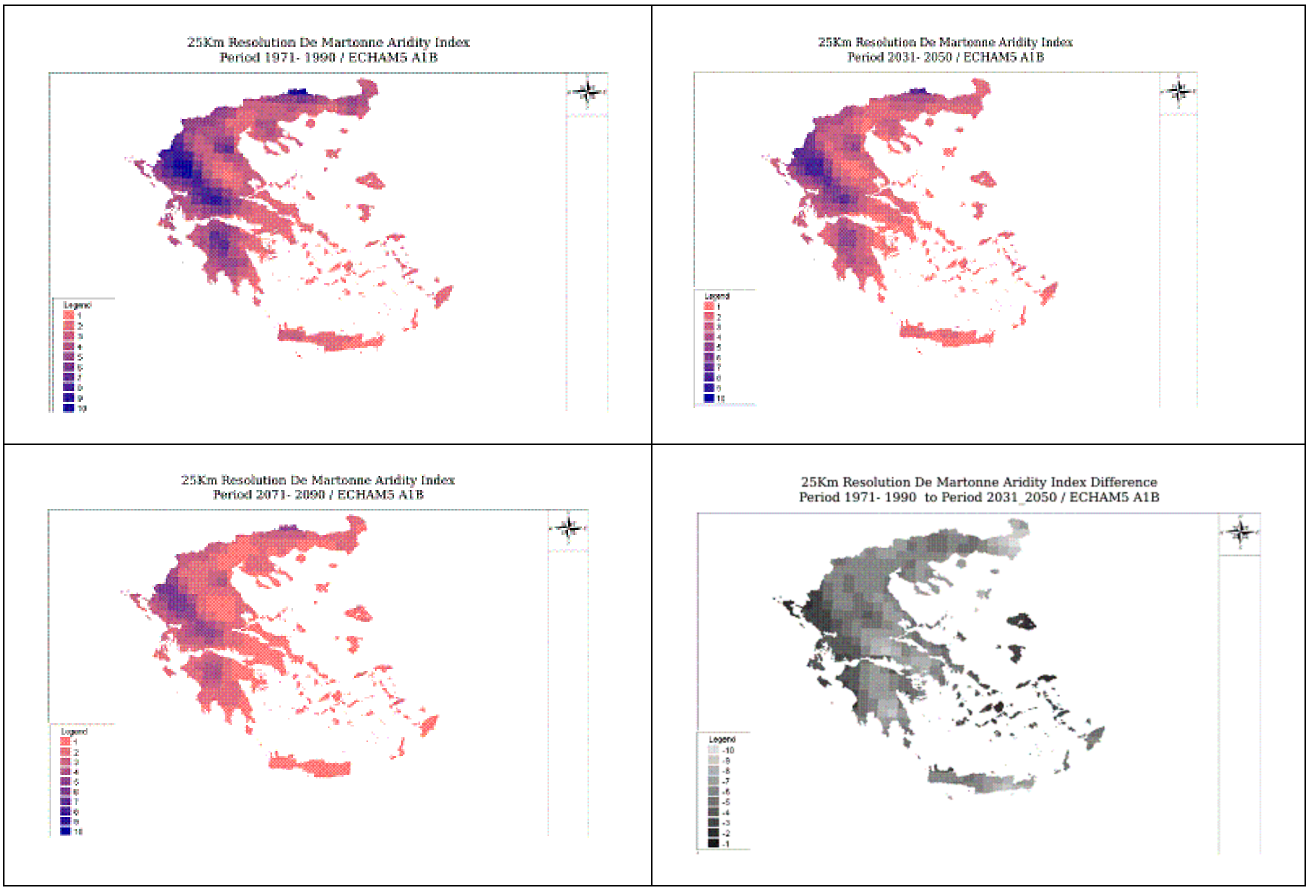


Case study 4 :

Spatial De Martonne Aridity Index – ECHAM5 A1B RACMO2 current and future conditions

Dimos P. Anastasiou

Abstract
The DeMartonne Aridity Index simulations were made based on NetCDF data acquired by the ENSEMBLES project, for the scenario ECHAM5 A1B Racmo2. The periods of analysis are 1971-1990, 2031-2050 and 2071-2090. This simulation was made at a spatial resolution of 25 KM, as the ENSEMBLES RCM scenario data available. Results are provided in relevant maps, so interested stakeholders can see the impacts at the spatial level of LAU1 or even LAU2 unit. De Martonne Aridity Index is found to be correlated with water demand from crops according to previous studies in Romania. Detailed results are provided at the maps below. Results show a decrease in De Martonne Index and thus a shift towards drier conditions, which may increase plant water stress in general, and demand in irrigation water for agriculture crops.



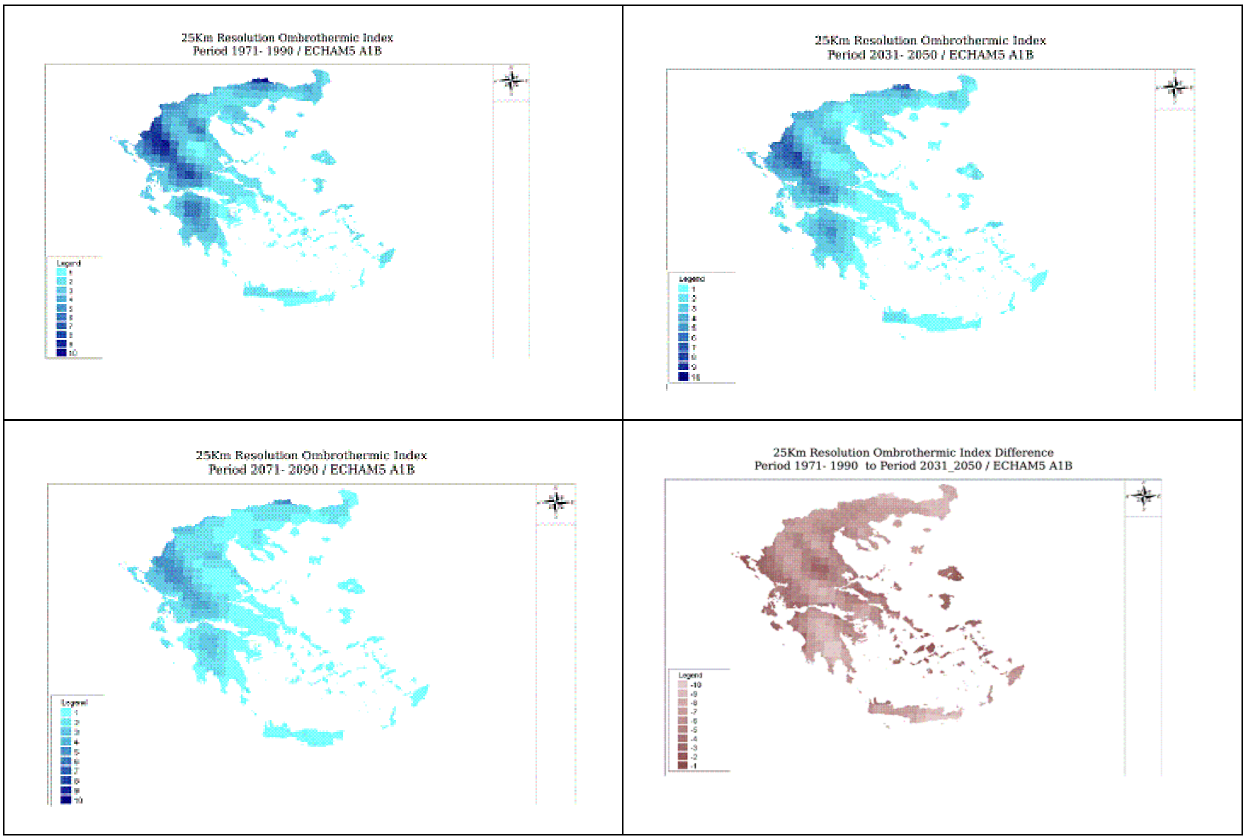
Case study 5 :

Spatial Ombrothermic Index – ECHAM5 A1B RACMO2 current and future conditions

Dimos P. Anastasiou

Abstract

Based on raw NetCDF data acquired by the ENSEMBLES project, for the scenario ECHAM5 A1B Racmo2, data was also analyzed in GIS to derive the Ombrothermic Index which is used as a bioclimatic indicator worldwide for classification of geographic areas. The periods of analysis are 1971-1990, 2031-2050 and 2071-2090. This simulation was made at a spatial resolution of 25 KM, as the ENSEMBLES RCM scenario data available. Results are provided in relevant maps, so interested stakeholders can see the impacts at the spatial level of LAU1 or even LAU2 unit. Results, as also explained in other parts of this report, show a decrease of the index in certain areas, while certain north areas and north western parts of the country to be less impacted than south eastern regions.



Case study 6 :

Spatial Length of Growing Period – ECHAM5 A1B RACMO2 current and future conditions

Dimos P. Anastasiou

Abstract

The Length of Growing Period was developed accordingly to the FAO Climpag website, but with the ratio threshold of 0,49 instead of 0,50. The calculations made in GIS, were from raw data, as this was acquired from NetCDF data of the ENSEMBLES project, for the scenario ECHAM5 A1B Racmo2. The periods of analysis are 1971-1990, 2031-2050 and 2071-2090. This simulation was made at a spatial resolution of 25 KM, as the ENSEMBLES RCM scenario data available. Results are provided in relevant maps, so interested stakeholders can see the impacts at the spatial level of LAU1 or even LAU2 unit. The changes of LGP monthly averages are in certain cases positively changing at currently colder mountainous regions or coastal areas, as the RCM data analysis indicates.

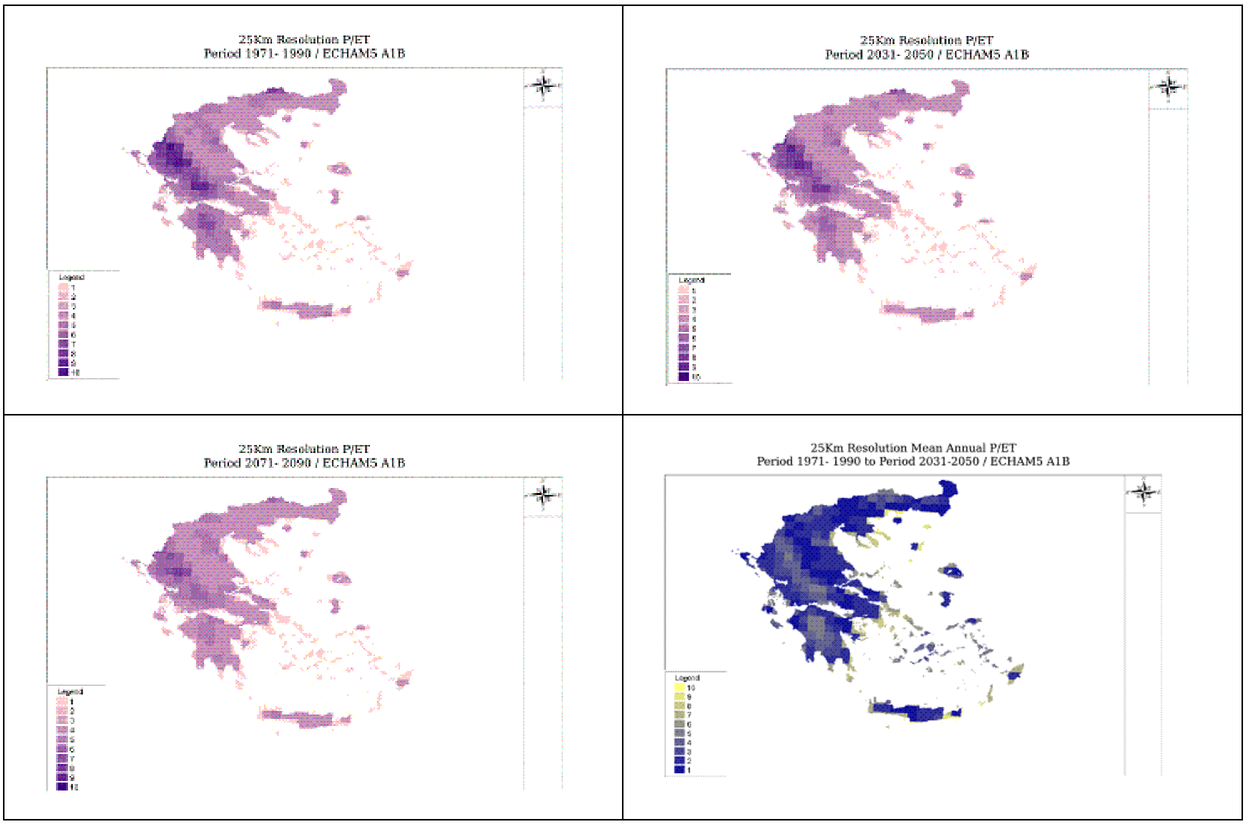
Case study 7 :

Spatial P/ET ratio – ECHAM5 A1B RACMO2 current and future conditions

Dimos P. Anastasiou

Abstract

The commonly used indicator of the ratio of precipitation to evapotranspiration is developed in this case study, based on NetCDF data acquired by the ENSEMBLES project, for the scenario ECHAM5 A1B Racmo2. The periods of analysis are 1971-1990, 2031-2050 and 2071-2090. This simulation was made at a spatial resolution of 25 KM, as the ENSEMBLES RCM scenario data available. Results are provided in relevant maps, so interested stakeholders can see the impacts at the spatial level of LAU1 or even LAU2 unit. Southern and eastern areas may face more changes than north and north western areas, based on the scenario data analysis made.



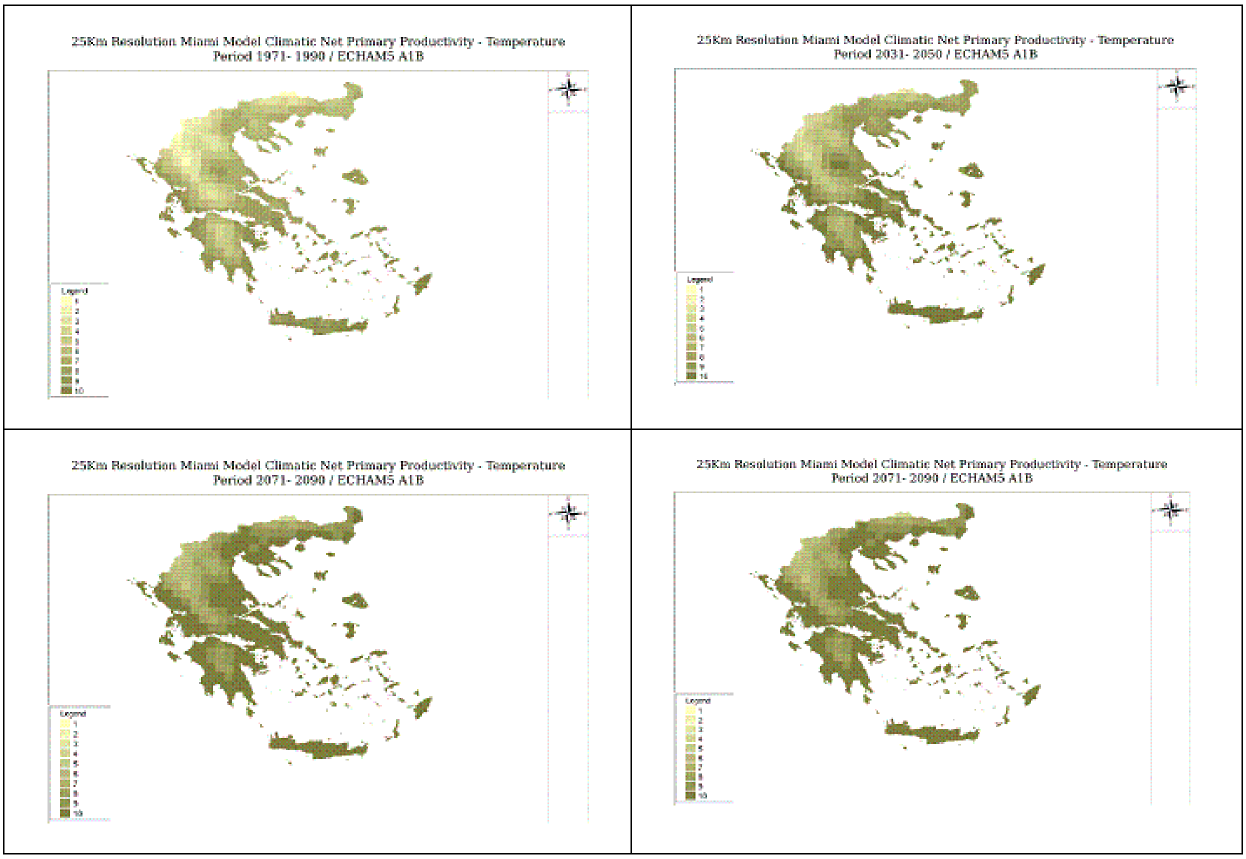
<u>Case study 8 :</u>

Miami Model Climatic Net Primary Productivity/Temperature – ECHAM5 A1B RACMO2 current and future conditions

Dimos P. Anastasiou

Abstract

The Miami Model of Climatic Net Primary Productivity was used for temperature, based on NetCDF data acquired by the ENSEMBLES project, for the scenario ECHAM5 A1B Racmo2. The periods of analysis are 1971-1990, 2031-2050 and 2071-2090. This simulation was made at a spatial resolution of 25 KM, as the ENSEMBLES RCM scenario data available. The ecosystem response to precipitation and temperature of the future conditions and their differences were analyzed for all Greece, and results are provided in relevant maps, so interested stakeholders can see the impacts at the spatial level of LAU1 or even LAU2 unit. Analyzing temperature only, it is seen that there is an increase in Net Primary Productivity. However, when considering the results of NPP based on precipitation, ecosystem climatic primary productivity is more affected in eastern and southern areas.



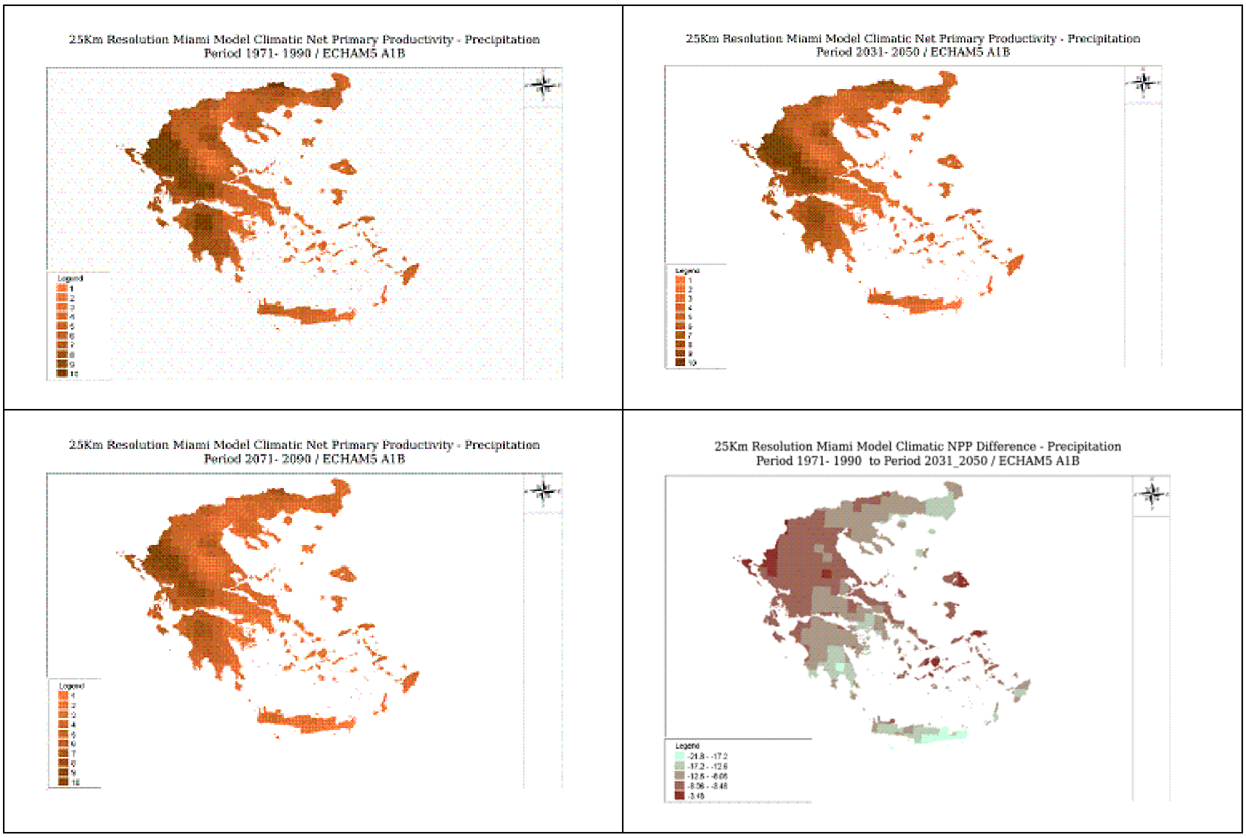
<u>Case study 9 :</u>

Miami Model Climatic Net Primary Productivity/Precipitation – ECHAM5 A1B RACMO2 current and future conditions

Dimos P. Anastasiou

Abstract

The Miami Model of Climatic Net Primary Productivity was used for Precipitation, based on NetCDF data acquired by the ENSEMBLES project, for the scenario ECHAM5 A1B Racmo2. The periods of analysis are 1971-1990, 2031-2050 and 2071-2090. This simulation was made at a spatial resolution of 25 KM, as the ENSEMBLES RCM scenario data available. The ecosystem response to precipitation and temperature of the future conditions and their differences were analyzed for all Greece, and results are provided in relevant maps, so interested stakeholders can see the impacts at the spatial level of LAU1 or even LAU2 unit. Similarly to what was reported for Miami Model Net Primary Productivity based on temperature, certain lower precipitation areas will have lower ecosystem climatic primary productivity.



<u>Case study 10 :</u>

27 Stardex Indicators – ECHAM5 A1B RACMO2 current and future conditions

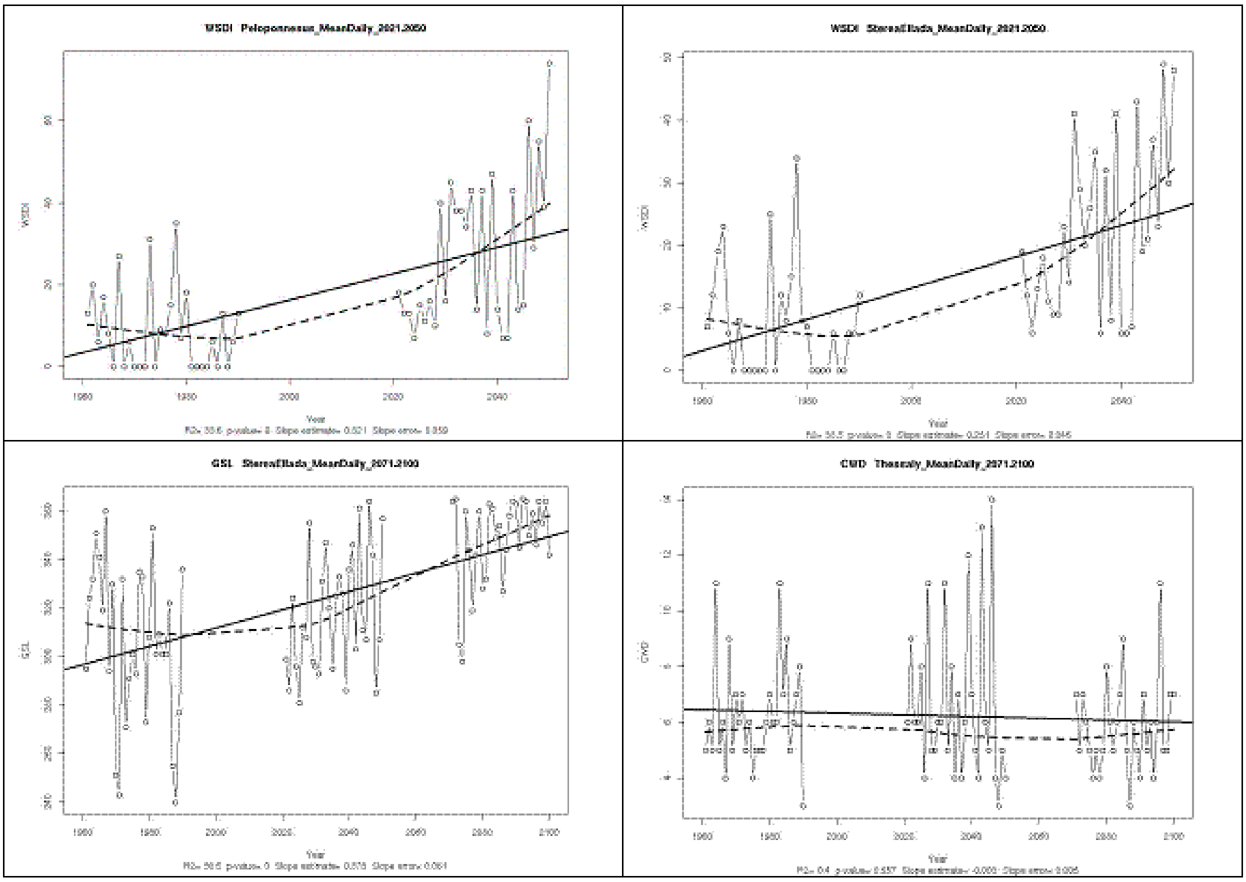
Dimos P. Anastasiou

Abstract

The 27 STARDEX Indicators were developed based on NetCDF data acquired by the ENSEMBLES project, for the scenario ECHAM5 A1B Racmo2. The periods of analysis are 1971-1990, 2031-2050 and 2071-2100, for the daily data available. This simulation was made at a spatial resolution of 25 KM, as the ENSEMBLES RCM scenario data. The complete series of simulations for 3 eastern/southern regions of Greece are available at the "Documents" page of the Greek Partner ADAGIO website.

Dry periods, or increase of them, or overall mean annual temperature increase and precipitation decrease, are obstacles that are more easily managed (ex. increasing irrigation and water availability) than temperature extremes. Especially the indicator WSDI (Warm Spell Duration Indicator) has a significant mean value increase on regional average for the 3 regions examined with Stardex Indicators. But, very interestingly, the CWD (Consecutive Wet Days) indicator decreases or stays stable for certain years .On the other hand, the CSDI (Cold Spell Duration Indicator) will decrease or be stable in certain years for the regions examined. Thus, heat and water stress are likely to be environmental plant stressors in the future, while sensitive to cold spells plants will have less possibilities to be affected by its occurrence. On the other hand, plants that need a "chilling period" during the winter, may be affected also by its occurrence variation .

Results are published at the Stardex Indicator Annex permanently available at the Greek National Project Website.



<u>Case study 11 :</u>

Number of days with Mean Daily Temperature Below 0 during March – ECHAM5 A1B RACMO2 current and future conditions

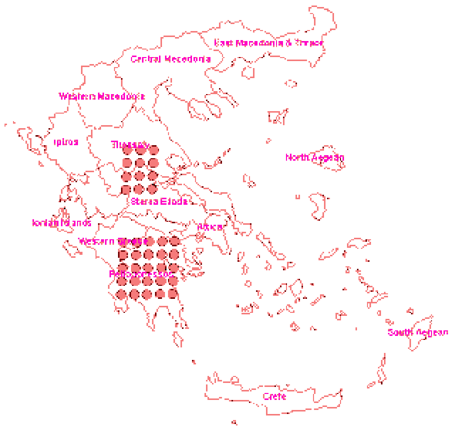
Dimos P. Anastasiou

Abstract

This application was developed after interpretation of the NetCDF data as acquired by the ENSEMBLES project server, for the scenario ECHAM5 A1B Racmo2 KNMI. The periods of analysis are 1971-1990, 2031-2050 and 2071-2100, for the daily data available. This simulation was made at a spatial resolution of 25 KM, as the ENSEMBLES RCM scenario data. The results for the downscaling points overlapping the regions of Thessaly, Sterea Ellada, and Peloponnesus. March frosts in Greece, in certain cases are considered as a cause of frost damage to several crops. Especially when a warm period of a few days is happening before a frost event, the frost event may cause more damage, to olive trees, or to humus crops for example. Analysis shows that frost days in total for the study points will be reduced, as in detail covered by the table below.

	1961-1990	2021-2050	2071-2100
Percentage of number of March days with Temp below 0 Celsius based on Reference period	Reference 100%	74.29	37.45

Percentage of number of March days with Temp below -8 Celsius based on Reference period	Reference 100%	34.50	10.92

Map of the Daily ECHAM5 A1B Racmo2 KNMI 25 km downscaling points used in the March Frost Days Analysis Daily periods 1961-1990, 2021-2050, 2071-2100	

Case study 12 :

Farmer and Expert Interviews and Questionnaire Survey

Dimos P. Anastasiou

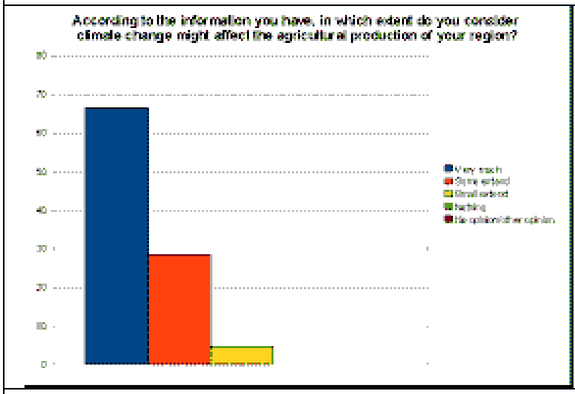
Abstract

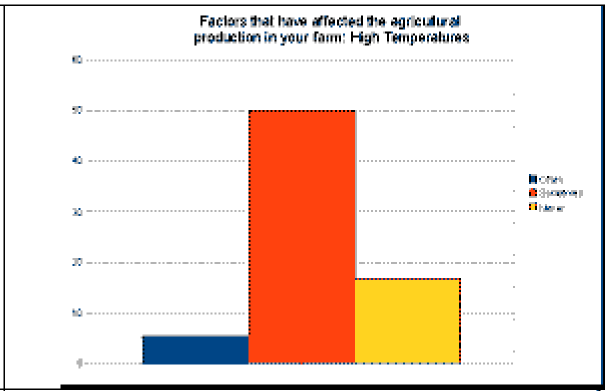
Based on a "bottom up" approach proposed by the Spanish Partner ITACYL during WP2 a local questionnaire survey was contacted in Greece to collect some input from farmers. The study was focused on interaction with farmers as a major objective of the ADAGIO Project and was based on common questionnaire provided by Dr. Angel Utset, ITACYL (Instituto Technologico De Castillia y Leon), which was then translated in Greek for distribution to farmers (also available for download at the Greek website of the project). Graphical results of the study are reported into numerous presentations of the project. Some of the most interesting results of the study were the collection of on the ground adaptation options by farmers (which are mentioned in detail in this report), and where possible, the field testing/experimentation of these options (for example: successive plowing and cereal cultivation for weed suppression). It was also observed during interviews and field visits, those farmers do have risk minimization approaches, and do apply adaptation options such as seeding dates change. Farmers do consider that climate extremes and pests are some of the most important issues, do adapt with seeding dates change (at least at the localities examined during ADAGIO assessment). Information exchange and straightforward directions from experts on new crops and cultivars are also considered from the farmers as valuable tools to adapt to local climatic and environmental variability.

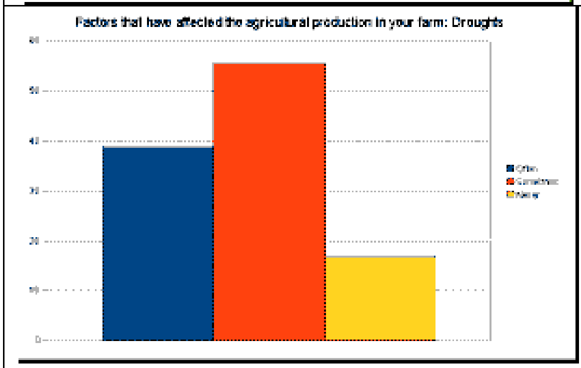
More specific information on the cooperation with NUTS3 agencies in Greece for the collection of such data and for consultations with local experts is available at the national Greek project website. Results are also published at:

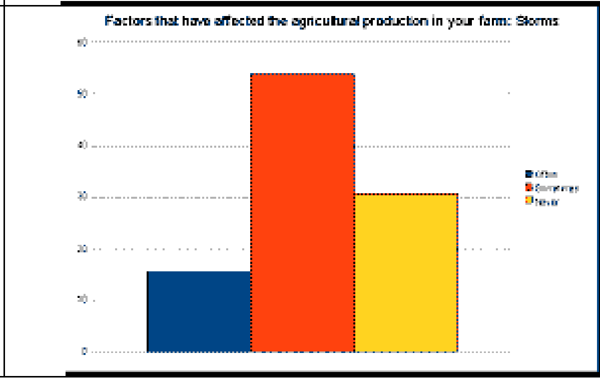
"Climate change and rural areas: Farmer's perspectives" Dimos P. Anastasiou, Presentation & Abstract; ENSEMBLES Project Meeting, September 2008, Athens, Greece

Graphical representation of a sample of Farmers under 40 years of age. Question: " Factors that have affected the agricultural production in your farm"









4.7.2 Regional vulnerabilities and reasons

For the detailed regional descriptions see the Tables 7.1 and 7.2 in the Appendix.

4.7.2.1 Summary description of the most significant identified vulnerabilities of the regions/agroecosystems in Greece

Greece, according to the FAO AQUASTAT data, has a mean country precipitation of 650 mm approximately, which is quite higher from other Mediterranean countries. This mean precipitation amount is unevenly distributed at the territory with great variation; certain areas of north western Greece receive more than 1000 mm of precipitation annually, whereas others, such as Attica or other parts of south eastern Greece, less than 500 of even 400 mm per year. The eastern and south eastern part of Greece – which receives less precipitation - is more developed historically, either at the urban, tourist, industrial or agricultural land use, with a simultaneous increase of water demand for land uses during the hot season, such as tourism and irrigated agriculture. Balancing and planning between all these actors, with the described temporal and spatial occurrence, is a task carried out by Govermental and local stakeholders for the last decades. Natural hazards of Greece regarding agriculture are related to droughts, heat waves, and water resource availability, and also to phenomena such as hale, ice waves and other climate extremes.
This natural complexity of the terrain and rainfall distribution, the mountainous and hilly interior of inland Greece, may create various climatic conditions and opportunities during future conditions. Therefore, within regions, significant variations are observed, between the low lands and the mountain sierras, for several indices, such as the De Martonne or the Ombrothermic Index. Mountainous sierras of the inland have significantly higher values than

lowland areas, and the trend is also observed to south eastern regions too, for the periods examined (1971-1990, 2031-2050, 2071-2090). North West regions too, have higher values than eastern and southern areas. For example the western areas of the Regions of Thessaly, Sterea Ellada and also the Region of Peloponnesus, show a higher De Martonne and Ombrothermic Index values than their eastern flatland areas. Region of Epirus, and Western Greece, also have higher values in certain areas for these two indices than the south eastern regions. These results are in detail given at the Agroclimatic index maps provided at this report.

Social issues and vulnerabilities (as in WP2 Report too) include: Population and population structure changes in mountains and rural areas during the last decades is a trend with a series of country and European resources dedicated to it, directly or indirectly (Ex. Common Agricultural Policy and Subsidies). However, urbanization and emigration is not a new trend for Greece, but occurs since the 1950's and even earlier in some cases: if agricultural primary sector profitability decreases due to climate variability, areas with smaller mean farm size and no alternative income sources than agriculture may face new population changes. Flatland agricultural areas close to major road networks and urban centers, where agricultural farm size is generally larger than mountain and hilly farm areas, show a trend which could be applicable for the future; part time farmers may have more suitable conditions, since a shift in agriculture (ex. from cotton to gardening products) for a part time income is evidently more possible than for rural citizens who are based only to primary sector income. Low farm size, and the need for change, is also a major vulnerability which influences profitability and it is an issue of Govermental and organizational studies and actions. Also, the economic dependency of whole farming communities to certain cash crops creates the need for alternative crops with similar net profit levels, or the creation of local alternative sources of income.

<table>
<tr><td colspan="3">CORINE 2000 CLC and Spatial Agroclimatic Indices for Greece (ECHAM 5 A1B Racmo2 ENSEMBLES)</td></tr>
<tr><td>CLC CODE</td><td>CORINE LABEL3</td><td>Spatial Agroclimatic Indices</td></tr>
<tr><td>211</td><td>Non-irrigated arable land</td><td rowspan="21">The Miami Model Climatic Net Primary productivity based on Temperature, and the 2 meter temperature will increase for the periods 2031-2050 and 2071-2090 when compared with the period 1971-1990. All other variables and indices, such as Precipitation, P/ET, Ombrothermic Index, De Martonne Aridity Index, Net Primary Productivity based on Precipitation show a mean decrease for the periods 2031-2050 and 2071-2090 when compared with the period 1971-1990.
Since mean country NPP/Precipitation decreases, Climatic NPP (Precip/Temp) is following the same trend. Regional means may follow different trends, based on RCM results.

Please note that these are mean results for the total of Greece, per land cover code, and per time period, based on the 25 KM RCM Grid.
Regional and local differences are provided at Maps and Tables.</td></tr>
<tr><td>212</td><td>Permanently irrigated land</td></tr>
<tr><td>213</td><td>Rice fields</td></tr>
<tr><td>221</td><td>Vineyards</td></tr>
<tr><td>222</td><td>Fruit trees and berry plantations</td></tr>
<tr><td>223</td><td>Olive groves</td></tr>
<tr><td>231</td><td>Pastures</td></tr>
<tr><td>241</td><td>Annual crops associated with permanent crops</td></tr>
<tr><td>242</td><td>Complex cultivation patterns</td></tr>
<tr><td>243</td><td>Land principally occupied by agriculture, with significant areas of natural vegetation</td></tr>
<tr><td>311</td><td>Broad-leaved forest</td></tr>
<tr><td>312</td><td>Coniferous forest</td></tr>
<tr><td>313</td><td>Mixed forest</td></tr>
<tr><td>321</td><td>Natural grasslands</td></tr>
<tr><td>322</td><td>Moors and heathland</td></tr>
<tr><td>323</td><td>Sclerophyllous vegetation</td></tr>
<tr><td>324</td><td>Transitional woodland-shrub</td></tr>
<tr><td>331</td><td>Beaches, dunes, sands</td></tr>
<tr><td>332</td><td>Bare rocks</td></tr>
<tr><td>333</td><td>Sparsely vegetated areas</td></tr>
<tr><td>334</td><td>Burnt areas</td></tr>
</table>

Also regarding Agroclimatic spatial indices mean temporal differences, a trend that it is observed when analyzing the 25 km dataset and a 100 meter contour line is: Until the 300 meters the majority of Agroclimatic indices show a smaller change between the periods of (1971-1990), (2031-2050) & (2071-2090). Above 300 meters the difference between those periods is slightly changed, and after the 2400 meters, the difference shows a further change. Please note, the above are mean temporal results for the total of Greece surface, spatially averaged per 100 meters altitude zone.
Important vulnerability of arid areas is that they need more time for biomass recruitment after natural or anthropogenic disturbances, which is relevant to the Climatic NPP(P,T) rates. Wild land fires is a disturbance of ecosystems in Mediterranean; successive wild land fires followed by excessive grazing may reduce the ecosystem ability for forest regeneration and growth, increase erosion and decrease biodiversity.
Under the current management regime, public lands are also used for pastures, from low to high altitude mountain areas. One major vulnerability of these areas is possible wind and precipitation caused soil erosion. Assuming that drier conditions will be more frequent in the future, xerothermic species surface may increase, and some other native species may face habitat surface loss, especially at higher altitudes. These simulated drier conditions may result to less ground cover for certain seasonal periods, which in turn is responsible for the higher erosion vulnerability.

4.7.3 Feasible and recommended adaptation options in Greece

For the detailed regional descriptions see the Table 7.3 in the Appendix.

4.7.3.1. National Overview of the identified most feasible adaptation options of the regions/agroecosystems in Greece

Appropriate crop selection and local spatial positioning of crops are traditional older methods of risk minimization applied empirically by farmers and proposed by experts also. Farmer and also members of expert and decision making stakeholders consider and the introduction and /or expansion of irrigation as also a major option for broadening the crop suitability of a region or specific location. Water quality and quantity, hydrological functions of ecosystems, biodiversity –which are all very important for agriculture- are directly or indirectly dependent to naturally or semi naturally vegetated areas, so any adaptation management option at the local or regional level should be holistic and integrated to be effective, not focused only at farm level, but at the whole watershed and regional ecosystem territory too.

4.7.3.2 Selected most important and feasible adaptation options at the farm level in Greece (detailed)

4.7.3.2.1 Planting dates change

Time horizon of implementation: 2020’s, 2050’s
Application level: Farm Level

Analysis and reasoning: The specific adaptation option is relevant to all regions having large arable lands (such as Thessaly and Central Macedonia, Eastern Macedonia and Thrace, Sterea Ellada) and to the country of Greece in general. The agroecosystem that the specific adaptation option applies at, are all rainfed, or partially irrigated crops. For parcels with more

than one crop or harvest per year, then maybe the variation of the seeding date may influence negatively the initiation of the following one.
Already observed as an adaptation practice to local climatic variability, farmers are responsive to environmental conditions. A feasible adaptation option for fall seeded crops, and also for early seeded maize or sunflower, when sown for example on March instead of May. Trends can be observed from year to year (if fall rains are late for example) and also comparisons can be made on the planting dates of past decades. Benefits of such a simple adaptation practice are numerous, as the preliminary assessment below indicates: 1) Securing initial seed investment – increase of yield. 2) Initial Investment protection from crop failure if bimodal rainfall occurs. (Initial investment protection: resources and labor associated with the sowing). 3) Empirical rain monitoring by farmers and local knowledge for soil Water Holding Capacity–As it was observed, farmers call certain high clay content soils as "heavy", which is -a water holding capacity classification-. 4) The input remains approximately the same, as in planting at a predefined date, since only seeding dates change. 5) Habitat is provided for migraine birds and other fauna and flora until plowing, since the after cereal harvest approximately 20cm high plant stem remaining are habitat for some birds. 6) Increased water holding capacity until plowing, erosion protection through more surface residue from previous year. 7) Beneficial for microorganisms even for this small time period, flora and fauna, by leaving last year debris inside until rain period. 8) Adaptive, response farming method, climate risk manageable by farmers. Possible downturn of this adaptive process: in timing with appropriate WSI conditions for crops, but has the risk of delaying the seeding. If a lot of rains occur for example, heavy agricultural machinery can not enter the field for immediate plow. However, in Mediterranean areas rainy and wet periods are followed by drier ones even within November or December, so this may not be such a significant problem.

4.7.3.2.2. LGP based planting date arrangement – avoiding False starts

Time horizon of implementation: 2020's, 2050's
Application: Farm Level (or larger geographical level)

Analysis and reasoning: As proposed by the FAO CLIMPAG website, and numerous literature sources on the subject, the seeding date can be arranged based on the Length of Growing Period value. Specifically, when the ratio of P/ET reaches more than 0, 50, it is recommended that seeding can take place minimizing the risk of false starts. In more detail, as "false start" we mean the failure of a crop to grow and survive due to an early seeding date. That can result to the demand of additional seed resources (to repeat the seeding in case of failure) and more labor, machinery work time, fossil fuel input for agricultural machinery and others.

4.7.3.2.3 Enhancement of long term economic interests of rural residents from sustainably managed forest ecosystem lands

Time horizon of implementation: 2020's, 2050's
Application: Local, Regional and National Level.

Although this adaptation option does not refer to private agricultural lands, but mostly to Govermental managed forest lands, it is applicable to rural areas and this is why it is included here.
Greece on contrary with many other European countries has the majority of its forest lands under public management and/or ownership. However, the national legal framework provides a lot of access rights to services, products and goods of forest lands to local residents

(Forestry Cooperatives, harvest and trade of timber and wood, grazing, NTFPs and others). The enhancement of, and development of economic interests can further aid to supplementary income for local populations, increase subsidiarity, plus possibly aid in the population structure of rural areas, all of which are goals of the European Union policy. For example, sustainably regulated free grazing, in combination with forest management, can aid to reduction of biomass density of rural lands (Agricultural Areas and Forest Areas of CLC 2000). Consequently, reduction of biomass density, results to lessen forest fire initiation risk, and wildland fire intensity and rate of spread. Additionally, when free grazing animals consume part of the biomass of the under storey of pine and oak forests for example, the possibilities of a small ground level fire to become a destructive crown fire are lessen. Woody biomass that is produced by certain rural areas (ex fuel wood) is used for energy subsidiarity, and same holds for hardwood and coniferous timber, and several NTFPs: further development of these land uses under sustainable forest management may help significantly rural communities.

Please note, that these management options are already taking place in Greece, what is proposed here is their further systematic long and short term development and expansion to more rural geographic areas, also considering local climatic variability and future climatic projections of RCMs and GCMs.

4.7.3.2.4 Extending and introducing Beekeeping

Time horizon of implementation: 2020’s 2050’s
Application: Farm or Regional Level

Analysis and reasoning: Beekeeping is either a full time job or a supplementary income source for either full or part time farmers, as revealed during ADAGIO assessment. A reason for this maybe the small initial investment required to develop a testing small unit (people testing the practice may start from 10 and up beehives). Each spring during reproduction season more beehives are generated by the initial ones, and therefore under appropriate management conditions the unit can be grown significantly each year. There is no need for investing on land (since in Greece at least public lands may be used as beehive establishment grounds after a permit from local forest management agencies), heavy tractor equipment, or other heavy machinery (basic specialized equipment is needed at least for small units). In Greece, at least at the units observed and farmers interviewed, this is a practice with a seasonal geographic positioning: with units to be partitioned into several locations, or carried altogether in one location (ex. spring in lowlands to harvest valley flower honey, on June at fir forests for fir (*Abies alba*) honey (approximately 700 meters and higher altitudes). This “nomadic” practice it’s by itself an advantage to climatic and environmental variability, since beekeepers move in suitable areas, and screen out unsuitable ones – as long as these have a certain accessibility level during their activities-. High quality honey is produced also by marginal dry areas (such as the islands and southern highlands). Additionally, if certain land use scenarios are realized and there will be more fallow land, or more abandoned agricultural land, or agricultural to grassland conversions happen, then more space will be available for beekeeping. Another issue to note here is that beekeepers (at least as assessed by the ADAGIO assessment) avoid intensive agricultural areas with chemical treatments (herbicides and pesticide applications) since it can damage their bee population; ecological agriculture increase, or land use changes mentioned (more fallow land, agriculture to grassland conversion, extensive management, abandonment) can create additional grounds for beekeeping. However, the market conditions and net profit available from beekeeping is also a crucially important factor which can influence of this adaptation option can take place or not.

4.7.3.2.5 Farmer Empirical/Traditional Land Classification – Farmer adaptation to site microclimate

Time horizon of implementation: 2020's, 2050's
Application: Farm level (could be broadly applied at regional level too)

Analysis and reasoning: At the landscape level, farmers do classify lands per land use, as observed by interviews during the ADAGIO assessment. For example, in areas where irrigation network is available, usually the cultivation applied is for rainfed crops or livestock farming, either extensive (ex. free grazing) or intensive. This is also a major drought adaptation method. Where possible, the investment of required infrastructure to convert soil, nutrient and water availability conditions to match their specific requirements for the new crop they wish to plant. A more traditional approach from older farmers was to classify the lands based on their characteristics and suitability, and plant accordingly to these guidelines. For example, as "tobacco fields" were named areas suitable for such crop based on traditional experience. Similarly, olives were not planted on any field, but on suitable locations with low frost risk, or not planted at all. This older approach is still in practice today, but also many investments for new land uses and crops are applied today to convert/improve land suitability, especially at irrigated lowlands.

4.7.3.2.6 Minimum or no tillage, leaving natural (or introduced) ground cover on extensive tree crops

Time horizon of implementation: 2020's, 2050's
Application: Farm Level

Analysis and reasoning: FAO Paper 54 analyzes the reduction of soil evaporation with the use of "non-active" ground cover. As non active we mean non transpiring plant cover, such as mulch. Erosion reduction is accomplished too, though the ground covers. The straightforward scenario is applicable to certain CORINE 3rd level land use codes, such as the codes referring to vineyards, olive grooves and tree orchards. As discussed already, this is an adaptation option based on existing observations from current practices. The total area covered in Greece by the CORINE 2000 Codes of "Fruit Trees and Berry Plantations", "Vineyards" and "Olive Grooves" is 822.619,96 Ha. Regions of Peloponnesus, Thessaly, Sterea Ellada, Central Macedonia, North and South Aegean and Crete, but also all other areas hosting such agricultural systems could potentially apply such a method. A very important issue that can be raised here for the ground cover, is that during flowering in spring and later in the growing season for the ground cover plant, the evapotranspiration will be increased, nutrients and soil resources will be consumed from the ground plant cover, which depending on site conditions and plant combinations may compete with the tree crops. A practice applied here by certain farmers is the plowing of the ground cover before flowering, so nutrients such as nitrogen are further incorporated into the soil. Another method can be the cut of ground cover stems before flowering, and deposition of the cut biomass onto the site. Please note, that results are site and management dependent. A similar method identified applied by farmers in mountainous regions of continental Greece (ex. Sterea Ellada) is the combination of walnuts –for walnut production- with medicago species for harvesting raw medigaco for dry animal feed, and for limited raw sheep grazing which is an irrigated system during the summer, applied in terraces traditionally. Please see the relevant case study and ADAGIO presentations for the scientific basis and rationale behind this option.

4.7.3.2.7 No or minimum tillage of arable crops

Time horizon of implementation: 2020's, 2050's
Application: Farm Level

No or minimum tillage of agricultural lands is reported to reduce erosion of agricultural lands as much as 80% (David L. Schertz "Conservation Tillage-A national perspective" USDA Soil Conservation Service, Washington DC, 20013). As in the previous adaptation option rationale and application, but applicable to arable crops, and thus to land cover code of "Arable Lands" of CORINE 2000 dataset for Greece. Its application is also site dependant. The rationale here is that based on the above, if both the plowing is reduced and the ground cover of harvest debris is left on site, there will be a) A decrease in bare soil surface, increase in dead mulch cover, so a decrease in bare soil evapotranspiration b) A decrease in erosion, due to the increased ground plant biomass and the reduction of plowing. Less is soil evaporation during dry season means more available soil water during the seeding season for the next growing season. As with all management options, its success depends on adoption from farmers, on site conditions, on land use history, and also on social and economic circumstances. Practitioners may also not consider this practice as suitable in certain cases, if they prefer deep plowing which increases infiltration of rain water into lower soil stratum and thus crop growth.

4.7.3.2.8 Successive plowing events prior to seeding

Time horizon of implementation: 2020's, 2050's
Application: Farm level

Analysis and reasoning: There are numerous field applied adaptation options by farmers, and also others proposed in the literature. A simple and effective method of controlling weeds in farmlands is the light plowing before seeding. The first plow event is to germinate the surface seed resource, the later to destroy the germinated weeds and then the seed application can be made at bare soil, with delayed weed seed emergence. However, on persistent irrigated land weeds, this method may not be applicable, since their strong root system and vegetative reproduction patterns may have the exactly opposite result, to further redistribute weed reproduction material into the farmland. Generally, this method can be an alternative way to herbicide application, depending on local conditions and weed nature.

4.7.3.2.9 Oats and/or Rye for weed suppression

Time horizon of implementation: 2020's, 2050's
Application: Farm level

Analysis and reasoning: Also proposed by farmers and by literature, this method has been applied as a case study in Greece, but has not yet been tested in a wider geographic extent or during many seasons. As in WP3 report, it was reported that oat can dominate over undesirable plant species, through below and above ground competition. (Similar to wild oat which is a common competitor for wheat). The next year(s) the farm can be sown and cultivated, or after a few years of natural re-seeding and growth of the species. Can be suitable for ecological farming and extensive agricultural practices, since it can reduce pesticide usage and other inputs, while possibly generating browsing biomass. Market demand (ex. From diary farming) can be combined with this method. The method needs farther systematic examination since only a field demonstration project for a single season was carried out at private agricultural land in Greece during ADAGIO assessment. But, the known aggressive nature of oat could support the possible local or wider geographic suitability of this method.

4.7.3.2.10 Change towards sustainable practices, added market value quality crops and products (Several governmental strategies)

Time horizon of implementation: Current Programmatic Period
Application: Farm or Regional Level

Analysis and reasoning: Quality food products and locally adapted agricultural products that can also be part of a certification scheme belong to these actions, including ecological farming and integrated agricultural management activities. Probability of success depends on market conditions, on vertical market integration (ex. Agricultural cooperatives marketing) and on the willingness of farmers to follow such practices. From the ecological or climatological point of view, these crops are adjusted to local conditions and meteorological patterns; less risk is associated with them, due to their local long term adaptability. Examples of such products are branded wines, olive oil, quality cheese and meat products, and other Mediterranean goods, focused on local and export markets. While Greece does not have the extensive grasslands or valleys of Central and Western European countries, it does have a natural completive advantage on environmental conditions to produce high quality food products of the Mediterranean climate. There are examples of successful agribusiness marketing such products for the last decades and being competitive in local and international markets.

4.7.3.2.11 Use of traditional genetic seed and animal resources, and development of new cultivars

Time horizon of implementation: Current, 2020's, 2050's
Application: Farm or Regional Level

Analysis and reasoning: Reduction of dependency on external markets for seed, capitalization of local genetic resources, enhancement of agricultural crop biodiversity, providing the opportunity to farmers to reproduce their own seed sources, producing high quality marketable local products, are some of the benefits one may assign to such an adaptation option. Several country and EU legislative documents are relevant to the promotion and protection of local agricultural genetic varieties; additionally a new economic front can be the production and marketing of local seed varieties.

4.7.3.2.12 Medicinal Herb cultivation (especially on mountainous, hilly, islands and marginal areas)

Time horizon of implementation: Current, 2020's, 2050's
Application: Farm (for the policy and promotion level this can be a regional or national strategy, but the basic application level is farm).

Analysis and reasoning: Widely used, either in medicine, in food processing or in medicine and cosmetics industry, herbs can create economic outputs even from marginal areas (as they ones they are usually found). Water input is not required for xerothermic species, or in much

smaller quantities than current “cash” crops (empirical knowledge states that ex. Oregano quality is much better quality from dry areas than humid or watered fields).
It is important here to stress that any new developments should take into consideration biodiversity issues: local seed and propagation material sources should be used for any herb cultivation. The proposal serves at least two important issues: protection of local biodiversity from introducing new varieties that could potentially dilute local biodiversity and introduction of pests and diseases that are not present at local cultivars.
As found during assessment – but is an issue needing further investigation for clarification - medicinal herbs, especially due to the oil substances they carry do not suffer as much as other crops by diseases or pests, which is another advantage. A debate here is that markets for such crops are small, and thus there may be no demand for large quantities. However current advices from several institutions promoting such practices state that market demand is at good levels and thus financial returns can be satisfactory for farmers.
Can serve as a main crop, or as a secondary one, at an extensive, rainfed agricultural system also in lower soil quality and productivity lands. This adaptation option can be combined with the beekeeping option, since the two systems are traditionally mutually beneficial to each other (herb pollination and honey production).

4.7.3.2.13 Maintaining or enhancing natural vegetation, natural fences on farm borders, open grown trees within farms

Time horizon of implementation: Current, 2020’s, 2050’s
Application: Farm (for the policy and promotion level this can be a regional or national strategy, but the basic application level is farm).

Analysis and reasoning: Similarly to other adaptation options which tend to focus on natural ecosystem functions, this specific one uses the “Edge effect” created by natural vegetation formations to benefit the crops and the field with certain bioclimatic phenomena, such as reduction of evapotranspiration on partially shaded areas, habitat for microorganisms and biodiversity useful to the crops, erosion protection, wind and snow natural breaks. Open grown trees in farms, are also useful, either as a structural, and life form biodiversity, as a shelter for birds and praying species of farm pests (ex. mice praying species, insect feeding birds), and also as future seed sources of forestry regeneration in case of land use shift towards extensive agro forestry or forestry systems. High conservation value farmland has such characteristics, and it is usually rich in flora and fauna biodiversity. Ecological agriculture can also be combined with such practices, since it is dependent on local and landscape biodiversity.

4.7.3.2.14 Enhancing crop, holding and landscape diversification

Time horizon of implementation: Current, 2020’s, 2050’s
Application: Farm (for the policy and promotion level this can be a regional or national strategy, but the basic application level is farm).

Analysis and Reasoning: The method is applicable to all agricultural and arable land with low ecosystem homogeneity. “Complex cultivation Patterns” areas, or areas classified as “Land principally occupied by agriculture, with significant parts of natural vegetation” (CORINE 2000 areas, Code Level 2 – Please see relevant CORINE 2000 Map) are closer to the goals of this adaptation option, than for example, intensive monocultures of great geographic extent. The method is traditionally and already applied to many regions of Greece; however extended monocultures of industrial crops may have altered this traditional regime in certain cases, thus the method can be proposed for the regions which have more extended monocultures of annual plants. Borrowing an economics term, "Portfolio Diversification" for Farmers is briefly to invest in many crops and land uses – which is done traditionally especially in hilly and mountainous regions. Optimal unit size for economic returns is an important factor here. Also, agricultural diversification was a fact on traditional farming communities for subsidiarity reasons. Especially in hilly and mountainous Greece the natural integration of tree crops, cereals, vineyards, grazing land, forest land, natural corridors and fences, in a few hectares provides ecosystem health in minor disturbances, and thus economic security if for example a pest affects one crop, while the rest can be productive.

4.7.4 Scientific basis of ADAGIO results

4.7.4.1 List of all literature used for national ADAGIO purposes, analysis etc. (national and international)

CORINE Land Cover Dataset. EEA, European Environment Agency, www.eea.org

Crop evapotranspiration - "Guidelines for computing crop water requirements - FAO Irrigation and drainage paper 56"by Richard G. Allen, Luis S. Pereira, Dirk Raes, Martin Smith. FAO - Food and Agriculture Organization of the United Nations, Rome, 1998

http://www.statistics.gr/gr_tables/S400_SPR_1_TB_00_A_6_Y.pdf Source of the data is from the Statistical Service of Greece, and specifically from the link provided above and from the Endnote No 2.

ΒΑΣΙΚΗ ΕΡΕΥΝΑ ΔΙΑΡΘΡΩΣΗΣ ΓΕΩΡΓΙΚΩΝ ΚΑΙ ΚΤΗΝΟΤΡΟΦΙΚΩΝ ΕΚΜΕΤΑΛΛΕΥΣΕΩΝ (ΑΠΟΓΡΑΦΗ ΓΕΩΡΓΙΑΣ-ΚΤΗΝΟΤΡΟΦΙΑΣ ΕΤΟΥΣ 1999-2000) Statistical Service of Greece. www.statistics.gr for Agriculture and Livestock Census 1999-2000.

Analysis of F.AD.N. Data – Technical and Economic results of the agricultural holdings in Greece, 1998. Athens, 2003 [ΑΝΑΛΥΣΗ ΣΤΟΙΧΕΙΩΝ ΔΙΚΤΥΟΥ ΓΕΩΡΓΙΚΗΣ ΛΟΓΙΣΤΙΚΗΣ ΠΛΗΡΟΦΟΡΗΣΗΣ (ΔΙ.ΓΕ.Λ.Π.-R.I.C.A.-F.AD.N.) ΤΕΧΝΙΚΟΟΙΚΟΝΟΜΙΚΑ ΑΠΟΤΕΛΕΣΜΑΤΑ ΤΩΝ ΓΕΩΡΓΙΚΩΝ ΕΚΜΕΤΑΛΛΕΥΣΕΩΝ ΣΤΗΝ ΕΛΛΑΔΑ, 1998. ΑΘΗΝΑ, 2003]

ΒΑΣΙΚΗ ΕΡΕΥΝΑ ΔΙΑΡΘΡΩΣΗΣ ΓΕΩΡΓΙΚΩΝ ΚΑΙ ΚΤΗΝΟΤΡΟΦΙΚΩΝ ΕΚΜΕΤΑΛΛΕΥΣΕΩΝ (ΑΠΟΓΡΑΦΗ ΓΕΩΡΓΙΑΣ-ΚΤΗΝΟΤΡΟΦΙΑΣ 1999/2000)

Table 25, Table 24, Statistical Agriculture and Livestock Census 1999-2000. [ΠΙΝΑΚΑΣ 25 : ΕΚΜΕΤΑΛΛΕΥΣΕΙΣ ΜΕ ΑΡΔΕΥΘΕΙΣΕΣ ΕΚΤΑΣΕΙΣ ΚΑΤΑ ΚΑΤΗΓΟΡΙΑ ΚΑΛΛΙΕΡΓΕΙΑΣ ΚΑΙ ΚΑΤΑ ΤΑΞΕΙΣ ΜΕΓΕΘΟΥΣ ΤΗΣ ΣΥΝΟΛΙΚΗΣ ΧΡΗΣΙΜΟΠΟΙΟΥΜΕΝΗΣ ΓΕΩΡΓΙΚΗΣ ΓΗΣ ΑΥΤΩΝ (Source: www.statistics.gr) ΠΙΝΑΚΑΣ 24 : ΕΚΜΕΤΑΛΛΕΥΣΕΙΣ ΜΕ ΑΡΔΕΥΘΕΙΣΕΣ ΕΚΤΑΣΕΙΣ ΚΑΤΑ ΤΡΟΠΟ ΑΡΔΕΥΣΗΣ ΚΑΙ ΛΗΨΗΣ ΝΕΡΟΥ ΚΑΙ ΚΑΤΑ ΤΑΞΕΙΣ ΜΕΓΕΘΟΥΣ ΤΗΣ ΧΡΗΣΙΜΟΠΟΙΟΥΜΕΝΗΣ ΓΕΩΡΓΙΚΗΣ ΕΚΤΑΣΗΣ ΑΥΤΩΝ] Statistical Service of Greece. www.statistics.gr

R Development Core Team (2008). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. ISBN 3-900051-07-0, URL http://www.R-project.org.

Package Rclimdex 1.0 by Xuebin Zhang and Feng Yang, Climate Research Branch, Environment Canada, Donsview, Ontario, Canada

Debian GNU/Linux Operating System www.debian.org

AGRO-ECOLOGICAL ZONING Guidelines. FAO Soils Bulletin 73, Soil Resources, Management and Conservation Service, FAO Land and Water Development Division, Food and Agriculture Organization of the United Nations. Rome, 1996

Climate Scenario Data Acknowledgment: "The ENSEMBLES data used in this work was funded by the EU FP6 Integrated Project ENSEMBLES (Contract number 505539) whose support is gratefully acknowledged"

DIVA-GIS Version 5.2 Manual. September 2005 Robert J. Hijmans, Luigi Guarino, Andy Jarvis,Rachel O'Brien, Prem Mathur, Coen Bussink Mariana Cruz, Israel Barrantes, and Edwin Rojas.

Nelson, A., G. LeClerc and M. Grum, 1997. The development of an integrated Tcl/Tk and C interface to determine, visualise and interogate infraspecifc bio-diversity. Internal CIAT document. GIS Laboratory, CIAT, Cali, Colombia (as referenced into the DIVA-GIS Version 5.2 Manual).

Lieth, H., 1972. "Modelling the primary productivity of the earth. Nature and resources", UNESCO, VIII, 2:5-10.

FAO CLIMPAG "Climate impacts on agriculture" Environment Climate Change and Bioenergy Division, FAO, Food and Agriculture Organization of the United Nations http://www.fao.org/nr/climpag/index_en.asp)

4.7.5 Dissemination activities during ADAGIO (during all project lifetime)

4.7.5.1 List of scientific ADAGIO publications (which include ADAGIO results). It means: ADAGIO related results which were published during the AGAIO project.

"Proposal on creating radiation maps for use in tree-crop agroecosystems modeling"; Dimos P. Anastasiou, Global Change Conference, March 2008, Sofia, Bulgaria

"Climate change and rural areas: Farmer's perspectives" Dimos P. Anastasiou, Presentation & Abstract; ENSEMBLES Project, September 2008, Athens, Greece

"Methods and spatial analysis for the ADAGIO agricultural adaptation assessment in Greece" Dimos P. Anastasiou; ADAGIO Symposium Abstract Publication (& Presentation), June 2009, BOKU, Vienna, Austria.

"Methods and spatial analysis for the ADAGIO agricultural adaptation assessment in Greece" Dimos P. Anastasiou, Mike Petrakis and Christos Giannakopoulos; ADAGIO Symposium Extended Abstract Publication "Impact of Climate Change and Adaptation in Agriculture", August 2009, BOKU, Vienna, Austria.

4.7.5.2 List of not yet published (manuscript status) scientific ADAGIO related publications (national or international).

"Modeling risks and benefits of spatial crop diversification versus mono-cultures based on decadal data produced from a climate change scenario at a small ephemeris river catchments in Central Greece" Under Development, JAS.

A 25 km resolution scPSDI spatial dataset for Greece for current and future climatologies: Under development.

4.7.5.3 List of published or not yet published (manuscript status) ADAGIO results specific designed for national farmers or stakeholders, which are more than common articles in newspapers (e.g. books, brochures, reports which can serve as a permanent source of information).

ADAGIO Brochure: 3 fold, 2 page ADAGIO brochures in Greek and English, explaining the methods and application of ADAGIO. Permanently available at the Greek national project website and also distributed in printed form at several interviewed practitioners and experts.

ADAGIO poster: an A0 size poster file (also permanently available at the national project website).

ADAGIO Website: Permanent website in Greek Language, providing basic information on the scientific approach on adaptation of agriculture and the importance of gathering farmer input and information. Pilot project applications with a local NUTS3 agency and a Public Equivalent Body are also posted at the Website.

ADAGIO Map Annexes: Spatial Index Maps / Climate Change Impacts Maps, from the spatial analysis of several Agroclimatic and other indices at 25 km resolution covering the total of the surface of Greece. Based, as all of the analysis, at the ENSEMBLES Project data of the ECHAM 5 A1B Racmo2 KNMI datasets for monthly and daily periods. All map annexes are permanently available at the national ADAGIO website for download in PDF format.

ADAGIO Brochure "Open grown trees and natural fences in farms"

ADAGIO Brochure "Drought hardy, annual and perennial biomass production plants"

ADAGIO Brochure "Biomass production trees and their management"

4.7.5.4 Other national public relation activities (e.g. lectures, farmer meetings, articles in newspapers), use the updated table below, for ALL ADAGIO period

Listed in the Thematic Group 4 report

4.8 Egypt

4.8.1 Abstracts of national case studies carried out during the ADAGIO project

Case study 1 :

Vulnerability and adaptation Assessment of agriculture sector in the Nile Delta Region

M. A. Medany and S. M. Attaher

Abstract
The Nile Delta is most important agricultural region in Egypt has about 1.8 million ha of the total cultivated area of about 3.36 million ha, and about 93 % of the total Nile Delta land is "old land". The overall agricultural system in the Nile Delta is considered as one of the highest intensive and complicated agriculture systems in the world. Although the Nile Delta has a moderate Mediterranean climate, the region is one of the highly vulnerable regions in the world to climate change; in terms of temperature increase and sea-level rise (SLR). The main objective of this study is to conduct a community-based multi-criteria vulnerability and adaptation assessments in the Nile Delta using a preset questionnaire. In the vulnerability assessment, the survey questionnaire covered (i) the main specifications of the questioned farmer and the agriculture systems, (ii) the current risks facing agriculture production, in terms of natural, human, management and political risks, and (iii) the current view of the farmers about the impacts of climate change on agriculture. Whereas, in the adaptation assessment, a list of possible adaptation measures for agriculture production at farm level was investigated by the farmers, then the adaptation options resulted were an objective to experts' evaluation. The study concluded that sea level rise, soil and water degradation, undiversified crop-pattern, yield reduction, pests and disease severity, and irrigation and drainage management were the main key factors that increased vulnerability of the agriculture sector in that region. On the other hand, the results indicated that the Nile Delta growers have strong perceptions to act positively to reduce the impacts of climate change. They reflected the need to improve their adaptive capacity based on clear scientific message with adequate governmental support to coop with the negative impacts of climate change. Moreover, the majority of the samples considered that "changing cultivars" and "changing crop pattern" are the most important adaptation measures for agricultural systems in the Nile Delta region could be applied at the national level. Whereas, "increasing irrigation requirements" and "changing sowing dates" came in the next level of adaptation priorities, and both adaptation measures could be applied at farm level. Improve the current irrigation and drainage systems are addressed as an efficient adaptation measures at regional level of implementation. Establishing insurance and financial systems to overcome the unfavorable weather conditions impacts on agriculture production, and/ or sustain the required resources for adaptation of the agriculture sector, is important emerging issue in adaptation planning. About one half of the sample believes that they have to find suitable solutions for this critical problem, through farmers' cooperative funds, special taxies, and private sector cooperation. The experts encouraging establishing adaptation tax on crops prices (less than 2% of the price) as one of the imitative answers to the required adaptation fund.

4.8.2 Regional vulnerabilities and reasons in Egypt

For the detailed regional descriptions see the Tables 8.1 and 8.2 in the Appendix.

4.8.2.1 Summary description of the most significant identified vulnerabilities of the regions/agroecosystems in Egypt

A multi-criteria analysis was conducted in the Nile Delta region, in order to analyze the vulnerability of agriculture systems to climate change. The analysis based on community pilot assessment using a preset questionnaire. The form of the questionnaire consisted of three sections. The first section investigated the main specifications of the questioned farmer and the agriculture systems. The second section focused on the current risks facing agriculture production. The third section assessed the current view of the farmers about the impacts of climate change on agriculture. Farmers were the main objected group of the survey, and the survey covered 276 farmers. Field surveys were conducted in 18 pilot locations in the Nile Delta, which classified into three sub-regions of northern, middle and southern Nile Delta.

The observed changes in climate conditions were addressed as natural keys of vulnerability of agriculture sector in the Nile Delta. A percent of 92, 97 and 87 % of the survey samples in north, middle and south Nile Delta respectively, observed some changes in climate conditions during the last twenty years. Temperature rise was the main indication of the observed change. The majority of the questioned farmers in the Nile Delta believe experienced some reduction in crops productivity in the last 10 years due to unfavorable climate conditions. The farmers in the Northern Nile Delta indicated the most reductions in vegetables and orchards by a range of 20- 50 % decrease from the normal average yield. Almost all the samples believe that the projected increase in temperature due to climate change will have a serious impact on crops production, in terms of crop-yields reduction, the increase in crop-water requirements, the intensifying of beast and diseases, crop-yields quality reduction, intensifying salinity problem, changing sowing and harvesting dates, and increase in fertilizers requirements. The previous mentioned impacts of temperature rise were listed in descending order according to its priority from the farmers' prospective.

One hundred percent of questioned farmers were using surface irrigation systems, which is the dominated irrigation system in the old lands in the Nile Delta. The high reliance in low efficient surface irrigation systems, limits the opportunities of improving on-farm irrigation management applications. When poor irrigation management coupled with water shortage and low water quality, produce high vulnerable situation to the increase in crop-water requirements. This situation becomes more critical in the Northern and middle Nile Delta, due to the growing salinity problems and poor irrigation management.

Regarding to Dasgupta *et al.* (2007), Nile Delta region is one of the highly vulnerable regions in the world to Sea Level rise (SLR). Therefore, SLR was on the top list of the natural keys of vulnerability in the Northern Nile Delta. Agriculture sector in Egypt is projected to experience a severe impact. Even with 1 m SLR, approximately 12.5% of the Egypt's agricultural extent would be impacted, this percentage reaches 35% with a 5m SLR.

Soil degradation due to lose of fertility, salinization and high water table is investigated in this assessment. The farmers believe that soil salinization and losing soil fertility will have serious impacts over crop-yields production in the future. Under the current situation, soil salinization problems in the Nile Delta are highly sever in the northern costal line, and the severity is becoming lower by moving towards the south. The farmers from the Northern Nile Delta believe that they will have a serious problems with soil degradation more than Middle and southern Nile Delta farmers. The problem is attributed to soil properties, sea-water intrusion, low water quality, poor fertilization management, and drainage problems. As well as, soil degradation is attributed to the high reliance on poor irrigation systems, poor drainage systems, high extensive cultivation system, unsustainable agriculture management.

More than 60% of the total questioned farmers believed that pests and diseases become more critical in the last two decades. The framers in the three sub regions emphasized Aphids and Therpis, as serious pests, which became more critical than before. Whereas, Dodder and Broomrape were emphasized as weeds, which become more critical in the last decades.

Cold and heat waves were addressed as environmental risks have a strong effect threaten the agriculture systems in the three sub-regions of the Nile Delta. Whereas, they identified sand storms as an environmental risk has stronger effect threaten fruit production in the southern Nile Delta, and it may cause a crop losing by 10 to 70%.

The reduction in agriculture land due to urbanization is one of the critical sources of vulnerability of agriculture sector. This reduction in arable land area is coupled with the reduction on the average size of land ownership. Regarding to the small size of land ownerships in the Northern and Southern Nile Delta, the integrated and sustainable management is not applicable and/or economically fruitful. On the other hand, the assessment study asserted that agriculture sector is facing a general serious reduction in agriculture labor force, especially in experienced labor required in orchards. The labor force shortage is very serious in the Middle Nile Delta. The questioned farmers attributed this reduction to the increase in the education level in the rural community, the emergence for new economical activities such as petrochemical companies that present better income than agriculture activities, and the immigration of young people from rural to urban.

Generally, the agriculture sector in the Nile Delta is suffering from the absence of financial and supporting systems. Under the current study, only 32 % of the sample addressed some problems under financial system (high prices of production inputs, low income of agriculture products, bank loans, absence of financing system), this because most of the farmers are preferring the self-financing more than the governmental systems. The ability of the farmers for self-financing is projected to decrease under continues increase in agriculture inputs prices, and the projected incoming pressures on production system and yields. The current problems related to agriculture products marketing systems (monopolization, market roles, governmental role, limited markets, and exporting conflicts), are decreasing the income of the agriculture products, and add more pressure in agriculture system, especially in the Northern and Middle Nile Delta. Moreover, the limited extension services and the unclear and conflicted agricultural polices increase the vulnerability of the agriculture sector in Delta region.

Bulled on the aforementioned results, the northern Nile Delta could be the highest vulnerable sub-region in the Nile Delta due to the combination effect of natural, human, agriculture management, and economical and political conditions. Sea level rise, soil and water degradation, limited crop-pattern, yield reduction, and irrigation and drainage management were the main key factors increase the vulnerability of the agriculture sector in this sub-region of the Nile Delta. The vulnerability of the agriculture sector in the middle and south Nile Delta is contributed to more human, management, and economical and political conditions. Urbanization and the reduction in the size of land ownership were the most remarkable sources of vulnerability in the south Nile Delta.

Generally, the increase in pests and diseases severity, salinity and drainage problems, seasonal water shortage, the harmful impact of heat and cold waves over agriculture production were the main critical biological and environmental problems addressed by the questioned farmers facing the agricultural production. Labor, agriculture requirements availability and costs, and marketing problems were the main sources of the socioeconomical vulnerability of the agriculture sector in The Nile Delta.

4.8.3 Feasible and recommended adaptation options

For the detailed regional descriptions see the Table 8.3 in the Appendix.

4.8.3.1 National Overview of the identified most feasible adaptation options of the regions/agroecosystems in Egypt

The goal of WP3 activities was to conduct a multi-criteria adaptation assessment in the Nile Delta Region, through community-based assessment. This assessment was conducted through focusing in three emerging issues of; (i) the acceptable options of adaptations at farmers' level, (ii) insurance and financial systems of adaptation, and (iii) the adaptation for land loss in the North Nile Delta due to SLR.

The results indicated by the farmers were objective to experts' evaluation in terms of cost/benefit, opportunities, limitations and risks.

The assessment results indicated that "changing cultivars" and "changing crop pattern" are the most important adaptation measures for agricultural systems in the Nile Delta region could be applied at the national level. Whereas, "increasing irrigation requirements" and "changing sowing dates" came in the next level of adaptation priorities, and both adaptation measures could be applied at farm level. Improve the current irrigation and drainage systems are addressed as an efficient adaptation measures at regional level of implementation. Establishing insurance and financial systems to overcome the unfavorable weather conditions impacts on agriculture production, and/ or sustain the required resources for adaptation of the agriculture sector, is important emerging issue in adaptation planning. About one half of the sample believes that they have to find suitable solutions for this critical problem, through farmers' cooperative funds, special taxies, and private sector cooperation. The experts encouraging establishing adaptation tax on crops prices (less than 2% of the price) as one of the imitative answers to the required adaptation fund.

4.8.3.2 Selected most important and feasible adaptation options at the farm level in Egypt (detailed)

4.8.3.2.1 Changing cultivars

Time horizon of implementation: 5-10 years
Application level: national

This adaptation option was considered as the first most important adaptation option to face climate change impacts over agriculture systems in the Nile Delta at the national level. The implementation of this option is meeting the objectives of the national agriculture policy, which encourage cultivars development n order to improve the national agriculture production and reduce the environmental hazards. It requires the available levels of technology and knowledge of the agriculture community. The cost/benefit ratio is estimated as medium to high value for this option. Whereas, it may increase the flexibility of the agroecosystems to face temperature and water requirements increase. Yet it could be not efficient to face SLR and soil degradation problems.

4.8.3.2.2 Changing crop pattern

Time horizon of implementation: less than 5 years
Application level: national

This adaptation option was considered as the second most important adaptation option to face climate change impacts over agriculture systems in the Nile Delta at the national level. This option requires the available levels of infrastructure, technology, and knowledge of the agriculture community. The cost/benefit ratio is estimated as medium value for this option. Whereas, the implementation of this option requires strong support and efforts of the extension services and the local agricultural administrations. This option may be limited by food security and marketing constrains. Hence market constrains have higher effect in controlling crop pattern than environmental pressures.

4.8.3.2.3 Improve the current irrigation & drainage systems

Time horizon of implementation: 10- 20 years
Application level: regional

Although the total costs proportional to the total income of this option estimated to be high, this option is highly recommended under the growing circumstances of water shortage in Egypt. The implementation of this option is meeting the objectives of the national agriculture policy of sustainable natural resources management and improve water use efficiency. The opportunity of implementing this option is very high in the middle Nile Delta, which was targeted by a number of pilot projects and national irrigation improvements projects.

4.8.3.2.4 Changing sowing dates

Time horizon of implementation: less than 5 years
Application level: farm
The results of the evaluation analysis recommended changing sowing dates as an adaptation measure at the farm level, which could increase the flexibility of the farming system to face temperature and water requirements increase due to climate change. Whereas, changing sowing dates could be not efficient to face SLR in Northern Delta and soil degradation problems. Moreover, it may be limited by the marketing rules, which may not match the new harvesting dates, especially for cash crops.

4.8.3.2.5 Switch cropping activates to aquaculture

Time horizon of implementation: 5-10 years
Application level: regional

The evaluation analyses recommended "switch cropping activates to aquaculture" as adaptation measures could be applied at regional level in the North Nile Delta. This measure could imply good impacts on the national food security, while it may induce new environmental pressure on the natural resources on the region. Moreover it remarked by high degree of uncertainty in terms of farmers acceptance of carrier change, the capacity of fishing industry, and the availability of financial resources.

4.8.3.2.6 Using environmental controlled production techniques for orchards

Time horizon of implementation: 5-10 years
Application level: farm

Using environmental controlled production techniques for orchards production is one of the recommendations of the evaluation analysis that could be applied in the three sub-regions of the Nile Delta. This measure will require high financial investments and technology level, which may led to a general increase in the total price of fruits. But, it may increase the flexibility of the production system to face temperature and water requirements increase.

4.8.3.2.7 Establishing climate insurance and adaptation self financial systems
Time horizon of implementation: less than 5 years
Application level: national

Establishing insurance and financial systems to overcome the unfavorable climate conditions impacts over agriculture production, and/ or sustain the required resources for adaptation of the agriculture sector, is important emerging issue in adaptation planning. Average results for the Nile Delta reflect the high dependency of about one half of the farmers on the government in handling the insurance and the financial loads under current and future conditions. Whereas, the other half of the sample believe that they have to find suitable solutions for this critical problem, through farmers' cooperative funds, special taxies, and private sector cooperation. The experts encouraging establishing adaptation tax on crops prices (less than 2% of the price) as one of the imitative answers to the required adaptation fund. Whereas, this tax may help in accelerating the adaptation implementation; by ensure the required adaptation fund. On the other hand, the consumers may refuse it because it will increase the prices of the agricultural products, and the required fund for adaptation may exceed this level.

4.8.3.2.8 Gradual switching of the current old land by reclaimed land in Upper Egypt
Time horizon of implementation: more than 20 years
Application level: national

The evaluation analyses recommended gradual switching of the current old land by reclaimed land in Upper Egypt, in order to face SLR impacts on the agricultural systems in the North Nile Delta. Although the implementation of this measure could be limited by many biophysical and socio-economical limitations and uncertainties, it may sustain the national agriculture production at the secure level of production. Therefore, the current assessment investigated the farmers' reactions with this measure, by asking them if they accept to replace the farms in old land by an alternative farms in new reclaimed land in Upper valley of Nile through a governmental program. And if they accept this offer, what is the appropriate area of the new land that should be offered by the program in order to meet the old land productivity. In addition to, the farmers were asked about the governmental stimulations that should be offered by the land replacement program in order to encourage the farmers to replace their lands. This high percent of refusal is attributed to the low productivity of the reclaimed lands compared to the productivity of the old lands, the high cost of agriculture management and production in reclamation regions, and the difficulties and complications related to marketing and governmental programs. For the same reason of productivity reduction in reclaimed land, most of the farmers, which accept land-replacement, believe that the area of reclaimed land should be the twice of the area of the old land. Moreover, they indicate the "Subsidies on production inputs" as the most important governmental stimulations, which should be addressed under the governmental program of land replacement.

4.8.4 Scientific basis of ADAGIO results

4.8.4.1 List of all literature used for national ADAGIO purposes, analysis etc. (national and international)

Abd-El Wahab, H.M., 2005. The impact of geographical information system on environmental development. M.Sc. Thesis, Fac. of Agric., Al-Azhar Univ, Cairo.

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Medany, M. A. and Attaher, S. M., 2008. Vulnerability Assessment of agriculture sector in the Delta Region, Proc. of the first international conference on Environmental Studies and Research " Natural Resources and Sustainable Development", 7-9 April, Sadat Academy of environmental science, Minofya, Egypt.

Medany, M. A., Attaher, S. M. and Abou-Hadid, A. F., 2007. Socio-economical analysis of agricultural stakeholders in relation to adapting capacity to climate change in Egypt, Proc. of the international conference on "climate change and their impacts on costal zones and River Deltas", Alexandria-Egypt, 23-25 April.

4.8.5 Dissemination activities during ADAGIO (during all project lifetime)

4.8.5.1 List of <u>scientific</u> ADAGIO publications (which include ADAGIO results). It means: ADAGIO related results which were published <u>during</u> the AGAIO project.

Medany, M. A. and Attaher, S. M., 2008. Vulnerability Assessment of agriculture sector in the Delta Region, Proc. of the first international conference on Environmental Studies and Research " Natural Resources and Sustainable Development", 7-9 April, Sadat Academy of environmental science, Minofya, Egypt.

Medany, M. A., Attaher, S. M. and Abou-Hadid, A. F., 2009, Possible adaptation measures of agriculture sector in the Nile Delta region, Jornal of agriculture systems- special volum for The Eighth EMS Annual Meeting and the Seventh European Conference on Applied Climatology (ECAC) (in press).

Medany, M. A., Attaher, S. M. and El Sawy, R., 2009. Observed vulnerability and continues adaptation of the rural community in Nile Delta coast. Proceeding of the Ninth International Conference of Dryland Development, "Sustainable Development in the Drylands- Meeting the challenges of global climate change", 7-10 November 2008, Alexandria, Egypt(in press).

Medany, M. A., Attaher, S. M. and Abou-Hadid, A. F., 2009, Adaptation of agriculture sector in the Nile Delta region to climate change at farm level, In: Eitzinger, J., Kubu, G. (eds.), (2009): Impact of Climate Change and Adaptation in Agriculture. Extended Abstracts of the International Symposium, University of Natural Resources and Applied Life Sciences (BOKU),Vienna, June 22-23 2009. BOKU-Met Report 17, ISSN 1994-4179 (Print), ISSN 1994-4187 (Online) - http://www.boku.ac.at/met/report

Medany, M. A., Attaher, S. M. and Abou-Hadid, A. F., 2009, Land-use change and adaptation in the Nile Delta region, In: Eitzinger, J., Kubu, G. (eds.), (2009): Impact of Climate Change and Adaptation in Agriculture. Extended Abstracts of the International Symposium, University of Natural Resources and Applied Life Sciences (BOKU),Vienna, June 22-23 2009. BOKU-Met Report 17, ISSN 1994-4179 (Print), ISSN 1994-4187 (Online) - http://www.boku.ac.at/met/report

4.8.5.2 List of not yet published (manuscript status) scientific ADAGIO related publications (national or international).

Medany, M. A., Attaher, S. M. and Abou-Hadid, A. F., Adaptation of agriculture sector in the Nile Delta region to climate change. Abstract submitted in Journal of Agricultural Sciences.

Medany, M. A., Attaher, S. M. and Abou-Hadid, A. F., Land-use change and adaptation in the Nile Delta region. Abstract submitted in Journal of Agricultural Sciences

Medany, M. A. and Attaher, S. M., Risk Assessment of Agriculture Sector in the Nile Delta to Climate Change. Abstract submitted in the Fourth International Conference of The Egyptian Society for Environmental Sciences, Ismailia, Egypt 10-11 November 2009

4.8.5.3 List of published or not yet published (manuscript status) ADAGIO results specific designed for national farmers or stakeholders, which are more than common articles in newspapers (e.g. books, brochures, reports which can serve as a permanent source of information).

A- 2 Extension publications in Arabic language:
- Vulnerability of agricultural systems.
- Adaptation of agricultural systems.

B- One page publications in Arabic of Climate papers series:
- Issue No. 4: Climate change and agriculture: the great challenge.
- Issue No. 5: Climate change: Q & A (Part 1)
- Issue No. 6: Climate change: Q & A (Part 2)
- Issue No. 7: Climate change and the Nile Delta: Sorry; we will not leave agriculture to another job!
- Issue No. 8: Climate change and the Nile Delta: when the farmer speaks we have to listen!
- Issue No. 9: Climate change and the Nile Delta: Who will bay the adaptation bill?

4.8.5.4 Other national public relation activities (e.g. lectures, farmer meetings, articles in newspapers), use the updated table below, for ALL ADAGIO period

Listed in the Thematic Group 4 report

4.9 Poland

4.9.1 Abstracts of national case studies carried out during the ADAGIO project

Case study 1 :

Irrigation and agricultural water management in Poland in the perspective of climate change

Leszek Łabędzki
Institute for Land Reclamation and Grassland Farming, Regional Research Centre in Bydgoszcz, Poland

Abstract
Irrigation in Poland has supplemental character, used in short periods during the growing season, especially in regions with severe and frequent droughts. Statistically irrigation is needed once in three years. There are years when crops cultivated in Poland do not require irrigation during the growing season. In wet years the role of irrigation is marginal. Only in fruit and vegetable farming irrigation is essential every year. Generally, taking into account the whole agricultural area in the country, the role of irrigation in agriculture is marginal because of very small irrigated area (0.5% of the total agricultural land area).
Irrigation in Poland plays an important role in mitigating the effects of drought on crop production locally, in areas of light soils with valuable crops, where dry spells are likely to occur, leading to substantial losses in yields. In extremely dry years (e.g. 1992 and 2000) up to 40% of the country area is affected by drought. Average decrease in crop yield is estimated to 10-40% as compared to the normal year.
The effects of climate change are suggesting the increase of water demand in agriculture by 30-50% in the next 20-30 years, increasing the competition for water between rural and urban as well as industrial areas. Much of this increased demand of water for agriculture will come from irrigated agriculture. Moreover, more water will be required per unit area and probably for unit crop productivity, decreasing crop water productivity. The possible increase in water shortage in agriculture may reinforce the current trends of increasing local water resources and their availability, intensification of irrigation and increase in water use efficiency.
Various measures could be recommended, all of them are means to accomplish the strategic goal – controlling the negative effects of possible change in climatic conditions in agriculture. Because climate changes will impact mostly water resources and hydrologic cycle components the main measures should lead to:
1) an increase in the standing and flowing water resources,
2) an increase in water use efficiency in agriculture,
3) a decrease in water needs for crops.
The significance of irrigation will increase with the intensification of agriculture (e.g. in horticulture, orchards, seed crops) and with negative effects of climate changes. Studies show that under conditions of climatic and economical changes as well as taking into account sustainable development of Polish agriculture, the irrigation area will increase up to 2.1 mln ha, of which 1.6 mln ha on permanent grasslands and 0.5 mln ha on arable land and in orchards. writes that 3-4% of arable land (without subirrigated area) should be irrigated in the near future.

Czarnecka M., Koźmiński Cz., Michalska B., Ratajkiewicz H., Leśny J., Mager P., Kasprowicz T., Farat R., Kuchar L., Łabędzki L. 2009: Climate changes and agriculture in Poland – impacts, vulnerabilities, mitigation measures (in polish). Poznań, pp 18. – Brochure for farmers.

Łabędzki L., 2009: DROUGHTS IN POLAND – THEIR IMPACTS ON AGRICULTURE AND MITIGATION MEASURES. Climate chnage and agriculture in Poland - impacts, mitigation and adaptation measures, ed. Leśny J., Acta Agrophysica, Rozprawy i Monografie, 2009, 1, 97-107.

Case study 2 :

Technical equipment for irrigation to adapt agriculture to climatic risks and to mitigate negative impacts

Leszek Łabędzki
Institute for Land Reclamation and Grassland Farming, Regional Research Centre in Bydgoszcz, Poland

Abstract

As far as the technique and the irrigation systems are concerned, they are and will be in the nearest future similar to the systems, used in other European countries. They are and they will include the sprinkling machines in agricultural field cultivations, sprinkling machines and drip irrigation systems in vegetable farming, various microirrigation systems in greenhouses and orchards. In near future, the role of microirrigation of intensive root, industrial and greenhouse crops, horticultural crops in open air and orchards in private farms will increase.
In recent years increase in the area of irrigated land using microirrigation, especially drip irrigation in vegetable and fruit farming using, has been observed. It is assumed that the development of this type of irrigation will run parallelly to the development and intensification of agriculture and with negative effects of climate changes. Microirrigation systems become more popular because of their high efficiency. It is expected that this trend will dominate in Polish agriculture. There is no need, with the exception of financial subsidies, to undertake any special actions to stimulate development of this type of irrigation.
On permanent valley grasslands, gravitational subirrigation systems will remain in the future as a source of fodder and a way of healthy feeding of cattle. They also have a great role in the preservation of biodiversity and organic soils in river valleys.
It may be stated that it is not the technique which will be the barrier to the development of irrigation in Poland but the economics and the availability of water, in sufficient quantities and of suitable quality. That is why there is an urgent need for the improvement and modernization of irrigation systems to make possible the use of modern energy- and water-saving methods and techniques of irrigation and to increase the effectiveness of irrigation and water use efficiency.
Nowadays modern irrigation technologies and equipment are available in Poland and can be bought and implemented in a farm from many private companies, either domestic or the representatives of foreign companies (e.g. from Israel, USA, Italy). These companies serve the full process of investment, beginning from advisory and design and ending with the advisory service and control on the stage of operation and management. The only barrier of common implementation of modern irrigation equipment is their price.
Nowadays under actual economic conditions in agriculture and crop market prices, irrigation of most field crops in Poland is an unprofitable measure. Only irrigation of potatoes brings benefits. Irrigation of most vegetable crops and orchards are profitable. It can be foreseen that the relation between the investment and operation costs of irrigation to benefits of irrigation will improve. From one side the reduction of prices of irrigation equipment can be expected; from the other side the market prices of agricultural products will make irrigation benefited for farmers.

Czarnecka M., Koźmiński Cz., Michalska B., Ratajkiewicz H., Leśny J., Mager P., Kasprowicz T., Farat R., Kuchar L., Łabędzki L. 2009: Climate changes and agriculture in Poland – impacts, vulnerabilities, mitigation measures (in polish). Poznań, pp 18. – Brochure for farmers.

Łabędzki L., 2009: DROUGHTS IN POLAND – THEIR IMPACTS ON AGRICULTURE AND MITIGATION MEASURES. Climate chnage and agriculture in Poland - impacts, mitigation and adaptation measures, ed. Leśny J., Acta Agrophysica, Rozprawy i Monografie, 2009, 1, 97-107.

Case study 3 :

Bird cherry-oat aphid (Rhopalosiphum padi (L.) as an indicator of higher temperature and drought in the natural environment. Importance for agriculture

Maria Ruszkowska
Institute of Plant Protection

Abstract

During long-term observations taking place in selected regions of Poland since 1971, aphids of *Rhopalosiphum padi*, have changed some elements in their development following the year 1989, which is the result of higher temperature of the environment. The main changes which have significance for agriculture are as follow:

Development of new forms that have not been registered in Poland previously by means of permanent parthenogenesis only:

These changes are important for plant protection because the new forms are practically the only vectors of Barley Yellow Dwarf Viruses (BYDV), which is the most economically important cereal disease in countries (regions) with a warmer climate. In 2008 the new forms settled winter wheat and winter barley in all the inspected regions of Poland (Opolskie (south-west). Wielkopolskie (middle-west), Łódzkie (centre), Lubuskie (middle west)), except of the region of Podlasie (north-eastern Poland). The cereals were infested by BYDV as an effect of the new form occurrence on winter cereals.

The temperature threshold $\geq 25^0$C, which is necessary for the initiation of changes in aphid life cycle and the development of new forms, did not appear only in the Podlasie region.

The percentage share of the new forms of *R. padi* – potential BYDV vectors in 2008 was 11.8% in all autumnal populations of this species. First invasive flights were registered 12th September and they were continued until 17th December. This data was obtained from catches by the suction trap operating in the Wielkopolska region which forecast strong infestation of winter cereals by BYDV in 2009.

The changes in the onset of *R. padi* aphid flights in the spring:

The first winged specimens were registered in 2008 on April 29th. It was about 3 weeks earlier in comparison with the previous years (1971-1988). This phenomenon is important for cereals. Aphids, which are sucking plant sap pests, are more dangerous for young plants, in tillering phase, which is a strategic time for cereal growth stage.

The changes in the time of occurrence and decrease in the number of *R. padi* males:

Many-a-year dynamics of *R. padi* male occurrence in the region of Wielkopolska points out to the later flights of these morphs and in consequence the fall in their numbers. First males were registered in 2008 in the 45th week of the year, whereas in 1973 in the 35th week of the year .

The delay in occurrence of aphid males is an effect of a warmer autumn. As a result of a later development of the males their number decreases. A warmer autumn in the beginning stimulates the life length of aphid summer generations. The morphs which give birth, i.e. the

‘mothers’ of males, develop later and therefore their male offspring have a shorter time of living, up to the critical value of temperature –6°C. The development of every new generation is strongly restricted very precisely by temperature.
The impact of earlier falling leaves of host trees (*Prunus padus* L.) is the another factor which decreases the aphid male number (apart from permanent parthenogenesis). This is the result of drought. The decrease in male occurrence limits gene fixation between this aphid species which is not favourable for fauna biodiversity.

Case study 4 :

Challenges in plant protection in Poland

Henryk Ratajkiewicz
Department Of Plant Protection Methods, Poznan University of Life Sciences

Abstract

Expected climate warming in Poland will provide conditions conducive of the extension of geographical range of more therophytic species. At the same time, changes will be observed also in cropping patterns, especially in terms of the extension of cultivation of more therophytic species and the introduction of new species, and along with them - the appearance of new agrophages and intensified incidence of many native pests. Intensifying overdrying of topsoil will require changes in cultivation methods, simplified tillage, which result in changes in the incidence of presently reported agrophages.
Monitoring of agrophages
The primary task in terms of response to changes in the harmfulness of agrophages as a result of progressing climate warming is to develop scenarios and analyses of increased risk posed by the presently occurring agrophages, as well as develop risk analyses concerning the penetration of new agrophages to Poland, including quarantine and invasive species. Agrophages registration and forecasting are primary tasks realized by the plant protection and seed production inspection services, supported by the activity of research centres. In terms of forecasting a fast and suitable tool may be model studies based on computer simulation programs, e.g. Climex or Dymex.
Another essential task is to develop effective methods and ways to delay the occurrence of agrophages in Poland by the consistent realization of adequately specific, efficient, detailed quarantine regulations, followed by programs to reduce population growth of both new and native agrophages. In the latter case, existing plant protection programs will require appropriate specification, especially since climate changes lead to changes in the incidence and extension of occurrence of numerous agrophages.
A positive effect of climate change may be a phenomenon observed together with the inhabitation of new agrophages species, i.e. the appearance of their natural enemies, such as e.g. a lady-beetle *Harmonia axyridis*.
Pests
Forecasts prepared so far indicate that it is necessary to develop or adapt appropriate plant protection programs resulting from an increased hazard to crops by at least the following pests: aphids and other insects from orders of both homopterans and heteropterans, thrips, mites and dart moths. We need to expect an increased hazard for maize cultivation posed by European corn borer, Western corn rootworm and knot grass, especially in view of the further expected increase in the area cropped to this plant species. The importance of Colorado beetle is also going to increase. We need to expect an increased hazard for rape posed by *ceutorrhynchid* beetles in the autumn season. With an intensified occurrence of aphids the

hazard for crops posed by viral diseases will also increase, thus it is also necessary to modify both cultivation technologies and viral disease control programs in specific cases.
It will be needed to develop the best methods to detect, monitor as well as implement realist methods of effective response in the first focuses of infection after species from southern Europe penetrate to Poland, such as San Jose scale and fall webworm.

Diseases

Forecasts of disease incidence in Poland indicate that the hazard to plants by viral, bacterial and fungal diseases, as well as those posed by other disease agents will increase. We need to expect an increased importance of such cereal diseases as powdery mildew, barley rust, yellow rust, barley scald and septoria leaf spot. A higher hazard will be posed for beets by cercospora leaf spot, powdery mildew and rhizomania. A higher hazard than that reported to date will be observed for rape by dry-rot of cabbage. In Poland population size of species from genus Phytophthora will increase, the range of some of the species, to date reported in indoor cultures, will be expanded to outdoor areas. A necessary task will thus be to specifically develop existing plant protection programs.

Weeds

Climate warming will create conditions conducive of the development of therophytic weed species, primarily earlier dates of their appearance in cropped areas. It seems necessary to further develop protection technologies for individual crops. We need to expect that species from southern Europe will penetrate to Poland, among which the most dangerous species will be ragweed. It is also forecasted that the development of phytophages on weeds will be accelerated, which will facilitate their more effective reduction and potential purposeful introduction of biological protection in relation to such species as bent-root amaranth, European glorybind and meadow buttercup. It seems advisable to further develop existing crop protection programs against weeds, especially as the efficiency of herbicides may be reduced in relation to deeper rooted weeds from species classified in terms of photosynthesis to category C3.

Czarnecka M., Koźmiński Cz., Michalska B., Ratajkiewicz H., Leśny J., Mager P., Kasprowicz T., Farat R., Kuchar L., Łabędzki L. 2009: Climate changes and agriculture in Poland – impacts, vulnerabilities, mitigation measures (in polish). Poznań, pp 18. – Brochure for farmers.

Ratajkiewicz H., 2009: ADAPTATION STRATEGIES OF AGRICULTURE TO CLIMATE CHANGE IN TERMS OF PLANT PROTECTION. Climate chnage and agriculture in Poland - impacts, mitigation and adaptation measures, ed. Leśny J., Acta Agrophysica, Rozprawy i Monografie, 2009, 1, 137–150

Case study 5 :

Cultivation technologies and plant protection methods in Poland

Henryk Ratajkiewicz
Department Of Plant Protection Methods, Poznan University of Life Sciences

Abstract

Increased hazard posed by many new diseases and pests may be significantly reduced by adequate modifications of existing plant protection programs, cultivation technologies and methods as well as application of crop protection preparations. However, the first and primary step is to delay the spread of new agrophages in Poland by the enforcement of quarantine.
Many problems resulting from the intensified occurrence and the appearance of new agrophages may be solved thanks to the selection of cultivars with reduced susceptibility or exhibiting considerable resistance in relation to certain pathogens, or even pests; a specific

example in this respect may be the application of a genetically modified maize cultivar with a gene of insecticidal bacterium *Bacillus thuringiensis*.

Cultivation

Protection against soil overdrying is connected with the application of simplified tillage technologies on large areas of arable land and it leads to an increased occurrence of many weed species. Such a situation requires adaptation of cultivation technologies in terms of minimization of weed infestation by modifying cultivating measures, dates of their application and finally the selection of herbicides and their doses. Simplified technologies lead also to an increased incidence of pests and especially diseases in case of monoculture. Thus it is necessary to streamline these technologies in the long-term perspective in the crop rotation system.

Herbicides

An extended vegetation season requires the application of plant protection measures also over extended periods of time, especially in terms of herbicide application.

Periods of topsoil overdrying, occurring more frequently and over longer periods, are connected with reduced efficiency of soil-applied herbicides. It seems necessary to improve existing programs of crop protection against weeds in terms of the application of foliar applied herbicides, supplemented with adjuvants when necessary. Technologies of multiple application of herbicides at lower doses or the so-called micro-doses need to be further developed for numerous crops.

The expected climate warming is also connected with a reduced importance of certain groups of herbicides, primarily from the group of pyrethroids, which efficiency decreases with an increase in temperature. On the other hand, temperature conditions will be conducive of a more effective action of numerous groups of crop protection preparations. In contrast, drought conditions occurring more frequently will not promote the penetration of herbicide active substances with systemic action. It is going to be necessary to gradually modify both the selection of herbicides in terms of coming climate changes and crop protection technologies.

Czarnecka M., Koźmiński Cz., Michalska B., Ratajkiewicz H., Leśny J., Mager P., Kasprowicz T., Farat R., Kuchar L., Łabędzki L. 2009: Climate changes and agriculture in Poland – impacts, vulnerabilities, mitigation measures (in polish). Poznań, pp 18. – Brochure for farmers.

Ratajkiewicz H., 2009: ADAPTATION STRATEGIES OF AGRICULTURE TO CLIMATE CHANGE IN TERMS OF PLANT PROTECTION. Climate chnage and agriculture in Poland - impacts, mitigation and adaptation measures, ed. Leśny J., Acta Agrophysica, Rozprawy i Monografie, 2009, 1, 137–150.

<u>Case study 6 :</u>

Extreme atmospheric phenomena in Poland

Czesław Koźmiński, Bożena Michalska

Abstract

Observed accelerated climate changes, especially in the last 30 years, have resulted in an increasing frequency and extreme intensity of atmospheric phenomena. A characteristic feature of climate in Poland is the non-simultaneous occurrence of adverse atmospheric phenomena and spatial variation in the frequency of their incidence in individual years. One of the effect of climate changes in Poland has been an increase in evapotranspiration, not only in summer, but also in winter, as a consequence of which e.g. water reserves in a 50cm soil layer, left after winter at the end of March, are reduced, resulting in a disturbed equilibrium of agri-climatic water balance of a given region. At the same time every year in Poland

thousands of hectares of arable crops, grassland and forests are allotted to expanding urban districts, warehouses, roads, which changes the structure of heat balance in agricultural landscape, leading to an increased frequency of adverse atmospheric phenomena.

In Poland there are about a dozen atmospheric phenomena disadvantageous for agriculture, such as e.g. atmospheric and soil droughts, hail storms, late frosts, excessive precipitation and floods, hurricanes, atmospheric storms, and in the winter season – soil thaws and strong frosts at a lack of snow cover..Throughout the country mean annual reduction of expected yields of cereals, due to the occurrence of adverse atmospheric conditions, depending on the region and species ranges from 8 to 18%, while for root crops it is from 8 to 10%.

Positive aspects of progressing climate changes include:

– earlier dates of spring field works and beginning of plant vegetation seasons,
– extended vegetation period,
– an increase in accumulated heat facilitating cultivation of thermophytes (e.g. soy, grain maize, grapevine) over a bigger area of the country,
– an increase in the total sunshine hours, which will make it possible to improve yield quality,
– an increase in the area cropped to catch crops.

Negative aspects of climate changes include:

– an increased frequency and extreme character of adverse atmospheric conditions,
– an increase in evapotranspiration causing increased negative values of climate water balance,
– occurrence of very warm and very cold winters,
– periodical excessive delay in dates of field works and beginning of plant vegetation seasons,
– regional and local adverse changes in active surface heat balance as a result of e.g. progressing anthropopressure,
– increased incidence and extreme character of early spring and summer floods.

Czarnecka M., Koźmiński Cz., Michalska B., Ratajkiewicz H., Leśny J., Mager P., Kasprowicz T., Farat R., Kuchar L., Łabędzki L. 2009: Climate changes and agriculture in Poland – impacts, vulnerabilities, mitigation measures (in polish). Poznań, pp 18. – Brochure for farmers.

Czarnecka M., Koźmiński Cz., Michalska B., 2009: CLIMATIC RISKS FOR PLANT CULTIVATION IN POLAND. Climate chnage and agriculture in Poland - impacts, mitigation and adaptation measures, ed. Leśny J., Acta Agrophysica, Rozprawy i Monografie, 2009, 1, 78-96.

4.9.2 Regional vulnerabilities and reasons in Poland

For the detailed regional descriptions see the Tables 9.1 and 9.2 in the Appendix.

4.9.2.1 Summary description of the most significant identified vulnerabilities of the regions/agroecosystems in Poland

The most serious threat for Polish agriculture under future climatic conditions will be the shortage of water. Based on historical sources it may be stated that the frequency of droughts occurrence in Poland is increasing. Until the 1980's dry periods were observed most frequently at the turn of March and April, May and June, and September and October, while in the last 20 years they have also been observed in the summer (July-August), becoming increasingly longer and more intensive. The Ministry of Agriculture and Rural Development assessed that as a result of drought in 2006 the biggest losses were found in meadows and pastures (mainly the 2nd and 3rd cuts - 40-100% losses), spring cereals – 20-60 % losses, winter cereals – 15-50% losses, rape – 15-45% losses, potatoes and sugar beets – 20-60%

losses, vegetables 30-60% losses. According to forecasts, this type of extreme phenomena will occur more and more often and may be increasingly intensive, thus situations similar to that in 2006 will have an increasingly adverse effect on agriculture. Simulations of future weather conditions carried out based on the model HadRM3-P for scenario A2 indicated that the duration of the longest dry period (daily precipitation ≤ 0.5 mm) can be extended by 5 to 10 days (for the whole central Europe). ,. Moreover, evapotranspiration and crop water demands can increase due to increased temperatures and the extent of the length of growing season. Thus, soil moisture can be depleted more quickly during the growing season, while surface runoff and groundwater recharge may decrease.

The observed effects of climate changes unambiguously show that the water demand of agriculture sector can increase by even 30-50% within the next 20-30 years, what will lead to , increasing competition for water resources between rural and urban as well as industrial areas. Much of this increased demand of water for agriculture will come from irrigated areas. Moreover, more water will be required per unit area and probably per unit of produced crop,. The possible increase of water shortages in agriculture may reinforce the already undertaken activities lead to increase of local water resources and their availability, intensification of microirrigation and increase of water use efficiency.

The forecasted warming will promote more intensive development of insects, which will cause their increasing distribution and population size, while for the same reason a more extensive development may be expected for fungal diseases and other plant diseases, especially in south-western Poland. Completely new pathogens may also appear, e.g. weeds such as *Ambrosia spp*. Increased activity of plant pathogens may be evidenced e.g. by the proven effect of increased temperature on bird cherry aphid (*Rhopalosiphum padi*). In the normal developmental cycle in the autumn aphids move from the secondary host (e.g. cereal) to the main host (bird cherry). It was shown that a minimum of 3 successive days with mean diurnal air temperature of ≥25ºC result in the occurrence of forms capable for parthenogenesis, which feed on autumn emergence of cereals and do not move to winter in bird cherry. *Aphid R. padi* is the most abundant species among the fauna of aphids found on cereals in Poland. Since aphids are carriers of barley yellow dwarf virus (BYDV) with an increase in their population the number of crops affected by this disease will also increase.
Diseases caused by viruses are quite new problem in Poland. Till now, most observed diseases were caused by pathogenic fungi's. However, during last few years farmers observed more frequently very essential yield losses (even 30-40%) of winter barley and winter wheat caused by BYDV. Farmers are not always well prepared for this new problem and they often are even not able to identify this disease. The second serious problem is related to Colorado Corn Rootworm. The first center of invasion was found in 2005 in south part of Poland, and right now in 2009 this pest can be found in the whole area of Poland.

What is more, extreme weather hazards such as hail, strong winds, strong precipitation or spring frosts will have essential impact onto Polish agriculture. Frequency of extreme weather phenomena occurrence in Poland has increased in last decades due to climate changes. The impact of extreme weather events and their consequences on agriculture is very big, particularly in early spring and summer. For example, in the May 2007, late frosts events occurred in the most part of Poland. During few consecutive days the air temperature decreased at night up to - 6°C, what finally destroyed up to 80% flowers in orchards (mostly in southern part of Poland).The economical losses throughout the country were estimated at approx. 216 million €. Thus, probably the best countermeasure is a development of the systems of crop insurance and persuading farmers to use these insurances. .A considerable weakness of Polish agriculture, not connected directly with climatic factors, results from traditional production methods maintained since the socialist times. Even after the transformation time, apart from the elimination of state ownership, the situation has not changed much. Polish agriculture is still dispersed and traditional to a considerable degree and requires in-depth structural transformations. Under such conditions the implementation of countermeasures for climatic changes may turn out to be problematic. Thus, it is necessary for the agricultural policy of Poland to include the effect of climatic changes on agriculture.

4.9.3 Feasible and recommended adaptation options in Poland

<u>For the detailed regional descriptions see the Table 9.3 in the Appendix.</u>

4.9.3.1. National Overview of the identified most feasible adaptation options of the regions/agroecosystems in Poland

Feasible adaptation options counteracting the impacts of climate change on regional water availability and on agro-ecosystems should include mainly forecasts of extreme weather events and early warnings as well as monitoring of effects of these events on agriculture. Forecasts and early warnings are of great importance in planning and preparation of any actions which will help to avoid or minimize the negative impacts of extreme events on agriculture. For the whole country this task is carried out by the Institute of Meteorology and Water Management and the Institute of Cultivation, Fertilization and Soil Sciences. In the recent years the regional systems of monitoring, forecasting and early warning have been developed and implemented (Western Poland).
In relation to damage caused in agriculture by hurricane-force winds and hail storms common insurance of farm buildings and crop plantations is recommended. In southern Poland damage caused in agriculture by hail is so significant that it would be economically justified to organize hail storm control.
Increased hazard posed by many new diseases and pests may be significantly reduced by adequate modifications of existing plant protection programs, cultivation technologies and methods as well as application of crop protection preparations. However, the first and primary step is to delay the spread of new agrophages in Poland by the enforcement of quarantine.

4.9.3.2 Selected most important and feasible adaptation options at the farm level in Poland (detailed)

4.9.3.2.1 Increase in water resources
Protection of water resources programs has been already implemented; time horizon of implementation depends on available finance sources; carried out at regional and national level.

The most visible adaptation actions are small water retention programs implemented throughout many regions of Poland. These programs are currently executed mostly in the regions with the serious water scarcity (Western, Eastern and Northern Poland). These works are co-financed by the local, regional and national funds of environmental protection and water management programs. The amount of money obtained from the National Fund for Environmental Protection and Water Management depends on the urgency of development of the small retention objects in selected regions of the country.

4.9.3.2.2 Increase in water use efficiency in agriculture
Partially executed; time horizon of implementation depends on available finances; farms and local level.

Another effective measure to mitigate the negative effects of climate change on agriculture is the irrigation of fields and grasslands. Sprinkling and microirrigation is concentrated chiefly in the western and central part of the country, in regions with relatively low precipitation and of fertile soils. This type of irrigation has to supplement a precipitation deficit, and thus maintain crops yields at the planned high level. In the dry years, the sprinkling irrigation is a prerequisite to obtain plant yields at least an average level. The effects of subirrigation of permanent grasslands with the irrigation-drainage systems are associated with the quality of exploitation of these systems. To achieve a high efficiency of these systems during drought and floods, systematic conservation of the network of ditches and all engineering constructions are necessary. Subirrigated systems are now largely degraded in Poland and used only to a small extent, or at all. . In order to be used more effectively, it is necessary to reconstruct and modernize these systems.

4.9.3.2.3 Water control system
Time horizon of implementation depends on available finance; local and regional level.

To mitigate negative effects of extreme events on agriculture, the appropriate adaptation methods and adaptation strategies should be developed and implemented in existing irrigation and agricultural water control systems. There are a lot of technical and organisational actions that have been already undertook and should be undertaken in near future in order to improve management, administration and decision making. They include:

- modernization of irrigation and water distribution systems to increase their effectiveness for supply and out-flow of water,
- improvement of O&M of irrigation and water systems,
- usage of modern energy- and water-saving methods and techniques of irrigation,
- improvement in the efficiency of irrigation,
- improvement of water use efficiency by crops,
- improvement of existing infrastructure for storage and distribution of water,
- increasing available water resources (in soils, streams, reservoirs),
- improvement and implementation of water distribution procedures towards dynamic and flexible water resources management with the use of multi-criteria optimization and modern automatic systems of monitoring of the state of water systems (groundwater table depths, stream water stages and stream flow discharge, monitoring of water structures),
- adjustment of water system control algorithms to changing climate conditions and extreme weather events,
- development of regional (local) systems of monitoring climate for the need of water system management,
- development of telecommunication systems,
- usage of remote-sensing methods and GIS in water system control.

4.9.3.2.4 Decrease in water needs of crops

Time horizon of implementation depends on education; farms and local level.

Actions undertaken in agriculture should lead to a change and optimization of productive space utilization, to modification in crop rotation, to selection of the proper drought resistant plant species and varieties and to changes in agricultural techniques. The preparation of a list of plant varieties commonly cultivated on a given area and resistant to drought is desirable. All complex reclamation measures like afforestation, introduction of grasslands, soil loosening, deep plowing and proper fertilization fall within these types of actions. They all may restrict the negative impacts on a given area to a large degree.

Particular actions, recommended and possible to be implemented are:

- the dissemination of technologies of soil cultivation that increase soil moisture and the degree of water utilization (retention of localized precipitation, increased infiltration, enlarging the active layer of roots water uptake),
- the improvement of the soil structure and of the physical and water properties of the deeper soil layers, which enables deeper rooting of plants and increases the amount of water available for plants (soil loosening, deep plowing),
- the improvement in plant species selection in crop rotation (drought resistance, a shorter vegetative period meaning lower water requirements, a deeper root system),
- an increased proportion of winter plants in the cropping structure at the expense of the area cropped to spring crops, since winter crops - utilizing more effectively winter water reserves in soil - are more tolerant to spring droughts,
- the dissemination of information concerning fertilization and reclamation measures that aid the development of a strong root system,
- the improvement in the social awareness of climate change, their effects and countermeasures.

4.9.3.2.5 Insurances programs

Executed, breadth of implementation depends on farmer’s knowledge; farms and local level.

In relation to damage caused in agriculture by hurricane-force winds, hail storms, torrential rains and floods common insurances of farm buildings and crop plantations are recommended.

4.9.3.2.6 Mitigation of frost damages and hazard of poor winter survival

Executed mostly at intensively managed orchards and vegetable fields, breadth of implementation depends on farmer’s knowledge; farms and local level.

In terms of damage caused by frost it would be necessary to:

- introduce sprinkling (ultra-low volume spraying) protecting plants against sub-zero temperatures to approx. -4°C,
- apply covers made from different materials,
- follow appropriate sowing or planting dates for plants with higher heat requirements,
- apply adequate micronutrient fertilization,
- provide warnings against frost sufficiently early by weather services or organizations providing meteorological support of agriculture,
- breed crop cultivars more tolerant to low temperatures,
- establish crop plantations taking into consideration the layout of land.

Apart from the above mentioned methods that can be implemented in order to prevent negative effects of frost on agriculture, the risk costs incurred due this weather phenomenon may be reduced by effective introduction of insurances.

The hazard of poor winter survival of crops may be prevented or its effects may be reduced by adequate crop allocation, breeding of new, more winter-hardy cultivars and insuring winter crops.

4.9.3.2.7 Cultivation technologies

Implemented, breadth of implementation depends on farmer's knowledge; farms level.

Increased hazard posed by many new diseases and pests may be significantly reduced by adequate modifications of cultivation technologies. Protection against soil overdrying is connected with the application of simplified tillage technologies on large areas of arable land and it leads to an increased occurrence of many weed species. Such a situation requires adaptation of cultivation technologies in terms of minimization of weed infestation by modifying cultivating measures, dates of their application and finally the selection of herbicides and their doses. Simplified technologies lead also to an increased incidence of pests and especially diseases in case of monocultures. Thus, it is necessary to streamline these technologies in the long-term perspective in the crop rotation system.

4.9.3.2.8 Plant protection methods

Increased hazard posed by many new diseases and pests may be significantly reduced by adequate modifications of existing plant protection programs, application of new crop protection substances. However, the first and primary step is to delay the spread of new agrophages in Poland by the enforcement of quarantine.

Many problems resulting from the intensified occurrence and the appearance of new agrophages may be solved thanks to the selection of cultivars with reduced susceptibility or exhibiting considerable resistance in relation to certain pathogens, or even pests; a specific example in this respect may be the application of a genetically modified maize cultivar with a gene of insecticidal bacterium *Bacillus thuringiensis*.

An extended vegetation season requires the application of plant protection measures also over extended periods of time, especially in terms of herbicide application.

Periods of topsoil overdrying, occurring more frequently and over longer periods, are connected with reduced efficiency of soil-applied herbicides. It seems necessary to improve existing programs of crop protection against weeds in terms of the application of foliar applied herbicides, supplemented with adjuvants when necessary. Technologies of multiple applications of herbicides at lower doses or the so-called micro-doses need to be further developed for numerous crops.

The expected climate warming is also connected with a reduced importance of certain groups of herbicides, primarily from the group of pyrethroids, which efficiency decreases with an increase in temperature. On the other hand, temperature conditions will be conducive of a more effective action of numerous groups of crop protection preparations. In contrast, drought conditions occurring more frequently will not promote the penetration of herbicide active substances with systemic action. It is going to be necessary to gradually modify both the selection of herbicides in terms of coming climate changes and crop protection technologies.

4.9.4 Scientific basis of ADAGIO results

4.9.4.1 List of all literature used for national ADAGIO purposes, analysis etc. (national and international)

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4.9.5 Dissemination activities during ADAGIO (during all project lifetime)

4.9.5.1 List of scientific ADAGIO publications (which include ADAGIO results). It means: ADAGIO related results which were published during the AGAIO project.

Juszczak R., Leśny J., Olejnik J. 2008. Cumulative degree-days values as an element of the agrometeorological forecast of the Wielkopolska Internet Based Agrometeorological information service (WISIA) (in Polish). Acta Agrophisica, 12(2): 409-426.

Serba T., Leśny J., Juszczak R., Olejnik J. 2009. Impact of climate changes on European agriculture, ADAGIO project (a review) (in Polish). Acta Agrophysica 13(2): 487-496

Łabędzki L., Leśny J. Consequences of drought in agriculture - present and forecasted effects in relation with forecasted climate change (in Polish).. Wiadomości Melioracyjne i Łąkarskie. Warszawa, nr 1/2008, str 7-9.

Leśny J. Juszczak R., Serba T., Olejnik J. 2008: Adaptation of agriculture in European regions at environmental risk under climate change (in Polish). In: Climate Changes, agriculture and rural areas. FDPA, Wrszawa: 41-50

Eitzinger J., Leśny J., Serba T., Juszczak R., Olejnik J., 2009: ADAPTATION OF AGRICULTURE IN EUROPEAN REGIONS AT ENVIRONMENTAL RISK UNDER CLIMATE CHANGE – PROJECT IMPLEMENTATION. Climate chnage and agriculture in Poland - impacts, mitigation and adaptation measures, ed. Leśny J., Acta Agrophysica, Rozprawy i Monografie, 2009, 1, 7-18.

Mager P., Kasprowicz T., Farat R., 2009: CHANGE OF AIR TEMPERATURE AND PRECIPITATION IN POLAND IN 1966-2006. Climate chnage and agriculture in Poland - impacts, mitigation and adaptation measures, ed. Leśny J., Acta Agrophysica, Rozprawy i Monografie, 2009, 1, 19-38.

Szwejkowski Z., Dragańska E., Panfil M., 2009: IMPACT OF WEATHER CONDITIONS ON CROP PRODUCTION IN POLAND. Climate chnage and agriculture in Poland - impacts, mitigation and adaptation measures, ed. Leśny J., Acta Agrophysica, Rozprawy i Monografie, 2009, 1, 39-51.

Kuchar L., 2009: APPLICATION OF MATHEMATICAL METHODS FOR CROP YIELD ESTIMATION UNDER CHANGING CLIMATIC CONDITIONS. Climate chnage and agriculture in Poland - impacts, mitigation and adaptation measures, ed. Leśny J., Acta Agrophysica, Rozprawy i Monografie, 2009, 1, 52-62.

Szwejkowski Z., Dragańska E., Suchecki S., 2009: SCENARIOS FOR DEVELOPMENT OF AGROCLIMATIC CONDITIONS AND ESTIMATION OF THE INFLUENCE OF EXPECTED GLOBAL WARMING IN 2050 ON THE YIELDS OF MAJOR CROPS IN POLAND. Climate chnage and agriculture in Poland - impacts, mitigation and adaptation measures, ed. Leśny J., Acta Agrophysica, Rozprawy i Monografie, 2009, 1, 63-77.

Czarnecka M., Koźmiński Cz., Michalska B., 2009: CLIMATIC RISKS FOR PLANT CULTIVATION IN POLAND. Climate chnage and agriculture in Poland - impacts, mitigation and adaptation measures, ed. Leśny J., Acta Agrophysica, Rozprawy i Monografie, 2009, 1, 78-96.

Łabędzki L., 2009: DROUGHTS IN POLAND – THEIR IMPACTS ON AGRICULTURE AND MITIGATION MEASURES. Climate chnage and agriculture in Poland - impacts, mitigation and adaptation measures, ed. Leśny J., Acta Agrophysica, Rozprawy i Monografie, 2009, 1, 97-107.

Walczak F., Tratwal A., 2009: IMPORTANCE OF PESTS AND DISEASES OBSERVED IN AGRICULTURAL PLANTS IN POLAND IN THE YEARS 1991-2008 IN THE CONTEXT OF CLIMATE CHANGES. Climate chnage and agriculture in Poland - impacts, mitigation and adaptation measures, ed. Leśny J., Acta Agrophysica, Rozprawy i Monografie, 2009, 1, 108-121.

Juszczak R., Leśny J., Serba T., Olejnik J., 2009: CUMULATIVE DEGREE-DAYS AS AN INDICATOR OF AGROCLIMATIC CONDITION CHANGES IN THE WIELKOPOLSKA REGION. IMPLICATIONS FOR CODLING MOTH DEVELOPMENT. Climate change and agriculture in Poland - impacts, mitigation and adaptation measures, ed. Leśny J., Acta Agrophysica, Rozprawy i Monografie, 2009, 1, 122-136.

Ratajkiewicz H., 2009: ADAPTATION STRATEGIES OF AGRICULTURE TO CLIMATE CHANGE IN TERMS OF PLANT PROTECTION. Climate chnage and agriculture in Poland - impacts, mitigation and adaptation measures, ed. Leśny J., Acta Agrophysica, Rozprawy i Monografie, 2009, 1, 137–150.

4.9.5.2 List of not yet published (manuscript status) scientific ADAGIO related publications (national or international).

In preparation: : Climatic vulnerabilities of agriculture and climate changes. Ed. Czesław Koźmiński, Bożena Michalska, Jacek Leśny.

J. Lesny, R. Juszczak, T. Serba, J. Olejnik, H. Ratajkiewicz 2009: Climate change and agriculture - impacts, mitigation and adaptation measures in Poland. Viena - in press

4.9.5.3 List of published or not yet published (manuscript status) ADAGIO results specific designed for national farmers or stakeholders, which are more than common articles in newspapers (e.g. books, brochures, reports which can serve as a permanent source of information).

Leśny J., 2008. Climate of Europe (in Polish). Farmer 10: 32-33.

Czarnecka M., Koźmiński Cz., Michalska B., Ratajkiewicz H., Leśny J., Mager P., Kasprowicz T., Farat R., Kuchar L., Łabędzki L. 2009: Climate changes and agriculture in Poland – impacts, vulnerabilities, mitigation measures (in Polish). Poznań, pp 18. – Brochure for farmers.

Climate change, vulnerability, and adaptation in agriculture –the situation and state of art in Poland (in Polish).. Ed. Leśny J., First Polish ADAGIO Conference – abstract of presentations, Poznań 2007 pp. 15

Climate change, vulnerability, and adaptation in agriculture –the situation and state of art in Poland (in Polish).. Ed. Leśny J., Second Polish ADAGIO Conference – abstract of presentations, Poznań 2007 pp. 11

4.9.5.4 Other national public relation activities (e.g. lectures, farmer meetings, articles in newspapers), use the updated table below, for ALL ADAGIO period

Listed in the Thematic Group 4 report

4.10 Russia

4.10.1 Abstracts of national case studies carried out during the ADAGIO project

<u>Case study 1 :</u>

Assessment of spatial and temporal trends in climate parameters and main limitations for agricultural productivity on the background of modern climate change in Russia

Lemeshko N., Nikolaev M., Uskov I.

Abstract
The components of the agroecological system: climate – hydrological regime – weather extrems –agroecosystems are studied for the last decades (the period of the highest antropogenic pressing). The combined study assessment of tendencies in temperature and precipitation regimes, soil moisture content, air humidity, evaporation was implemented on the background of modern climate change. Statistical analyses of the long-term time series made it possible to evaluate mean and extreme values of air temperature, precipitation, evaporation rate and evaluate common tendencies and trends for study area. Since the late 19th century the mean annual air temperature has increased by about 1.29ºC for the Russian territory, which is above the global annual air temperature increase. On average, the warming of 1.33ºC in Russia for 1976-2006 was more pronounced in the winter-spring period. In the autumn period, on contrary, some cooling has taken place in western European Russia up to 2000. Changes in precipitation totals have not any clear tendency over the area under study for last decades. The decade 1981-1990 appears to be the most humid for the European part of Russia (ETR), which corresponds to the 1920s conditions (Lemeshko & Speranskaya, 2006). Decrease of annual precipitation by 5-10% is characteristic for the 1975-2006 in the central area of European Russia; upward tendencies in precipitation prevail for spring and autumn periods.

The number of days with heavy precipitation of more than 10mm/day has decreased for the larger part of ETR. At the same time, it has significantly increased in North Caucasus, Krasnodar and Rostov Region. For the last three decades trend in the duration of dry period have extended up to 4 days/10years. Heavy rainfalls and droughts affect crop production sporadically in many semi-arid regions of European part of Russia, but upward trends in drought events during last 50 years were not discovered, while the drought periods were concentrated through in the 1990s. Minimal winter temperature increased by 3-4^{o}C in last two decades and coldest month moves from January to February, December and even to November (Fig. 1.1.1.) (Lemeshko et. al., 2009). The frequency of winters with minimum soil temperatures hazardous to winter crops decreased, especially in Chernozem zone (from 22% to 8%) and in the Northern Caucasus - from 10% to 4%. The largest increase in minimum and maximum daily temperature occurred in the cold season. The number of frosty days decreased on 4-5 days per 10 years for 1976-2006.

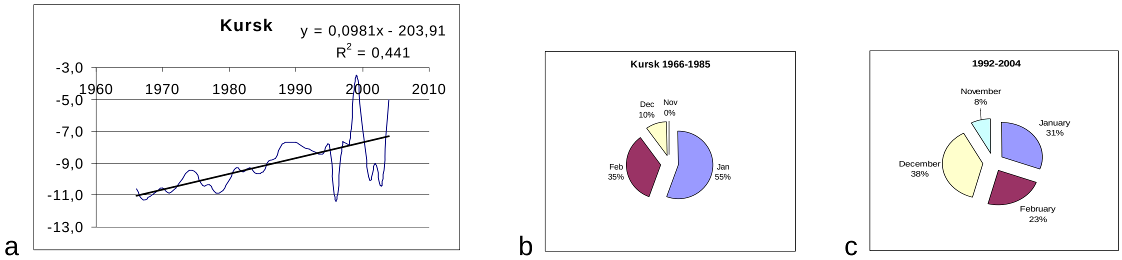

Fig.1.1.1. Minimal winter temperature for the meteorological station Kursk (Central Chernozem Region): a) 1960-2005; b) frequency of coldest months for the 1966-1985 (%); c) frequency of coldest months for the 1992-2000 (%).

The process of warming is evaluated in the growth of the vegetation period duration at high latitudes more than 7 days, mean over Russia 5 days from the 60-s. The sum of daily temperature higher than 10°C increased on 40-120°C/10years for 1980-2004 except eastern areas.

Lemeshko N.A., Speranskaya N.A. 2006. The peculiarities of moisture regime of European territory of Russia with climate change. Present situation in hydrometeorology. "Asterion", 38-54, (in Russian).

Lemeshko N. A., Nikolaev M. V., Uskov I. B. 2009. Adaptation of agriculture to climate change. "Lema", 34 (in Russian).

<u>Case study 2 :</u>

Climate change forcing and main limitations for agricultural productivity in Russia

Lemeshko N., Nikolaev M,, Uskov I.

Abstract

The peculiarities of Russia location as a northern area result in high vulnerability of it agricultural environment in north and not less vulnerability of agricultural production in the south caused mainly by high demand and low supply of water resources. About 70% of arable lands do not have sufficient heat and water resources. Climate change will have significant effects on agricultural production, which has been considered as the most weather-dependent among all the human activities. In spite of the fact that there is an evident relationship between climate and agricultural production, climate change is not still taken into account in agricultural practice in Russia, but it is especially actually for Russia with its vast territory and diversity of climate and natural conditions.

Impacts of rapid climate change are manifested in the increase of extreme weather event frequency which cause huge socio-economic losses and have a direct impact on critically vital economy sectors such as water resources and agriculture (Nikolaev, Semenov, 2007; Uskov, 2007; Nikolaev, 2008).

Natural and anthropogenic climate and environment changes can have both positive and negative consequences for crop yield. Negative effects are exhibited by higher probabilities of the extreme hydrometeorological events that can prove to be harmful to farming from which the water-related hazards make up 70% of all ecological disasters. Among these disasters, the main part is connected with droughts (52%) and 11% with floods. The analysis of information on extreme events over ER from official publications makes it possible to conclude that the number of those, influencing agriculture, has increased almost twice from 1999 to 2005. The largest economic losses are from droughts and floods (about 41,6 bln rubls). About 7 mln sq. km agricultural lands are flooded in spring. Processes of soil degradation, aridization and

flooding became real in the wide regions: 35 mln ha of agricultural lands are overmoisturning or waterlogged, 6 mln ha- saline soils, more than 45% - are suffering from the effects of water&wind erosion.

Nowadays one of the most important effects of climate warming is a significant decrease in frequency of winters with minimum soil temperatures hazardous to winter crops. The annual maxima and minima of daily surface air temperature increased, and the difference between them decreased (minima grew faster than maxima). The largest increase in minimum and maximum daily temperature occurred in the cold season. The number of frosty days decreased on 4-5 days per 10 years. Decreased frost killing risk in the two last decades moderated the danger of winter crops perish in the Lower Volga, Southern Pre-Ural Region and in some areas of Northern Caucasus Region. The example of such positive influence of warming for crop production in the cultivation zone of southern part of European Russia was 2008. Optimal moisture and temperature conditions in 2008 had ensured the increase in productivity of cereal and leguminous crops on 30-40% compare with 2007.

Further warming may create favorable conditions for expansion of heat-loving agricultural plants to the north and winter crop acres to the Northern Caucasus, steppe regions of the Volga area, the Southern Urals, and Western Siberia.

However, increase in vegetation period duration forcing by air temperature raise in spring and autumn can be not only a positive factor. The main limitation is total water requirement of plants increases with vegetation period prolongation. For example, buckwheat during its vegetation period of 93 days consumes 12 cm of water, while corn over 131 days of its vegetation period consumes 32 cm of water. Thus, in spite of longer vegetation period growing of more heat-loving crops would be difficult because of insufficient moisture in some region. The water supply is one of the most significant resources for agriculture in the arid and semi-arid zones (Middle and Low Volga, Northern Caucasus), where there are different tendencies in water resourses: increase of water resources of Volga and Kuban River basins and decrease of River Don runoff for last decades (Lemeshko, Gronskaya, 2006, Lemeshko, 2008).

Lemeshko N.A. 2008. Lakes level changes. /in Book Water resources of Russia and their use. Edited by I.A.Shiklomanov. St.Petersburg: State Hydrological Institute. 600 p.

Lemeshko N.A., Gronskaya T. P. 2005. Changes in hydrological regime of reservoirs and largest lakes of Russia: consequences for humans. Human dimension and global environmental changes. IHDP Proceedings.“ Zvenigorod“, pp. 203-209.

Nikolaev M.V. 2009. Adaptation of crop management practice to climate change in Russia. Extended Abstracts - International Symposium – “Climate Change and Adaptation Options in Agriculture”, Vienna, 22-23 June 2009.

Nikolaev M.V.and V.A.Semyonov, 2007. Agroclimatological background of the North-Western territory of Russia for landscape adapted agricultural systems planning. In book "Research and investigations for empirical basis of landscape adapted agricultural systems planning". St.Petersburg State Technical University issue, 2007, p.14-23 (in Russian)

Uskov I. B, Agrometeorological factors of productivity. Book of Lectures on “National School for Young Researchers/Practical Experts on Precession Agriculture”. St.-Petersburg. P.25-49.

Case study 3 :

Actual trends in soil moisture in Russia

N. Lemeshko

Abstract

Moisture in active soil layer is practically the only source for plants mass increase in some regions and one of the major factors, determining the conditions of agricultural crops growth

and land cultivation. For most of agricultural regions instability of crop yields from year to year is caused by the fact that soil moisture content is not sufficient for plants to grow. The dependence of crop yield on soil moisture is detected for all regions. It can be supposed that any changes in modern zonal soil moisture regime can induce negative consequences which need additional adaptation options for apply.

Precipitation increasing and air temperature decrease in the summer-autumn period observed for last 40 years force changes in soil moisture regime over the central regions of European Russia and, in particular, its increase during this season. Increase of soil moisture content in the forest and steppe zones exceed field capacity. Changes in main force factors of the land moistening regime lead to decrease of evaporation from the water surface and to increase of evaporation from the soil over the most part of the European territory of Russia. Tendencies in precipitation changes over European Russia are caused by intra-century changes in Circulation Epochs and increasing intensity of the Centres of Atmospheric Action and NAO (Lemeshko, Speranskaya, 2006).

Soil moisture increase, being a favourable factor for vegetation in the regions with insufficient moisture, become a factor intensifying negative processes in the soils of these and other regions: waterlogging and secondary salinization in depression and shallow water table, erosion, scour of the top fertile soil, gully formation, gley formation in the humid zone, soil podzolization (degradation) in the forest zone, etc.(Recommendations, 2009). These processes occur in soils all the time, but with changes in moisture conditions they can be more intensive. These processes are rather dangerous as they are developed rapidly (gley formation takes 2 years to develop, while reclamation of soils takes dozens of years. It takes 20 years to reclaim soil after its secondary salinization, if changes do not became irreversible.

Lemeshko N.A., Speranskaya N.A. 2006. The peculiarities of moisture regime of European territory of Russia with climate change. Present situation in hydrometeorology. “Asterion”, 38-54, (in Russian).

Recommendations for decision making in erosion-preventive practice. 2009. Ed.: I.Uskov RAAS issue.

<u>Case study 4 :</u>

Water use in agriculture

N. Lemeshko

Abstract

Water use in agriculture have been studied for southern regions of European Russia as a significant vulnerability of agricultural production in these areas caused by high demand and low supply of water resources.

The water supply is one of the most significant resources for agriculture in the arid and semi-arid zones (Middle and Low Volga, Northern Caucasus), where there is a tendency to decrease in water use for irrigation from 1990 (Fig, 1,1,4,1.) because of destroyed irrigation systems (canals, ponds and small reservoirs). These processes come on the back ground of increasing water resources of Volga and Kuban River basins and decreasing runoff of River Don (Lemeshko, 2008). The water withdrawal for irrigation purposes should be granted for use and tax depend on the river basin (according to the Water code of the Russian Federation). The costs for water used increased in 3-5 times over last decade. The water use for private farms is free. The large economic losses in agriculture are from floods (about 41,6 bln rubls) especially in the south ETR. About 7 mln sq. km agricultural lands are subjected to floods (Lemeshko, Gronskaya, 2005; Taratunin, 2000).

At National meeting and Workshop “Actual trends in water use in the southern Russia”, held in Saint-Petersburg, Russian group leaders and invited experts presented the situation in different regions according to climate change, vulnerability, and adaptation in agriculture.

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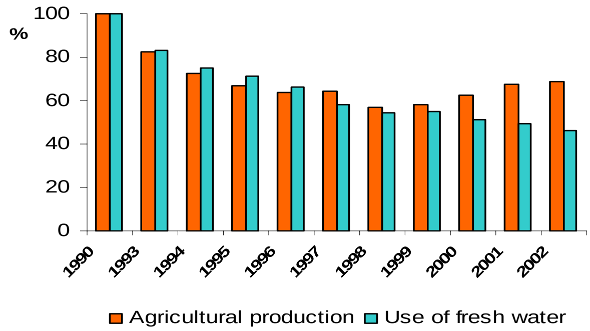
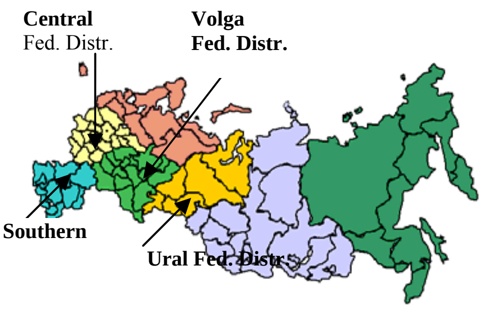


Fig. 1.1.4.1.Water-used for irrigation and other demands in agriculture and agricultural productivity. Russia, % from mean for 1990.

In the southern areas of Russia there is a growing gap between decreasing water resources and increasing demands for water supply. Dynamics of irrigation lands in Federal Districts of Central and southern territories of Russia show (Fig. 1.1.4.2) that period of sharp increase in construction of irrigation systems began in the middle of last century and continued up to 1985-1990 than areas of irrigated lands decreased slowly till now, especially in Volga Federal District. The main problem of the Russian water resources is its uneven distribution over the country’s area not meeting with water demand According to experts estimates these problem will increase in the nearest future

a)



b)

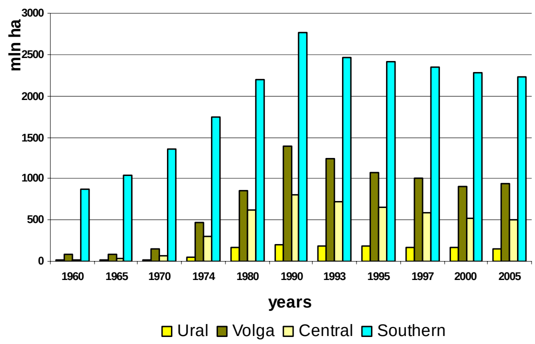


Fig. 1.1.4.2 Dynamics of irrigation lands (b) in Federal Districts of Russia (a).

Lemeshko N.A., Gronskaya T. P. 2005. Changes in hydrological regime of reservoirs and largest lakes of Russia: consequences for humans. Human dimension and global environmental changes. IHDP Proceedings. “Zvenigorod“, pp. 203-209.

Lemeshko N. 2008.The largest lakes and reservoirs of Russia as a priority water resource for society, Global change research. Abstracts. New Methodologies and Interdisciplinary Approaches in Global Change Research. pp.70-71.

Case study 5 :

Modelling of global warming influence on climatic and hydrological regimes using empirical scenarios.

N. Lemeshko

Abstract

A conceptual hydrological model has been developed to estimate the changes in the heat-water balance of Russia (Lemeshko, 2002). The model is based on the semi-empirical calculation method (Budyko, 1974) and on paleoclimatic scenarios for the three warm epochs of the past, considered as analogs of future climate: Holocene optimum (6.2-5.3 KA B.P.), when global temperature was 1ºC higher than modern one, Last Interglacial-Eem (125 KA B.P.) corresponds to global warming by 2ºC, Pliocene optimum (4-3 ma B.P.) with global temperature by 3-4ºC higher than modern global temperature.

The scenarios consist of the regional data on deviation of annual precipitation, winter and summer air temperature from mean for 1881-1965. This method allows to calculate the mean monthly values of evaporation, runoff and moisture content of active soil layer (1 m) using data on mean monthly values of surface air temperature, air humidity, precipitation, cloudiness, surface albedo and solar radiation, both for the modern climatic conditions, and for climatic conditions different from the present ones (Borzenkova, Lemeshko, 2005). For this task this method was adopted and some additional assumptions have been made to realise transition from annual and seasonal deviation in air temperature and precipitation for the past to their monthly changes in the future. The current climatic data was averaged for 1881-1965 - air temperature and precipitation, 1940-1965 - cloudiness, 1900-1960 - air humidity. The calculated mean values of potential evaporation and evaporation (monthly, seasonal, annual), runoff (annual) have been compared with observed data. The comparison shows their good agreement.

Changes in soil moisture, evaporation, river runoff, snow cover duration, warm period duration were estimated for global warming by 1º, 2º and 3-4ºC. The obtained estimates show that the duration of the warm period of a year is likely to increase in Eurasia (Russia and neighboring countries) by 20-60 days in the high and middle latitudes and by 5-20 days in the southern part of this territory. Increasing potential evaporation due to growing air temperature and duration of the warm period is an important factor responsible for decreasing soil moisture content in summer and autumn. The total annual potential evaporation increases by 3-7 cm with global warming by 1 C and by 10-15 cm with higher level of the warming. The important parameter is the duration of snow cover period for Russia and Byelorussia territories and for Baltic countries. Special attention should be paid to one of its characteristics - the date of stable snow cover melting for it major determines stored soil moisture in spring and the terms of sowing, which is especially important for northern agricultural regions. According to the calculations, snow cover is expected to melt 10-25 days earlier, while the period with stable snow cover would decrease by 20-60 days with global warming by 1-2 C. In this case, snow cover would not form on large areas, in particular, in some regions of Baltic States, Byelorussia and Ukraine. Changes in soil moisture, duration warm season and dates of snow cover melting would primarily effect the terms of agricultural works. For example, it would be possible to start sowing of agricultural crops earlier than usual. Due to longer warm season and vegetation period agricultural zone could extended farther northward from its modern boundary.

Lemeshko N. A. 2002. Hydrological regime of land with doubling of CO_2 concentration in the atmosphere. In Book: Current climate changes and their consequences. “ Nauka”, pp. 251-259.
Borzenkova I.I., Lemeshko N.A. 2005. Water balance of the River Volga basine in the beginning of XXI (based on paleoclimatic scenarios). Meteorology and hydrology, №7, pp.52-60.

Case study 6 :

Modelling the soil moisture change for global warming on 1, 2°C and 3°C.

N. Lemeshko

Abstract
To asses the impact of forthcoming climate change on soil moisture and water balance the heat-water balance model have been used (Lemeshko, 2007). Changes in soil moisture were estimated for global warming by 1, 2 and 3°C for all seasons for the Russia using the empirical scenarios. Special attention is paid to soil moisture changes in summer as the conclusion about summer dessication was drawn using calculations by GCMs.
The response of soil moisture content to global warming varies. The area north of 55°N and between 30°N and 100°E, shows consistent soil moisture decreases with all considered levels of global warming. The values of moisture content decreasing range from 1 to 2 cm of available moisture in 1 m layer. With the global warming by 1°C the area where soil moisture is expected to decrease is the largest. It covers almost all major regions of agricultural production in Russia, Ukraine and Northern Kazakhstan. However, on large areas soil moisture is likely to increase compared with its modern value. Soil moisture increases by 2-2.5 cm in the forest, forest-steppe and steppe zones with 2°C global warming. With global warming by 1°C and 3°C in these zones soil moisture also exceed the modern ones, but not more than by 1.0 cm. Soil moisture content is projected to decrease in the high latitudes which are characterized by excessive and sufficient moistening, while in the southern regions with insufficient moistening soil moisture would increase. These changes would be similar to the results of drainage measures in these zones taken to balance soil moisture in the arid zones and regions with excessive moistening. Thus, it can be supposed that changes in soil moisture can be favorable for agriculture.
Calculations for spring season show that soil moisture would increase by about 1 cm, compared with current value, with the considered levels of warming. It means that increase in soil moisture is likely to partially compensate for moisture deficit and spring soil drought is likely to become more rare due to soil moisture increase. Also, it would make for better germinating capacity of the crops even in the years with insufficient precipitation. In summer in the middle latitudes stored soil moisture is expected to be lower than its multi-year mean values due to potential evaporation increase.
Even in the regions with sufficient and excessive moisture special measure will be needed to control soil moisture: in spring excessive moisture should be removed and in summer agricultural fields will need additional irrigation This supposition is confirmed by the fact that as a result of drainage measures, complex drainage-irrigation systems were developed on the areas occupied with wetlands (Uskov, 2008).
Soil moisture decrease in summer, which is expected to occur, according to the estimates, obtained by the GCMs for large areas and by empirical paleoanalogue method for the zone northward of 55°N, is a factor, intensifying desertification, wind erosion and other negative processes. The estimates by GCM s, predicting aridization on the continents,

are indicative of a higher scale of negative changes than that predicted by empirical paleoclimatic scenarios.

Lemeshko N.A. 2007. Climate change. Scenarios of Global Warming. Regional changes in temperature, precipitation and soil moisture content. Book of Lectures on "National School for Young Researchers/Practical Experts on Precession Agriculture". St.-Petersburg. P.144-171.
Uskov I.B. 2008. Global warming comes… What should farmer doing? "Agrarian expert", № 2, p.6-9. (in Russian).

Case study 7 :

Global warming impact assessment on the cropping system using different scenarios.

M. Nikolaev

Abstract

To asses the impact of forthcoming climate change on crop production and crop management practice, the conceptual model have been used. This model is based on the statistical methods and on the modified paleoanalogue model for the Last Interglacial- Eem(125 KA B.P.) climatic optimum conditions, when the global mean temperature was 2°C higher than at present.. This scenario is considered as a paleoanalog of global warming by 2020-2030. The results obtained from this modified paleoanalogue model considered as scenario estimates been compare with simulation results from transient GCMs (ECHAM4A, ECHAM5, HadCM3 and GFDL) for time slice 2020-2030.

Thus, the scenario estimates indicate an increment of ∑ T> 10°C up to 300-400 °C in the northern parts of ET Russia, and up to 100-200 °C in the central and southern parts. Such changes result in the opportunities to switch to more later season cultivars and also to grow new crops (e.g., buckwheat, sugar beet and maize hybrids) in Humid zone, including Boreal and Subboreal belts. In fact, we observe a potential shift in distribution of crops and cultivars northward , under reducing the area where heat shortage limit cropping systems diversity at present .

In semiarid regions of ET Russia (Dry Agriculture zone and surrounding territories), the conditions are predicted also favorable to enlarging the areas under several crops. So, there is an opportunity to enlarging areas under winter wheat and winter barley due to decreasing frost killing risk (as an indicator of winter severity the value of mean monthly temperature in coldest month is used). Moreover, an increase in temperature sums may has resulted positively for maize and wheat durum cultivation (Nikolaev, 2008).

The simulation results from GCMs such as ECHAM4A, ECHAM5, HadCM3 and GFDL give close estimates of potential changes in thermal conditions, while the HadCM3 scenario simulates temperature increases under more arid climate.

In conditions of earlier dates of sowing, cultivation of new crops is expected against changing background of mineral nutrient consumption by plants. According to paleoanalog scenario, the largest yield growth is to be expected in the Lower Volga sub-region on chestnut soils as on these the efficiency of fertilizers sharply increase with additional natural soil wetting. Spatial analysis of changes in irrigation rates indicates that they should be increased in the semiarid regions north of 52°N, and they also should be decreased in more southern regions, excluding North Caucasus (Nikolaev, 2007).

Forthcoming climate change may results a number of adverse effects on crop production. It is expected that will be a significant increase in rotting- and wetting out risks for winter rye and winter wheat due to predicted more mild and damp winters. On average, the losses of winter

cereals may increase by 13-15 % by 2020-2030. At the same time, such climatic extremes as droughts may occur sporadically over the ET Russia’s territory.

To assess the drought recurrence, the G.T.Selianinov’s Hydro-Thermal Coefficient for May-July (HTC_{V-VII}) and time interval between subsequent droughts τ (in years) statistically determined by Yu.L. Rauner were compared (Rauner, 1981). There is a strong correlation (r = 0,953±0,045) between spatial distribution of HTC_{V-VII} values and spatial distribution of τ values. Based on this relationship, the maps are composed, which reflect geographic distributions of τ at current and future climatic conditions (Fig.1.1.1).

As seen, over the ET Russia’s territory drought recurrence is expected to increase by 1,5 times in case of implementing the scenario of more arid climatic conditions by 2020-2030. In case of implementing the scenario of more humid climatic conditions by 2020-2030, drought recurrence is expected to decrease, also by 1,5 times. Of course, under change in drought climatology also climatology of drought accompanying phenomena such as dry winds and dust storms and producing water- and wind erosions will be changed (Nikolaev, 2009).

present-day conditions | by 2020-2030 (HadCM3 scenario) | by 2020-2030 (Paleoanalog scenario)

Fig. 1.1.7. Distribution of time intervals between subsequent droughts τ (years).

Literature:

Nikolaev, M.V., Yakushev, V.P.(2004): Adaptation of the agro-technologies and potential distribution of field crops in a changing climate. In: A.Ivanov (Ed.) Consequences of Global Climate Change for Agricultural Sector of Economy. RAAS issue, Moscow, 274-299.

Nikolaev,M.V.(2007a): Cereal crop zonation in a changing climate. In: Physical, Chemical and Climatic Factors of Land Productivity. Institute of Nuclear Physics issue, St.-Petersburg, 307-319.

Nikolaev, M.V. (2007c): Climate change effects on cereal cropping in Russia and options for adaptation. Meteorologicky Casopis (Meteorological Journal),10/2, 75-80, Slovak Hydrometeorological Institute issue, Bratislava

Nikolaev, M.V. (2008): General tasks of field research and national experience in adaptation of cereal cropping to climate change in Russia. In: Almanac Field Investigator (Field Research for Sustainable Development of Agriculture and Countryside). NW Russia’s Institute of Agricultural Engineering and Electrification issue, St.-Petersburg, 7-9

Nikolaev, M.V. (2009): Adaptation of crop management practice to climate change in Russia. Extended Abstract. - ADAGIO Symposium - “ Climate Change and Adaptation Options in Agriculture”, Vienna, 22-23 June 2009

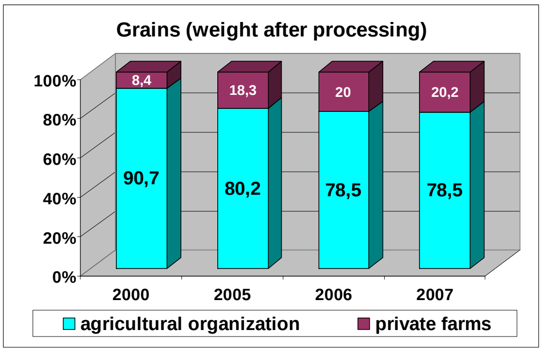
Case study 8 :

The socioeconomic peculiarities of Russian agriculture.

N. Lemeshko

Abstract
Climate change coincides with changes in political and economic changes in Russia for last two decades. These economic changes affected agriculture as well. During last 15 years large state collective farms transfer to smaller private farms with mean size from 50-120 ha in the North-West ETR, 70-150 ha in the central ETR to 150-300 ha in the southern regions. Prevailing size is still lower in 3-5 times than mean ones. It leads to changes in structure of agricultural output. Main producers of grains are as before large agricultural organizations but main output of potatoes and vegetables gives by household farms (Fig.1.1.8.). In addition poverty dimensions of rural people are much larger than that of urban dwellers. ¾ of rural people have average income below minimal living wage and 61% rural families have all resources at their disposal (including all kinds of income) below poverty line. Large poverty in Russia rural areas and rational natural resources management are incompatible (Sdasyuk, 2005). Rural people, especially young people prefer emigrate abroad from the western regions (Kaliningrad) and to the cities from Pskov, Vologda regions. Common problem for rural people – their mean age are more than 55 years old, as this work is not attractive for young people.

a)



b)

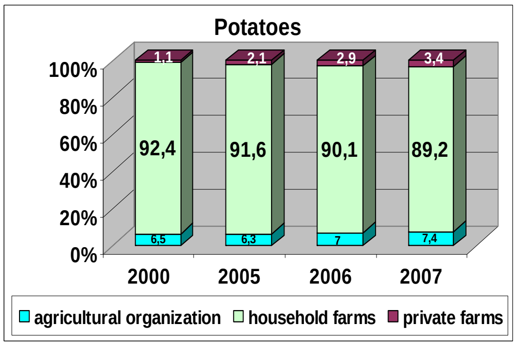


Fig.1.1.8.Output of main agricultural products by types of farms: (a) grain, (b) potato (percent of total volume of production of all farms).

Lemeshko N. 2009. Agriculture in Russia and Climate change. Extended Abstracts - International Symposium – "Climate Change and Adaptation Options in Agriculture", Vienna, 22-23 June 2009.

Sdasyuk G.V. 2005. Globalization and Global Change: A case of Russia. Human dimension and global environmental changes, 213-218.

Case study 9 :

Most significant identified vulnerabilities of agriculture

Nikolaev M., Uskov I.

Abstract
Based on assessment of spatial and temporal trends in air temperature, precipitation, groundwater table, soil moisture evaporation, duration of warm season, dates of snow cover melting, weather extremes and agricultural production in last 25 years over European Russiahave been described most vulnerable areas. Common tendencies in yield and climate parameters were calculated used hydrothermal indexes (Coefficient by Selyaninov (1967) as an indicator of dry conditions.
The four most vulnerable areas under climate change in Russia have been selected: North-Western ETR (European Territory of Russia), Central ETR, Chernozem region and South ETR. (Nikolaev, 2007(b,c); Nikolaev 2009).
For these vulnerable areas, each larger than 135000 sq. km, have been selected specific regions:
North-Western ETR – Leningrad region, Kaliningrad region and Pskov region, which differ one from other by domination agroecosistems.
Central ETR – Kostroma, Smolensk and Orel regions, where crop farming prevails.
Chernozem (Black-Earth soil) area – Kursk, Boronez, Belgorod regions with domination crop farming like in Central ETR, but have unique soils.
Southern ETR- Saratov region, Tatarstan and Bashkortostan with dry climate.
Among these regions most affected areas are South and North-West Russia.
The main vulnerabilities for North-Western Russia's agriculture under climate change are as follows: increase of water logging; increase of rotting out; increasing vulnerability of crops to insect pests and diseases including not specific for the NW Russia; introducing new weeds in crops (moving from the southern regions); increasing risk of snow mold on winter crops; dry spell hazards in early summer leading to reducing fertilizer efficiently and need for additional irrigation.
The main vulnerabilities for Central Russia's agriculture (and the same for Middle Volga area) are as follows: increase ice crust and frost killing; dry winds; spring and summer droughts; heat waves; water and wind erosion; floods.
The main vulnerabilities for Lower Volga agriculture as follows: increase of frequency and duration of droughts; dry winds; heat waves; water and wind erosion.
The main vulnerabilities for Northern Caucasus's agriculture under climate change are as follows: increase ice crust and frost killing; floods; mudflows; water and wind erosion; hail.
Among these vulnerabilities the next in importance should be highlighted:

1. Increase of heat waves, droughts and dry spell frequency.
2. Increasing of water and wind erosion.
3. Intensifying soil degradation, gully formation, ravines.
4. Ruined drainage-irrigation system.
5. Intensifying the process of bogginess.
6. Increase of heavy rains and floods frequency.
7. Increase of number of returning frosts on soil.
8. Increase of wetting and rotting out of winter crops frequency.
9. More weeds in crops.
10. Increasing risk of crop damage be pests and diseases.
11. Northward shift of insect pests and pathogens

Nikolaev M.V. 2007(b).Application of spatial analogs method to evaluation of climate change impacts on agroecological conditions in the North-Western territory of Russia. In book:" Research and investigations for empirical basis of landscape adapted agricultural systems planning". St.Petersburg State Technical University issue, p.147-153 (in Russian).
Nikolaev M.V. 2007 (c).Application of spatial analogs method to evaluation of climate change impacts on agroecological conditions in the North-Western territory of Russia. In book:" Research and investigations for empirical basis of landscape adapted agricultural systems planning". St.Petersburg State Technical University issue, p.147-153 (in Russian).
Nikolaev M.V. 2009. Vulnerability and adaptation of agriculture to climate change. In book: Global climate change: consequences for agriculture." Russian Academy of Agricultural Sciences, Moscow. (in Russian) (in press).
Uskov I. B, 2007. Agrometeorological factors of productivity. Book of Lectures on "National School for Young Researchers/Practical Experts on Precession Agriculture". St.-Petersburg. P.25-49.

4.10.2 Regional vulnerabilities and reasons in Russia

For the detailed regional descriptions see the Tables 10.1 and 10.2 in the Appendix.

4.10.2.1 Summary description of the most significant identified vulnerabilities of the regions/agroecosystems in Russia

There is a number of limitations and vulnerabilities affecting crop production in Russia.
Among them: availability of zones where heat or water shortages limit cropping systems diversity and crop yield levels as well as areas with low fertile acid and alkali-affected soils and soil degradation processes evidence.
Vulnerabilities for sustainable crop management practice may be subdivided in to: 1)vulnerabilities during growing season;2)vulnerabilities for crop wintering and 3)agroecological climate-related vulnerabilities.
The most critical vulnerabilities during growing season are droughts and accompanying phenomena. As usual, drought over the territory of Russia is related to cold and dry Arctic air mass invasions. After moving to south, the air masses become hotter and drier. As a result, very hot and dry weather conditions occur in the interior areas (especially over Volga-, Chernozem Centre- and North Caucasus Regions) , and atmospheric drought appears. Rather seldom the atmospheric drought occurs due to dry and hot air mass invasions from semi-desert regions (from Republic of Kazakhstan). For soil drought prediction, also it is necessary to take into consideration the fractional composition of soils. Drought is usually accompanied by dry winds and dust storms, and drought regime also results wind- and water erosion in semiarid regions. The retrospective analysis of drought recurrence since 1950 shows that droughts occur more frequent in the1990s.
The most critical vulnerabilities for crop wintering are as following: frost killing, rotting out and wetting out.
Crops frost killing is their death as a result of a long-term severe frost impact. It occurs as a consequence of soil temperature decrease at the depth of a tillering node (3 cm) up to the "critical temperature" limits, which characterize frost resistance of crops. Most often winter cereals are subjected to frost killing in the regions with a thin snow cover (especially in the Middle/Lower Volga and Southern Pre-Ural Regions). During five last decades, due to increase in winter temperatures (by 30-32% relative to annual means) frost killing recurrence in these regions sharply decreased.

Rotting out is a process resulting from the long-term crops staying under a thick snow cover at the temperature close to 0°C at the depth of a tillering node. Under such conditions, crops are subject to fungus disease from the effect of which they are finally destroyed.
Wetting-out is a long-term staying of crops under water during thawings, as well as early and late in winter. The degree of crops wetting-out is determined by the depth of crops flooding and duration of their staying under water and water temperature.
These phenomena are characteristic for the regions with moderate/mild and dump winters (e.g., North-West Russia, Central Russia and Middle Pre-Ural Regions). In these regions the recurrence of rotting- and wetting out increased by 15-17% during five last decades.
The most critical agroecological climate related vulnerabilities are pests, diseases and weeds.
Over the last decades, the insect population growth has been observed with strong attacks on crops. The rapid pest infestation into large areas is registered more frequently than before; several species migrate northward, especially within North-West Russia territory. For example, the area of occupation and acclimatization (due to mild winters) by Colorado beetle has moved to high latitudes (to 63-64° n. l.). A number of new pathogens and weeds is been enlarged in the northern regions, and harmfulness of leaf diseases has intensified.
Obviously, under projected climate change the distribution of climatic limitations will be subject to considerable spatial shift as well as climatology of droughts and wintering conditions may change significantly. Moreover, agroecological vulnerabilities may also intensify.

To asses the impact of forthcoming climate change on crop production and crop management practice, the Last Interglacial climatic optimum is considered as a paleoanalog scenario of global warming by 2020-2030, this conditions been compared with simulation results obtained from such transient GCMs as ECHAM4A, ECHAM5, HadCM3 and GFDL for same “time slices”.
The input data include a number of climatic indicators including drought frequency index. Moreover, the spatial analogs method is applied to defining the areas potentially vulnerable to new insect pests, pathogens and weeds under projected climate change.
It should be noted, that both options for climate prediction give close estimates of potential change in thermal conditions, while the HadCM3 scenario simulates temperature increases under more arid climate.
In spite of predicted opportunities for cultivation of crops in several agricultural zones and regions (due to more favorable conditions during growing season and reducing frost killing risk), forthcoming climate change may results a number of adverse effects on crop production [Nikolaev and Yakushev, 2004]; [Nikolaev, 2007a]; [Nikolaev, 2010].
Thus, over European Territory of Russia, drought recurrence is expected to increase by 1,5 times in case of implementing the scenario of more arid climatic conditions by 2020-2030 (HadCM3 scenario by 2020-2030). While, in case of implementing the scenario of more humid climatic conditions by 2020-2030 (Paleoanalog scenario by 2020-2030), drought recurrence is expected to decrease, also by 1,5 times (for assessing drought recurrence, the relationship between the G.T.Selianinov’s Hydro-Thermal Coefficient for May-July and time interval between subsequent droughts τ ,in years, statistically determined by Yu.L. Rauner is used). Of cause, change in drought frequency will results change in frequency of dry winds and dust storms as well as degree of intensifying wind and water erosion. In turn, the northern boundary of so-called ‘ Dry Agriculture zone’ will be subject to significant shift (towards subhumid regions in case of implementing the scenario of more arid climatic conditions, and towards arid regions in case of implementing the scenario of more humid climatic conditions) [Nikolaev, 2009].

present-day conditions | by 2020-2030 (HadCM3 scenario) | by 2020-2030 (Paleoanalog scenario)

Distribution of time intervals between subsequent droughts τ (years).

For assessing the expected change in rotting- and wetting out risks, the winter wetness index is used as a ratio of precipitation sums to accumulated temperatures for cold period. This index estimates are compared with the frequency of rotting- and wetting out, i.e., the percent of years, when the losses of cereal plants after wintering (due to rotting- and wetting out) took place in more than 20% of planted areas to the beginning of spring. It is expected that will be a significant increase in rotting- and wetting out risks due to predicted more dump and mild winters. The losses of winter cereals may increase up to 13-15% in the North-West Russia and Volga-Viatka Regions by 2020-2030 [Nikolaev, 2010].

For assessing penetration of pests, pathogens and weed flora under projected climate change, the spatial analogue method has been developed [Nikolaev, 2007b]. This approach is based qn an analysis of analog regions under current and future climate regimes according to the following criteria: (1) similarity in annual course of daily temperatures; (2) similarity in annual precipitation amounts; (3) similarity in soil type and fractional composition (wide range of field crops adaptation to light factor taken into consideration). In this approach Paleoanalog scenario of global warming by 2020-2030 is applied. Then, comparison was made of spatial analogs with those by O.D.Sirotenko and V. N. Pavlova. Their approach is based on HadCM3 and GFDL simulation results fore "time slice" 2020-2030, and the following criteria is used: (1) similarity in values of accumulated temperatures above 10° C; (2) similarity in values of evaporation deficit during the period with temperature above 10° C; (3) similarity in values of mean monthly temperature in coldest moth. Despite discrepancies between analogue criteria and climate prediction options, the vector direction are from south-west (e.g., from Forest belt) to north-east (e.g., to Subboreal and Boreal belts), i.e. from warmer regions to cooler regions [Nikolaev, 2007c].

Thus, the vulnerability analysis for ongoing and forthcoming climate change testifies about the necessity of search for adaptation options to realize sustainable crop management in a changing climate [Nikolaev, 2008].

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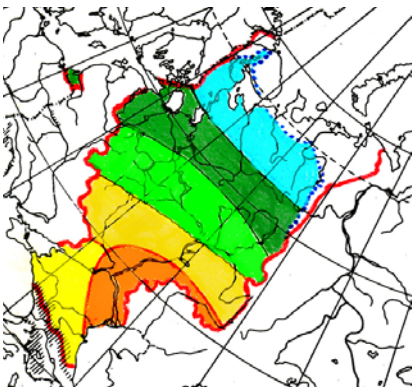
4.10.3 Feasible and recommended adaptation options

<u>For the detailed regional descriptions see the Table 10.3 in the Appendix.</u>

4.10.3.1. National Overview of the identified most feasible adaptation options of the regions/agroecosystems in Russia

Although there is a number of common adaptation options, including similar adaptation measures which could be applicable to all agroecological regions (e.g., adjustments in timing of farm operations, optimum fertilization, doses of chemicals and irrigation rates, etc.), yet regional agro-technologies are considerably differentiated due to existing differences in regional climates. Therefore, the agroclimatological design for regionalization of feasible adaptation measures in agricultural sector of economy within European part of Russia is created (see Fig. 1.3.2.1).



- ET Russia north 61° n.l.

  (Type of climate: cool temperate, humid)
- North-West Russia

  (Type of climate: temperate, humid)
- Central Russia

  (Type of climate: temperate, humid/subhumid)
- Chernozem Centre and Middle Volga

  (Type of climate: temperate, semiarid)
- Lower Volga and Southern Pre-Ural

  (Type of climate: temperate, semiarid/arid)
- North Caucasus

  (Type of climate: warm temperate, semiarid/subhumid)

Fig. 1.3.2.1 . Agroclimatological design for regionalization of feasible adaptation measures.

This map is made on the basis of integrated analysis of spatial distributions in agroclimatic resources, environmental risks, soil types and agricultural specialization.

Further, we describe briefly a number of most important and feasible adaptation options, taking in to consideration their time horizons of implementation, application levels, and also extent of application for specific agroecological conditions under climate change.

Overall assessment on feasibility of recommended adaptation options.

(M.V. Nikolaev)

Based on the observed trends in agroclimatic conditions and crop management practice including results from farmer's questionnaires as well as climate scenarios and expert assessments, the following aspects for feasibility of recommended adaptation options are summarized:

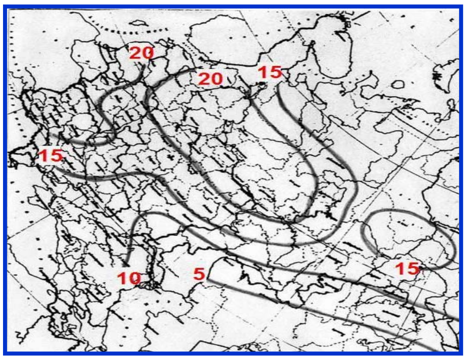
1. There is a number of adaptation options which are considered as low cost and may be implemented within a short-term period: for example, adjustments in timing of farm operations, adapted tillage practice and biological methods for crop protection. Last option is of exclusive importance under climate change. Under the corrected application of these options, they do not damage the environment. Besides, these options may be applied in different agroecological regions.
2. Considerably low cost and short-term are such options as snow rolling, snow piling and snow plowing for regulation of soil climate during cold season. However, they have specific application by regions, and also they are environmentally-friendly options.
3. Adjustments in recommended use of fertilizers may be considered as short- term adaptation options. They are applied to different agroecological conditions. However, under climate change the efficiency of fertilizers may be significantly changed. Meanwhile, incorrect fertilizer application may lead to environmental pollutions, especially watersheds. Moreover, application of several kinds of fertilizers may increase the GHG emission into the atmosphere. At the same time, increasing in costs of fertilizers resuts in adverse effects on volumes of farm production.
4. Adjustments in soil liming and soil gypsuming standards (medium-term adaptation options), obviously influence beneficially the soil fertility and additional yields under climate change.
5. Improvement of crop rotation systems is a long-term adaptation option. This option requires considerable money investments in to seeds, machinery and equipment and human labor. However, the efficiency of this option are expected to be high under climate change in terms of agroecosystems productivity.
6. Application of protective belts and agroforestry as well as windbreaks is rather high cost, because requires transplants and care of plants. However, this option is very effective for application in semiarid regions. At the same time, applying adaptation measure such as snow hedges is low cost.
7. Agricultural land use planning and crop selection are long-term adaptation options, which may be considered as adaptation strategies. They are widely used and require great money investments. Under climate change these options are of exclusive importance.
8. Effective water use in agriculture requires money investments, especially for construction (or modernization) of irrigation systems. However, separate irrigation methods may prove low cost and effective enough.
9. It appears that agricultural insurance development will results in raising the efficiency of farmer's labor in Russia.
10. Application of more ecologically-pure agricultural techniques are increasingly wide implemented in Russia (e.g., application of vermicompost as a manure fertilizer).

4.10.3.2 Selected most important and feasible adaptation options at the farm level in Russia (detailed)

4.10.3.2.1 Adjustments in timing of farm operations.

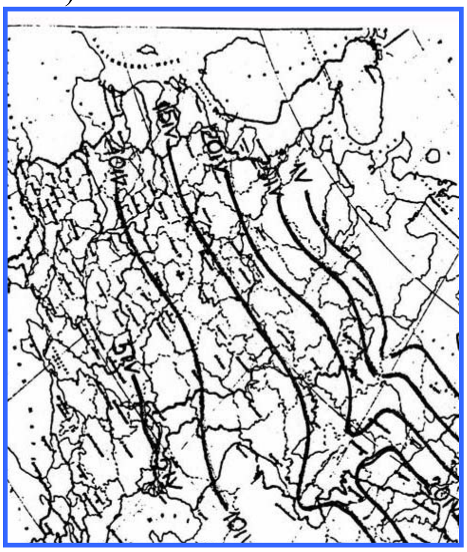
Time horizon of implementation for this option is 1 year.
Application levels are: farm, regional and national levels.

This adaptation option includes: changes in the dates of tillage and planting, sowing, fertilizer applying including additional fertilizer applying, chemical spraying as well as timing of flooding in irrigation. This dates and application timing may be vary from year to year depending on weather/climatic situation of each year.
In particular, the analysis of predicted changes in the dates of temperature rise above 0° C in spring and dates of snowmelt indicates a possible earlier spring tillage in the regions with stable snow cover. Fig. 1.3.2.2.1 - 1.3.2.2.3

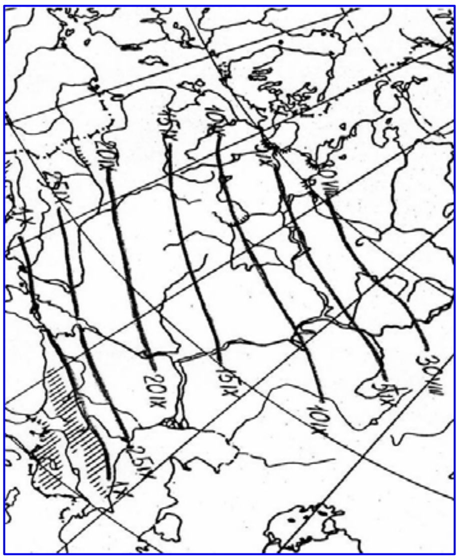


Changes in regular dates of spring tillage (days) by 2020-2030

In turn, an earlier temperature rise above 5° C in spring and later temperature fall below 5° C in autumn may provide earlier spring sowing and later autumn sowing (Fig. 1.3.2.2.1 - 1.3.2.2.3).



Predicted regular dates of sowing by 2020-2030 (spring wheat)



Predicted regular dates of sowing by 2020-2030 (winter wheat)

According to paleoanalog scenario course of daily temperature (obtained from long-term mean course of daily temperature by affine transformation), by 2020-2030 in the northern regions of the European Territory of Russia (e.g., North-West Russia) spring wheat sowing should be moved from 15-20 days earlier than regular dates; winter wheat sowing should be postponed about 2 weeks.

4.10.3.2.2 Adapted tillage practice.

Time horizon of implementation for this option is 1 – (6) year.
Application levels are: farm, regional and national levels.

In particular, adaptation of tillage practice consists in:
a) Application of improving harrowing in the purpose of fine-grained soil structure creation and reduction of evaporation losses from soils. Harrowing widely use in different agroecological regions of ET Russia including southern part of North-West Russia and also Central Russia.
In semiarid regions plowing application for water uptake from melt snow into soil is most effective, especially within Chernozem Centre and Middle Volga Regions, where soils are subjected water erosion.. Fall tillage and deep plowing (more than 30 cm of depth) is widely applied within North Caucasus Region, especially in the eastern portion of the Region with semiarid climate.
In the semiarid/arid regions (Lower Volga and Southern Pre-Ural Regions),which are sporadically subjected severe droughts and wind erosion, such measures as stubble mulching, soil loosing in autumn and deep tillage (more than 40 cm of depth) are most effective as well as application of subsurface tillage due to existing wind erosion.
b) Improving tillage practice including conservation tillage by variation in depth of tillage in order to keep up soil water storage in optimum under changing climatic conditions.
c) Implementation of new tillage practice by using new effective techniques or steady switching to traditional tillage practice that use at the moment in the regions considered as present-day climate analogs for future climatic conditions in the territory under study.
d) Improving tillage practice for suppression of soil pest population (including winter pests) and pathogens survivability.
e) Improving tillage practice against weed flora spread.
Effective implementation of such agricultural practice destruction of plant remains.

4.10.3.2.3 Adaptation of soil climate (and plant environment) regulation techniques during cold season.

Time horizon of implementation for this option is 1 year.
Application levels are farm and regional levels.

These adaptation measures may consist in:

- snow rolling to reduce soil temperature in the depth of tillering node in order to reduce a risk of crops rotting out in the regions with mild/moderate winters and thick snow cover (e.g., in the North-West Russia and Central Russia);
- snow piling for snow accumulation in the regions where crops are subjected to frost killing and water erosion is observed (e.g., in the Chernozem Centre and Middle Volga Regions);
- snow plowing for snow retention in the regions where crops are subjected to frost killing and wind erosion is observed (e.g., in the Lower Volga and Southern Pre-Ural Regions);
- techniques for protection of warm-weather crops against frosts (e.g., in the North Caucasus).

Improving methods for these techniques may be applied under climate change.

4.10.3.2.4 Adjustments in recommended use of fertilizers.
Time horizon of implementation for this option is 1year.
Application level: farm, regional and national levels.

Doses of fertilizers under the crops may be vary from year to year depending on weather/climatic situations in a concrete region. At the same time, doses of mineral fertilizers vary in space significantly depend on soil moisture conditions, which determine efficiency of fertilizers. As a result, recommended doses of fertilizer (full NPK consumption, kg/ha) reduce from humid regions to semiarid regions. High fertilizer doses apply to podzolic soils, which are characteristic for humid regions, and low fertilizer doses apply to light chestnut soils, which are characteristic for drylands. However, under irrigation the efficiency of fertilizers sharply increases.
By means of the soil hydrology model the potential additional yields as a result of change in optimum fertilization under changing soil water storage were estimate (see Tabl 1.3.2.2.1). The predicted changes in soil water storage based on the soil moisture conditions obtained from paleoanalog scenario of the global warming by 2020-2030.

Tabl 1.3.2.2.1 Potential additional yields as a result of change in optimum fertilization under changing water storage (spring wheat, rainfed crops)

Agroecological province and soil type	Current climatic regime					According to paleoanalog of the global warming by 2020-2030		
	Soil water storage (w, mm) in layer 0-100 cm	NPK opti-mum, kg/ha	Yield, kg/ha		Addi-tional yield, kg/ha	Change in soil water storage (Δw, mm)	Change in NPK opti-mum, Δ kg/ha	Change in additi-onal yield, Δ kg/ha
			Without ferti-lizers	With ferti-lizers				
Middle Russia's southern tayga (humid), sward-podzolic	152	210	1250	2220	970	5	8	29
Pre-Ural forest steppe (subhumid), leached chernozem	121	160	1830	2570	740	16	27	113
Lower Volga dry steppe (semiarid), dark chestnut	61	60	1100	1500	400	23	63	187

As seen, according to this scenario the largest yield growth is to be expected in semiarid regions on chestnut soils as on these the efficiency of mineral fertilizer sharply increases with additional natural soil wetting.

4.10.3.2.5 Adjustment of soil liming and soil gypsuming standards.
Time horizon of implementation for this option more than 2 years.
Application levels are farm and regional levels.

Soil liming application rate under acid soils depends mainly upon soil freezing intensity. Under intensifying soil freezing process, the soil acidification is also increasing. Therefore, frequency of soil liming and magnitude of liming standard have tendency to increase towards Subboreal and Boreal belts (e.g., within North-West Russia). Under projected climate change soil freezing in this region is expected to decrease, and liming standards may be reduced.

Soil gypsuming is applied to alkali-affected soils, in particular. Soil gypsuming is most effective in combination with deep plowing (40-50 cm of depth) and also manures application, irrigation, snow retention and bsnow melt water retention. Under projected climate change soli salinization process may intensify due to increase in drought frequency and aridization (e.g., in Lower Volga Region). Therefore, soil gypsuming standards should be increased here as well as soil gypsuming timing.

4.10.3.2.6 Improvement of crop rotation systems.
Time horizon of implementation for this option 3 - 7 years.
Application levels: farm, regional and national levels.

Adaptation optios for crop rotation systems may consist in improvement of short- and long-term rotation in order to maintain soil climate regime in optimum and to increase crop diversity for further resulting increase in productivity of crops under changing climatic conditions. It may be reached by:

- improving lea- and grass arable rotation by enlarging generic composition of annual and perennial grasses (e.g., clover varieties) in Humid zone;
- effective application of full fallowing (e.g., in Central Russia);
- effective application of bare fallowing and soil protective crop rotation in semiarid regions where soils are subjected to water erosion (e.g., in Chernozem Center and Middle Volga Regions);
- enlarging the grass diversity in pasture crop rotation as well as widely use in crop rotation systems such crops as alfalfa and vetch (e.g., in Lower Volga and Southern Pre-Ural Regions);
- effective application of bare- and legume fallowing (e.g., in North Caucasus Region);
- improving crop rotation systems by introduction of alternative crops as well as use of new cultivars.

4.10.3.2.7 Effective application of protective belts and agroforestry.
Time horizon of implementation for this option more than 5 years.
Application level is regional level.

More effective application of protective belts and agroforestry for snow accumulation, regulation of soil moisture and water erosion protection is very important in changing climatic conditions for agricultural activity in the Chernozem Centre and Middle Volga Regions with temperate semiarid type of climate and chernozem (black earth) type of soils which predominated in soil cover. It may be reached , on a one hand, by effective application of different kinds of afforestation: conservation-, slope- and gully afforestation. On the other hand, by the enlarging generic composition of forest belts (e.g., by trees plating with additional oak, maple and hornbeam replanting in pine- and birch forest belts). In this consequence the opportunities for reservation and acclimatization of new entomophages are enlarge in these belts.

4.10.3.2.8 Effective application of windbreaks and snow hedges.
Time horizon of implementation for this option 3-5 years.
Application level is regional level.

More effective application of windbreaks and snow hedges become very important in changing climatic conditions for agricultural activity in the Lower Volga and Southern Pre-Ural Regions with temperate semiarid/arid type of climate and chestnut type of soils which predominated in soil cover, the expected more favorable conditions for crop wintering (due to observed and predicted reducing frost killing risk in these regions) taken into consideration.
More effective application of wind breaks and afforestation of sands for protection against wind erosion and dust storms as well as for snow retention purposes may be reached by:

- regulating the height and width of windbreaks;
- spreading the generic composition of windbreaks (e.g., by application of blackhorn and hawthorn in windbreaks consisting of acacia);
- extending forest plantations consisting of other drought-tolerant trees, especially in the sandy areas.

More effective application of snow hedges based on improving their wind protection, soil protection and snow regulation effects under climate change. This improvement may be reached by:

- spreading the generic composition of snow hedges;
- optimizing the dimensions of snow hedges and their interspaces under change in wind conditions;
- optimizing the snow hedges configuration considering the potential shift in anticyclone activity under climate change.

4.10.3.2.9 Agricultural land use planning and crop selection.
Time horizon of implementation for this option more than 7 years.
Application levels: farm, regional and national levels.

The observed trends in planted areas dynamics and questionnaires for farmers show that practice of cultivation adapt to ongoing climate change. Thus, there is a tendency towards enlarging planted areas under spring barley and spring wheat in the northern regions of ET Russia due to more favorable conditions during growing season. Wider practice take place for buckwheat cultivation in the northern portion of Central Russia and maize for grain cultivation in the Middle Volga and Southern Pre-Ural Regions. Meanwhile, winter wheat and winter barley cultivation is spreading in the Lower Volga Region and some portions of North Caucasus due to reducing frost killing risk.
In turn, Tabl. 1.3.2.2.2 show some opportunities for cultivation of cereal crops under projected climate change.

Tabl.1.3.2.2.2 Prospective crops in certain agricultural regions under climate change by 2020-2030

Agroecological belt	Type of soil	Current climate		2020-2030		Cereal crop	Agricultural region
		Accumulated effective temperatures ºC	Mean monthly temperature of the most cold month ºC	Accumulated effective temperatures ºC	Mean monthly temperature of the most cold month ºC		
Boreal forest	podzolic	1420	-14,1	1815	-7,4	spring wheat spring barley	North-West Russia

Subboreal forest (west)	sward-podzolic (sandy loam, loam)	1892	-8,4	2165	-3,1	winter wheat	West of NW Russia
Subboreal forest (central)	sward-podzolic (sandy loam, loam)	1850	-10,3	2180	-4	spring wheat, oats, buckwheat	South of NW Russia, North of Central Russia
Subboreal forest (earst)	sward-podzolic	1845	-13,4	2187	-6,3	Winter,spring wheat	Middle Pre-Ural
Forest-steppe (central)	leached chernozem	2460	-12,7	2670	-5,5	maize for grain	Middle Volga
Forest-steppe (earst)	leached chernozem	2275	-14,6	2467	-7,2	Winter wheat maize for grain	Middle/Southern Pre-Ural
Steppe/semidesert - steppe	common chernozem	2645	-14,1	2740	-8,5	maize for grain winter barley	Southern Pre-Ural, Lower Volga
Semidesert -steppe	dark- and ligth chestnuts	3304	-9,4	3375	-5,8	winter wheat, winter barley, maize for grain	Lower Volga, Earst of Northern Caucasus

As seen , adaptation options for agricultural land use planning by 2020-2030 may consist in :

- switching from summer crops to winter crops (e.g., to winter wheat and winter barley) in the regions with reduced frost killing risk (in Lower Volga and Southern Pre-Ural Regions);
- enlarging the areas under buckwheat in the northern part of Central Russia;
- extending areas under maize for grain in Volga region.

Moreover, the programme for wide winter rye cultivation within North-West Russia using local rye cultivars may be implement with widening areas under rape and silage sunflowers as well as possible shift in the planted areas under winter barley and vineyards towards elevation (in North Caucasus Region).

However, changing land use will also requires:

- supply of the regions where conditions are expected to be favorable for new fertilizer-responded crops by additional amounts of mineral fertilizers;
- diversification of pesticides, fungicides and herbicides for further applying in the regions potentially vulnerable to new insect pests, viruses and weeds.

In crop selection, it is necessary to improve stress resistant/tolerant properties in cultivars under adverse climate change impacts. In particular, it may be reached by:

- breeding new cultivars with high resistant to climatic and environmental stresses;
- widening areas under snow mold resistant cultivars in the regions with increasing rotting out risk: overwise switching from winter crops to summer crops in most vulnerable regions;
- enlarging the areas under cultivars high tolerant to drought stress: overwise switching to crops that use less water (e.g., millet and sorghum);
- enlarging the areas under salt tolerant cultivars in the regions where soils are subjected to salinization process;
- expansion areas under cultivars high resistant to pests, diseases and weeds in all agroecological regions.

4.10.3.2.9 Effective water use in agriculture.
Time horizon of implementation for this option 1 – 8 years.
Application level: farm, regional and national levels.

This option may be reached by:

- improvement of different kinds of irrigation including surface, subsurface, drop and mist irrigation;
- concentration of irrigation water during peak growth period for best crop response, taking into account a possible shift in peak growth period under climate change;
- optimizing sprinkler irrigation including fertilizer sprinkling in the subhumid/semiarid regions the precipitation conditions are expected to be unfavorable to wide cultivation of high productive crops (e.g., in the southern portion of Central Russia; in Chernozem Centre Region);
- optimizing frost control sprinkling in the regions with warm temperate climate (e.g., within North Caucasus Region);
- improving basin irrigation in the costal lands of the Black sea coastal zone and Volga Delta for irrigation of warm weather cultivars of cereal crops (in North Caucasus and Lower Volga Regions);
- improving bench border irrigation in terracing practice for cultivation of crops in foothills (within North Caucasus Region including the Caspian sea costal zone);
- installation of more efficient irrigation systems by improving system of canals in drylands (Lower Volga Region and eastern portions of North Caucasus Region) or construction of new irrigation systems;
- installation of more efficient drainage systems by improving water regulating drainage (in particular by improving furrow- and pumped well drainage) in wettlads (e.g., in North-West Russia and in the western portions of Central Russia);
- wide use of water harvesting practice, and also artesian waters for irrigation in semiarid regions.

4.10.3.2.10 Improvement of biological methods for crop protection.
Time horizon of implementation for this option 1-7 years.
Application levels: farm, regional and national levels.

Improvement of biological methods for crop protection, including pest management may be reached by:

- more carefully analyses of virus – vector – host plant interactions under changing climatic conditions for determination of potential virulentability of crops for further undertaking measures using more distant planting from host plant agglomerations which produce conditions favorable for insect pest life cycles;
- more effective application of aboriginal entomophges in the regions where pest population growth is observed or predicted;
- introduction of new entomophages into the regions potentially vulnerable to new insect pests under climate change through agroecosystems restructuring leaving the reservation for introduced entomophages, and also investigation of interactions between introduced entomophages and aboriginal pests in order to detect entomophague species most adaptable to new conditions. (It is interesting to notice the fect of acclimatization of such entomophage as harmonia axyridis against aphids in North –West Russia during the last 7 years owing to climate warming. It should be noted that this entomophage could not be acclimatized in this region during preceding 50 years);

- introduction of useful insects into new regions as well as increasing their populations in the ordinary regions under future favorable conditions;
- introduction of some useful flora species from southern regions to northern regions for the purpose of establishing reservation for acclimatization of introduced entomophages and new useful insects;
- introduction of entapathogens for suppressing pathogens activity in potentially vulnerable regions, and also breeding of new entapathogens;
- implementation of environmentally-friendly biopreparations.

4.10.3.2.11 Agricultural insurance.

(N.A. Lemeshko)

Time horizon of implementation for this option is 1year.

Application levels: farm, regional and national levels.

One of the most important conclusions made from Questionnaires analyzing are the necessity of development of insurance in agroindustrial production in two dimensions: from farm level to national level and from one year to tree-five years. Nowadays in the farm level policy of insurance is expensive for most of farmers and cover not all weather risks and for a one season only. Some positive steps in this directions made by Ministry of Agriculture of the Russian Federation.

Ministry of Agriculture of the Russian Federation instituted «Federal Agency of State support of insurance in agroindustrial production". Agency has performed its activity since July, 2003. The main purpose of Agency's activity is to exercise administrative and control functions, which provide for the state support of insurance in the region of agroindustrial production. The Agency should assist to develop the state-supported insurance of agricultural crops' harvest, develop proposals concerning the modality and conditions of organization and implementation of such type of insurance; methodology of rates definition to calculate the subsidies during insurance, as well as to exercise control for effective application of funds from the federal budget designated to pay 50% of the insurance premiums for the state-supported insurance.

Currently, with an active participation of the Agency the Russian agricultural insurance pool has been instituted and still functions, whose members are 31 large insurance companies operating in the Russian market. From the number of the directors of insurance companies, Pool's Supervisory Board has been elected, there has been set up an Executive Committee and three working groups from the number of employers of insurance companies - members of the Pool. A training center has been opened under the Agency, there are carried on a regular basis educational seminars on the questions of insurance in agroindustrial complex; Methodical recommendations have been elaborated concerning the insurance organization in the region of agroindustrial production with state support; a Program of crediting the insurance premiums of the companies of agroindustrial complex for the state-supported insurance of agricultural crops' harvest has been developed.

4.10.4 Scientific basis of ADAGIO results

4.10.4.1 List of all literature used for national ADAGIO purposes, analysis etc. (national and international)

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4.10.5 Dissemination activities during ADAGIO (during all project lifetime)

4.10.5.1 List of <u>scientific</u> ADAGIO publications (which include ADAGIO results). It means: ADAGIO related results which were published <u>during</u> the AGAIO project.

Lemeshko N. 2008.The largest lakes and reservoirs of Russia as a priority water resource for society, Global change research. Abstracts. New Methodologies and Interdisciplinary Approaches in Global Change Research. p.70-71.
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Uskov I. B, Agrometeorological factors of productivity. Book of Lectures on “National School for Young Researchers/Practical Experts on Precession Agriculture”. St.-Petersburg. P.25-49.
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Uskov I.B. 2008. Global warming comes… What should farmer doing? “Agrarian expert”, № 2, p.6-9. (in Russian).
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4.10.5.2 List of not yet published (manuscript status) scientific ADAGIO related publications (national or international).

Nikolaev M.V. Vulnerability and adaptation of agriculture to climate change. In book: Global climate change: consequences for agriculture. " Russian Academy of Agricultural Sciences issue, Moscow.
Uskov I.B. et al. Agrometeorological factors and potential productivity.
Lemeshko N. 2009. Agriculture in Russia and Climate change. Extended Abstracts - International Symposium – “Climate Change and Adaptation Options in Agriculture”, Vienna, 22-23 June 2009.

4.10.5.3 List of published or not yet published (manuscript status) ADAGIO results specific designed for national farmers or stakeholders, which are more than common articles in newspapers (e.g. books, brochures, reports which can serve as a permanent source of information).

Uskov I.B. 2008. Global warming comes… What should farmer doing? “Agrarian expert”, № 2, p.6-9. (in Russian).
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4.10.5.4 Other national public relation activities (e.g. lectures, farmer meetings, articles in newspapers), use the updated table below, for ALL ADAGIO period

Listed in the Thematic Group 4 report

4.11 Romania

4.11.1 Abstracts of national case studies carried out during the ADAGIO project

<u>Case study 1 :</u>

Quantitative assessment of some adaptation measures to climate changes for arable crops in Romania

Catalin SIMOTA, George COJOCARU

Abstract

The most vulnerable agroecosystems in Romania were evaluated considering the baseline climate (1961-1990) and climate change predictions (for 2011-2040 time horizon using ECHAM4 and HADCM3 – A2 scenarios)

The identification of the most vulnerable agroecosystems in Romania was based on:

- The evaluation of the actual status of the agroecosystems in Romania including socio-economic aspects (agriculture exploitation structure, crop pattern, population indicators)
- The evaluation of changes in some specific indicators related to:
  - Indicators defining aridity: Bagnouls-Gaussen indicator; UNESO Aridity Index
  - Specific agrophysical indicators evaluating the productivity of agroecosystems: Number of growing days defined as the number of days in an year with average air temperature over 4^0C and soil available water over half of potential evapotranspiration;
  - Number of workable days
  - Evaluation of environment sensitivity to climate and land use changes – ESAI indicator developed in MEDALUS project
  - Changes in crop yields based on simulation models

Most vulnerable areas to climate changes were defined at the level of county administrative units (NUTS3) using the set of indicators calculated for each mapping units (intersection between soil, climate and land use mapping units).

The most vulnerable agroecosystems in Romania are crop farming dominated by cereals (winter wheat and maize) and crop farming for oilseed crops in South (Arges, Calarasi, Ialomita, Teleorman), South-East (Constanta), South-West (Dolj, Olt), West (Timis) and North-East (Vaslui) regions of Romania. The vulnerabilities detected in the dominating agroecosystems are:

- the small areas of agriculture exploitations (mainly in counties with low average income – Olt, Dolj, Vaslui)
- reduced number of crops (winter wheat, maize, sunflower)
- decreasing level of water availability that is not counter balanced by introducing management practices for water conservation in dry farming (winter water harvesting, minimum tillage, using new cultivars fitting better with the climate changed conditions)
- conservative atitude of rural population

Probably on a short and medium time horizon (2020) changes in rural space induced by introducing CAP and aggregation of land will be more important than the changes induced by climate changes.

The main effects of climate changes in Romania are related to the yield decrease – mainly for arable crops- due to increasing water deficits. Therefore, the main adaptation methods to climate changes are related to water conservation.
At this moment the farm structure of Romania (very small farms) and the age of farmers (over 50) provide a very conservative farmer community. Even in this case some trends for adaptation to climate changes (increasing the number of years with water scarcity in the last decade) are manifested: increasing the percentage of winter crops, changing cultivars from late to earlier varieties, land abandonment or asking for irrigation.
The list of the most discused in mass media and farmer communities possible adaptation options (minimum tillage, use of irrigation, changing cultivars and sowing timing) were quantitative evaluated for the future time horizons. Evaluations used ROIMPEL and SIDASS model linked with soil, climate and terrain databases.

4.11.2 Regional vulnerabilities and reasons

For the detailed regional descriptions see the Tables 11.1 and 11.2 in the Appendix.

4.11.2.1 Summary description of the most significant identified vulnerabilities of the regions/agroecosystems in Romania

The identification of the most vulnerable agroecosystems in Romania was based on:

- The evaluation of the actual status of the agroecosystems in Romania including socio-economic aspects (agriculture exploitation structure, crop pattern, population indicators)
- The evaluation of changes in some specific indicators related to:
    - Climate specific indicators defining aridity:
        - Bagnouls-Gaussen indicator;
        - Ratio between precipitation and potential evapotranspiration.
    - specific agrophysical indicators developed to evaluate on a common base over Europe the productivity of agroecosystems not considering a specific crop:
        - Number of growing days defined as the number of days in an year with average air temperature over 5^0C and soil available water over half of potential evapotranspiration
        - Number of workable days
    - Evaluation of environment sensitivity to climate and land use changes – ESAI indicator developed in MEDALUS project
    - Changes in crop yields based on simulation models

Definition and calculation methodology of the indicators are defined elesewhere. Their evaluation was based **on national databases for**:

- Soil : 1:1,000,000 and 1:200,000 digital soil databases
- Climate : monthly averages of standard meteo data (air temperature, rainfall, sunshine hours, potential evapotranspiration using Thornthwaite-Mathers approach) for past long time series (1901-1960, 1961-1990, 1991-2000) and future scenarios (2041-2050, 2071-2080 based on HADCM3 GCM output for the business as usual A2 storyline) in a 10’ x 10’ longitude x latitude grid over the country (data from FP5 – ATEAM project)
- Land use : Corine Land Cover (2000)
- Population and Agriculture National Statistics at NUTS5 level (commune).

and agro-pedo-climatic simulation models (ROIMPEL developed in FP5 project – ACCELERATES).

Most vulnerable areas to climate changes were defined at the level of county administrative units (NUTS3) using the set of indicators calculated for each mapping units (intersection between soil, climate and land use mapping units).
The vulnerabilities are evaluated at the level of NUTS3 administrative units (counties) considering the evaluations based on soil-terrain units at the scale 1:200,000.

The most vulnerable agroecosystems in Romania are crop farming dominated by cereals (winter wheat and maize) and crop farming for oilseed crops in South (Arges, Calarasi, Ialomita, Teleorman), South-East (Constanta), South-West (Dolj, Olt), West (Timis) and North-East (Vaslui) regions of Romania. Table 1 shows the actual land use and the main indicators for the baseline (1961-1990) and 2041-2050 time horizon (A1F2 – HADCM3).
The vulnerabilities detected in the dominating agroecosystems are:

- the small areas of agriculture exploitations (mainly in counties with low average income – Olt, Dolj, Vaslui)
- reduced number of crops (winter wheat, maize, sunflower)
- decreasing level of water availability that is not counter balanced by introducing management practices for water conservation in dry farming (winter water harvesting, minimum tillage, using new cultivars fitting better with the climate changed conditions)
- conservative atitude of rural population

Probably on a short and medium time horizon (2020) changes in rural space induced by introducing CAP and aggregation of land will be more important than the changes induced by climate changes.

4.11.3 Feasible and recommended adaptation options

<u>For the detailed regional descriptions see the Table 11.3 in the Appendix.</u>

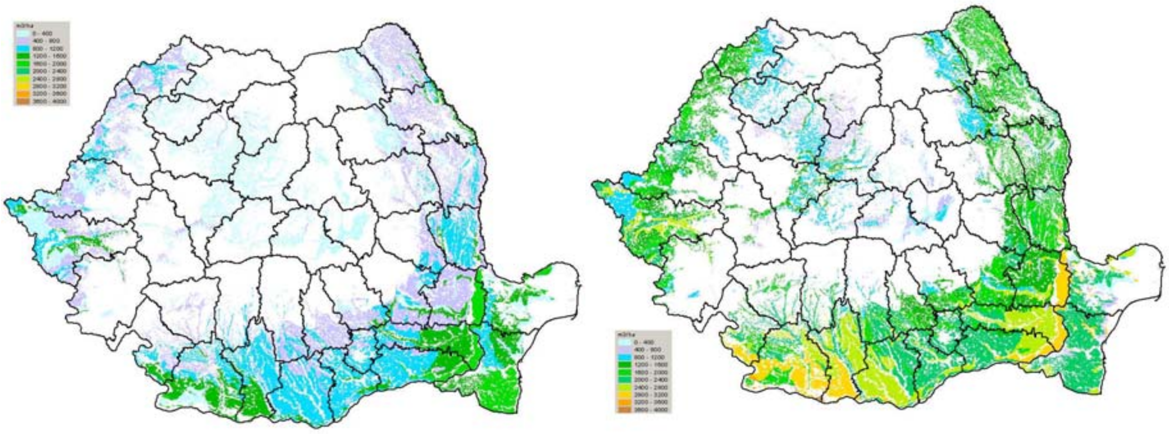
4.11.3.1 National Overview of the identified most feasible adaptation options of the regions/agroecosystems in Romania

The main effects of climate changes in Romania are related to the yield decrease – mainly for arable crops- due to increasing water deficits. Therefore, the main adaptation methods to climate changes are related to water conservation.
Various international organisations (WMO, FAO) have listed various adaptation options to climate changes. Ost of these measures were inclded in national action plans for mitigation of climate change effects or in national strategies to combat drought.
At this moment the farm structure of Romania (very small farms) and the age of farmers (over 50) provide a very conservative farmer community. Even in this case some trends for adaptation to climate changes (increasing the number of years with water scarcity in the last decade) are manifested: increasing the percentage of winter crops, changing cultivars (e.g. from late to early varieties for maize), land abandonment or asking for irrigation.
The list of the most discused in mass media and farmer communities possible adaptation options were quantitative evaluated for the future time horizons. Evaluations used ROIMPEL and SIDASS model linked with soil, climate and terrain databases.
Three adaptation options were selected from the list considering their effectiveness for mitigating climate change effects on agriculture systems: irrigation, minimum tillage, change of cultivars.

4.11.3.2 Selected most important and feasible adaptation options at the farm level in Romania (detailed)

4.11.3.2.1 Irrigation

Even if considered the best way for adaptation (at least in mass-media and by policy makers) the increases of the amounts of water (Figure: e.g. in Dolj from 1200-1600 m^3 ha^{-1} to 2800-3200 m^3 ha^{-1}, Calarasi from 800 – 1600 m^3 ha^{-1} to 3200 m^3 ha^{-1}) linked with the need of fertilisers (with higher proces estimated for future scenarios) and increasing competition for water will make this adaptation measure not economic feasible on large areas in the future.



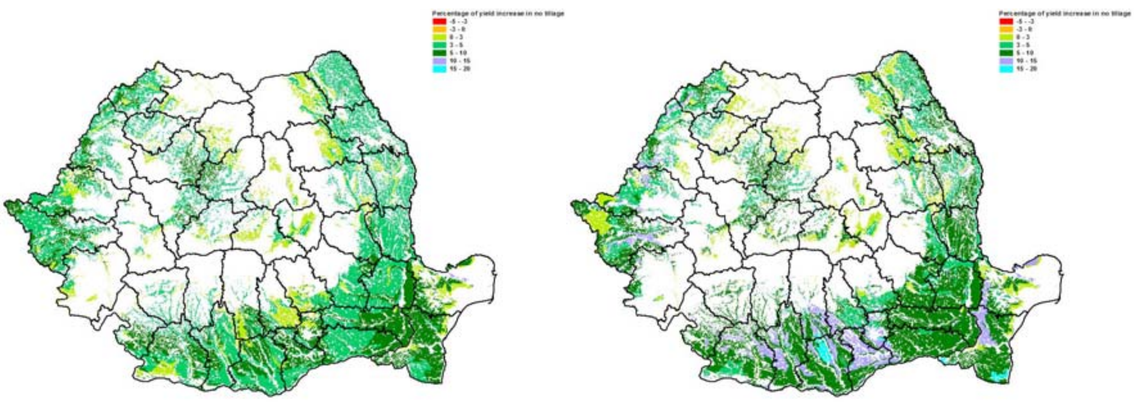
1961-1990 **2041-2050 A2 HADCM3**

Figure Needs for irrigation water (m^3 ha^{-1}) for baseline (1961-1990) and 2041-2050 time horizon

4.11.3.2.2 Minimum tillage

Minimum tillage will increase spring crop yields in South Romania up to 20% (Figure) by the conservation of water.

The main limitations are related to the costs of tillage implements and the needs of trainings for farmers. This problem could be solved in the process of aggregation of small farms and the creation of new large agriculture entreprises.

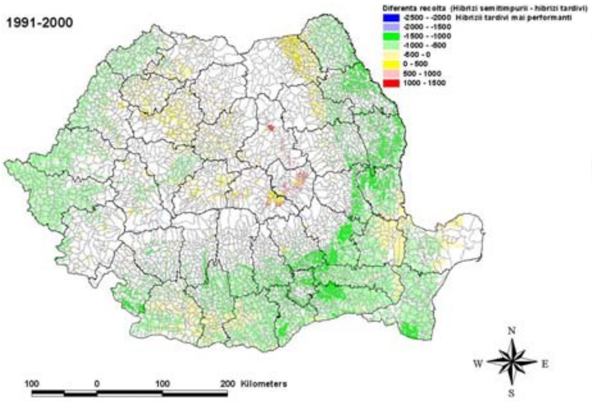


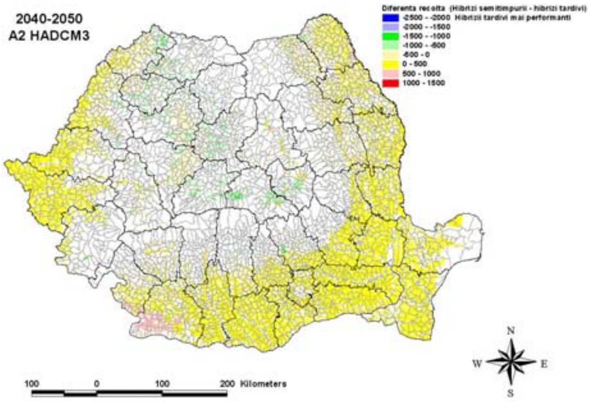
1961-1990 **2041-2050 A2 HADCM3**

Yield change (%) of spring crops for minimum tillage management practice compared to conventional system

4.11.3.2.3 Changing the cultivar structure

Figure shows the difference of maize yields between early and late cultivars. If for the baseline the late cultivars are more productive (up to 1 t ha^{-1}) in the future climate change scenario (2041-2050) in South Romania the two types of cultivars gives similar yields (in Dolj county the early cultivars will give higher yields up to 1000 kg ha^{-1}. Therefore, will be more profitable to use early cultivars due to low costs of their technology of production.





1991-2000

2041-2050
A2 HADCM3

4.11.4 Scientific basis of ADAGIO results

4.11.4.1 List of all literature used for national ADAGIO purposes, analysis etc. (national and international)

Anonymus, 2000-2008. National Statistical Yearbook.

Anonymus, 2006.

A. Fassio , C. Giupponi , R. Hiederer, A. Povellato and C. Simota, 2002, A Decision Support tool for implementing alternative policies affecting water resources: an application at the European scale, Proc.of the Conference “European policy and tools for sustainable water management”, 21-23 November, Venice, Italy.

Horn, R., Paul, R., Simota, C., Fleige, H., 2002. Schutz vor mecanischer Belastung. Hanbuch der Bodenkunde 14, Erg. Lfg. 12/2002

Dumitru, M., Simota, C., Dorneanu, E., Geambasu, N., Stanciu, P., Tiganas, L., Iliescu, H., Togoe, I., Munteanu, I., Dumitru, E., Mitroi, A., 2003. Cod de bune practici agricole – Protectia apelor impotriva poluarii cu fertilizanti proveniti din agricultura si prevenirea fenomenelor de degradare a solului provocate de practicile agricole. (Code for Good Agriculture Practice – Water protection against pollution with fertilsers from agriculture and prevention of soil degradation phenomena caused by agricultural practices), Ed. Expert, Bucuresti, 159 pp. (http://www.icpa.ro)

Simota,C., Horn,R., Fleige,H., Dexter,A., Czyz,E., Diaz-Pereira,E, Mayol,F., Rajkaj.K., De la Rosa,D., 2005. SIDASS project. Part 1. A spatial distributed simulation model predicting the dynamics of agro-physical soil state for selection of management practices to prevent soil erosion. Soil & Tillage Research, 82: 15-19

Dexter, A.R., Czyz, E., Birkas, M., Diaz-Pereira, E., Dumitru, E., Enache, R., Fleige, H., Horn, R., Rajkaj, K., De la Rosa, D., Simota, C., 2005. SIDASS project. Part 3. The optimum and the range of water content for tillage – further developments. Soil & Tillage Research, 82: 29-39

Horn, R., Fleige, H., Richter, F.-H., Czyz,E., Dexter, A., Diaz-Pereira, E., Dumitru, E., Enache, R., Mayol, F., Rajkaj, K., De la Rose, D., Simota, C. 2005. SIDASS project. Part 5. Prediction of mechanical strength of arable soils and its effects on physical properties at various map scales. Soil & Tillage Research, 47-55

Audsley,E., Pearn,K.R., Simota,C., Cojocaru,G.,Koutsidou,E., Rounsevell,M.D.A., Trnka,M., and V.Alexandrov. 2006. What can scenario modelling tell us about future European scale agricultural land use, and what not?, Environmental Science and Policy, 9, 148-162

Akker, van den, J.J.H. and C.Simota (2008), Soil quality indicators and risk assessment methodologies for subsoil compaction, Eurosoil Congress University of of Natural Resources and Applied Life Sciences (BOKU), Vienna, Austria, August 2008-08-04, Book of Abstracts (Winfied Blum, Martin Gerzabek and Manfred Vodraska eds.) ISBN: 978-3-902382-05-4, S16.F.01, pp: 102

C. L. van Beek, T. Toth, A. Hagyo, G. Toth, L. Recatala Boix, J. Malet, O. Maquaire, J. van den Akker, C. Simota, O. Oenema. (2008) Harmonization of Risk Assessment Methodologies for Soil Threats in Europe. Eurosoil Congress University of of Natural Resources and Applied Life Sciences (BOKU), Vienna, Austria, August 2008-08-04, Book of Abstracts (Winfied Blum, Martin Gerzabek and Manfred Vodraska eds.) ISBN: 978-3-902382-05-4, S10.H.02, pp: 69

4.11.5 Dissemination activities during ADAGIO (during all project lifetime)

4.11.5.1 List of scientific ADAGIO publications (which include ADAGIO results). It means: ADAGIO related results which were published during the AGAIO project.

Wirsig,A., Henseler,M., Simota,C., Krimly,T., and S.Dabbert. 2007. Modelling the impact of global change on regional agricultural land use in alpine regions. Agrarwirtschaft und Agrarsoziologie, 1:101-116

Simota, C., Dumitru, S., and G.Cojocaru. (2008). Evaluation of an index for spatial assessment of environ,emtal sensible areas to desertification at national scale. Eurosoil Congress University of of Natural Resources and Applied Life Sciences (BOKU), Vienna, Austria, August 2008-08-04, Book of Abstracts (Winfied Blum, Martin Gerzabek and Manfred Vodraska eds.) ISBN: 978-3-902382-05-4, S05.M.02, pp: 35-36

Simota, C., (2008). Common biophysical criteria for defining areas which are less favoured for agriculture in the context of expected climate changes. Global Change Conference, Sofia, May 2008

Simota, C., (2009). Quantitative assessment of some adaptation measures to climate changes for arable crops. International Symposium „Climate Change and Adaptation Options in Agriculture", 21-23 June 2009, BOKU Wien

4.11.5.2 List of not yet published (manuscript status) scientific ADAGIO related publications (national or international).

No pending publications

4.11.5.3 List of published or not yet published (manuscript status) ADAGIO results specific designed for national farmers or stakeholders, which are more than common articles in newspapers (e.g. books, brochures, reports which can serve as a permanent source of information).

4.11.5.4 Other national public relation activities (e.g. lectures, farmer meetings, articles in newspapers), use the updated table below, for ALL ADAGIO period

Listed in the Thematic Group 4 report

APPENDIX A

APPENDIX A – TABLES of regional climate change impacts and recommended adaptation options per Country (ADAGIO partners)

Table A1: Farm typology according to Reidsma (2007) as used for following Country Reports (First Tables). Each farm is characterized by a land use, size and intensity dimension.

	Dimension and type	Definition
Land use		*(Specialization), Land use type rule*[a]
1	Arable/cereal	(1+6), < 12.5% fallow and >= 50% cereals
2	Arable/fallow	(1+6), >= 12.5% fallow
3	Arable/specialized crops	(1+6), >= 25% of arable land in specialized crops
4	Arable/others	(1+6), other arable
5	Dairy cattle/permanent grass	(4.1), >= 50% grass and < 50% temporary grass
6	Dairy cattle/temporary grass	(4.1), >= 50% grass and >= 50% temporary grass
7	Dairy cattle/land independent	(4.1), UAA = 0 or LU/ha => 5
8	Dairy cattle/others	(4.1), other dairy cattle
9	Beef and mixed cattle/permanent grass	(4.2 and 4.3), as 5
10	Beef and mixed cattle/temporary grass	(4.2 and 4.3), as 6
11	Beef and mixed cattle/land independent	(4.2 and 4.3), as 7
12	Beef and mixed cattle/others	(4.2 and 4.3), other beef and mixed cattle
13	Sheep and goats/land independent	(4.4), as 7
14	Sheep and goats/others	(4.4), other sheep and goats
15	Pigs/land independent	(5.1), as 7
16	Pigs/others	(5.1), other pigs
17	Poultry and mixed pigs/poultry	(5.2)
18	Mixed farms	(7)
19	Mixed livestock	(8)
20	Horticulture	(3)
21	Permanent crops	(2)
Size		
1	Small scale	< 16 ESU
2	Medium scale	>= 16 ESU and < 40 ESU
3	Large scale	>= 40 ESU
Intensity		
1	Low intensity	Total output per ha < €500 euro
2	Medium intensity	Total output per ha >= €500 and < €3000
3	High intensity	Total output per ha >= €3000

[a] The specialization dimension is based on the EU/FADN farm typology (http://ec.europa.eu/comm/agriculture/rica/diffusion_en.cfm). Only the most important land use type rules are described here; the % of area relates to the utilized agricultural area (uaa). A full description is given in Andersen et al. (2006).

1 - AUSTRIA

Table 1.1. List of identified vulnerable regions to climate change in Austria and their characteristics (expert assessment)

No.	Dominating Agroeco-system	Geographical region	National name of region	Approx size of the region (km²)	Annual temperature, precip. and sea level of the region (from-to)	Dominating soil conditions (describe)	Irrigation applied and dominating type of irrigation	Topography of the region	Dominating LAND USE types and INTENSITY according toTable 1.1a (Refer to numbers of first column)	CLASSIFICATION of agroecosystem according to Table 7.2 and 7.3 (class numbers and proportion*)	Percentage of organic farmers	Mean farm size, and dominating farm size (ha)
1	**Grassland**	North ern Austria	Mühlviertel, Waldviertel	3000	6-8 °C; 600-950mm; 400-900m	Light soils with low soil water capacity, good drainage,	No irrigation	dominated by complex topography, hilly region mixed with flat areas	First: 5 (intensity 2) Second: 9 (intensity 2) Third:13 (intensity 2) Fourth: 16 (intensity 2)	First : 44 (ca.60%); Second : 42 (ca. 25%); Third : 45 (ca. 15%)	15 %	dominating : 10-20ha
2	**Grassland**	East Austria	Bucklige Welt, Burgenland Sued	500	7,5-9 °C 700-800mm 200-800m	Medium soils, mediumto high soil water capacity	No irrigation	dominated by complex topography, hilly region, some flat areas	First: 5 (intensity 2) Second: 9 (intensity 2) Third:13 (intensity 2) Fourth: 16 (intensity 2)	First : 44 (ca.60%); Second : 42 (ca. 10%); Third : 45 (ca. 30%)	15%	dominating : 10-40ha
3	**Orchards mixed with crops and grassland**	South-east Austria	Südost-steiermark	500	8-9°C 700-850mm 250-600m	Medium soils, mediumto high soil water capacity	Partly sprinkler irrigation in orchards	dominated by complex topography, hilly region,	First: 21 (intensity 3) Second: 18 (intensity 2) Third:19 (intensity 2)	First : 15,13,17 (ca. 20,10,10%));	20%	dominating : 10-20ha
4	**Vineyards mixed with crops**	North.-east Austria	Weinviertel without Marchfeld	1500	8-10°C 450-600mm 200-600m	Medium soils, medium to high soil water capacity	Sprinkler irrigation on some summer crops	Slightly hilly region	First: 1 (intensity 2) Second: 21 (intensity 3)	First : 15,13,17 (ca.30,10,10%); Second : 15 (ca. 30%)	10%	dominating : 20-60ha
5	**Crop farming dominated by cereals**	North-east Austria	Marchfeld and Burgenland Nord	1000	10-11°C 500-600mm 200-300m	Low (sandy) to high soil water capacity (tschernosem), high spatial variability	Sprinkler irrigation on some summer crops (vegetables, potatoes, maize, sugar beet)	Mostly flat region	First: 1 (intensity 2) Second: 20 (intensity 3)	First : 15,13,17 (ca.50,30,5%); Second : 15 (ca. 10%)	<5%	dominating : 50-100ha
6	**Crop farming dominated by maize**	South-east Austria	Leibnitzer Feld	500	8-10°C 800-900mm 200-400m	Medium soils, medium to high soil water capacity	Sprinkler irrigation on maize occasionally	Mostly flat till slightly hilly region	First: 3 (intensity 2) Second: 16 (intensity 3)	First : 15,13,17 (ca.40,10%)	<5%	dominating : 20-50ha

Table 1.2. List of identified vulnerable regions to climate change in Austria and their main limitation and trends (expert assessment)

No	Dominating Agroecosystem	Geographical region	National name of region	Main limitations	Observed trends	Socio-economic conditions and problems	Main identified vulnerabilities to climate change
1	**Grassland**	North-west Austria	Mühlviertel, Waldviertel	Topography (hilly), small farm size, low temperature, precipitation and low soil water capacity	Structural change to bigger farms, change to niches (e.g.biogas), ecological farming, combination with crops (e.g. potatoes)	Weak economic conditions of small farms, low milk price	**Grassland drought and heat damage**, increasing grassland yield variability, pest risk increasing (especially also in forests)
2	**Grassland**	South-east Austria	Bucklige Welt, Burgenland Sued	Topography, precipitation	Structural change to bigger farms, Comination with cash crops (orchards), change to niches(e.g.biogas), ecological farming	Weak economic conditions of small farms, low milk price	**Grassland drought**, heat damage, pest risk increasing, (especially also in forests)
3	**Orchards mixed with crops and grassland**	South-east Austria	Südost-steiermark	Topography	Structural change to bigger farms, change to niches (e.g.biogas), ecological farming	Weak economic conditions of small farms	Heat waves and drought, **hail**; frost damage of orchards by early growing periods; faster pests and diseases developement; more pest damage in forests, **soil erosion**
4	**Vineyards mixed with crops**	North.-east Austria	Weinviertel without Marchfeld	Precipitation	Structural change to bigger farms, change to niches (bioenergy crops), ecological farming	Weak economic conditions of small farms	**Drought and heat for summer crops**, pests risk increasing, change in wine quality, **soil erosion**
5	**Crop farming dominated by cereals**	North-east Austria	Marchfeld and Burgendlanf North	Precipitation (summer droughts), sandy soils,	Increassing drought and water demand	No main problems	Drought and heat for summer crops, increasing yield variability
6	**Crop farming dominated by maize**	South-east Austria	Leibnitzer Feld	Soil nitrogen leaching, soil erosion	Structural change to bigger farms,	No main problems	Drought (maize) and heat waves (increasing risk and costs for pig and poultry production), **soil erosion**

Table 1.3. Summary table on identified adaptation options in vulnerable regions and production systems in Austria

Dominating Agroecosystem	Geographical region	National name of region	Agroecosystem, related to common agroclimatic etc. indicators	Observed trends in adaptations to climate change (farm level, regional level, national level)	Recommended feasible adaptation options to climate change	Identified limitations for adaptation options to climate change	Uncertainties, cost/benefits, risks (including economic risks), opportunities of adaptation options	Mitigation effects (assessment)
Crop farming dominated by cereals in dry/warm areas	N-E Austria	Marchfeld, Weinviertel	Maize growing production region (based on temperature sums and water balance)	Farm level Trends: Trend to bigger farms, reduced soil cultivation, change to different cultivars/crops; enhancing irrigation systems (increasing efficiency and decreasing energy consumption), shift in timing of field operations;	Alternative crops (e.g. soybean, more winter crops);	market price driven	partly increasing irrigation needs (soybean) with new crops new pest and diseases may occur	Positive: better use of the production potential without higher energy input could lead to less emissions per unit of output
					Change of field operations timing	shift to earlier dates could increase problems with soil wetness in spring	interactions with increasing frost risk (spring); higher costs due to higher flexibility	Positive: higher yield levels and stability increases production potential (see above)
					Enhancing irrigation systems and methods	No costs of water, still low energy costs, no low orders	High demand for capital in same cases where regional water resources management needs improved infrastructure; competition for precious water resources in relatively dry region	Positive, if appropriate irrigation leads to better use of N-fertilizer
					Reduced soil cultivation or minimum tillage (replacing ploughing) and mulching	Not suitable for all soils, limited water saving effect.	More problems with certain pest and weeds, partly more herbizides needed. Effective against soil erosion	Positive: lower need for fossil fuels; less soil erosion: reduced soil carbon losses

					Use of more drought and heat resistant cultivars	Existing cultivars are limited available	Only medium term measure (breeding)	Possitive: Better use of local production potential
					Improve pest and disease monitoring systems			More effective use of chemicals
					Change to ecological farming	labour costs, market price fluctuations	medium term measure; multiple positive effects	multiple positve effects on THGemissions
				Regional level	Improving landscape structures (landuse planning), e.g. more windbreaks or hedgerows	loss of productive areas	higher crop water use efficiency and yield, saving soil water reserves, Combination with biomass production is possible; increasing landscape attractivity	positive: Carbon storage in soils and biomass increased, less N-fertilization by decreasing fertilized area
					Regional Water conservation measures and water storage systems	e.g. protecting groundwater resources	high costs	
					crop diversification, adapting crop rotation (also on farm scale)	lower production risk against biotic and climatic damaging factors	higher costs	
					Water managment regulations between regions should be improved/introduced	regional competition on water resources	enhanced general water use efficiency	

Grassland farming in regions with limiting precipitation (in combination with dairy farming)	E-Austria, N-Austria	Bucklige Welt Mühlviertel	grassland and potatoe growing regions	Farm level: Structural change to bigger farms, intensification and specializations; combination with bioenergy (biogas) production as additional income source	alternative fodder crop production introduce perennial crops according to climatic conditions (orchards, vinyards, wood biomass) increase farm size and grass production area (to compensate lower area productivity) change from dairy to sheep farming (extensivication) combination with alternative incomes (e.g. tourism) adapt stables (against heat stress) and increase fodder storage capacity Regional Water conservation measures and water storage systems Strengthen market price stability of milk price	terrain (slopes) soil conditions, high investments in new infrastructure higher costs (machinery, energy) investments necessary, market availability inverstments necessary e.g. protecting groundwater resources	higher productivity possible; potential negative or positive effects on landscape functions (attractivity) forced by ongoing structural changes higher flexibilty to climatic extremes) high costs Allows better planning/lowering risks for adaptation options without change	negative: THG emssison increase by landuse change from grassland to crops possible without main change in landuse (only partly cultivated soil, except vineyards) higher use of fossile energy positive (less fossil energy use due to higher percentage of pastures)

				Regional level National level	Support drought insurance for grassland production systems		of farming system costs	
Perennial crops in current production regions (orchards, vineyards)	E and S Austria	Steiermark, Burgen-land	Maize and wine production regions (agroecological zones)	Farm level: changing wine cultivars, white to red wine varieties; change to ecological production; introduction of mulching systems; quality defintions by terroir descriptions (enhancing local identification)	Change of cultivars, change from white to red wine varieties Using mulching systems, protection against soil erosion adapted fertilization regime to drought conditions (optimizing N-fertilization, potassium) adapted crop management (vineyards) shift of phenology and timing of harvest and crop management measures Improving pest and disease management and monitoring/warning change to ecological	medium term measure adaptation in fertilization regime needed (timing, amount) additional effects on quality aspects (wine) several measures (e.g. leaf management) autonomous adaptation; potential multiple effects on quality aspects new pest/diseases needs continuous adaptation multiple positive	low investments low investments low investments low investments potential higher harvest costs, and labour costs (e.g. night time harvests)	positive: more effective use of fetilizers less use of chemicals positive: less fossil

					farming	effects (see above)		energy use, improved soil carbon storage
					Introducing/improving irrigation opportunities	investments needed, regional water resources limitation		
				Farm/regional	protection against hail and late frost damage	invest in relevant facilities and/or crop insurance		

2 - SPAIN

Table 2.1. List of identified vulnerable regions to climate change in Spain and their characteristics (expert assessment)

Dominating Agroeco-system	Geographical region	National name of region	Approx size of the region (km²)	Annual temperature, precip. and sea level of the region (from-to)	Dominating soil conditions (describe)	Irrigation applied and dominating type of irrigation	Topography of the region	Dominating LAND USE types and INTENSITY according toTable 3.3 (Refer to numbers of first column)	CLASSIFICATION of agroecosystem according to Table 7.2 and 7.3 (class numbers and proportion*)	Percent of organic farmers	Mean farm size, and dominating farm size (ha)
Barley and wheat	Northern Spanish Plateau	Castilla y León plataeu	60000	5-17 °C; 500-700mm; 700-1100m	Mean and light soils as Luvisols, Acrisols and Cambisols	No irrigation or occasional supplementary irrigation	mostly flat areas, some hills or small valleys	1 (intensity 1-2)	11(31)		16 >100
Summer crops	Tierra de Campos, Paramos, Tierras de Leon, Zamora	Valladolid, Palencia, Leon, Zamora, Salamanca	12000	6-19 °C; 400-500mm; 600-900m	Mean to clayey soils as Cambisols and Fluvisols	Flooding and sprinkler irrigation	Flat, close to rivers and channels	3 (intensity 2-3)	17(37)	10	5 25
Vineyards	Central plateau	Duero river catchment	2000	6-19 °C; 400-500mm; 600-900m	Light and sandy soils as Acrisols and Luvisols	Very controlled Drip or no irrigation	Flat, close to rivers and channels	4 (intensity 3)	16(36)		5 35

Table 2.2. List of identified vulnerable regions to climate change in Spain and their main limitation and trends (expert assessment)

Dominating Agroecosystem	Geographical region	National name of region	Main limitations	Observed trends	Socio-economic conditions and problems	Main identified vulnerabilities to climate change[1]
Barley and wheat	Northern Spanish Plateau	Castilla y León plataeu	Prices fluctuations, climate variability, CAP reform influences	Introducing conservation tillage, precision farming and new cultivars; farmers incorporation to cooperatives, promoting added values and agro-industry	Very aged farmers Countryside depopulation and farm abandoning. Income differences with industry and services	Increment of drought and heat waves frequencies, new and stronger pests and diseases
Summer crops	Tierra de Campos, Paramos, Tierras de Leon, Zamora, Salamanca	Valladolid, Palencia, Leon, Zamora, Salamanca	Prices fluctuations, CAP reform and WFD influences, freezes risk	Systems modernisation, increment of sprinkler area and water savings, Free on-line availability of Irrigation Advisory Systems	Very aged farmers and Countryside depopulation. Small farm sizes and large percent of land renting, limiting modernisation investments	New and stronger pests and diseases, water scarcity[2]
Vineyards	Central plateau	Duero river catchment (most important)	Prices fluctuations, CAP and Wine Market reform influences, freezes risk, pests and diseases risks	Highly input intensive agriculture, Strong agronomic control by Origin Signatures Corporations, linking with tourism	Very aged farmers and Countryside depopulation.	New and stronger pests and diseases, water scarcity[2], temperature increment[2]

[1] This identification was made through a survey applied to farmers.
[2] Not identified by farmers as a climate risk yet, but most of the Climate-Change assessments have pointed out that it could be an important climate limitation.

Table 1.3. Summary table on identified adaptation options in vulnerable regions and production systems in Spain

3 - BULGARIA

Table 3.1. List of identified vulnerable regions to climate change in Bulgaria and their characteristics (expert assessment)

Identified vulnerable agroecosystem	**..within geographical region**	**National name of region**	**Main vulnerabilities to climate change**
Vine farming/ Crop farming	Northwestern Bulgaria (NUTS2)	Severozapadna Bulgaria	Drought, frost, hail, dry winds
Crop farming/ Vine farming	Northern Bulgaria (NUTS2)	Severna Bulgaria	Drought, frost, hail, dry winds, heat waves
Crop farming Dominated by cereals	Northeastern Bulgaria (NUTS2)	Severoiztochna Bulgaria	Drought, frost, hail, dry winds, soil erosion, soil slide
Orchard farming	Southwestern Bulgaria (NUTS2)	Jugozapadna Bulgaria	Drought, frost, soil erosion, forest fires
Crop farming Dominated by vegetables	Southern Bulgaria (NUTS2)	Jujna Bulgaria	Drought, heat waves, hail, dry winds, soil erosion, intensive rain, flooding,
Crop farming/ Orchard farming	Southeastern Bulgaria (NUTS2)	Jugoiztochna Bulgaria	Drought, heat waves, hail, dry winds, soil erosion, intensive rain, flooding

Table 3.2. List of identified vulnerable regions to climate change in Bulgaria and their main limitation and trends (expert assessment)

Identified vulnerable agroecosystem	..within geographical region	Main limitations	Observed trends	Socio-economic conditions
Vine farming/ Crop farming	Northwestern Bulgaria (NUTS2)	higher farmer's age, inappropriate rural infrastructure; lack of modern irrigation systems and other machines, high cost of water	Slow change to bigger farms, Expectation of EU subsidies	Weak economic conditions, cheap labour cost, low efficiency and productivity
Crop farming/ Vine farming	Northern Bulgaria (NUTS2)	small farm size, higher farmer's age, inappropriate rural infrastructure; lack of modern irrigation systems and other machines, high cost of water	Slow change to bigger farms, Expectation of EU subsidies	Weak economic conditions, cheap labour cost, low efficiency and productivity
Crop farming Dominated by cereals	Northeastern Bulgaria (NUTS2)	higher farmer's age, inappropriate rural infrastructure; lack of modern irrigation systems and other machines, high cost of water	change to bigger farms, foreign investments	Weak economic conditions, cheap labour cost, low efficiency and productivity
Orchard farming	Southwestern Bulgaria (NUTS2)	Topography, small farm size, higher farmer's age, inappropriate rural infrastructure; lack of modern irrigation systems, high cost of water	Slow change to bigger farms, Expectation of EU subsidies	Weak economic conditions, cheap labour cost, low efficiency and productivity
Crop farming Dominated by vegetables	Southern Bulgaria (NUTS2)	higher farmer's age, inappropriate rural infrastructure; lack of modern irrigation systems and other machines, high cost of water	change to bigger farms, foreign investments	Weak economic conditions, cheap labour cost, low efficiency and productivity
Crop farming/ Orchard farming	Southeastern Bulgaria (NUTS2)	small farm size, higher farmer's age, inappropriate rural infrastructure; lack of modern irrigation systems and other machines, high cost of water	Slow change to bigger farms, Expectation of EU subsidies, foreign investments	Weak economic conditions, cheap labour cost, low efficiency and productivity

Table 3.3. Summary table on identified adaptation options in vulnerable regions and production systems in Bulgaria

Dominating Agroecosystem (as given in Del. 3-5 report)	**Geographical region**	**National name of region**	**Agroecosystem, related to common agroclimatic etc. indicators**	**Observed trends in adaptations to climate change (distinguish between farm level, regional level, national level)**	**Recommended feasible adaptation options to climate change**	**Identified limitations for adaptation options to climate change**	**Uncertainties, cost/benefits, risks (including economic risks), opportunities of adaptation options**	**Mitigation effects (assessment)**
Vine farming/ Crop farming	Northwestern Bulgaria (NUTS2)	Severozapadna Bulgaria	Climatic water balance; precipitation sums; GDD	No trend is observed	Dry resistant cultivars (>2020s) Drip irrigation	topographical limitations, farmer behaviour, legislation bareers;	higher costs for machinery; farmer incomes	**na**
Crop farming/ Vine farming	Northern Bulgaria (NUTS2)	Severna Bulgaria	Climatic water balance; precipitation sums; GDD	Earlier sowing, harvesting	Dry resistant cultivars (>2020s) Irrigation changes	topographical limitations, farmer behaviour, legislation bareers	change to other crops increases flexibility; higher costs for machinery; farmer incomes	**na**
Crop farming Dominated by cereals	Northeastern Bulgaria (NUTS2)	Severoiztochna Bulgaria	Climatic water balance; precipitation sums; GDD	Earlier sowing, harvesting	Dry resistant cultivars (>2020s) Irrigation changes	topographical limitations, farmer behaviour, legislation bareers	change to other crops increases flexibility; higher costs for machinery; farmer incomes	**na**
Orchard farming	Southwestern Bulgaria (NUTS2)	Jugozapadna Bulgaria	Climatic water balance; precipitation sums; GDD	No trend is observed	Dry resistant cultivars (>2020s) Drip irrigation	topographical limitations, farmer behaviour, legislation bareers	higher costs for machinery; farmer incomes	**na**
Crop farming Dominated by vegetables	Southern Bulgaria (NUTS2)	Jujna Bulgaria	Climatic water balance; precipitation sums; GDD	Earlier sowing, harvesting	Dry resistant cultivars (>2020s) Irrigation changes	topographical limitations, farmer behaviour, legislation bareers	change to fodder crops increases flexibility; higher costs for machinery; farmer incomes	**na**
Crop farming/ Orchard farming	Southeastern Bulgaria (NUTS2)	Jugoiztochna Bulgaria	Climatic water balance; precipitation sums; GDD	Earlier sowing, harvesting	Dry resistant cultivars (>2020s) Irrigation changes	topographical limitations, farmer behaviour, legislation bareers	change to fodder crops increases flexibility; higher costs for machinery; farmer incomes	**na**

4 - SERBIA

Table 4.1. List of identified vulnerable regions to climate change in Serbia and their characteristics (expert assessment)

Dominating Agroeco-system (can be completed)	**Geographical region**	**National name of region**	**Approx size of the region (km²)**	**Annual temperature, precip. and sea level of the region (from-to)**	**Dominating soil conditions (describe)**	**Irrigation applied and dominating type of irrigation**	**Topography of the region**	**Dominating LAND USE types and INTENSITY according toTable 3.3 (Refer to numbers of first column)**	**CLASSIFICATION of agroecosystem according to Table 7.2 and 7.3 (class numbers and proportion*)**	**Percentage of organic farmers**	**Mean farm size, and dominating farm size (ha)**
Orchards - apple	Fruška gora	Fruškogorski rejon	13.36	10,9 °C/ 641 mm/ 155 m/	Gajnjaca	None	Hilly region	20 Horticulture 1. Apple 36.4% (intesity 2) 2. Peach 32.2% (intesity 2) 3. Pear 22.3% (intesity 2)		0	Mean: 4ha Dominating: 2ha
Orchards - apple	Bela Crkva	Belocrkvanski rejon	6.19	11,5 °C/ 656 mm/ 84 m/	Gajnjaca i smonica	Drip irrigation	Flat to mild hilly	20 Horticulture 1. Apple 55.4% (intesity 2) 2. Peach 21.5% (intesity 2) 3. Pear 14.9% (intesity 2)		0	Mean: 8ha Dominating: 4ha
Orchards - apple	Subotica	Subotičko-horgoški rejon	14.93	10,7 °C/ 537 mm/ 102 m	Sandy soil	Drip irrigation	Flat	20 Horticulture 1. Apple 78.2% (intesity 2) 2. Apricot 6.2% (intesity 2) 3. Pear 5.3% (intesity 2)		0	Mean: 8ha Dominating: 4ha
Orchards – raspberry	Arilje	Arilje	349	9 – 10.5 ^{0}C 743 mm 330-1382	Light soil with small water capacity, good drenaige	None	Hilly region with nice valleies close to the rivers Moravica and Veliki Rzav	first – 3 second – 6 third - 20	first – 42 second - 44	0%	meat – 4 ha dominatio n – 2 ha

Crop farming dominated by cereals	Northern Vojvodina	Northern Bačka, Northern Banat	20000	9.5 to 12 ^{o}C Mean 11 ^{o}C 350 to 850 mm Mean 550 mm 70-90 m	Light sandy soils (Bačka) Heavier soils soils (Banat) with good soil water capacity	No irrigation	Flat region	First: 3 (intensity 1) Second: 4 (intensity 2)	First: 11 (ca.60%); Second : 15 (ca. 25%); Third : 16 (ca. 15%)	0,1 %	Mean: 3.6 ha, dominating : 1-3ha
Crop farming dominated by maize	Southern Vojvodina	Southern Bačka and Srem	7000	9.5 to 12 ^{o}C Mean 11 ^{o}C 450 to 950 mm Mean 600 mm 70-150 m	High quality soils, černozem with good soil water capacity	No irrigation	Flat region	First: 3 (intensity 2) Second: 4 (intensity 2)	First : 15 (ca.60%); Second : 11 (ca. 20%); Third : 16 (ca. 20%)	0,1 %	Mean: 3.6 ha, dominating : 1-3ha
Crop farming dominated by vegetables	Southern Vojvodina	Southern Bačka, Southern Banat	10000	9.5 to 12,5 ^{o}C Mean 11 ^{o}C 450 to 950 mm Mean 650 mm 70-90 m	High quality soils, černozem with good soil water capacity	Less then 3 %	Flat region	First: 3 (intensity 3) Second: 4 (intensity 2)	First : 17 (ca.5%); Second : 16 (ca. 35%); Third : 15 (ca. 60%)	0,1 %	Mean: 3.6 ha, dominating : 1-3ha

Table 4.2. List of identified vulnerable regions to climate change in Serbia and their main limitation and trends (expert assessment)

Dominating Agroecosystem	**Geographical region**	**National name of region**	**Main limitations**	**Observed trends**	**Socio-economic conditions and problems**	**Main identified vulnerabilities to climate change**
Orchards - apple	Fruška gora	Fruškogorski rejon	Small farm size	More intensive fruit production	Weak economic conditions of small farms, limitted storage capacities, placement problem	Large amplitude of daily temperature during vegetation period, frequency and intensity of spring frost, amount and distribution of precipitation during egetation period, hail, temperature fluctuations during winter period, high summer temperatures and drought
Orchards - apple	Bela Crkva	Belocrkvanski rejon		Change from crop to fruit production	Weak economic conditions of small farms, limitted storage capacities, placement problem	low winter temperatures, late spring frosts, hail, temperature fluctuations during winter period, high summer temperatures and drought
Orchards - apple	Subotica	Subotičko-horgoški rejon		Change from crop to fruit production	Weak economic conditions of small farms, limitted storage capacities, placement problem	low winter temperatures, late spring frosts, hail, temperature fluctuations during winter period, high summer temperatures and drought
Orchards – raspberry	Arilje	Arilje	Topography (hilly), small farm size	Introduction of new fruits – blackbarry, hucklebarry	Weak economic conditions of small farms, limitted storage capacities, placement problem	low winter temperatures, late spring frosts, hail, temperature fluctuations during winter period, high summer temperatures and drought
Crop farming dominated by cereals	Northern Vojvodina	Northern Bačka, Northern Banat	- Small farms - No irrigation	- Farm size expansion - Increasing numbers of organic farmers	Unstable agro economic policy. Without clear development strategy	Drought during spring and summer Decreasing winter precipitation Weather storms.
Crop farming dominated by maize	Southern Vojvodina	Southern Bačka and Srem	- Small farms - No irrigation	- Joining farmers to association - Development of cattle breeding	No strategy of agro industry and cattle breeding development	Drought during summer Decreasing winter precipitation Weather storms.
Crop farming dominated by vegetables	Southern Vojvodina	Southern Bačka, Southern Banat	-Small farms -Weak irrigation	- Joining farmers toassociation, - Organizing local stock market for vegetables	Weak financial potential of people. Chaotic market of vegetables.	Drought and high temperatures during summer. Weather storms.

Table 4.3. Summary table on identified adaptation options in vulnerable regions and production systems in Serbia

Dominating Agroecosystem (as given in Del. 3-5 report)	**Geographical region**	**National name of region**	**Agroecosystem, related to common agroclimatic etc. indicators**	**Observed trends in adaptations to climate change (distinguish between farm level, regional level, national level)**	**Recommended feasible adaptation options to climate change**	**Identified limitations for adaptation options to climate change**	**Uncertainties, cost/benefits, risks (including economic risks), opportunities of adaptation options**	**Mitigation effects (assessment)**
Orchards	Fruška gora	Fruškogorski rejon		farm: regional: plans for regional irrigation system national: more anti-hail nets covers (shade benefits)	**Farms (current climate):** Adoptation of Integrated Fruits Production **Regional (current climate):** hail nets	High introducing costs High costs	Less costs for plant protection, nutrition, added value Reduced production risks, more maschinery needed	**Negative: /** **Positive:** Enviromental benefits, less water used **Negative: /** **Positive:/**
	Bela Crkva	Belocrkvanski rejon		farm: regional: more anti-hail nets covers (shade benefits) national: more anti- hail nets covers (shade benefits)	**Farms (current climate):** Adoptation of Integrated Fruits Production **Regional (current climate):** hail nets	High introducing costs High costs	Less costs for plant protection, nutrition, added value Reduced production risks, more maschinery needed	**Negative: /** **Positive:** Enviromental benefits, less water used **Negative: /** **Positive:/**
	Subotica	Subotičko-horgoški rejon		farm: regional: bare soil system in orchards, moving orchards to less light soils	**Farms (current climate):** Adoptation of Integrated Fruits Production **Farms (>2008):** enhancement of	High introducing costs Manure needed	Less costs for plant protection, nutrition, added value Benefits only in case of optimal application	**Negative: /** **Positive:** Enviromental benefits, less water used **Negative:** higher N2O emissions

				national: more anti- hail nets covers (shade benefits)	organic contents in soils **Regional (current climate):** hail nets	 High costs	date Reduced production risks, more maschinery needed	**Positive:** More stable sand light soils **Negative: /** **Positive:/**
	Arilje	Arilje		farm: regional: no response to climatic changes national:	**Farms (current climate and beyond):** Alternative, earlier species and table cultivars	Undeveloped market	Higher fruits proces	**Negative:** More intensive cultivation **Positive:**
Crop farming dominated by cereals	Northern Vojvodina	Northern Bačka, Nortern Banat		Decrease land under wheat and increase land under barley and triticale Increase farmers interest for climatic changes Enhance farmers interest for expert advices Insufficient help by government Greater involvement of experts and advisory services	• Optimal soil cultivation time • Optimal sowing time • Optimal plant density per area unit • Judicious use of NPK fertilizers • Maintenance of good plant health • Incorporatio n of plant residues into the soil	• Farmers income • Unfavorable bank credits • Non existence of subventions for plant production • Unsure cereal market • Unfinished privatization of food industry • Non existence of national adaptation strategy • Great number of farms is out of advisory service programs • Old machinery	• Suggested measures of adaptation do not increase production expenses • Application of these measures would increase production stability • Farmers do not have influence on prices of input or output • Association of farmers is very slow • Crisis in animal production is also a problem	• Adaptation measures should improve soil fertility • Judicious fertilizing of cereals will decrease soil, water and food pollution
Crop farming dominated	Southern Vojvodina	Southern Bačka and Srem		Greater percentage of early cultivars in sowing structure	• Use of plant rotation (example: maize sown after	• Farmers income • Non existence	• Crisis in animal production decreases local corn	• More frequent interrow cultivation expedite organic matter

by maize				Increase plant density per unit area Quicker adjustment of big farms to adaptation measures Enhance farmers interest for expert advices Insufficient help by government	cereals) • Plant residues incorporation with nitrogen application • Decrease of plant density per unit area in dry plant growing systems • Judicious use of NPK fertilizers • Optimal time and quality of seedbed preparation and sowing	of subventions for plant production • Still great density of weeds on arable land • Old machinery reduces soil cultivation quality • Scarce information of the farmers	prices • Great variation of income prices increases economical risks • Corn is more often devastated by summer drought or hail	mineralization, so there is need for incorporating organic matter under corn • Use of corn for ethanol production will change growing technology • Farmers cooperation is at very low level • Burning of organic matter (increasing CO_2 concentration)
Crop farming dominated by vegetables	Southern Vojvodina	Southern Bačka, Southern Banat		Increase farmers interest for climatic changes Rapid construction and application of irrigation systems Introduction of new plant cultivars Improvement of technical discipline Application of modern pesticides	• Introduction of alternative species in the production • Greater use of organic fertilizers • Judicious use of NPK fertilizers (Nitrogen control) • Maintaining good health of plants • Good water management	• Unreliable incomes • Undeveloped refining industry • Haotic market coditions • Great number of small farms, pulverised production • Insufficient number of special machinery • Insufficient production of manure	• Uncertain placement of agricultural products on market (cabbage, potato) • Uncontrolled import of vegetable • High farmer dependence from trade sector	• Vegetable production is the most intensive production with highest accumulation and financial effects • Raised temperatures and irrigation will enhance quality of many vegetable products (tomato, pepper, onion, etc.)

5 – CZECH REPUBLIC

Table 5.1. List of identified vulnerable regions to climate change in Czech Republic and their characteristics (expert assessment)

Dominating Agroeco-system (can be completed)	**Geographical region**	**National name of region**	**Approx size of the region (km²)**	**Annual temperature, precip. and sea level of the region (from-to)**	**Dominating soil conditions (describe)**	**Irrigation applied and dominating type of irrigation**	**Topography of the region**	**Dominating LAND USE types and INTENSITY according toTable 3.3 (Refer to numbers of first column)**	**CLASSIFICATION of agroecosystem according to Table 7.2 and 7.3 (class numbers and proportion*)**	**Percentage of organic farmers**	**Mean farm size, and dominating farm size (ha)**
Crop farming dominated by cereals (Maize, wheat)	South-east Czechia (Region 1)	Znojmo & Břeclav	2800	8.7 – 9.2 °C 470-490 mm 150-300 m	Fluvisoils, chernozems mixed with lower quality soils locally	Limited irrigation (not used for field crops)	In some regions rather complex topography. Most of arable land in flat areas	First: 1 (intensity 2) First: 4 (intensity 2) First: 11 (intensity 2) First: 15 (intensity 2)	First 46 (ca.60%) Second 43 (40%)	1.6%	Mean : 80 Dominating > 500 ha
Crop farming dominated by cereals (sugar-beet, barley, wheat)	Central-East (Region 2)	Kroměříž & P5erov	2000	8.4 – 8.7 °C 605-650 mm 200-350 m	Fluvisoils, chernozem – high quality soil	Limited irrigation (not used for field crops)	In some regions rather complex topography. But almost entire arable land in flat areas	First: 1 (intensity 2) First: 4 (intensity 2) First: 11 (intensity 2) First: 15 (intensity 2)	First 46 (ca.60%) Second 43 (40%)	7.5%	Mean : 80 Dominating > 500 ha
Crop farming dominated by cereals (forage crops, barley, wheat, potato,)	Central-West (Regeion 3)	Žďár & Jihlava	3000	6.8 °C 605-650 mm 400-800 m	Brown soils and cambisoils with shallow profiles and rel. High acidity	Not used	Complex topography with areas prone to soil erosion	First: 1 (intensity 2) First: 4 (intensity 2) First: 11 (intensity 2) First: 15 (intensity 2)	First 46 (ca.60%) Second 43 (30%) Third 42 (10%)	1%	Mean : 80 Dominating > 500 ha

Table 5.2. List of identified vulnerable regions to climate change in Czech Republic and their main limitation and trends (expert assessment)

Dominating Agroecosystem (as given in Del. 3-5 report)	**Geographical region**	**National name of region**	**Agroecosystem, related to common agroclimatic etc. indicators**	**Observed trends in adaptations to climate change (distinguish between farm level, regional level, national level)**	**Recommended feasible adaptation options to climate change**	**Identified limitations for adaptation options to climate change**	**Uncertainties, cost/benefits, risks (including economic risks), opportunities of adaptation options**	**Mitigation effects (assessment)**
Crop farming Dominated by cereals in dry/warm areas	Region 1	Znojmo, Břeclav	Maize growing production region (based on temperature sums and water balance)	Structural change to bigger farms and less labor intensive activities, Focus on other more drought resistant crops e.g. sunflower; irrigation consideration; shift in timing of field operations;	Alternative crops (e.g. soybean);	Lack of expertise and lack of demand;	Need for new markets; higher vulnerability to management errors	Positive: better use of the production potential per unit of energy Negative: risk associated with previously unknown crops or technologies;
					Change of field operation timing	Time pressure on the availability of machinery at the right time.	More uneven spread of machinery use (less efficient)	Possitive: relatively low cost and enables adaptation to all farmers;
					Irrigation	Underfunded infrastructure and limited water sources;	High demand for capital (state subvences?) and depended on water	Possitive: higher yield levels and stability Negative: competition for precious water resources in relatively dry region
					Minimum tillage, mulching	Not suitable for all soils and cannot yield significant portion of water (but still attractive for farmers;	Tillage techniques have only limited ability to improve water balance	Possitive: lower need for fossil fuels; Negative: potential for higher survival of

								some pests
					Drought resistant cultivars	Only limited benefit (but still attractive for farmers as it requires no other change of behavior);	Only unconvincing evidence of suitable cultivars	Possitive: almost no need to change present technology; Negative: might be "trap" – relying on unreliable product
					Climate risk insurance	Would partly insulate famers from effects of climate change;	State intervention needed.	Possitive: more security for farmers; Negative: less proactive behavior in damage mitigation when crops are insured;
Crop farming Dominated by cereals in wet/warm areas	Region 2	Přerov, Olomouc	Sugar beet growing production region (based on temperature sums and water balance)	Ongoing increase of farm size with highly innovative technology (e.g. precise farming); focus on high quality production; high demand for new more weather tolerant cultivars; minimum tillage; shift to alternative sources of income (agrotourism)	Alternative crops (e.g. grain maize, vineyard);	Lower profitability and higher yield variability	Need for new markets; higher vulnerability of yields and lower profit margins	Positive: better use of the production potential per unit of energy under given climate conditions
					Change of field operation timing	Time pressure on the availability of machinery at the right time.	More uneven spread of machinery use (less efficient)	Positive: relatively low cost and enables adaptation to all farmers;
					Irrigation	Underfunded infrastructure and limited water sources;	High demand for capital (state subvences?) and depended on water;	Possitive: higher yield levels and stability Negative: competition

								for precious water resources in relatively dry region
					Minimum tillage, mulching	Not suitable for all soils and cannot yield significant portion of water (but still attractive for farmers;	Tillage techniques have only limited ability to improve water balance	Possitive: lower need for fossil fuels; Negative: potential for higher survival of some pests
					Drought resistant cultivars	Only limited benefit (but still attractive for farmers as it requires no other change of behavior);	Only unconvincing evidence of suitable cultivars	Possitive: almost no need to change present technology; Negative: might be "trap" – relying on unreliable product
					Climate risk insurance	Would partly insulate famers from effects of climate change;	State intervention needed.	Positive: more security for farmers; Negative: less proactive behavior in damage mitigation when crops are insured;
Crop farming Dominated by cereals in wet/cool areas	Region 3	Žďár n/S; Havlíčků v Brod	Cereal growing production region (based on temperature sums and water balance)	Ongoing increase of farm size; extensification of the production; Shift from the production to other agro-bussiness activities e.g. Higher prevalence of organic farms and agro-tourism.	Alternative crops (e.g. sugar beet, bionergy biomass plantations etc.);	In many cases untested technologies	Need for new markets; even worse predictability of profit margins	Positive: better use of the production potential per unit of energy under given climate conditions; Possible CO_2 sequestration strategy

					Change of field operation timing	Time pressure on the availability of machinery at the right time.	More uneven spread of machinery use (less efficient)	Positive: relatively low cost and enables adaptation to all farmers;
					Irrigation (only in some years)	No infrastructure but potential available water sources;	High demand for capital (state subvences?) probably unprofitable	Possitive: higher yield
					Drought/Frost resistant cultivars	Only limited benefit (but still attractive for farmers as it requires no other change of behavior);	Only unconvincing evidence of suitable cultivars and tradeoff between cultivar high resistance and low productivity and/or quality	Possitive: almost no need to change present technology; Negative: might be "trap" – relying on unreliable product
					Climate risk insurance	Would partly insulate famers from effects of climate change;	State intervention needed.	Positive: more security for farmers; Negative: less proactive behavior in damage mitigation when crops are insured;

Table 5.3. Summary table on identified adaptation options in vulnerable regions and production systems in Czech Republic

Dominating Agroecosystem (as given in Del. 3-5 report)	**Geographical region**	**National name of region**	**Agroecosystem, related to common agroclimatic etc. indicators**	**Observed trends in adaptations to climate change (distinguish between farm level, regional level, national level)**	**Recommended feasible adaptation options to climate change**	**Identified limitations for adaptation options to climate change**	**Uncertainties, cost/benefits, risks (including economic risks), opportunities of adaptation options**	**Mitigation effects (assessment)**
Crop farming Dominated by cereals in dry/warm areas	Region 1	Znojmo, Břeclav	Maize growing production region (based on temperature sums and water balance)	Structural change to bigger farms and less labor intensive activities, Focus on other more drought resistant crops e.g. sunflower; irrigation consideration; shift in timing of field operations;	Alternative crops (e.g. soybean);	Lack of expertise and lack of demand;	Need for new markets; higher vulnerability to management errors	Positive: better use of the production potential per unit of energy Negative: risk associated with previously unknown crops or technologies;
					Change of field operation timing	Time pressure on the availability of machinery at the right time.	More uneven spread of machinery use (less efficient)	Possitive: relatively low cost and enables adaptation to all farmers;
					Irrigation	Underfunded infrastructure and limited water sources;	High demand for capital (state subvences?) and depended on water	Possitive: higher yield levels and stability Negative: competition for precious water resources in relatively dry region
					Minimum tillage, mulching	Not suitable for all soils and cannot yield significant portion of water (but still attractive for farmers;	Tillage techniques have only limited ability to improve water balance	Possitive: lower need for fossil fuels; Negative: potential for higher survival of some pests

					Drought resistant cultivars	Only limited benefit (but still attractive for farmers as it requires no other change of behavior);	Only unconvincing evidence of suitable cultivars	Possitive: almost no need to change present technology; Negative: might be "trap" – relying on unreliable product
					Climate risk insurance	Would partly insulate famers from effects of climate change;	State intervention needed.	Possitive: more security for farmers; Negative: less proactive behavior in damage mitigation when crops are insured;
Crop farming Dominated by cereals in wet/warm areas	Region 2	Přerov, Olomouc	Sugar beet growing production region (based on temperature sums and water balance)	Ongoing increase of farm size with highly innovative technology (e.g. precise farming); focus on high quality production; high demand for new more weather tolerant cultivars; minimum tillage; shift to alternative sources of income (agrotourism)	Alternative crops (e.g. grain maize, vineyard);	Lower profitability and higher yield variability	Need for new markets; higher vulnerability of yields and lower profit margins	Positive: better use of the production potential per unit of energy under given climate conditions
					Change of field operation timing	Time pressure on the availability of machinery at the right time.	More uneven spread of machinery use (less efficient)	Positive: relatively low cost and enables adaptation to all farmers;
					Irrigation	Underfunded infrastructure and limited water sources;	High demand for capital (state subvences?) and depended on water;	Possitive: higher yield levels and stability Negative: competition for precious water

								resources in relatively dry region
					Minimum tillage, mulching	Not suitable for all soils and cannot yield significant portion of water (but still attractive for farmers;	Tillage techniques have only limited ability to improve water balance	Possitive: lower need for fossil fuels; Negative: potential for higher survival of some pests
					Drought resistant cultivars	Only limited benefit (but still attractive for farmers as it requires no other change of behavior);	Only unconvincing evidence of suitable cultivars	Possitive: almost no need to change present technology; Negative: might be "trap" – relying on unreliable product
					Climate risk insurance	Would partly insulate famers from effects of climate change;	State intervention needed.	Positive: more security for farmers; Negative: less proactive behavior in damage mitigation when crops are insured;
Crop farming Dominated by cereals in wet/cool areas	Region 3	Žďár n/S; Havlíčků v Brod	Cereal growing production region (based on temperature sums and water balance)	Ongoing increase of farm size; extensification of the production; Shift from the production to other agro-bussiness activities e.g. Higher prevalence of organic farms and agro-tourism.	Alternative crops (e.g. sugar beet, bionergy biomass plantations etc.);	In many cases untested technologies	Need for new markets; even worse predictability of profit margins	Positive: better use of the production potential per unit of energy under given climate conditions; Possible CO2 sequestration strategy

					Change of field operation timing	Time pressure on the availability of machinery at the right time.	More uneven spread of machinery use (less efficient)	Positive: relatively low cost and enables adaptation to all farmers;
					Irrigation (only in some years)	No infrastructure but potential available water sources;	High demand for capital (state subvences?) probably unprofitable	Possitive: higher yield
					Drought/Frost resistant cultivars	Only limited benefit (but still attractive for farmers as it requires no other change of behavior);	Only unconvincing evidence of suitable cultivars and tradeoff between cultivar high resistance and low productivity and/or quality	Possitive: almost no need to change present technology; Negative: might be "trap" – relying on unreliable product
					Climate risk insurance	Would partly insulate famers from effects of climate change;	State intervention needed.	Positive: more security for farmers; Negative: less proactive behavior in damage mitigation when crops are insured;

6 - ITALY

Table 6.1. List of identified vulnerable regions to climate change in Italy and their characteristics (expert assessment)

Dominating Agroeco-system	Geographical region	National name of region	Approx size of the region (km²)	Annual temperature, precip. and sea level of the region (from-to)	Dominating soil conditions (describe)	Irrigation applied and dominating type of irrigation	Topography of the region	Dominating LAND USE types and INTENSITY according toTable 3.3 (Refer to numbers of first column)	CLASSIFICATION of agroecosystem according to Table 7.2 and 7.3 (class numbers and proportion*)	Percentage of organic farmers	Mean farm size, and dominating farm size (ha)
Grassland	Northern Italy	Emilia Romagna (22000 km^2)	8500	8-17°C; 700-1200 mm; 20-2000 m	Deep soils with good soil water capacity, calcareous	No/Supplemental irrigation	hilly region mixed with flat areas (Pianura Padana)	First: 5 (intensity 2) Second: 16 (intensity 3) Third: 9 (intensity 2)	First : 44 (ca.60%); Second : 42 (ca. 20%); Third : 45 (ca. 20%)	12 %	Mean : 6 ha, dominating : 5-10ha
	Southern Italy	Puglia and Basilicata (29000 km^2)	2800	10-20°C; 400-700 mm; 20-2200 m	From loam to clay, silt deep soils	No irrigation	hilly region mixed with flat areas (Tavoliere)	First: 5 (intensity 2) Second: 9 (intensity 2)	First : 44 (ca.70%); Second : 45 (ca. 30%)	15 %	Mean : 6 ha, dominating : 5-10ha
Orchards	Northern Italy	Emilia Romagna	1900	8-17°C; 700-1200 mm; 20-2000 m	Loam-Clay soils, good fertility and soil water capacity	Localized irrigation	hilly region mixed with flat areas (Pianura Padana)	20 (intensity 2 – 3)	17	3 %	Mean : 3 ha, dominating : 3-5ha
	Southern Italy	Puglia and Basilicata	2200	10-20°C; 400-700 mm; 20-2200 m	From sand to clay soils	No irrigation/ Sprinkler localized irrigation	hilly region mixed with flat areas (Tavoliere and Arco Jonico)	20 (intensity 1 – 3)	17 (ca. 60%) 11 (ca. 20%) 13 (ca. 20%)	4 %	Mean : 1.5 ha, dominating : 1-2ha
Vineyards	Southern Italy	Puglia and Basilicata	1200	10-20°C; 400-700 mm; 20-2200 m	From sand to clay soil	Sprinkler localized irrigation	hilly region mixed with flat areas (Tavoliere and Arco Jonico)	20 (intensity 1 – 3)	17 (ca. 60%) 11 (ca. 20%) 13 (ca. 20%)	4 %	Mean : 1 ha, dominating : 1-2ha

Crop farming dominated by cereals and industrial crops	Northern Italy	Emilia Romagna	4800	8-17°C; 700-1200 mm; 20-2000 m	Clay soils, limited drainage, shallow groundwater	Supplemental irrigation (sprinkler)	hilly region mixed with flat areas (Pianura Padana)	First: 1 (intensity 1) Second: 2 (intensity 1-2) Third: 3 (intensity 2)	First: 11 (ca. 40%) Second: 11 (ca. 10%) Third: 17 (ca. 50%)	2 %	Mean: 7 ha Dominating: 5-10 ha
	Southern Italy	Puglia and Basilicata	5400	10-20°C; 400-700 mm; 20-2200 m	Deep soil, clay, clay-loam, good soil ater capacity	No irrigation; localized for tomato	hilly region mixed with flat areas (Tavoliere)	First: 1 (intensity 1) Second: 2 (intensity 1-2) Third: 3 (intensity 2)	First: 11 (ca. 50%) Second: 2 (ca. 10%) Third: 17 (ca. 40%)	3 %	Mean: 6 ha Dominating: 5-10 ha
Crop farming dominated by vegetables	Northern Italy	Emilia Romagna	800	8-17°C; 700-1200 mm; 20-2000 m	Loam soils, limited drainage, shallow groundwater	Sprinkler or localized irrigation	Flat areas (Pianura Padana)	3 (intensity 2)	17	4 %	Mean: 4 ha Dominating: 3-5 ha
	Southern Italy	Puglia and Basilicta	1500	10-20°C; 400-700 mm; 20-2200 m	Light and shallow soils with limited water retention	Localized irrigation	Flat areas (Tavoliere and Arco Jonico)	3 (intensity 2-3)	17	4 %	Mean: 1.5 ha Dominating: 1-3 ha

Table 6.2. List of identified vulnerable regions to climate change in Italy and their main limitation and trends (expert assessment)

Dominating Agroecosystem (can be completed)	**Geographical region**	**National name of region**	**Main limitations**	**Observed trends**	**Socio-economic conditions and problems**	**Main identified vulnerabilities to climate change**
Grassland	Northern Italy	Emilia Romagna (22000 km^2)	Topography (hilly), soil erosion, small farm size;	Structural change to bigger farms, change to ecological farming; irrigation as norma practice (alfalfa)	Weak economic conditions of small farms; rural depopulation (hilly zones)	Grassland drought; reduction of summer yield; water availability for irrigation
	Southern Italy	Puglia and Basilicata (29000 km^2)	Topography (hilly), soil erosion, small farm size	Structural change to bigger farms, change to ecological farming	Weak economic conditions of small farms; rural depopulation (hilly zones)	Grassland drought, soil erosion.
Orchards	Northern Italy	Emilia Romagna	Availability and cost of water resources; lowering of soil water table depth	Increment of high quality production; modernization of irrigation method (low pressure); structural change to bigger farms	High work load and labour cost; variability of annual income	water availability for irrigation; shortening of phenological phases; spring late freezing; damages by heat waves on yield and quality
	Southern Italy	Puglia and Basilicata	Availability and cost of water resources; Salinization of coastal areas	Increment of high quality production, structural change to bigger farms	High work load and labour cost; variability of annual income	Water availability for irrigation; Shortening of phenological phases; Increment or new risk of pest and diseases
Vineyards	Southern Italy	Puglia and Basilicata	Availability and cost of water resources; Salinization of coastal areas; lowering of soil water table depth	Increment of high quality production; intensive cropping systems; structural change to bigger farms	High work load and labour cost; very high variability of annual income; high economical investment	Water availability for irrigation; Shortening of phenological phases; damages by heat waves on yield and quality
Crop farming dominated by cereals and industrial crops	Northern Italy	Emilia Romagna	Availability and cost of water resources (for spring/summer crops); lowering of soil water table depth	Substitution of soft wheat by winter wheat; normal irrigation for maize; drip irrigation for tomato; mechanical harvest (tomato)	Intensive crop rotation; uncertainty about crop choice	Shortening of crop cycle; increase of evapotraspirative demand of the atmosphere; Increment or new risk of pest and diseases; spring late

						freezing; damages by heat waves on yield and quality
	Southern Italy	Puglia and Basilicata	Availability and cost of water resources (for spring/summer crops) Salinization of coastal areas	Increase of durum wheat cultivation because of high prices	Intensive crop rotation; uncertainty about crop choice	Increment or new risk of pest and diseases; damages by heat waves on yield and quality (tomato)
Crop farming dominated by vegetables	Northern Italy	Emilia Romagna	Availability and cost of water resources (for spring/summer crops)	Increment of localized irrigation	Variability of annual income; high economical investment	Shortening of crop cycle; Increment or new risk of pest and diseases; damages by heat waves on yield and quality (summer crops)
	Southern Italy	Puglia and Basilicata	Availability and cost of water resources (for spring/summer crops); Salinization of coastal areas	Increment of high quality production; structural change to bigger farms	Variability of annual income; high economical investment	Shortening of crop cycle; Increment or new risk of pest and diseases; damages by heat waves on yield and quality (summer crops)

Table 6.3. Summary table on identified adaptation options in vulnerable regions and production systems in Italy

Dominating Agroecosystem (as given in Del. 3-5 report)	**Geographical region**	**National name of region**	**Agroecosystem, related to common agroclimatic etc. Indicators (see table of indicators)**	**Observed trends in adaptations to climate change**	**Recommended feasible adaptation options to climate change**	**Identified limitations for adaptation options to climate change**	**Uncertainties, cost/benefits, risks (including economic risks), opportunities of adaptation options**	**Mitigation effects (assessment)**
Grassland	Northern Italy	Emilia Romagna (22000 km^2)	**TP,PA** SPI, WBC, ΔT°C	Farm: earlier cutting dates; irrigation as normal practice (alfalfa) Regional-National: Structural change to bigger farms, change to ecological farming.	>2008 farm More extensive production Earlier cutting dates Scheduled irrigation Fertilization	Farmers income Water availability	Milk price	**positive:** less manures produced (lower N_2O emissions) **negative**: if grassland is changed to arable land
					>2020 farm Alternative fodder crops	Topography (hilly) Soil erosion Small farm size	Change to fodder crops increases flexibility; Higher costs for machinery Highly sensitivity to milk price	
	Southern Italy	Puglia and Basilicata (29000 km^2)	**TP,PA** SPI, WBC, ΔT°C	Farm: earlier cutting dates; irrigation as normal practice (alfalfa) Reg.National: Structural change to bigger farms Change to ecological farming	>2008 Farm Fertilization	Farmers income	Milk price	**positive:** less manures produced (lower N_2O emissions) **negative**: if grassland is changed to arable land
					>2020 Farm Alternative fodder crops	Topography (hilly) Soil erosion Small farm size	Change to fodder crops increases flexibility; Higher costs for machinery; Highly sensitivity to milk price	
Orchards	Northern Italy	Emilia Romagna	**TP,PA** SPI, WBC, ΔT°C **ND_30,**	Farm – Reg: Increment of high quality production Modernization of irrigation method	>2008 Farm Irrigation scheduling and fertirrigation Controlled grassing PDW manag	Availability and cost of water resources Lowering of soil water table depth	Increase of productive stability Uncontrolled import of products	Growing grass in orchards is positive for protection and soil fertility Reduction of N_2O are

			ND_35	(low pressure); Structural change to bigger farms	Irrigation system change			expected with optimized fertilization
					>2020 Farm - Regional New varieties Enhancement irrigation network and scheduling; Precision agriculture Remote sensing	Economic availability		
	Southern Italy	Puglia and Basilicata	**TP,PA** SPI, WBC, ΔT°C **ND_30,** **ND_35**	Farm-Reg: Increment of high quality production Structural change to bigger farms	>2008 Farm Irrigation scheduling and fertirrigation; Controlled grassing PDW manag	Availability and cost of water resources Salinization of coastal areas	Increase of productive stability Uncontrolled import of products	Growing grass in orchards is positive for protection and soil fertility Reduction of N_2O are expected with optimized fertilization
					>2020 Farm Regional New varieties Ehancement irrigation network and scheduling; Using urban water; Precision agriculture Remote sensing	Economic availability Lack of public organization		
Vineyards	Southern Italy	Puglia and Basilicata	**TP,PA** SPI, WBC, ΔT°C **ND_30,** **ND_35** HI SD FD MD	Farm-Reg: Increment of high quality production; Intensive cropping systems Structural change to bigger farms	>2008 Farm Irrigation scheduling and fertirrigation; PDW manag Advanced harvest	Availability and cost of water resources; Salinization of coastal areas; lowering of soil water table depth	Increase of productive stability No control for farmers on prices products	Reduction of N_2O are expected with optimized fertilization
					>2020 Farm Regional New varieties Enhancement irrigation network and scheduling; using urban water; Precision agriculture Remote sensing	Economic availability Lack of public organization		
Crop farming dominated by cereals and industrial	Northern Italy	Emilia Romagna	**TP,PA** SPI, WBC, ΔT°C **ND_30,** **ND_35**	Farm: Substitution of soft wheat by winter wheat Normal irrigation for maize	>2008 (possible) Farm Sowing/transplanting time; Varieties/species; Change from summer to winter crop (cereals)	Availability and cost of water resources (for spring/summer crops)	Not necessarily increase production expenses; increase of productive stability	Positive effects on C sequestration are expected by minimum or conservative tillage benefits in terms of N2O emission are

crops				Drip irrigation for tomato Mechanical harvest (tomato)	Irrigation scheduling; Conservation soil water; PDW manag Drip, LEPA and ULDI irrigation for tomato;			questionable. Reduction of N_2O are expected with optimized fertilization
					>2020 Farm Regional New varieties Precision agriculture Remote sensing	Economic availability Lack of public organization		
	Southern Italy	Puglia and Basilicata	**TP,PA** SPI, WBC, ΔT°C **ND_30,** **ND_35**	Farm: Increase of durum wheat cultivation Reduction of sugar beet cultivation	>2008 Farm Sowing/transplanting time; Varieties/species; Change from summer to winter crop (cereals) Irrigation scheduling and fertirigation; Conservation soil water; Saline irrigation water PDW manag	Availability and cost of water resources (for spring/summer crops) Salinization of coastal areas Small farm size	Not necessarily increase production expenses; increase of productive stability	Positive effects on C sequestration are expected by minimum or conservative tillage; benefits in terms of N2O emission are Questionable. Reduction of N2O are expected with optimized fertilization and precision agriculture
					>2020 Farm regional New varieties; Enhancement irrigation network and scheduling; Using urban water; Precision agriculture Remote sensing	Economic availability Lack of public organization Small farm size		
Crop farming dominated by vegetables	Northern Italy	Emilia Romagna	**TP,PA** SPI, WBC, ΔT°C **ND_30,** **ND_35**	Farm-Region: Increment of localized irrigation	>2008 Farm Sowing/transplanting time; Selecting varieties/species; Optimal irrigation scheduling and fertirrigation; Irrigation system Conservation of soil water; PDW manag Drip, LEPA and ULDI	Availability and cost of water resources (for spring/summer crops) Salinization of coastal areas Small farm size	Not necessarily increase production expenses; increase of productive stability No control for farmers on prices products	Reduction of N2O are expected with optimized fertilization and precision agriculture

					irrigation			
					>2020 Farm regional New varieties; Enhancement irrigation network and scheduling Precision agriculture Remote sensing	Economic availability		
	Southern Italy	Puglia and Basilicta	**TP,PA** SPI, WBC, ΔT°C **ND_30,** **ND_35**	Farm-Reg: Increment of high quality production; structural change to bigger farms Regional: Enhancement of water distribution and control	>2008 Farm Sowing/transplanting time Varieties/species Change from summer to winter vegetables Irrigation scheduling and fertirigation; Saline irrigation water Conservation soil water; PDW manag	Availability and cost of water resources (for spring/summer crops) Salinization of coastal areas	Not necessarily increase production expenses; increase of productive stability No control for farmers on prices products	Reduction of N_2O are expected with optimized fertilization and precision agriculture
					>2020 Farm regional New varieties Enhancement irrigation network and scheduling Using urban water Precision agriculture Remote sensing.	Economic availability Lack of public organization;		

7 - GREECE

Table 7.1. List of identified vulnerable regions to climate change in Greece and their characteristics (expert assessment)

Dominating Agroeco-system	**Geographical region**	**National name of region**	**Approx size of the region (km²)**	**Annual temperature, precip. and sea level of the region (from-to)**	**Dominating soil conditions (describe)**	**Irrigation applied and dominating type of irrigation (6) (7) (8)**	**Topography of the region**	**Dominating LAND USE types and INTENSITY according toTable 3.3 (Refer to numbers of first column) (5)**	**CLASSIFICATION of agroecosystem according to Table 7.2 and 7.3 (class numbers and proportion*) (5)**	**Percentage of organic farmers (4)**	**Mean farm size, and dominating farm size (ha) (1) and (2)**
Olive Grooves	Cenral East Greece	Region of Sterea Ellada	15.549	16-17 Celcious 400-1400 mm precip 0-2200 m alt.	Coastal flatlands with higher water holding capacity and hilly terrain-good drainage, high to low productivity	Usually rainfed except on Table Olive Production dripping.	Complex topography, mostly mountainous and semi-mountianous & hilly, rich river deltas and flatlands	LU: 21 First: 3 high intensity Second: 2 medioum intensity	First: 35 (98%) Second 31 (2%)	Regional number (1,09%)	Mean 1,39 and 1-1,9 median
Olive Grooves	Cenral East Greece	Region of Thessaly	13903	16-17 Celcoius 400-1200 mm precip 0-2917 m alt.	Valleys with alluvious deposits, high productivity and hilly/mountanous lighter soils	Irrigated and rainfed, dripping	Hosts a large flatland intensive agricultural area-Hilly and protected area mountains	LU: 21 First: 2 mediuom intensity	First: 36 (99,5%)	Regional number (2,31%)	Mean 1,28 and 1-1,9 median
Olive Grooves	Peloponeese Peninsula	Region of Peloponeese	15490	18-19,5 Celcious 400-1400 mm precip 0-2224 m alt.	Producitve, heavier at coastal flatlands and lighter marginal	Irrigated and rainfed, dripping	Mostly mountainous with hilly and coastal agricultural areas	LU: 21 First: 3 high intensity First: 2 mediuom intensity	First: 36 (95%) Second: 35 (5%)	Regional number (1.88%)	Mean 2,14 and 1-1,9 median

					soils, with low water holding capacity						
Orchards Apple	Cenral East Greece	Region of Thessaly	As above	As above	As above	Irrigated, dripping and surficial	As above	LU: 21 First: 2 mediоum intensity	NA	As above	Mean 0,77 and median 0,2-0,49
Orchards Apple	Cenral East Greece	Region of Sterea Ellada				Irrigated, dripping and surficial		LU: 21 First: 2 mediоum intensity	NA		Mean 0,211 and median <= 0,19
Orchards Apple	Peloponnes us Peninsula	Region of Pelopone ssus				Irrigated, dripping and surficial		LU: 21 First:2 mediоum intensity	NA		Mean 0,52 and median 0,2-0,49
Orchards Pear	Cenral East Greece	Region of Thessaly				Irrigated, dripping and surficial		LU: 21 First: 2 mediоum intensity	NA		Mean 0,67 and median 0,2-0,49
Orchards Pear	Peloponnes us Peninsula	Region of Pelopone ssus				Irrigated, dripping and surficial		LU: 21 First: 2 mediоum intensity	NA		Mean 0,406 and median 0,2-0,49
Vineyards	Cenral East Greece	Region of Sterea Ellada				Irrigated (especially for table fruit) and rainfed, mostly dripping		LU: 21 LU: 21 First: 2 mediоum intensity First: 1 low intensity	First: 36		Mean 0,38 and median 1,0-1,9
Vineyards	Cenral East Greece	Region of Thessaly				As above		LU: 21 First: 3 high intensity	First 36		Mean 0,37 and median 3,0-4,9
Vineyards	Peloponeese Peninsula	Region of Pelopone ese				As above		LU: 21 First: 3 high intensity	First 36		Mean 0,97 and median 3,0-4,9

Crop farming dominated by common wheat	Cenral East Greece	Region of Sterea Ellada				**No irrigation**		**LU 1** 2 mediuom intensity	**Cereals First 15(99%) Second: 11 (1%)**		Mean 1,72 and median 1,0-1,9
Crop farming dominated by common wheat	Cenral East Greece	Region of Thessaly				**No irrigation (sprinkler, if applied)**		**LU 1** 2 mediuom intensity	**First 15**		Mean 2,1 and median 1,0-1,9
Crop farming dominated by common wheat	Peloponeese Peninsula	Region of Pelopone ese				**No irrigation**		**LU 1** 2 mediuom intensity	**First 15**		
Crop farming dominated by durum wheat	Cenral East Greece	Region of Sterea Ellada				**No irrigation**		**LU 1** 2 mediuom intensity	**Cereals First 15(99%) Second: 11 (1%)**		Mean 3,65 and median 1,0-1,9
Crop farming dominated by durum wheat	Cenral East Greece	Region of Thessaly				**No irrigation**		**LU 1** 2 mediuom intensity	**First 15**		Mean 3,9 and median 1,0-1,9
Crop farming dominated by durum wheat	Peloponeese Peninsula	Region of Pelopone ese				**No irrigation**		**LU 1** 2 mediuom intensity	**First 15**		Mean 2,55 and median 1,0-1,99
Crop farming dominated by Tabaco	Cenral East Greece	Region of Sterea Ellada				**Irrigated**		**LU3** 3 high intensity	**First 16**		Mean 1,2 and median 1,0-1,9
Crop farming dominated by Tabaco	Cenral East Greece	Region of Thessaly				**Irrigated**		**LU3** 2 mediuom intensity 3 high intensity	**First 16**		Mean 1,5 and median 1,0-1,9
Crop farming	Cenral East Greece	Region of Sterea				**Irrigated, surficial**		**LU3** 2 mediuom intensity	**First 16**		Mean 5,56 and

dominated by Cotton		Ellada				**and sprincling**					median 5,0-9,9
Crop farming dominated by Cotton	Cenral East Greece	Region of Thessaly				**Irrigated, surficial and sprincling**		**LU3** 2 medioum intensity	**First 16**		Mean 5,7 and median 5,0-9,9
Crop farming dominated by maize	Cenral East Greece	Region of Sterea Ellada				**Irrigated, surficial and sprincling**		**LU1** Under cereals-common category with wheat	**As in cereals**		Mean 1,04 and median <=0,5
Crop farming dominated by maize	Cenral East Greece	Region of Thessaly				**Irrigated, surficial and sprincling**		**LU1** Under cereals-common category with wheat	**As in cereals**		
Crop farming dominated by rice	Cenral East Greece	Region of Sterea Ellada				**Irrigated, surficial in coastal areas**		**LU1** 2 medium intensity	**First 16**		

Table 7.2. List of identified vulnerable regions to climate change in Greece and their main limitation and trends (expert assessment)

Dominating Agroeco-system (can be completed)	**Geographical region**	**National name of region**	**Main limitations**	**Observed trends**	**Socio-economic conditions and problems**	**Main identified vulnerabilities to climate change**
Olive Grooves	Cenral East Greece	Region of Sterea Ellada	Farmer product prices Competition with imported products	Increase of cultivated surface, (similar to wheat) Biological agriculture increase	Farmer product prices Source of income for part time farmers due to environmental suitability and low necessary input of time resources (same holds for wheat and cereals)	Irrigated table olives are vulnerable Winter frost events (-8 Degrees Celsius threshold) Increased heat waves and wind during May can reduce germination and cause flower loss
Olive Grooves	Cenral East Greece	Region of Thessaly	Collection costs Irrigation water	Biological agriculture increase	As in previous row	As in previous row

Dominating Agroeco-system (can be completed)	**Geographical region**	**National name of region**	**Main limitations**	**Observed trends**	**Socio-economic conditions and problems**	**Main identified vulnerabilities to climate change**
Olive Grooves	Peloponeese Peninsula	Region of Peloponeese	Collection costs Irrigation water	Biological agriculture increase	As in previous row	As in previous row
Orchards Apple	Cenral East Greece	Region of Thessaly	Water availability for irrigation	Reduction by 10% approximately	Reduced prices is a general picture of the producer buyers	High vulnerability: radiation and heat, and associated diseases-pests.
Orchards Apple	Cenral East Greece	Region of Sterea Ellada				As in the previous rows
Orchards Apple	Peloponnesus Peninsula	Region of Peloponessus				As in the previous rows
Orchards Pear	Cenral East Greece	Region of Thessaly	Market prices Input costs	Certain local varieties present better market performance	Reduced prices. Local varieties with higher market price need promotion	High vulnerability: radiation and heat, and associated diseases-pests.
Orchards Pear	Peloponnesus Peninsula	Region of Peloponessus				As in the previous rows
Vineyards	Cenral East Greece	Region of Sterea Ellada	Global product prices Irrigation water availability for irrigated cultures Radiation and heat stress	Increasing trends of winery cultivation Large farm unit establishment Application of PDO, PGI certification	Increased collection costs New regulations and changes in management (CAP)	Irrigated cultures are vulnerable Radiation and heat may damage certain varieties depending on site conditions Less vulnerable from cotton or maize
Vineyards	Cenral East Greece	Region of Thessaly	Increased collection costs	Increase of location based certification. Increase of biological cultivations. Increase of local processing activities	New regulations and changes in management (CAP) Initial inputs costs and maintenance for the years until production	As in previous row
Vineyards	Peloponeese	Region of	Increased collection	High production of table	New regulations and changes in	Vulnerabilities similar to the

Dominating Agroeco-system (can be completed)	**Geographical region**	**National name of region**	**Main limitations**	**Observed trends**	**Socio-economic conditions and problems**	**Main identified vulnerabilities to climate change**
	Peninsula	Peloponeese	costs Irrigation water availability especially for table wines	vines Brand name wine products Place of origin certification	management (CAP) Initial inputs costs and maintenance for the years until production	previous row
Crop farming dominated by common wheat	Cenral East Greece	Region of Sterea Ellada	Dry periods during seeding time and during spring	Increase of cultivated surface Change of seeding dates	As in Durum wheat for Sterea Ellada Region	Dry period during seeding time and Spring
Crop farming dominated by common wheat	Cenral East Greece	Region of Thessaly	As in row above	Reduction by 65% but is now increasing	More productive than the Durum wheat at the regional conditions	Vulnerable, but more resilient to adverse climate conditions (droughts, reduced precip) than the Durum wheat
Crop farming dominated by common wheat	Peloponeese Peninsula	Region of Peloponeese	As in row above. Possible more water stress due to lowest precip Higher inpur costs			
Crop farming dominated by durum wheat	Cenral East Greece	Region of Sterea Ellada	Dry periods during seeding time and during spring Higher input costs	Similar to Durum wheat Change of seeding dates	As in olive grooves, source of income for part time farmers due to environmental suitability and low necessary input of time resources	Dry period during seeding time and May
Crop farming dominated by durum wheat	Cenral East Greece	Region of Thessaly	As in row above	Stability Change of seeding dates	Low prices at the past, possibly reduced supply at the future. Also a solution for part-time farmers.	>>
Crop farming dominated by durum wheat	Peloponeese Peninsula	Region of Peloponeese	As in row above also			Same as in other regions, with increased vulnerability of dry period and consecutive dry days increase and lower precip.
Crop farming dominated by Tobacco	Cenral East Greece	Region of Sterea Ellada	Low (net) financial output without subsidies. Low product price	Huge reduction (100%) of cultivation in foreign varieties, and general	Foreign varieties cover the vast majority of the cultivated area-no alternative variety or crop is	Irrigated crop- water resource is necessary – highly vulnerable to adverse climate

Dominating Agroeco-system (can be completed)	**Geographical region**	**National name of region**	**Main limitations**	**Observed trends**	**Socio-economic conditions and problems**	**Main identified vulnerabilities to climate change**
			(farmers) High financial input The until present managerial-cultivation practices and their relation with the New CAP and Best Practices applied.	cultivation for the Region. Input costs increase (fuel, chemicals, etc)	cultivated. Unemployment of youth (alternative crops are needed with the same financial output) Need for alternative crop with similar net farmer profit: otherwise unemployment and associated social results	
Crop farming dominated by Tobacco	Cenral East Greece	Region of Thessaly (Karditsa, Ellasona, Prefecture of Larissa)	The until present managerial-cultivation practices and their relation with the New CAP and Best Practices applied. Low product price (farmers) High financial input	Change of the traditional varieties with imported foreign ones in the past. Huge reduction (100%) in certain cases. Traditional varieties persist on specific areas.	Unemployment of youth (alternative crops are needed with the same financial output)	Irrigated crop- water resource is necessary None new physical vulnerability identified
Crop farming dominated by Cotton	Cenral East Greece	Region of Sterea Ellada	Increased cost of cultivation (fuel and chemicals) Water Availability for irrigation	Reduced chemical input due to increased cost (which is a plus for the environment and WFD objectives) Slight area/production reduction due to social-economic conditions and regulations	New CAP regulations Nitrate regulations Cross-Compliance Uncertainty into financial (stock) markets High dependence of local population – need for alternative crop with similar net profit Price increase	Water availability and irrigation need increase Environmental issues related to intensive irrigated agriculture Highly vulnerable to drought
Crop farming dominated by Cotton	Cenral East Greece	Region of Thessaly	Increased cost of cultivation (fuel and chemicals) Water Availability for irrigation	Reduced chemical input due to increased cost (which is a plus for the environment and WFD objectives) Reduction by 25% due to social-economic conditions	New CAP regulations Nitrate regulations Cross-Compliance Uncertainty into financial (stock) markets High dependence of local	Water availability and irrigation need increase Environmental issues related to intensive irrigated agriculture Highly vulnerable to drought

Dominating Agroeco-system (can be completed)	Geographical region	National name of region	Main limitations	Observed trends	Socio-economic conditions and problems	Main identified vulnerabilities to climate change
				and regulations.	population – need for alternative crop with similar net profit	
Crop farming dominated by maize	Cenral East Greece	Region of Sterea Ellada	Irrigation water availability Input costs	Potential reduction of cultivated surface (decadal comparison)	New CAP regulations Nitrate regulations Cross-Compliance Price increase	Water availability and irrigation need increase Highly vulnerable to drought
Crop farming dominated by maize	Cenral East Greece	Region of Thessaly	Irrigation water availability Input costs	Potential reduction of cultivated surface (decadal comparison)	New CAP regulations Nitrate regulations Cross-Compliance	Water availability and irrigation need increase Highly vulnerable to drought
Crop farming dominated by maize	Peloponeese Peninsula	Region of Peloponeese	Irrigation water availability Input costs	Potential reduction of cultivated surface (decadal comparison)	New CAP regulations Nitrate regulations Cross-Compliance	Water availability and irrigation need increase Highly vulnerable to drought
Crop farming dominated by rice	Cenral East Greece	Region of Sterea Ellada	Soil salinity in coastal swamp regions Irrigation water Surface irrigation system	Reduction of suitable and cultivated area due to water availability	New CAP regulations Nitrate regulations Cross-Compliance	Water availability and irrigation need increase Highly vulnerable to drought Salinity in coastal areas

*** Qualitative Table analysis and crop selection for the 3 indicative regions, vulnerability and characteristics are complied based on expert consultation during WP2 and WP3. Please see acknowledgments for complete references.**

Table 7.3. Summary table on identified adaptation options in vulnerable regions and production systems in Greece

Dominatin g Agroecosys tem	Geograph ical region	National name of region	Agroecosystem, related to common Agroclimatic etc. indicators	Observed trends in adaptations to climate change (distinguish between farm level, regional level, national level)	Recommended feasible adaptation options to climate change Time Horizon:2020s	Identified limitations for adaptation options to climate change	Uncertainties, cost/benefits, risks (including economic risks), opportunities of adaptation options	Mitigation effects (assessment)
Olive Grooves	Central East	Region of Sterea	Periods: 1971-1990, 1961-1990,	Farm: Increase of cultivated surface,	As also in previous column	Irrigated table olives are vulnerable	Farmer product prices are very low in certain	Minimum or reduced tillage prevents soil

Dominatin g Agroecosys tem	Geograph ical region	National name of region	Agroecosystem, related to common Agroclimatic etc. indicators	Observed trends in adaptations to climate change (distinguish between farm level, regional level, national level)	Recommended feasible adaptation options to climate change Time Horizon:2020s	Identified limitations for adaptation options to climate change	Uncertainties, cost/benefits, risks (including economic risks), opportunities of adaptation options	Mitigation effects (assessment)
	Greece	Ellada	2031-2050, 2021-2050, 2071-2090, 2071-2100 ECHAM5 A1B 25 km. Racmo2 KNMI 27 Extreme weather events indicators, Miami Model Net primary (Temp/Precip)Productivity Climatic Water Balance (P/ET) De Martonne Aridity Index Ombrothermic Index Length of Growing Period (Monthly y P/ET>0.49) Precipitation Sums Temperature March Frost Days	(similar to wheat preference due to low input) Farm/National Biological agriculture increase Trees do adapt to extended drought conditions, farmers apply a permanent regime: either 1) irrigate or 2) not at all. Urbanization and part time farming is more and more focusing at such low labor input practices Great environmental suitability – only extremes are a caveat Provides soil cover and biodiversity – comparing to other annual plant monocultures	Reduced or no tillage Added market value through biological agriculture Cover crop dead mulch reduces evapotranspiration Increase acreage for part time farming Shift to extensive farming	Winter frost events (-8 Degrees Celsius threshold) especially on March Increased heat waves and hot wind events during May can reduce germination and cause flower loss – follows reduction in production Dry winters followed by dry spring may reduce production. (As in 2007).	years (Farming may not break even financially) High input value for commercial production and low price of olive oil As exported product, high sensitivity to market prices Olive planting in lowland areas, at high productivity agricultural lands. Opportunities: High environmental value when compared to intensive cash crops – biodiversity important	erosion and increases WHC Great environmental suitability and low necessary input of time resources (same holds for wheat and cereals) Increased microorganisms and biodiversity Positive: If abandoned succeeds to forest land with great environmental value but-negative- has increased forest fire risk Negative: cover crop may communicate wildfires more efficiently (!)
Olive Grooves	Central East Greece	Region of Thessaly	Please see first row	FARM/National Biological agriculture increase	As in previous row	As in previous row	As in previous row	As above

Dominating Agroecosystem	**Geographical region**	**National name of region**	**Agroecosystem, related to common Agroclimatic etc. indicators**	**Observed trends in adaptations to climate change (distinguish between farm level, regional level, national level)**	**Recommended feasible adaptation options to climate change Time Horizon:2020s**	**Identified limitations for adaptation options to climate change**	**Uncertainties, cost/benefits, risks (including economic risks), opportunities of adaptation options**	**Mitigation effects (assessment)**
				As previous row also				
Olive Grooves	Peloponnesus Peninsula	Region of Peloponnesus	Please see first row	Farm/National Biological agriculture increase As previous row also		As in previous row May need irrigation in this region – Irrigation water increase Frost danger is lower at this region (south)	As in previous row	As above
Orchards Apple	Central East Greece	Region of Thessaly	Please see first row	Irrigation	Reduced or minimum tillage	High vulnerability: radiation and heat, and associated diseases-pests.	Reduced prices Irrigation water need	Positive: Minimum or reduced tillage prevents soil erosion and increases WHC Increased microorganisms and biodiversity Possibly negative: ground cover may host pests
Orchards Apple	Central East Greece	Region of Sterea Ellada	Please see first row	Farm level: Local increase at certain mountainous regions, more suitable climate and WHC conditions	Reduced or minimum tillage Spatial adaptation – establishment on adapted, cool sites and semi mountainous regions with higher air humidity conditions	As in the previous rows Radiation and heat may damage certain varieties depending on site conditions Irrigation water availability	Irrigation water increase, heat and radiation damage Possible higher irrigation water need and financial yield variability Increased costs and market price variation	As above
Orchards Apple	Peloponnesus Peninsula	Region of Peloponnesus	Please see first row	Farm: Irrigation National: education and development	Reduced or minimum tillage	Radiation and heat may damage certain varieties depending on site conditions	Irrigation water increase, heat and radiation damage Possible higher	As above

Dominating Agroecosystem	Geographical region	National name of region	Agroecosystem, related to common Agroclimatic etc. indicators	Observed trends in adaptations to climate change (distinguish between farm level, regional level, national level)	Recommended feasible adaptation options to climate change Time Horizon:2020s	Identified limitations for adaptation options to climate change	Uncertainties, cost/benefits, risks (including economic risks), opportunities of adaptation options	Mitigation effects (assessment)
				of infrastructure and irrigation networks		Irrigation water availability	irrigation water need and financial yield variability Increased costs and market price variation	
Orchards Pear	Central East Greece	Region of Thessaly	Please see first row	Regional Market adaptations of better performing varieties Irrigation (dripping)	Reduced or minimum tillage	High vulnerability: radiation and heat, and associated diseases-pests.	Irrigation water increase, heat and radiation damage Possible higher irrigation water need and financial yield variability Increased costs and market price variation	As above
Vineyards	Central East Greece	Region of Sterea Ellada	Please see first row	Regional/National increasing trends of winery cultivation Large farm unit establishment Local varieties are also popular	Local traditional varieties with adaptation to water stress Local varieties with added market value Cover crop	Radiation and heat may damage certain varieties depending on site conditions Irrigation water availability	Increased collection costs International production competition Increased costs and market price variation	Positive: Increased competitive values of local varieties Positive: Minimum or reduced tillage prevents soil erosion and increases WHC Increased microorganisms and biodiversity If not applied: increased evaporation and erosion potential Biodiversity reduction
Vineyards	Central East Greece	Region of Thessaly	Please see first row	Farm based production and vertical integration	Local traditional varieties with adaptation to water	As in previous row	Increased collection costs International	Positive: Increased competitive values of local varieties

Dominating Agroecosystem	Geographical region	National name of region	Agroecosystem, related to common Agroclimatic etc. indicators	Observed trends in adaptations to climate change (distinguish between farm level, regional level, national level)	Recommended feasible adaptation options to climate change Time Horizon:2020s	Identified limitations for adaptation options to climate change	Uncertainties, cost/benefits, risks (including economic risks), opportunities of adaptation options	Mitigation effects (assessment)
				Dripping irrigation Increase of local processing activities	stress Local varieties with added market value Cover crop		production competition Increased costs and market price variation	Positive: Minimum or reduced tillage prevents soil erosion and increases WHC Increased microorganisms and biodiversity If not applied: increased evaporation and erosion potential Biodiversity reduction
Vineyards	Peloponnesus Peninsula	Region of Peloponnesus	Please see first row	Farm based production and vertical integration Dripping irrigation Increase of local processing activities	Local traditional varieties with adaptation to water stress Local varieties with added market value Cover crop	Vulnerabilities similar to the previous row More xerothermic environment may cause increased water stress	Increased collection costs International production competition Increased costs and market price variation	Positive: Increased competitive values of local varieties Positive: Minimum or reduced tillage prevents soil erosion and increases WHC Increased microorganisms and biodiversity Negative: If not applied: increased evaporation and erosion potential Biodiversity reduction
Crop farming dominated by common wheat	Central East Greece	Region of Sterea Ellada		Change of seeding dates National: long term development of local varieties and	Seeding dates change	Dry period during seeding time and May. Needs water during big leaf emergence – dry	Increased Harvest costs – very low price the last year International production competition	Positive: Increased yield - initial seed and sowing expenses protection

Dominating Agroecosystem	Geographical region	National name of region	Agroecosystem, related to common Agroclimatic etc. indicators	Observed trends in adaptations to climate change (distinguish between farm level, regional level, national level)	Recommended feasible adaptation options to climate change Time Horizon:2020s	Identified limitations for adaptation options to climate change	Uncertainties, cost/benefits, risks (including economic risks), opportunities of adaptation options	Mitigation effects (assessment)
				seed sources by national institutes		period stagnant growth	Increased costs and market price variation	Negative: false start
Crop farming dominated by common wheat	Central East Greece	Region of Thessaly	Please see first row	Farm: Change of seeding dates National: long term development of local varieties and seed sources by national institutes	Seeding dates change	Vulnerable, but more resilient to adverse climate conditions (droughts, reduced precip) than the Durum wheat	Increased Harvest costs – very low price the last year International production competition Increased costs and market price variation	Positive: Increased yield - initial seed and sowing expenses protection Negative: false start
Crop farming dominated by common wheat	Peloponnesus Peninsula	Region of Peloponnesus	Please see first row	Farm: Change of seeding dates National: long term development of local varieties and seed sources by national institutes	Seeding dates change Minimal plowing, Successive plowing events for	Vulnerable, but more resilient to adverse climate conditions (droughts, reduced precip) than the Durum wheat	As above	Positive: Increased yield - initial seed and sowing expenses protection Negative: false start
Crop farming dominated by durum wheat	Central East Greece	Region of Sterea Ellada	Please see first row	Farm: Change of seeding dates National: long term development of local varieties and seed sources by national institutes	Seeding dates change	Dry period during seeding time and May Dry period during big leaf emergence	As above	Positive: Increased yield - initial seed and sowing expenses protection Negative: false start
Crop farming dominated by durum wheat	Central East Greece	Region of Thessaly	Please see first row	Farm: Change of seeding dates National: long term development of local varieties and seed sources by national institutes	Seeding dates change	>>	As above	Positive: Increased yield - initial seed and sowing expenses protection Negative: false start

Dominating Agroecosystem	Geographical region	National name of region	Agroecosystem, related to common Agroclimatic etc. indicators	Observed trends in adaptations to climate change (distinguish between farm level, regional level, national level)	Recommended feasible adaptation options to climate change Time Horizon:2020s	Identified limitations for adaptation options to climate change	Uncertainties, cost/benefits, risks (including economic risks), opportunities of adaptation options	Mitigation effects (assessment)
Crop farming dominated by durum wheat	Peloponnesus Peninsula	Region of Peloponnesus	Please see first row	Farm: Change of seeding dates National: long term development of local varieties and seed sources by national institutes	Seeding dates change	Same as in other regions, with increased vulnerability of dry period and consecutive dry days increase and lower precipitation since this is the south part of Greece.	Increased Harvest costs – very low price the last year International production competition Increased costs and market price variation	Positive: Increased yield - initial seed and sowing expenses protection Negative: false start
Crop farming dominated by Tobacco	Central East Greece	Region of Thessaly (Karditsa, Ellasona, Prefecture of Larissa)	Please see first row	Traditional varieties persist on specific areas – generally the crop has faced a huge reduction (100% approx). Regional: Certain farmers produce ecological tobacco	Crop change – medicinal herbs an option as proposed by institutions ecological tobacco farming	Due to current market reasons, funding, low price ranges and quotas, a very small part of the surface remains under cultivation of this crop.	Unemployment of youth (alternative crops are needed with the same financial output) Crop change is necessary	Positive: New economic front creation Employment and social welfare of rural areas
Crop farming dominated by Tobacco	Central East Greece	Region of Sterea Ellada	Please see first row	Huge reduction in acreage Regional: Certain farmers produce ecological tobacco	Crop change – medicinal herbs an option as proposed by institutions ecological tobacco farming	As above	As above	Positive: New economic front creation Employment and social welfare of rural areas Negative: If not adapted, no new crop or solution: possible rural area depopulation, emigration
Crop farming	Central East	Region of Sterea	Please see first row PLUS: Mapping	Farm: Some	Change cultivars or crop	Water availability and irrigation need increase	Market price fluctuations	Positive: reduction in water resource usage

Dominating Agroecosystem	Geographical region	National name of region	Agroecosystem, related to common Agroclimatic etc. indicators	Observed trends in adaptations to climate change (distinguish between farm level, regional level, national level)	Recommended feasible adaptation options to climate change Time Horizon:2020s	Identified limitations for adaptation options to climate change	Uncertainties, cost/benefits, risks (including economic risks), opportunities of adaptation options	Mitigation effects (assessment)
dominated by Cotton	Greece	Ellada	areas below 5m altitude	farmers apply early seeding during spring National: Irrigation systems development in the past National: proposals for new land uses and crop varieties – promotion-education	Irrigation is also an already option-very costly financially and environmentally. Spring seeding	Environmental issues related to intensive irrigated agriculture Highly vulnerable to drought	Environmental conditions	Social effects and welfare in case of a new crop adaptation Negative: water resource reduction and non point source pollution
Crop farming dominated by Cotton	Central East Greece	Region of Thessaly	Please see first row	As above	Change cultivars or crop Irrigation is also an already option-very costly financially and environmentally. Spring seeding	Water availability and irrigation need increase Environmental issues related to intensive irrigated agriculture Highly vulnerable to drought	Market price fluctuations Environmental conditions	Positive: reduction in water resource usage Social effects and welfare in case of a new crop adaptation Negative: water resource reduction and non point source pollution
Crop farming dominated by maize	Central East Greece	Region of Sterea Ellada	Please see first row	Farm: Reduction of area due to water resources availability decrease Farm: New crop	Change cultivars or crop Irrigation is also an already option, but very costly financially and environmentally.	Water availability and irrigation need increase Highly vulnerable to drought	Market price fluctuations Environmental conditions	As above

Dominating Agroecosystem	Geographical region	National name of region	Agroecosystem, related to common Agroclimatic etc. indicators	Observed trends in adaptations to climate change (distinguish between farm level, regional level, national level)	Recommended feasible adaptation options to climate change Time Horizon:2020s	Identified limitations for adaptation options to climate change	Uncertainties, cost/benefits, risks (including economic risks), opportunities of adaptation options	Mitigation effects (assessment)
				cultivars and new crops				
Crop farming dominated by maize	Central East Greece	Region of Thessaly	Please see first row	Farm: Reduction of are due to water resources availability reduction Farm: New crop in place of maize	As above	Water availability and irrigation need increase Highly vulnerable to drought	Market price fluctuations Environmental conditions	As above
Crop farming dominated by maize	Peloponnesus Peninsula	Region of Peloponnesus	Please see first row		As above	Water availability and irrigation need increase Highly vulnerable to drought	Market price fluctuations Environmental conditions	As above
Crop farming dominated by rice	Central East Greece	Region of Sterea Ellada	Please see first row PLUS: Mapping areas below 5m altitude	Reduction of suitable and cultivated area due to water availability – adaptation to lack of water resources	Change cultivars or crop (salinity resistant crops can be most successful)	Water Hungry Stalinization of coastal swamp areas Prices and costs	Market price fluctuations Environmental conditions	As above

* Qualitative Table analysis and crop selection for the 3 indicative regions, vulnerability and characteristics are complied based on expert consultation during WP2 and WP3. Please see acknowledgments for complete references.

8 - EGYPT

Table 8.1. List of identified vulnerable regions to climate change in Egypt and their characteristics (expert assessment)

Identified vulnerable agroecosystem	..within geographical region	National name of region	Main vulnerabilities to climate change
Field crops	Northern Delta	Beharea, Damitta, Kafer Elshaikh	Land loss due to SLR, soil & water degradation, crop yield reduction, crop quality reduction, pests and disease, seasonal water shortage, high intensity and frequency of cold and heat waves.
Orchards and palms			Land loss due to SLR, soil & water degradation, crop yield reduction, crop quality reduction, pests and disease, seasonal water shortage, high intensity and frequency of cold and heat waves, sand storms.
Field crops	Middle Delta	Sharkia, Gharbia	Soil degradation, crop yield reduction, crop quality reduction, pests and disease, high intensity and frequency of cold and heat waves.
Vegetable crops			Soil degradation, crop yield reduction, crop quality reduction, pests and disease, high intensity and frequency of cold and heat waves.
Orchards and palms			Soil degradation, crop yield reduction, crop quality reduction, pests and disease, high intensity and frequency of cold and heat waves, sand storms.
Field crops	Sothern Delta	Qalubia (Qunater-Banha)	Soil & water degradation, crop yield reduction, crop quality reduction, pests and disease, high intensity and frequency of cold and heat waves.
Vegetable crops			Soil & water degradation, crop yield reduction, crop quality reduction, pests and disease, high intensity and frequency of cold and heat waves.
Orchards and palms			Soil & water degradation, crop yield reduction, crop quality reduction, pests and disease, high intensity and frequency of cold and heat waves, sand storms.

Table 8.2. List of identified vulnerable regions to climate change in Egypt and their main limitation and trends (expert assessment)

Identified vulnerable agroecosystem	geographical region	Main limitations	Observed trends	Socio-economic conditions
Field crops	Northern Delta	- Financial support & investments. - Agric. policy. -Seasonal water shortage. -Low water quality - Poor extension service	- Field crops domination in cultivated area - Light to medium soil. - High levels of soil salinity - Medium to small land ownership. - High water table.	- Poor irrigation system. - Poor drainage systems. -switching from conventional agric. to aqua culture. - Agric. policy conflicts

Identified vulnerable agroecosystem	geographical region	Main limitations	Observed trends	Socio-economic conditions
		- Markets availability		
Orchards and palms		- Agric. policy. -Seasonal water shortage. -Low water quality - Poor extension service	- Light to medium soil. - High levels of soil salinity - Medium to small land ownership. - High water table.	- Poor irrigation systems. - Poor drainage systems. - Shortage in expert labor. - switching from date palms to orchards. - switching from orchards to field crops. - switching from conventional agric. to aqua culture.
Field crops	Middle Delta	-Financial support & investments. -Agric. policy -Seasonal water shortage. -Poor extension service - Markets availability	- Wide domination of field crops. - Large to small land ownership -Clay loamy soil. - Medium to high soil salinity level. - Ongoing irrigation improvements	- Poor irrigation systems. - Poor drainage systems. - Agric. policy conflicts. -Immigration from rural to urban. - High population.
Vegetable crops		-Financial support & investments. -Agric. policy -Seasonal water shortage. -Poor extension service -Labors shortage - Markets availability	- Medium to small areas of vegetables. - Large to small land ownership -Clay loamy soil. - Medium to high soil salinity level. - ongoing irrigation improvement	- Poor irrigation systems. - Poor drainage systems. - Agric. policy conflicts. -Immigration from rural to urban. - High population.
Orchards and palms		-Agric. policy -Seasonal water shortage. -Poor extension service -Expert labors shortage	-Small areas of fruits. - Large to small land ownership -Clay loamy soil. - Medium to high soil salinity level.	- Poor irrigation systems. - Poor drainage systems. - Agric. policy conflicts. -Immigration from rural to urban. - High population.
Field crops	Sothern Delta	-Financial support & investments. - Agric. policy -size of land ownership. Poor extension service - Urbanization.	-Small land ownership. - High intensity of pest & diseases - Small areas of field crops. - Heavy Soil. - Low water quality. - Agric. Land shrinking due to urbanization.	- Poor irrigation systems. - Poor drainage systems. - Agric. policy conflicts. -Immigration from rural to urban. - High population.
Vegetable crops		-Financial support & investments.	-Small land ownership. - High intensity of pest & diseases	- Poor irrigation systems. - Poor drainage systems.

Identified vulnerable agroecosystem	geographical region	Main limitations	Observed trends	Socio-economic conditions
		- Agric. policy -size of land ownership. Poor extension service - Urbanization.	- The main sources of supplying the capital by vegetables. -Heavy Soil. - Low water quality. - Agric. Land shrinking due to urbanization.	- Agric. policy conflicts. -Immigration from rural to urban. - High population.
Orchards and palms		- Agric. policy -size of land ownership. Poor extension service - Urbanization. - Expert labors shortage	-Small land ownership. - High percentage of the cultivated land is cultivated by fruits. -Heavy Soil. - Low water quality. - Agric. Land shrinking due to urbanization.	- Poor irrigation systems. - Poor drainage systems. - Agric. policy conflicts. -Immigration from rural to urban. - High population

Table 8.3. Summary table on identified adaptation options in vulnerable regions and production systems in Egypt

Dominating Agroecosystem	Geographical region	National name of region	Agroecosystem, related to common agroclimatic etc. indicators (to be defined in detail in a separate list)	Observed trends in adaptations to climate change (distinguish between farm level, regional level, national level)	Recommended feasible adaptation options to climate change	Identified limitations for adaptation options to climate change	Uncertainties, cost/benefits, risks (including economic risks), opportunities of adaptation options	Mitigation effects (assessment)
Field crops	North Nile Delta	Behiara, Kafr El Sheikh, Dakahlia, Damietta	-Temperature increase. -Crop-water requirements increase -SLR -Soil degradation.	Farm: changing sowing dates- increasing irrigation requirements- modifying plant protection programs- Continues supply by extra amounts agricultural gypsum and compost, to avoid SLR impacts on soil. Regional: improving irrigation and drainage	Farm: changing sowing dates.	-Marketing constrains. -Technology limitations.	-Increase the flexibility to face temperature and water requirements increase. -Changing sowing dates could be not efficient to face SLR and soil degradation problems. -To how far crops flexibility are available to changing sowing dates!	Not identified

Dominatin g Agroecosys tem	Geogra phical region	National name of region	Agroecosystem, related to common agroclimatic etc. indicators (to be defined in detail in a separate list)	Observed trends in adaptations to climate change (distinguish between farm level, regional level, national level)	Recommended feasible adaptation options to climate change	Identified limitations for adaptation options to climate change	Uncertainties, cost/benefits, risks (including economic risks), opportunities of adaptation options	Mitigation effects (assessment)
				systems- switching to aquaculture-establishing farmers' adaptation cooperative-fund. National: Changing cultivars- Gradual increase in cultivating salinity tolerant crops- recycling agricultural drainage water in irrigation	Regional: improve the current irrigation & drainage systems	Financial resources	The total costs proportional to the total income may be high	Reduce CH_4 from rice cultivation
					Regional: switch cropping activates to aquaculture	-Financial resources -Environmental hazards	It may improve the food security situation at the national level. The farmers may not able to change their carrier. The required knowledge may be not ready or available. The capacity of the fishing industry could be limited to handle the production. The environmental impacts of this measure are highly uncertain.	Not identified
					National: changing cultivars	-Scientific knowledge limitations -Marketing constrains.	Increase the flexibility to face temperature and water requirements increase. It could be not efficient to face SLR and soil degradation problems. The cost of breeding cultivars could be very high.	May reduce the fertilization requirements, which reduce N_2O emissions
					National: Changing crop pattern	Food security constrains	Market constrains have higher effect in controlling crop pattern than environmental pressures.	May reduce the fertilization requirements, which reduce N_2O emissions

Dominating Agroecosystem	Geographical region	National name of region	Agroecosystem, related to common agroclimatic etc. indicators (to be defined in detail in a separate list)	Observed trends in adaptations to climate change (distinguish between farm level, regional level, national level)	Recommended feasible adaptation options to climate change	Identified limitations for adaptation options to climate change	Uncertainties, cost/benefits, risks (including economic risks), opportunities of adaptation options	Mitigation effects (assessment)
					National: gradual switching of the current old land by reclaimed land in Upper Egypt	-Inhabitants' national distribution balance. -Farmers' income. -Financial resources -Socio-economical constrains	It may sustain the national agriculture production at the secure level of production. The available land resources for reclamation in Upper Egypt, and the required water resources for reclamation and production are uncertain. The total costs proportional to the total income may be very high.	Not identified
					National: establishing adaptation tax on crops prices (less than 2% of the price).	-National income per capita. -Standard of living. -Marketing constrains.	It may help in accelerating the adaptation implementation; by ensure the required adaptation fund. The consumers may refuse it because it will increase the prices of the agricultural products. The required fund for adaptation may exceed this level.	Not identified
Orchards and palms	North Nile Delta	Behiara, Kafr El Sheikh, Dakahlia, Damietta	-Temperature increase. -Crop-water requirements increase	Farm increasing irrigation requirements- modifying plant protection programs- Continues supply by extra amounts agricultural	Farm: using environmental controlled production techniques.	Financial resources Technology limitations	Increase the flexibility to face temperature and water requirements increase. The total costs proportional to the total income may be high	Fertilizers reduction, reduce N2O emissions

Dominating Agroecosystem	Geographical region	National name of region	Agroecosystem, related to common agroclimatic etc. indicators (to be defined in detail in a separate list)	Observed trends in adaptations to climate change (distinguish between farm level, regional level, national level)	Recommended feasible adaptation options to climate change	Identified limitations for adaptation options to climate change	Uncertainties, cost/benefits, risks (including economic risks), opportunities of adaptation options	Mitigation effects (assessment)
			-SLR -Soil degradation.	gypsum and compost, to avoid SLR impacts on soil. Regional: improving drainage systems- Establishing farmers' adaptation cooperative-fund. National: recycling agricultural drainage water in irrigation	Regional: improve the current irrigation & drainage systems	Financial resources	The total costs proportional to the total income may be high	Reduce CH_4 from rice cultivation
					Regional: switch cropping activates to aquaculture	Financial resources Environmental hazards	It may improve the food security situation at the national level. The farmers may not able to change their carrier. The required knowledge may be not ready or available. The capacity of the fishing industry could be limited to handle the production. The environmental impacts of this measure are highly uncertain.	Not identified
					National: changing cultivars	Scientific knowledge limitations	Increase the flexibility to face temperature and water requirements increase. It could be not efficient to face SLR and soil degradation problems. The cost of breeding cultivars could be very high.	May reduce the fertilization requirements, which reduce N_2O emissions

Dominatin g Agroecosys tem	**Geogra phical region**	**National name of region**	**Agroecosystem, related to common agroclimatic etc. indicators (to be defined in detail in a separate list)**	**Observed trends in adaptations to climate change (distinguish between farm level, regional level, national level)**	**Recommended feasible adaptation options to climate change**	**Identified limitations for adaptation options to climate change**	**Uncertainties, cost/benefits, risks (including economic risks), opportunities of adaptation options**	**Mitigation effects (assessment)**
					National: gradual switching of the current old land by reclaimed land in Upper Egypt	Inhabitants' national distribution balance. Farmers' income. Financial resources Socio-economical constrains	It may sustain the national agriculture production at the secure level of production. The available land resources for reclamation in Upper Egypt, and the required water resources for reclamation and production are uncertain. The total costs proportional to the total income may be very high.	Not identified
					National: establishing adaptation tax on crops prices (less than 2% of the price).	National income per capita. Standard of living. Marketing constrains.	It may help in accelerating the adaptation implementation; by ensure the required adaptation fund. The consumers may refuse it because it will increase the prices of the agricultural products. The required fund for adaptation may exceed this level.	Not identified
Field crops	Middle Nile Delta	Gharbia, Sharkia, Menoufia	-Temperature increase. -Crop-water requirements increase -Soil degradation.	Farm changing sowing dates- increasing irrigation requirements. Regional: improve the current irrigation & drainage systems- governmental plan for adaptation finance.	Farm: changing sowing dates.	Marketing constrains	Increase the flexibility to face temperature and water requirements increase.	Not identified
					Regional: improve the current irrigation & drainage systems	Financial resources	Middle Egypt was targeted by a number of pilot projects and national irrigation improvements projects. The total costs proportional to the total income may be high	Reduce CH4 from rice cultivation

Dominating Agroecosystem	Geographical region	National name of region	Agroecosystem, related to common agroclimatic etc. indicators (to be defined in detail in a separate list)	Observed trends in adaptations to climate change (distinguish between farm level, regional level, national level)	Recommended feasible adaptation options to climate change	Identified limitations for adaptation options to climate change	Uncertainties, cost/benefits, risks (including economic risks), opportunities of adaptation options	Mitigation effects (assessment)
				National: Changing cultivars- changing crop pattern-	National: changing cultivars	Scientific knowledge limitations	Increase the flexibility to face temperature and water requirements increase. The cost of breeding cultivars could be very high.	May reduce the fertilization requirements, which reduce N2O emissions
					National: Changing crop pattern	Food security constrains	Market constrains have higher effect in controlling crop pattern than environmental pressures.	May reduce the fertilization requirements, which reduce N2O emissions
					National: establishing adaptation tax on crops prices (less than 2% of the price).	National income per capita. Standard of living. Marketing constrains.	It may help in accelerating the adaptation implementation; by ensure the required adaptation fund. The consumers may refuse it because it will increase the prices of the agricultural products. The required fund for adaptation may exceed this level.	Not identified
Vegetable crops	Middle Nile Delta	Gharbia, Sharkia, Menoufia	-Temperature increase. -Crop-water requirements increase -Soil degradation.	Farm changing sowing dates- increasing irrigation requirements. Regional: improve the current irrigation & drainage systems- governmental plan for adaptation finance. National: Changing	Farm: changing sowing dates.	Marketing constrains	Vegetable crops are more fixable in sowing dates Increase the flexibility to face temperature and water requirements increase.	Not identified
					Regional: improve the current irrigation & drainage systems	Financial resources	Middle Egypt was targeted by a number of pilot projects and national irrigation improvements projects. The cost of breeding cultivars could be very high.	Reduce CH4 from rice cultivation

Dominating Agroecosystem	Geographical region	National name of region	Agroecosystem, related to common agroclimatic etc. indicators (to be defined in detail in a separate list)	Observed trends in adaptations to climate change (distinguish between farm level, regional level, national level)	Recommended feasible adaptation options to climate change	Identified limitations for adaptation options to climate change	Uncertainties, cost/benefits, risks (including economic risks), opportunities of adaptation options	Mitigation effects (assessment)
				cultivars- changing crop pattern.	National: changing cultivars	Scientific knowledge limitations	Increase the flexibility to face temperature and water requirements increase. The cost of breeding cultivars could be very high.	May reduce the fertilization requirements, which reduce N2O emissions
					National: Changing crop pattern	Food security constrains	Market constrains have higher effect in controlling crop pattern than environmental pressures.	May reduce the fertilization requirements, which reduce N2O emissions
					National: establishing adaptation tax on crops prices (less than 2% of the price).	National income per capita. Standard of living. Marketing constrains.	It may help in accelerating the adaptation implementation; by ensure the required adaptation fund. The consumers may refuse it because it will increase the prices of the agricultural products. The required fund for adaptation may exceed this level.	Not identified
Orchards and palms	Middle Nile Delta	Gharbia, Sharkia, Menoufia	-Temperature increase. -Crop-water requirements increase	Farm: increasing irrigation requirements. Regional: improve the current irrigation &	Farm: using environmental controlled production techniques.	Financial resources Technology limitations	Increase the flexibility to face temperature and water requirements increase. The total costs proportional to the total income may be high	May reduce the fertilization requirements, which reduce N2O emissions

Dominatin g Agroecosys tem	Geogra phical region	National name of region	Agroecosystem, related to common agroclimatic etc. indicators (to be defined in detail in a separate list)	Observed trends in adaptations to climate change (distinguish between farm level, regional level, national level)	Recommended feasible adaptation options to climate change	Identified limitations for adaptation options to climate change	Uncertainties, cost/benefits, risks (including economic risks), opportunities of adaptation options	Mitigation effects (assessment)
			-Soil degradation.	drainage systems- governmental plan for adaptation finance. National: Changing cultivars	Regional: improve the current irrigation & drainage systems	Financial resources	Middle Egypt was targeted by a number of pilot projects and national irrigation improvements projects. The cost of breeding cultivars could be very high.	Reduce CH4 from rice cultivation
					National: changing cultivars	Scientific knowledge limitations	Increase the flexibility to face temperature and water requirements increase. The cost of breeding cultivars could be very high.	May reduce the fertilization requirements, which reduce N2O emissions
					National: establishing adaptation tax on crops prices (less than 2% of the price).	National income per capita. Standard of living. Marketing constrains.	It may help in accelerating the adaptation implementation; by ensure the required adaptation fund. The consumers may refuse it because it will increase the prices of the agricultural products. The required fund for adaptation may exceed this level.	Not identified
Field crops	South Nile Delta	Qalyoubia	-Temperature increase. -Crop-water requirements increase -Soil degradation.	Farm changing sowing dates- increasing irrigation requirements- modifying plant protection programs- changing fertilization requirements Regional: Establishing farmers' adaptation	Farm: changing sowing dates.	Marketing constrains	Increase the flexibility to face temperature and water requirements increase.	Not identified
					Regional: improve the current irrigation & drainage systems	Financial resources	The total costs proportional to the total income may be high	Reduce CH4 from rice cultivation

Dominating Agroecosystem	**Geographical region**	**National name of region**	**Agroecosystem, related to common agroclimatic etc. indicators (to be defined in detail in a separate list)**	**Observed trends in adaptations to climate change (distinguish between farm level, regional level, national level)**	**Recommended feasible adaptation options to climate change**	**Identified limitations for adaptation options to climate change**	**Uncertainties, cost/benefits, risks (including economic risks), opportunities of adaptation options**	**Mitigation effects (assessment)**
				cooperative fund National: Changing cultivars- changing crop pattern-	National: changing cultivars	Scientific knowledge limitations	Increase the flexibility to face temperature and water requirements increase. The cost of breeding cultivars could be very high.	May reduce the fertilization requirements, which reduce N2O emissions
					National: Changing crop pattern	Food security constrains	Market constrains have higher effect in controlling crop pattern than environmental pressures.	May reduce the fertilization requirements, which reduce N2O emissions
					National: establishing adaptation tax on crops prices (less than 2% of the price).	National income per capita. Standard of living. Marketing constrains.	It may help in accelerating the adaptation implementation; by ensure the required adaptation fund. Northern Delta have a wider opportunities for marketing with less transforming cost, therefore the effect of the adaptation tax on the agricultural products prices could be limited The required fund for adaptation may exceed this level.	Not identified
Vegetable crops	South Nile Delta	Qalyoubia	-Temperature increase. -Crop-water requirements increase	Farm changing sowing dates- increasing irrigation requirements- modifying plant protection programs- changing fertilization	Farm: changing sowing dates.	Marketing constrains	Vegetable crops are more fixable in sowing dates Increase the flexibility to face temperature and water requirements increase.	Not identified

Dominating Agroecosystem	Geographical region	National name of region	Agroecosystem, related to common agroclimatic etc. indicators (to be defined in detail in a separate list)	Observed trends in adaptations to climate change (distinguish between farm level, regional level, national level)	Recommended feasible adaptation options to climate change	Identified limitations for adaptation options to climate change	Uncertainties, cost/benefits, risks (including economic risks), opportunities of adaptation options	Mitigation effects (assessment)
			-Soil degradation.	requirements Regional: Establishing farmers' adaptation cooperative fund	Regional: improve the current irrigation & drainage systems	Financial resources	The total costs proportional to the total income may be high	Reduce CH4 from rice cultivation
				National: Changing cultivars- changing crop pattern-	National: changing cultivars	Scientific knowledge limitations	Increase the flexibility to face temperature and water requirements increase. The cost of breeding cultivars could be very high.	May reduce the fertilization requirements, which reduce N2O emissions
					National: Changing crop pattern	Food security constrains	Market constrains have higher effect in controlling crop pattern than environmental pressures.	May reduce the fertilization requirements, which reduce N2O emissions
					National: establishing adaptation tax on crops prices (less than 2% of the price).	National income per capita. Standard of living. Marketing constrains.	It may help in accelerating the adaptation implementation; by ensure the required adaptation fund. Northern Delta have a wider opportunities for marketing with less transforming cost, therefore the effect of the adaptation tax on the agricultural products prices could be limited The required fund for adaptation may exceed this level.	Not identified

Dominatin g Agroecosys tem	Geogra phical region	National name of region	Agroecosystem, related to common agroclimatic etc. indicators (to be defined in detail in a separate list)	Observed trends in adaptations to climate change (distinguish between farm level, regional level, national level)	Recommended feasible adaptation options to climate change	Identified limitations for adaptation options to climate change	Uncertainties, cost/benefits, risks (including economic risks), opportunities of adaptation options	Mitigation effects (assessment)
Orchards and palms	South Nile Delta	Qalyoubia	-Temperature increase. -Crop-water requirements increase -Soil degradation.	Farm changing sowing dates- increasing irrigation requirements- modifying plant protection programs- changing fertilization requirements Regional: Establishing farmers' adaptation cooperative fund National: Changing cultivars- changing crop pattern-	Farm: using environmental controlled production techniques.	Financial resources Technology limitations	Increase the flexibility to face temperature and water requirements increase. The region is too close to the agri-business companies that may provide the farmers by improved technologies and required supplies. The total costs proportional to the total income may be high	May reduce the fertilization requirements, which reduce N2O emissions
					Regional: improve the current irrigation & drainage systems	Financial resources	The total costs proportional to the total income may be high	Reduce CH4 from rice cultivation
					National: changing cultivars	Scientific knowledge limitations	Increase the flexibility to face temperature and water requirements increase. The cost of breeding cultivars could be very high.	May reduce the fertilization requirements, which reduce N2O emissions

Dominating Agroecosystem	Geographical region	National name of region	Agroecosystem, related to common agroclimatic etc. indicators (to be defined in detail in a separate list)	Observed trends in adaptations to climate change (distinguish between farm level, regional level, national level)	Recommended feasible adaptation options to climate change	Identified limitations for adaptation options to climate change	Uncertainties, cost/benefits, risks (including economic risks), opportunities of adaptation options	Mitigation effects (assessment)
					National: establishing adaptation tax on crops prices (less than 2% of the price).	National income per capita. Standard of living. Marketing constrains.	It may help in accelerating the adaptation implementation; by ensure the required adaptation fund. Northern Delta have a wider opportunities for marketing with less transforming cost, therefore the effect of the adaptation tax on the agricultural products prices could be limited The required fund for adaptation may exceed this level.	Not identified

9 - POLAND

Table 9.1. List of identified vulnerable regions to climate change in Poland and their characteristics (expert assessment)

Dominating Agroeco-system (can be completed)	**Geographical region**	**National name of region** Provinces:	**Approx size of the region (km²) (percent of region**	**Annual temperature, precip. and sea level of the region (from-to)**	**Dominating soil conditions (describe)**	**Irrigation applied and**	**Topography of the region**	**Dominating LAND USE types and INTENSITY according toTable 3.3 (Refer to numbers of first column)**	**CLASSIFICATION of agroecosystem according to Table 7.2 and 7.3 (class numbers and proportion*)**	**Percentage of organic farmers**	**Mean farm size, and dominating farm size (ha)**
Grassland/dairy farming	Northern Poland	zachodniopomorskie, pomorskie, warmińsko-mazurskie	65375 9.5%	8.1-9.4 °C 551-618 mm 50-200 m	In the western part soils built on loamy sands with average soil water capacity. In the central part soils built on weak loamy sands with low soil water capacity. In the eastern part soils built on light loams with high soil water capacity.	No irrigation	dominated by flat areas, some postglacial hills, some depressions near the sea	First: 5 (intensity 1) Second: 15 (intensity 2) Third: 16 (intensity 1)	First : 42 (ca.70%); Second : 44 (ca. 25%); Third : 42 (ca. 5%)	n/d	Mean : 7.4 ha,dominating : 5 – 10 ha
	Eastern Poland	mazowieckie, podlaskie, lubelskie, łódzkie, świętokrzyskie	110795 13.4%	7.4 -9.0 498-625 100-200 m	In most areas soils built on loamy sand with average soil water capacity. In the south soils built on loess with high soil water capacity, but susceptible to erosion.	No irrigation	dominated by flat areas,	First: 5 (intensity 1) Second: 9 (intensity 1) Third: 16 (intensity 1)	First : 42 (ca. 50%); Second : 42 (ca. 25%); Third : 42 (ca. 5%)	n/d	Mean : 7.1 ha, dominating : 5 – 10 ha
	Southern	małopolskie,	45363	7.9-9.0	Soils built on	No	hilly region	First: 5 (intensity 1)	First : 42	n/d	Mean : 1.4

	Poland	podkarpackie, śląskie	13.0%	679-843 200-300 m	loess. In the south weak mountain soils.	irrigat ion	with mountains in the south	First: 14 (intensity 1)	(ca.70%); Second : 42 (ca. 30;		ha, dominating : 1 – 2 ha
	Western Poland	lubuskie, wielkopolski e, kujawsko-pomorskie, opolskie, dolnośląskie	91144 7.5%	8.3 – 9.6 511-643 100-200 m	Light soils with low soil water built on weak loamy sands. In the south soils built on loess and weak mountain soils.	No irrigat ion	dominated by flat areas, with mountains in the south	First: 5 (intensity 1) Second: 15 (intensity 2) Third: 16 (intensity 1) Fourth: 17 (intesity 1)	First : 42 (ca.50%); Second : 44(ca. 25%); Third : 42 (ca. 20% Fourth : 42 (ca. 5%)	n/d	Mean : 7.3 ha, dominating : 5 – 10 ha
Crop farming dominated by cereals with maize	Northern Poland	ditto	ditto 21.8%	ditto	ditto	ditto	ditto	First: 1 (intensity 1)	15 (ca 100%)	ditto	ditto
	Eastern Poland	ditto	ditto 29.9%	ditto	ditto	ditto	ditto	First: 1 (intensity 1)	15 (ca 100%)	ditto	ditto
	Southern Poland	ditto	ditto 17.4%	ditto	ditto	ditto	ditto	First: 1 (intensity 1)	15 (ca 100%)	ditto	ditto
	Western Poland	ditto	ditto 40.9%	ditto	ditto	ditto	ditto	First: 1 (intensity 2)	16 (ca 100%)	ditto	ditto
Orchard farming	Northern Poland	ditto	ditto 0.2%	ditto	ditto	ditto	ditto	First: 20 (intensity 1)	15 (ca 100%)	ditto	ditto
	Eastern Poland	ditto	ditto 2.3%	ditto	ditto	ditto	ditto	First: 20 (intensity 1)	15 (ca 100%)	ditto	ditto
	Southern Poland	ditto	ditto 3.2%	ditto	ditto	ditto	ditto	First: 20 (intensity 2)	15 (ca 100%)	ditto	ditto
	Western Poland	ditto	ditto 0.5%	ditto	ditto	ditto	ditto	First: 20 (intensity 1)	15 (ca 100%)	ditto	ditto
Potatoes	Northern Poland	ditto	ditto 1.1%	ditto	ditto	ditto	ditto	First: 4 (intensity 1)	15 (ca 100%)	ditto	ditto
	Eastern Poland	ditto	ditto 2.3%	ditto	ditto	ditto	ditto	First: 4 (intensity 1)	15 (ca 100%)	ditto	ditto
	Southern Poland	ditto	ditto 2.8%	ditto	ditto	ditto	ditto	First: 4 (intensity 1)	11 (ca 100%)	ditto	ditto
	Western Poland	ditto	ditto 1.9%	ditto	ditto	ditto	ditto	First: 4 (intensity 2)	16 (ca 100%)	ditto	ditto

Table 9.2. List of identified vulnerable regions to climate change in Poland and their main limitation and trends (expert assessment)

Dominating Agroecosystem (can be completed)	**Geographical region**	**National name of region**	**Main limitations**	**Observed trends**	**Socio-economic conditions and problems**	**Main identified vulnerabilities to climate change**
Grassland /dairy farming	Northern Poland	zachodniopomorskie, pomorskie, warmińsko-mazurskie	high cost of irrigation, water availability	low intensity of production, the biggest livestock density per farm	big farms, low milk price, bad conditions after PGR* liquidation	drought
	Eastern Poland	mazowieckie, podlaskie, lubelskie, łódzkie, świętokrzyskie	high cost of irrigation,	low intensity of production, low livestock density per farm	small farms, low milk price,	drought
	Southern Poland	małopolskie, podkarpackie, śląskie	high cost of irrigation,	low intensity of production, the lowest livestock density per farm	smallest farms, low milk price,	drought
	Western Poland	lubuskie, wielkopolskie, kujawsko-pomorskie, opolskie, dolnośląskie	high cost of irrigation, water availability	high intensity of production, high livestock density per farm	big farms, low milk price, bad conditions after PGR* liquidation	high vulnerability to drought
Crop farming dominated by cereals with maize	Northern Poland	zachodniopomorskie, pomorskie, warmińsko-mazurskie	water availability and high cost of irrigations	big farms are developing intensively and they buy more land, small farms search for profits outside agricultural production, after Poland's accession to the EU a huge part of subsidies is used to modernize farms	big farms producing about 50% of commodity production, small farms producing only for their own needs,	drought, heat stress, hail
	Eastern Poland	mazowieckie, podlaskie, lubelskie, łódzkie, świętokrzyskie	overgrinding area of farms, small farms have not enough money for modernization		small farms producing only for their own needs	drought, heat stress, hail, new pests, diseases
	Southern	małopolskie,	overgrinding area of		small farms producing only for	drought, heat stress, hail, new

	Poland	podkarpackie, śląskie	farms, small farms have not enough money for modernization		their own needs	pests, diseases
	Western Poland	lubuskie, wielkopolskie, kujawsko-pomorskie, opolskie, dolnośląskie	bad soils, low precipitation, water availability and high cost of irrigations	high intensity of production, the biggest commodity production, growing area of farms with commodity production, after Poland's accession to the EU a huge part of subsidies is used to modernize farms	high level of agronomical knowledge, highest level of yields, after Poland's accession to the EU a huge part of subsidies is used to modernize farms	drought, heat stress, hail, new pests, diseases observed
Orchard farming	Northern Poland	zachodniopomorskie, pomorskie, warmińsko-mazurskie	water availability, high cost of irrigations and insurance		Small number of orchards	high and low temperatures, new pests, diseases, ground frost, extreme phenomena: hail, wind, frost
	Eastern Poland	mazowieckie, podlaskie, lubelskie, łódzkie, świętokrzyskie	water availability, high cost of irrigations and insurance	big farms are developing intensively, after Poland's accession to the EU a huge part of subsidies is used to modernize farms	small farms producing only for their own needs	high and low temperatures, new pests, diseases, ground frost, extreme phenomena: hail, wind, frost
	Southern Poland	małopolskie, podkarpackie, śląskie	water availability, high cost of irrigations and insurance	big farms are developing intensively, after Poland's accession to the EU a huge part of subsidies is used to modernize farms	small farms producing only for their own needs	high and low temperature, new pests, diseases, ground frost, extreme phenomena: hail, wind, frost
	Western Poland	lubuskie, wielkopolskie, kujawsko-pomorskie, opolskie, dolnośląskie	water availability, high cost of irrigations and insurance	big farms are developing intensively, after Poland's accession to the EU a huge part of subsidies is used to modernize farms	highest level of yields, after Poland's accession to the EU a huge part of subsidies is used to modernize farms	high and low temperature, new pests, diseases, ground frost, extreme phenomena: hail, wind, frost
Potatoes	Northern Poland	zachodniopomorskie, pomorskie, warmińsko-mazurskie	water availability, high cost of irrigations, no enough money in small farms for investment in irrigation	Systematic decrease of potato production	big farms producing for food industry, small farms producing only for their own needs,	drought, heat stress, hail
	Eastern Poland	mazowieckie, podlaskie,	water availability, high cost of irrigations, no	Systematic decrease of potato production	small farms producing only for their own needs	drought, heat stress, hail

		lubelskie, łódzkie, świętokrzyskie	enough money in small farms for investment in irrigation			
	Southern Poland	małopolskie, podkarpackie, śląskie	water availability, high cost of irrigations, no enough money in small farms for investment in irrigation	Systematic decrease of potato production	small farms producing only for their own needs	drought, heat stress, hail
	Western Poland	lubuskie, wielkopolskie, kujawsko-pomorskie, opolskie, dolnośląskie	water availability, high cost of irrigations, no enough money in small farms for investment in irrigation	Systematic decrease of potato production	big farms producing for food industry, small farms producing only for their own needs,	drought, heat stress, hail

Table 9.3. Summary table on identified adaptation options in vulnerable regions and production systems in Poland

Dominating Agroeco-system	**Geographical region**	**National name of region** Provinces:	**Agroecosystem, related to common agroclimatic etc. indicators (to be defined in detail in a separate list)**	**Observed trends in adaptations to climate change (distinguish between farm level, regional level, national level)**	**Recommended feasible adaptation options to climate change**	**Identified limitations for adaptation options to climate change**	**Uncertainties, cost/benefits, risks (including economic risks), opportunities of adaptation options**	**Mitigation effects (assessment)**
Grassland/ dairy farming	Northern Poland	zachodniopomorskie, pomorskie, warmińsko-mazurskie		Farm: - modernization and reconstruction of irrigation-drainage systems, - restoration the existing irrigation-drainage systems to	Farm: - modernization and reconstruction of irrigation-drainage systems, - restoration the existing irrigation-drainage systems to operation, - adequate soil cultivation for	- costs of irrigation-drainage systems, - lack of funds for O&M of irrigation-drainage systems, - water resources scarcity disposable for irrigation, - lack of rules for co-operation leading to undertaking	- creation of favorable economic conditions in agriculture for investment, maintenance and performance of irrigation, - creation of legal,	**positive**: increase of irrigated area, increase of water use efficiency, increase of water resources

			operation Regional: - monitoring and forecasting systems, - regional water distribution systems National: - small-scale water retention program	increasing soil water retention Regional: - monitoring and forecasting systems, - regional water distribution systems, - improvement of existing infrastructure for storage and distribution of water National: - small-scale water retention program	common actions by agencies responsible for irrigation, - lack of organizations responsible for integrated water management in small river catchments, satisfying needs of all water users, among them irrigation systems	financial and institutional possibilities for regional water supply systems for irrigation,	disposal for crop production
	Eastern Poland	mazowieckie, podlaskie, lubelskie, łódzkie, świętokrzyskie	Farm: - modernization and reconstruction of irrigation-drainage systems, - restoration the existing irrigation-drainage systems to operation Regional: - monitoring and forecasting systems, - regional water distribution systems National: - small-scale water retention program	Farm: - modernization and reconstruction of irrigation-drainage systems, - restoration the existing irrigation-drainage systems to operation, - adequate soil cultivation for increasing soil water retention Regional: - monitoring and forecasting systems, - regional water distribution systems, - improvement of existing infrastructure for storage and distribution of water National: - small-scale water retention program	- costs of irrigation-drainage systems, - lack of funds for O&M of irrigation-drainage systems, - water resources scarcity disposable for irrigation, - lack of rules for co-operation leading to undertaking common actions by agencies responsible for irrigation, - lack of organizations responsible for integrated water management in small river catchments, satisfying needs of all water users, among them irrigation systems	- creation of favorable economic conditions in agriculture for investment, maintenance and performance of irrigation, - creation of legal, financial and institutional possibilities for regional water supply systems for irrigation,	**positive**: increase of irrigated area, increase of water use efficiency, increase of water resources disposal for crop production,
	Southern Poland	małopolskie, podkarpackie, śląskie	Farm: - modernization and reconstruction of drainage systems, - restoration the existing drainage systems to operation Regional: - monitoring and forecasting systems of floods,	Farm: - modernization and reconstruction of drainage systems, - restoration the existing drainage systems to operation, - adequate soil cultivation for increasing infiltration and run-off of excessive water Regional: - monitoring and forecasting	- costs of drainage systems, - lack of funds for O&M of drainage systems,	- creation of favorable economic conditions in agriculture for investment, maintenance and performance of drainage systems,	**positive**: decrease of losses in fodder production due to floods,

				systems warning of flood threats,			
	Western Poland	lubuskie, wielkopolskie, kujawsko-pomorskie, opolskie, dolnośląskie	Farm: - modernization and reconstruction of irrigation-drainage systems, - restoration the existing irrigation-drainage systems to operation Regional: - monitoring and forecasting systems, - regional water distribution systems, National: - small-scale water retention program	Farm: - modernization and reconstruction of irrigation-drainage systems, - restoration the existing irrigation-drainage systems to operation, - adequate soil cultivation for increasing soil water retention Regional: - monitoring and forecasting systems, - regional water distribution systems, - improvement of existing infrastructure for storage and distribution of water National: - small-scale water retention program	- costs of irrigation-drainage systems, - lack of funds for O&M of irrigation-drainage systems, - water resources scarcity disposable for irrigation, - lack of rules for co-operation leading to undertaking common actions by agencies responsible for irrigation, - lack of organizations responsible for integrated water management in small river catchments, satisfying needs of all water users, among them irrigation systems	- creation of favorable economic conditions in agriculture for investment, maintenance and performance of irrigation, - creation of legal, financial and institutional possibilities for regional water supply systems for irrigation,	**positive**: increase of irrigated area, increase of water use efficiency, increase of water resources disposal for crop production
Crop farming dominated by cereals with maize	Northern Poland	ditto	Farm: - introducing modern irrigation devices and systems, Regional: - monitoring and forecasting systems, - regional water distribution systems, - very high regional and local variation in agri-climatic conditions, requiring the need for regionalization of new plant cultivars National: - small-scale water retention program	Farm: - introducing modern irrigation devices and systems, - introducing new crop variates resistant to water scarcity, - adequate soil cultivation for increasing soil water retention, Regional: - monitoring and forecasting systems, - regional water distribution systems, - improvement of existing infrastructure for storage and distribution of water National: - small-scale water retention program,	- costs of irrigation devices and systems, - water resources scarcity disposable for irrigation - lack of rules for co-operation leading to undertaking common actions by agencies responsible for irrigation - lack of organizations responsible for integrated water management in small river catchments, satisfying needs of all water users, among them irrigation systems - high variation in date of beginning of vegetation in spring (up to 4 weeks) incidence of snow cover persisting up to two weeks after the period of early spring	- creation of favorable economic conditions in agriculture for investment, maintenance and performance of irrigation, - creation of legal, financial and institutional possibilities for regional water supply systems for irrigation, - an increase in climate hazard for cultivation of plants mainly in the spring season due to adverse meteorological phenomena, such as variation in beginning of farming periods	**positive**: increase/maintainance of irrigated area, increase of water use efficiency, increase of water resources disposal for crop production **positive**: advantageous climate water balance in the vegetation period **negative**: high time and spatial variation in weather

					- an increase in area cropped to rape and seed-potatoes -at the expense of spring plants	warmer spell. Late spring frosts, hail, especially in the Kaszuby Lake District	frost, snow cover. Periodically an increased hazard for winter crops due to excessive snow cover in north-eastern part of the region	conditions, losses due to considerable retardation in vegetation, especially in the Warmińsko-mazurskie province
	Eastern Poland	ditto		Farm: - introducing modern irrigation devices and systems, - modernization and reconstruction of irrigation-drainage systems Regional: - monitoring and forecasting systems, - regional water distribution systems, - earlier beginning of field works and plant vegetation. Cultivation of plants with high insolation requirements National: - small-scale water retention program	Farm: - introducing modern irrigation devices and systems, - modernization and reconstruction of irrigation-drainage systems, - introducing new crop variates resistant to water scarcity, - adequate soil cultivation for increasing soil water retention, Regional: - monitoring and forecasting systems, - regional water distribution systems, - improvement of existing infrastructure for storage and distribution of water National: - small-scale water retention program, - insurance of crops against atmospheric droughts, hail and results of poor winter	- costs of irrigation devices and systems, - water resources scarcity disposable for irrigation - lack of rules for co-operation leading to undertaking common actions by agencies responsible for irrigation - lack of organizations responsible for integrated water management in small river catchments, satisfying needs of all water users, among them irrigation systems, - increased frequency and intensity of atmospheric and soil droughts, hail hazard for crops ranging from small in the lower Bug basin to high in the Lubelska and Małopolska Uplands. Years with poor winter survival rates may occur after adverse winters	- creation of favorable economic conditions in agriculture for investment, maintenance and performance of irrigation, - creation of legal, financial and institutional possibilities for regional water supply systems for irrigation, - increased costs in plant production due to atmospheric and soil droughts (mainly in the Mazowieckie province), hail and poor winter survival rates.	**positive**: increase/maintainance of irrigated area, increase of water use efficiency, increase of water resources disposal for crop production **positive**: longer vegetation period, higher total temperatures for cultivation of thermophytic plants, higher insolation, **negative**: increase in extreme character of adverse phenomena, higher hazard

			survival			for plants due to diseases and pests
Southern Poland	ditto	<u>Farm:</u> - modernization and reconstruction of drainage systems <u>Regional:</u> - monitoring and forecasting systems, - regional water distribution systems - changes in land use structure <u>National:</u> - national program of flood control	<u>Farm:</u> - modernization and reconstruction of irrigation-drainage systems, - introducing new crop variates resistant to water scarcity, - adequate soil cultivation for increasing soil water retention, <u>Regional:</u> - monitoring and forecasting systems, - regional water distribution systems, - improvement of existing infrastructure for storage and distribution of water - increase in area cropped to thermophytic plants such as soy, grapevine in the Sandomierska and Oświęcimska Basins <u>National:</u> - implementation of flood control strategy	- investment costs of drainage systems, - increased frequency of southerly circulation causes an increase in air temperature in the Foothills mainly in winter and early spring, as well as winter and early spring thaws	- creation of favorable economic conditions in agriculture for investment, maintenance and performance of drainage, - high hazard for crops due to floods and hail	**positive**: increase/maintainance of irrigated area, increase of water use efficiency, increase of water resources disposal for crop production **positive**: increased air temperature in the Foothills, **negative**: a change in energy and matter cycles as a result of progressing anthopopressure
Western Poland	ditto	<u>Farm:</u> - introducing modern irrigation devices and systems, - modernization and reconstruction of irrigation-drainage systems <u>Regional:</u> - monitoring and	<u>Farm:</u> - introducing modern irrigation devices and systems, - modernization and reconstruction of irrigation-drainage systems, - introducing new crop variates resistant to water scarcity, - adequate soil cultivation for	- costs of irrigation devices and systems, - water resources scarcity disposable for irrigation - lack of rules for co-operation leading to undertaking common actions by agencies responsible for irrigation - lack of organizations responsible for integrated	- creation of favourable economic conditions in agriculture for investment, maintenance and performance of irrigation, - creation of legal, financial and institutional	**positive**: increase/maintainance of irrigated area, increase of water use efficiency, increase of water resources disposal for crop

			forecasting systems, - regional water distribution systems, - the longest vegetation period of 220 – 235 days. Earlier sowing and harvest dates National: - small-scale water retention program	increasing soil water retention, Regional: - monitoring and forecasting systems, - regional water distribution systems, - improvement of existing infrastructure for storage and distribution of water, - an increase in area cropped to winter cereals at the expense of spring cereals. Cultivation of catch crops, and in the Lower Silesia thermophytic plants National: small- scale water retention program	water management in small river catchments, satisfying needs of all water users, among them irrigation systems - the highest negative climate water balance especially in mid-western part, deepening soil droughts, losses caused by hail	possibilities for regional water supply systems for irrigation, - increased cultivation costs due to sprinkling and storage of winter waters	production **positive**: high accumulated heat **negative**: insufficient precipitation totals in mid-western part, high variation of farming period dates in spring, frost hazard, floods
Orchard farming	Northern Poland	ditto	Farm: - introducing modern microirrigation devices and systems, Regional: - monitoring and forecasting systems, - regional water distribution systems, - progressing climate changes improve agri-meteorological conditions for orchard production National: - small-scale water retention program	Farm: - introducing modern microirrigation devices and systems, - adequate soil cultivation for increasing soil water retention, Regional: - monitoring and forecasting systems, - regional water distribution systems, - improvement of existing infrastructure for storage and distribution of water, - planting of trees with increased tolerance to sub-zero temperatures in winter, especially in the Warmińsko-mazowieckie province National: small-scale water retention program	- costs of irrigation devices and systems, - water resources scarcity disposable for irrigation - lack of rules for co-operation leading to undertaking common actions by agencies responsible for irrigation - lack of organizations responsible for integrated water management in small river catchments, satisfying needs of all water users, among them irrigation systems, - despite expected increase of temperatures in winter, the incidence of years with periodically low temperatures in that season need to be taken into consideration	- creation of favourable economic conditions in agriculture for investment, maintenance and performance of irrigation, - creation of legal, financial and institutional possibilities for regional water supply systems for irrigation, - hazard due to low sub-zero temperatures in winter and late spring frosts. Periodically poor colouring of fruits due to increased overcast in summer	**positive**: increase of irrigated area, increase of water use efficiency, increase of water resources disposal for crop production **positive**: increased temperatures and hours of insolation, advantageous moisture conditions. **negative**: late spring frosts, high variation in dates of beginning of temperatures of 5, 10 and 15^{o}C, strong frosts in

								winter in the Warmińsko-mazurskie province
	Eastern Poland	ditto		Farm: - introducing modern microirrigation devices and systems, Regional: - monitoring and forecasting systems, - regional water distribution systems, - observed warming will promote earlier ripening and harvesting of fruits National: - small-scale water retention program	Farm: - introducing modern microirrigation devices and systems, - adequate soil cultivation for increasing soil water retention, Regional: - monitoring and forecasting systems, - regional water distribution systems, - improvement of existing infrastructure for storage and distribution of water - potential for increase in area of grapevine cultivation, especially on slopes with S, SW and SE exposure in the Lubelskie and Świętokrzyskie provinces National: small-scale water retention program	- costs of irrigation devices and systems, - water resources scarcity disposable for irrigation - lack of rules for co-operation leading to undertaking common actions by agencies responsible for irrigation - lack of organizations responsible for integrated water management in small river catchments, satisfying needs of all water users, among them irrigation systems - topographic features may be a limiting factor for the size of orchards	- creation of favourable economic conditions in agriculture for investment, maintenance and performance of irrigation, - creation of legal, financial and institutional possibilities for regional water supply systems for irrigation, - increasing frequency of soil droughts will require periodical sprinkling in orchards, covers protection against spring frost may also be used	**positive**: increase of irrigated area, increase of water use efficiency, increase of water resources disposal for crop production **positive**: good insolation and high accumulated heat **negative**: periodically low temperatures in winter, hail, periodical precipitation shortage

Southern Poland	ditto	Farm: - introducing modern microirrigation devices and systems, Regional: - monitoring and forecasting systems, - regional water distribution systems, - increasingly advantageous agri-climatic conditions in the Sandomierska Basin and the Carpathian Foothills create increasingly conducive conditions for orchard production National: - small-scale water retention program	Farm: - introducing modern microirrigation devices and systems, - adequate soil cultivation for increasing soil water retention, Regional: - monitoring and forecasting systems, - regional water distribution systems, - improvement of existing infrastructure for storage and distribution of water, - climatic conditions for the development of specialist orchards are found National: small-scale water retention program	- costs of irrigation devices and systems, - water resources scarcity disposable for irrigation - lack of rules for co-operation leading to undertaking common actions by agencies responsible for irrigation - lack of organizations responsible for integrated water management in small river catchments, satisfying needs of all water users, among them irrigation systems, - topographic features and high variation in weather conditions in the Foothills in winter and spring may be a limiting factor for the size of orchards	- creation of favourable economic conditions in agriculture for investment, maintenance and performance of irrigation, - creation of legal, financial and institutional possibilities for regional water supply systems for irrigation, - hazard due to hail and regional atmospheric pollution in the Silesia-Kraków conurbation	**positive**: increase of irrigated area, increase of water use efficiency, increase of water resources disposal for crop production **positive**: stable high accumulated heat and precipitation total **Negative**: fruit quality deteriorating due to hail
Western Poland	ditto	Farm: - introducing modern microirrigation devices and systems, Regional: - monitoring and forecasting systems, - regional water distribution systems, - extending vegetation period and earlier fruit ripening National: - small-scale water retention program	Farm: - introducing modern microirrigation devices and systems, - adequate soil cultivation for increasing soil water retention, Regional: - monitoring and forecasting systems, - regional water distribution systems, - improvement of existing infrastructure for storage and distribution of water, - increased area of grapevine cultivation in the Lubuskie and Dolnośląskie provinces National: small-scale water retention program	- costs of irrigation devices and systems, - water resources scarcity disposable for irrigation - lack of rules for co-operation leading to undertaking common actions by agencies responsible for irrigation - lack of organizations responsible for integrated water management in small river catchments, satisfying needs of all water users, among them irrigation systems - negative climatic water balance	- creation of favourable economic conditions in agriculture for investment, maintenance and performance of irrigation, - creation of legal, financial and institutional possibilities for regional water supply systems for irrigation, - high hazard due to frequent incidence of soil droughts in the Wielkopolskie and Lubuskie Lake Districts, locally also due to hail.	**positive**: increase of irrigated area, increase of water use efficiency, increase of water resources disposal for crop production **positive**: high accumulated heat and high insolation in the Wielkopolskie Lake District **negative**: precipitation shortage and high evapotranspirati on

Potatoes	Northern Poland	ditto	Farm: - introducing irrigation devices and systems, Regional: - monitoring and forecasting systems, - regional water distribution systems, - present good conditions for potato cultivation may deteriorate, especially in western part of the Zachodniopomorskie province as a result of increased air temperature and incidence of soil droughts National: - small-scale water retention program	Farm: - introducing water-efficient irrigation devices and systems, - introducing new variates resistant to water scarcity, - adequate soil cultivation for increasing soil water retention, Regional: - monitoring and forecasting systems, - regional water distribution systems, - improvement of existing infrastructure for storage and distribution of water, - in areas excluded from seed-potato growing - introduction of e.g. rape growing National: small-scale water retention program	- costs of irrigation devices and systems, - water resources scarcity disposable for irrigation - lack of rules for co-operation leading to undertaking common actions by agencies responsible for irrigation - lack of organizations responsible for integrated water management in small river catchments, satisfying needs of all water users, among them irrigation systems, - periodical variation of temperature and moisture conditions having an adverse effect on yielding stability, in the harvest period intensification of wet days in northern part of the region	- creation of favourable economic conditions in agriculture for investment, maintenance and performance of irrigation, - creation of legal, financial and institutional possibilities for regional water supply systems for irrigation, - increased costs due to plantation protection as a result of high variation in weather conditions	**positive**: increase of irrigated area, increase of water use efficiency, increase of water resources disposal for crop production **positive**: early planting dates, appropriate moisture conditions in northern and eastern parts of the region **negative**: periodical water shortage, rainy periods during harvest
	Eastern Poland	ditto	Farm: - introducing irrigation devices and systems, Regional: - monitoring and forecasting systems, - regional water distribution systems - in the Mazowieckie and Podlaskie provinces increased frequency of soil droughts National: - small-scale water retention program	Farm: - introducing water-efficient irrigation devices and systems, - introducing new variates resistant to water scarcity, - adequate soil cultivation for increasing soil water retention, Regional: - monitoring and forecasting systems, - regional water distribution systems, - improvement of existing infrastructure for storage and distribution of water, National: small-scale water retention program - need to be insured against soil droughts	- costs of irrigation devices and systems, - water resources scarcity disposable for irrigation - lack of rules for co-operation leading to undertaking common actions by agencies responsible for irrigation - lack of organizations responsible for integrated water management in small river catchments, satisfying needs of all water users, among them irrigation systems, - limiting factors are periodical precipitation shortage and too high air temperature	- creation of favourable economic conditions in agriculture for investment, maintenance and performance of irrigation, - creation of legal, financial and institutional possibilities for regional water supply systems for irrigation, - risk of losses due to floods in areas adjacent to rivers	**positive**: increase of irrigated area, increase of water use efficiency, increase of water resources disposal for crop production **positive**: high insolation **negative**: potential reduction of yield in over 10% due to insufficient soil moisture content in the Mazowiecka

								Lowland and the Polesie region
	Southern Poland	ditto		<u>Farm:</u> - introducing irrigation devices and systems, <u>Regional:</u> - monitoring and forecasting systems, - regional water distribution systems, - increased frequency and extreme character of spring and summer floods <u>National:</u> - small-scale water retention program	<u>Farm:</u> - introducing water-efficient irrigation devices and systems, - introducing new variates resistant to water scarcity, - adequate soil cultivation for increasing soil water retention, <u>Regional:</u> - monitoring and forecasting systems, - regional water distribution systems, - improvement of existing infrastructure for storage and distribution of water, <u>National:</u> small-scale water retention program - insurance of crops against soil droughts and floods	- costs of irrigation devices and systems, - water resources scarcity disposable for irrigation - lack of rules for co-operation leading to undertaking common actions by agencies responsible for irrigation - lack of organizations responsible for integrated water management in small river catchments, satisfying needs of all water users, among them irrigation systems, - land layout and altitude, limited cultivation in the Silesia-Kraków conurbation due to atmospheric pollution and frequent rainy periods in autumn	- creation of favourable economic conditions in agriculture for investment, maintenance and performance of irrigation, - creation of legal, financial and institutional possibilities for regional water supply systems for irrigation, - risk of yield instability due to floods and hail in the hail track zone	**positive**: increase of irrigated area, increase of water use efficiency, increase of water resources disposal for crop production **positive**: positive climatic water balance, cultivation of early potato cultivars **negative**: too high air temperature in the Sandomierska and Oświęcimska Basins, throughout the region increased frequency of rainy periods during harvests

	Western Poland	ditto	<u>Farm:</u> - introducing irrigation devices and systems, <u>Regional:</u> - monitoring and forecasting systems, - regional water distribution systems, - extension of farming periods mainly due to earlier beginning of spring field works and resumed vegetation <u>National:</u> - small-scale water retention program	<u>Farm:</u> - introducing water-efficient irrigation devices and systems, - introducing new variates resistant to water scarcity, - adequate soil cultivation for increasing soil water retention, <u>Regional:</u> - monitoring and forecasting systems, - regional water distribution systems, - improvement of existing infrastructure for storage and distribution of water <u>National:</u> small-scale water retention program, - insurance of crops against soil droughts and floods	- costs of irrigation devices and systems, - water resources scarcity disposable for irrigation - lack of rules for co-operation leading to undertaking common actions by agencies responsible for irrigation - lack of organizations responsible for integrated water management in small river catchments, satisfying needs of all water users, among them irrigation systems, - in the Lubuskie and Wielkopolskie Lake Districts the limiting factor is deepening shortage of precipitation	- creation of favourable economic conditions in agriculture for investment, maintenance and performance of irrigation, - creation of legal, financial and institutional possibilities for regional water supply systems for irrigation, - increased costs due to the need of periodical irrigation of plantations, and in the Opolskie and Dolnośląskie provinces - due to occurring floods	**positive**: increase of irrigated area, increase of water use efficiency, increase of water resources disposal for crop production **positive**: early dates of beginning of vegetation **negative**: deepening negative climatic balance in mid-eastern part of the region

10 - RUSSIA

Table 10.1. List of identified vulnerable regions to climate change in Russia and their characteristics (expert assessment)

Dominating Agroeco-system	geographical region	National name of region	Approx size of the region (km²)	Annual temperature precip. and sea level of the region (from-to)	Dominating soil conditions (describe)	Irrigation applied and dominating type of irrigation	Topography of the region	Dominating LAND USE types and INTENSITY according toTable 3.3 (Refer to numbers of first column)	CLASSIFICATION of agroecosystem according to Table 7.2 and 7.3 (class numbers and proportion*)	Percentage of organic farmers	Mean farm size, and dominating farm size (ha)
Grassland /dairy farming	North-Western part of ETR	Vologda	145700	2.-2.5°C 500-580 mm 130-200 m	sward-podzolic soils, loam high water content in soils	Drainage systems Sprinkling (partly)	high percent of forest-clad relief; bogginess	First 5 (intensity 2)	First 41 (50%) Second 42 (50%)	5	54 7
Potatoes farming	North Western ETR	Pskov	55300	4.5-5.5 °C 560-650 mm 30-100 m	sward-podzolic soils, loam,sandy loam, peat extra humid soils	Drainage systems	high percent of forest-clad relief; bogginess	First:3 (intensity 1)	First 11 (80%) Second 15 (20%)	2	51 7
Vegetable farming	North Western ETR	Leningrad	85900	4-5 °C 550-600mm 0-80 m	sward-podzolic soils, loam high water content in soils	Drainage systems Sprinkling (partly)	high percent of forest-clad relief; bogginess	First 3 (intensity 3) Second 17 (intens. 3)	First 14 (70%) Second 13 (15%) Third 12 (15%)	45	24 10
Crop farming Dominated by cereals	North Western ETR	Kaliningrad	15100	7-7.5°C 800-870 mm 10-50 m	sward-podzolic, sandy loam high water content in soils	Drainage systems	high percent of forest-clad relief; bogginess	First 1 (intens 2) Second 8 (intens. 2)	First 15 (70%) Second 11 (10%) Third 16 (20%)	8	18 7
Grassland /dairy farming	Central ETR	Kostroma	60000	3-4 °C 500-550 mm 100-150 m	sward-podzolic soils, loam high water content in soils	Drainage systems	high percent of forest-clad relief; bogginess	First 6 (intensity 1)	First 42 (70%) Second 44 (30%)	5	77 11
Crop farming Dominated by spring barley	Central ETR	Smolensk	49800	4.1-5.1°C 600-650 mm 150-250 m	sward-podzolic soils, loam, sandy loam, peat extra humid soils	Drainage systems	high percent of forest-clad relief; bogginess	First 3 (intensity 2)	First 15 (60%) Second 11 (40%)	3	76 7
Crop farming Dominated by buckwheat	Central ETR	Orel	24700	4.5-5.7 °C 500-550 mm 200-500 m	gray wooded soils, podzolic chernozem , loam,	Sprinkling 10%	ravines and gully relief	First 3 (intensity 2)	First 15 (70%) Second 11 (30%)	2	150 75

					clay medium water content in soils						
Dominating Agroecosystem	geographical region	National name of region	Approx size of the region (km²)	Annual temperature precip. and sea level of the region (from-to)	Dominating soil conditions (describe)	Irrigation applied and dominating type of irrigation	Topography of the region	Dominating LAND USE types and INTENSITY according toTable 3.3 (Refer to numbers of first column)	CLASSIFICATION of agroecosystem according to Table 7.2 and 7.3 (class numbers and proportion*)	Percentage of organic farmers	Mean farm size, and dominating farm size (ha)
Crop farming Dominated by winter wheat and buckwheat.	Chernozem Center	Kursk	29800	4.7-5.7oC 550-600 mm 200-500 m	Modal and leached chernozems, loam, clay medium water content in soils	Sprinkling 15%	ravines and gully relief	First 1 (intensity 2)	First 15 (80%) Second 11 (20%)	3	165 75
Crop farming Dominated by sugar beet	Chernozem Center	Belgorod	27100	6.3-7.3 oC 600-650 mm 150-300 m	Modal chernozem, loam medium water content in soils	Sprinkling 15-20%	ravines and gully relief	First 3 (intensity 3)	First 16 (65%) Second 15 (15%) Third 16 (20%)	3	100 6
Crop farming Dominated by winter and spring wheat	Chernozem Center	Voronez	52400	5.4-6.5 oC 530-570 mm 100-250 m	Common and southern chernozems, loam, clay medium/low water content in soils	Canal systems 20-25%	ravines and gully relief, plains	First 2 (intensity 2)	First 15 (65%) Second 17 (20%) Third 11 (15%)	2	150 35
Crop farming Dominated by spring wheat and millet	Middle Volga	Tatarstan and Bashkortostan	211600	3.5-5.0 oC 400-480 mm 100-200 m	Leached chernozem, loam, clay medium/low water content in soils	Sprinkling, canal systems 20-25%	ravines and gully relief	First 3 (intensity 3) Second 14 (intens. 2)	First 16 (60%) Second 17 (20%) Third 11 (10%) Forth 14 (10%)	3	175 35
Crop farming: wheat durum and maize hybrids	LowVolga	Saratov, Volgograd	246000	7,7-8,7 oC 420-470 mm 200-500 m	Deep- and light chestnut soils, loam, clay, solonetz low water content in soils	Large irrigation systems	plains, drylands	First 3 (intensity 2)	First 15 (40%) Second 17 (40%) Third 11 (20%)	1	300 75
Crop farming Dominated by hard winter wheat/ maize	Northern Caucasus	Krasnodar Stavropol Rostov	266000	8-9 oC 450-500 mm 200-500 m	Black-, common- and southern chernizems; Deep-	Sprinkling, large irrigation	plains (including dry plains), uplands,	First 3 (intensity3)	First 16 (30%) Second 17 (30%) Third 14 (10%)	Horticulture 36%	350 90

for grain, sugar beet, Sunflower, Horticulture					and light chestnut soils medium/low water content in soils	systems	foothills,elevations		Forth 20 (30%)	Crop farmin g 3%	

Table 10.2. List of identified vulnerable regions to climate change in Russia and their main limitation and trends (expert assessment)

Dominating Agroeco-system	geographical region	National name of region	Main limitations	Observed trends	Socio-economic conditions and problems	Main identified vulnerabilities to climate change
Grassland /dairy farming	North-Western part of ETR	Vologda	forest-clad relief, bogginess, acid soils	decrease in soil acidification	modernization of drainage systems, additional irrigation ,if necessary	increasing rotting out risk, new pests, diseases and weeds
Potatoes farming	North Western ETR	Pskov	bogginess, extra humid soils, acid soils	decrease in soil acidification	modernization of drainage systems	increasing rotting- and wetting out risks, new pests and diseases
Vegetable farming	North Western ETR	Leningrad	forest-clad relief, bogginess, acid soils	decrease in soil acidification	modernization of drainage systems, additional irrigation ,if necessary	increasing rotting- and wetting out risks, new pests, diseases and weeds
Crop farming Dominated by cereals	North Western ETR	Kaliningrad	forest-clad relief	decrease in soil acidification	modernization of drainage systems, additional irrigation ,if necessary	Wet spells, increasing risk of wetting out
Grassland /dairy farming	Central ETR	Kostroma	forest-clad relief, bogginess, acid soils	decrease in soil acidification	modernization of drainage systems, additional irrigation ,if necessary, weak economic conditions, migration of agricultural population	increasing rotting out risk, new pests and diseases
Crop farming Dominated by spring barley	Central ETR	Smolensk	forest-clad relief, bogginess, extra humid soils, acid soils	decrease in soil acidification	modernization of drainage systems	wet spells, lodging, increasing rotting- and wetting out risks
Crop farming Dominated by buckwheat	Central ETR	Orel	Ravines and gully relief, water erosion	increase in water erosion	more large farms	dry spells, increasing drought recurrence, increasing water erosion
Crop farming Dominated by winter wheat/buckwheat	Chernozem Center	Kursk	Ravines and gully relief, water erosion	increase in water erosion	more large farms	dry winds, increasing drought recurrence, increasing water erosion
Dominating Agroeco-system	**geographical region**	**National name of region**	**Main limitations**	**Observed trends**	**Socio-economic conditions and problems**	**Main identified vulnerabilities to climate change**
Crop farming Dominated by sugar	Chernozem Center	Belgorod	Ravines and gully relief, water erosion	increase in water erosion	more large farms, breed farming	dry winds, increasing drought recurrence, increasing water

beet						erosion
Crop farming Dominated by winter and spring wheat	Chernozem Center	Voronez	Ravines and gully relief, water erosion	increase in water erosion	more large farms, switching to winter crops	dry winds, increasing drought recurrence, increasing water and wind erosion, decreasing frost killing risk
Crop farming Dominated by spring wheat and millet	Middle Volga	Tatarstan and Bashkortostn	Ravines and gully relief, water erosion	increase in water erosion	breed farming development, switching to winter crops	dry winds, increasing drought recurrence, increasing water and wind erosion, decreasing frost killing risk
Crop farming Dominated by wheat durum and maize gibrids	Low Volga	Saratov	Alkali-affected soils, dust storms, wind erosion, aridization	increasing wind erosion	improving irrigation systems, specialization of farmers for cash crops, more large farms, switching to winter crops	increasing drought recurrence, increasing wind erosion, decreasing frost killing risk, increasing percent of alkali-affected soils
Crop farming Dominated by hard winter wheat and maize for grain, sugar beet, Sunflower, Horticulture	Northern Caucasus	Krasnodar Stavropol Rostov	floods, mudflows, dust storms, water and wind erosion	increasing wind erosion, increasing floods and mudflow occurence	improving irrigation systems and techniques against floods and mudflows specialization of farmers for cash crops, switching to winter crops in certain regions	increasing floods and mudflows recurrence, increasing drought recurrence, increasing water and wind erosion, decreasing frost killing risk

Table 10.3. Summary table on identified adaptation options in vulnerable regions and production systems in Russia

Dominating Agroecosystem (as given in Del. 3-5 report)	Geographical region	National name of region	Agroecosystem, related to common agroclimatic etc. indicators	Observed trends in adaptations to climate change (distinguish between farm level, regional level, national level)	Recommended feasible adaptation options to climate change	Identified limitations for adaptation options to climate change	Uncertainties, cost/benefits, risks (including economic risks), opportunities of adaptation options	Mitigation effects (assessment)
Winter wheat	Chernozem zone	Chernozem Centre and Middle Volga Region	HTC (Hydrotermal coefficient by Selianinov) Indexes by Shashko, Procerov	farm: succession cropping Regional: including silage maize + barley into crop rotation system National: bare fallowing	improving protective belt systems in the plain areas (for improving snow cover management) improving snow arresting tree belts	ravine/gully systems in topography; water erosion; dry winds; droughts	decreasing frost killing risk; intensified harmfulness of such winter insect pest as chinch bug	adjusting nitrogenous additional fertilizing; improving tillage practice to suppress winter pest population into soil improving biological methods for crop protection
Winter wheat	South-East of ETR	Lower Volga& Southern Pre-Ural Region	HTC, Indexes by Shashko, Procerov	farm: fall tillage regional: manures applying, improving crop rotation system by introduction of alfalfa	effective snow hedge application	solonetz-like soils, solonetz formation, sands	reducing frost killing risk	optimizing snow hedge dimension and interspaced as well configuration improving irrigation systems
Spring barley and spring wheat	Chernozem zone	Chernozem Centre &Middle Volga Region	HTC, Indexes by Shashko, Procerov	farm: conservation tillage; soil rolling in the dry spring Regional: earlier sowing dates National: use of drought tolerant cultivars	improving ravine and bully afforestation for soil erosion protection	ravine/gully systems in topography water erosion dry winds droughts	intensify of dry winds and droughts intensified harmfulness of frit fly	use of more drought tolerant cultivars improving biological and chemical methods for crop protection increasing manures efficiency
Maize for silage and grain	Chernozem zone	Chernozem Centre &Middle Volga Region	HTC, Indexes by Shashko, Procerov	farm: water conservation tillage Regional: water management afforestation National: more productive cultivars	slope terracing introduction of new hybrids	ravine/gully systems in topography water erosion dry winds droughts	intensified harmfulness of corn bug	adjusting doses of fertilizers

Maize for grain	South of ETR	Northern Caucasus	HTC, Indexes by Shashko, Procerov	deep plowing, application of dozes of fertilizers in optimum, use of perennial grasses in crop rotation systems	introducing cultivars responded to fertilizers, effective application of basin irrigation in costal zone	dry winds, floods, mudflow	floods	introducing new more productive cultivars and hybrids, optimizing sprinker irrigation in summer season
Wheat durum	South-East of ETR	Lower Volga & Southern Pre-Ural Region	HTC, Indexes by Shashko, Procerov	farm: soil loosing in autumn, in-deep tillage, sub-surface plowing, Regional: soil gypsuming, stubble – mulch tillage, use of manures, additional phosphorous fertilization	effective application of wind break belts, afforestation of sands	solonetz-like soils, solonetz formation, sands	droughts, dry winds, dust storms	regulation the height and width of belts, belts configuration, spreading generic composition
Spring wheat	Central part of ETR	Non-Chernozem Centre &Volga-Viatka Region	HTC, Indexes by Shashko, Procerov	farm: improving crop rotation system including alternative crops regional: introducing grass arable rotation and meadow grass rotation	improving practice for water erosion protection improving practice for water accumulation into soil	spring drought	reducing frost killing risk	adjusting dozes of fertilizer and timing of farm operations
Winter rye	Central Russia	Non-Chernozem Centre& Volga-Viatka Reg.	HTC, Indexes by Shashko, Procerov	intensification of surface runoff, deep drainage	introducing cultivars more resistant to rots	extra-wetted soils	increasing rotting-out risk	application of entomophages against Agriotes lieatus and Phyelotreta vittuka
Winter rye	NW Russia	North-West Russia	HTC, Indexes by Shashko, Procerov	farm: improving crop rotation system by introducing perennial grasses, increasing fertilization including manure application Regional: soil liming, different kind of drainage	change in timing of farm operation, adjusting dozes of fertilizers and liming	forest-clad relief, bogginess, low soil fertility, soil acidification	increasing wetting- and rotting out, lodging, pest, diseases and weeds	rye cultivars more resistant to snow mold, application of entomophages
Potatoes	Central	Non-	HTC,	use of responded to	earlier ripening	extra-wetted soils	increasing harmfulness of	cultivars resistant to

	Russia	Chernozem Centre Volga-Viatka Region	Indexes by Shashko, Procerov	fertilization cultivars	cultivars		potatoes diseases	Erwinia phytophthora Beg and Phytophtora infestanse
Potatoes	NW Russia	North-West Russia	HTC, Indexes by Shashko, Procerov	improving resistantability of potatoes cultivars to intensifying potatoe diseases	more productive cultivars	forest-clad relief, bogginess, low soil fertility, soil acidification	increasing distribution of insect pests, diseases and weeds, new insect pest acclimatization	more resistant cultivars, application of introduced and aboriginal entomophages
Hard Winter wheat	South of ETR	Northern Caucasus	HTC, Indexes by Shashko, Procerov	farm: application of early spring- and autumnal irrigation, adjusting dozes of fertilizers Regional: bare- and legume fallowing, soil gypsuming	wide use of grasses varieties in crop rotation system, including alfalfa, effective use of wind – break belts	solonetz –like soils and sands, mountains droughts ,dry winds, dust storms, floods, mudflow	droughts	drought tolerant cultivars
Winter barley	South of ETR	Northern Caucasus	HTC, Indexes by Shashko, Procerov	improving fall tillage and deep plowing, introducing in crop rotation system sunflower	improving bench border irrigation	solonetz –like soils and sands, mountains droughts ,dry winds, dust storms, floods, mudflow	reducing frost killing risk, mudflow	enlarging planted areas introducing new cultivars towards elevations
Rice	South of ETR	Northern Caucasus	HTC	rice system cultivation in optimum, adjusting dozes of fertilizers, irrigation rates and timing	improving basin check irrigation, fertilizer irrigation, channel irrigation	solonetz –like soils dust storms, floods, mudflow	intensifying rice diseases	computerized irrigation
Grape	South of ETR	Northern Caucasus		maintaining heat and water regime in optimum, control for surface runoff	techniques for protection grape against early autumn and later spring frosts, slope terracing		grape insect pest and diseases harmfulness	enlarging grape planted areas towards elevations

11 – ROMANIA

Table 11.1. List of identified vulnerable regions to climate change in Romania and their characteristics (expert assessment)

Dominating Agroeco-system	Geographic region	National name of region	Approx. size of the region km^2	Annual temperature precipitation and altitude	Dominating soil condition	Irrigation applied and dominated type of irrigation	Topography of the region	Dominating land use types and intensity	Classification according to Table 7.2 and 7.3	% of organic farmers	Mean farm size Dominating farm size ha	INDICATORS • MEDALUS ESAI [1] • Growing degree days[2] • BGI Aridity Index • Prec/PET	Land by use km^2 Cereals km^2 Main cereals % Oilseed km^2 Main oilseed crops % Fallow %
Crop farming dominated by cereal	Romania South-Muntenia	Arges	6826.3	8.1-10.1^{o}C 510-650 mm 100-450 m	Medium and heavy soils with low soil water capacity, poor drainage and high mechanical resistance	No irrigation	From south to north: flat plian, ondulating plain, hills with steep slopes, mountain	1 Intensity:1	15 (37%) 11 (63%)		Mean: 2.16 Dom.: 600	• fragile1-2$_{1961-1990}$ • fragile2-3$_{2041-2050}$ • 60-120d$_{1961-1990}$ • 80-150d$_{2041-2050}$ • < 50$_{1961-1990}$ • < 50$_{2041-2050}$ • plain: 0.989 hills: 1.1	Arable 1631.24 km^2 Grassland 1491.24 km^2 Vine&Orch 264 km^2 **Cereals** 1300.47 km^2 W.wheat 50.44% Maize 34.4% **Oilseed** 140.43 km^2 sunflower 88.5% oilseed rape 10.32% **Fallow** 7.01%
Crop farming dominated by cereal	Romania South-Muntenia	Calarasi	5087.9	10.4-11.3^{o}C 450-550 mm 26-82 m	Medium soils with good water storing capacity, good drainage and medium soil mechanical resistance	No irrigation 90% Irrigation 10% (sprinkler)	Flat plain	1 Intensity:1	16 (10%) 15 (70%) 11 (20%)		Mean: 5.42 Dom.: 690	• fragile2-critical2$_{1961-1990}$ • fragile3-critical3$_{2041-2050}$ • 120-250d$_{1961-1990}$ • 150-300d$_{2041-2050}$ • 50-75$_{1961-1990}$ • 50-75$_{2041-2050}$ • 0.77	Arable 3727.77 km^2 Grassland 55.10 km^2 Vine&Orch 50.0 km^2 **Cereals** 2258.33 km^2 W.wheat 62.23% Maize 27.38% **Oilseed** 1025.37 km^2 sunflower 62.9% soyabeans 23.09% **Fallow** 4.34%

Crop farming dominated by cereal	Romania South-Muntenia	Ialomita	4452.9	10.4-10.6^oC 450-500 mm 30-137 m	Medium soils with good water storing capacity, good drainage and medium soil mechanical resistance	No irrigation	Flat plain	1 Intensity:1	15 (74%) 11 (26%)		Mean: 5.17 Dom.: 690	• fragile2$_{1961-1990}$ • fragile2$_{2041-2050}$ • 200-250d$_{1961-1990}$ • 250-300d$_{2041-2050}$ • 30-75$_{1961-1990}$ • 50-75$_{2041-2050}$ • 0.754	Arable 3374.22 km^2 Grassland 188.22 km^2 Vine&Orch 42.02 km^2 **Cereals** 1920.57 km^2 W.wheat 51.76% Maize 36.83% **Oilseed** 1043.76 km^2 sunflower 71.9% soyabeans 18.31% **Fallow** 2.12%
Crop farming dominated by cereal	Romania South-Muntenia	Teleorman	5789.8	10.8-11.0^oC 495-550 mm 40-190 m	Medium soils with good and medium water storing capacity, good/medium drainage and medium/high soil mechanical resistance	No irrigation	Flat plain	1 Intensity:1	15 (55%) 11 (45%)		Mean: 3.83 Dom.: 600	• fragile1-fragile2$_{1961-1990}$ • fragile3$_{2041-2050}$ • 80-250d$_{1961-1990}$ • 100-250d$_{2041-2050}$ • $<50_{1961-1990}$ • 50-100$_{2041-2050}$ • 0.85	Arable 4151.38 km^2 Grassland 357.93 km^2 Vine&Orch 68.63 km^2 **Cereals** 3220.0 km^2 W.wheat 64.8% Maize 26.35% **Oilseed** 660.0 km^2 sunflower 92.7% soyabeans 4.31% **Fallow** 3.31%
Crop farming dominated by cereal	Romania South-West Oltenia	Dolj	7414	9.7-11.5^oC 480-520 mm 40-315 m	Medium and heavy soils with medium/low water storing capacity, poor drainage and high mechanical resistance. In South: sandy soils with low water storing capacity and high drainage	No irrigation	Flat plain / ondulating plain	1 Intensity:1	15 (22%) 11 (78%)		Mean: 3.76 Dom.: 3.22	• fragile2-fragile3$_{1961-1990}$ • fragile3$_{2041-2050}$ • 80-200d$_{1961-1990}$ • 100-250d$_{2041-2050}$ • 30-75$_{1961-1990}$ • 50-100$_{2041-2050}$ • 0.843	Arable 4896.96 km^2 Grassland 713.87 km^2 Vine&Orch 256.35 km^2 **Cereals** 3781.01 km^2 W.wheat 64.2% Maize 30.35% **Oilseed** 321.81 km^2 sunflower 89.5% oilseed rape 9.99% **Fallow** 8.4%

Crop farming dominated by cereal	Romania South-West Oltenia	Olt	5498.3	10.6-11.2°C 480-550 mm 40-435 m	Medium and heavy soils with medium/low water storing capacity, good/poor drainage and medium/high mechanical resistance.	No irrigation	Flat plain / ondulating plain / hills	1 Intensity:1	15 (30%) 11 (70%)		Mean: 3.45 Dom.: 3.11	• fragile1-fragile2$_{1961-1990}$ • fragile3-critical2$_{2041-2050}$ • 60-200d$_{1961-1990}$ • 100-250d$_{2041-2050}$ • <50$_{1961-1990}$ • 50-100$_{2041-2050}$ • plain: 0.87 hills: 0.94	Arable 3905.69 km^2 Grassland 316.59 km^2 Vine&Orch 149.37 km^2 **Cereals** 2969.34 km^2 W.wheat 59.6% Maize 32.7% **Oilseed** 379.57 km^2 sunflower 94.0% **Fallow** 7.6%
Crop farming dominated by cereal	Romania South-East	Constanta	7071.3	10.9-11.3°C 350-450 mm 0-207 m	Light and medium soils with good water capacity, good drainage and medium/low mechanical resistance	No irrigation 75% Irrigation 25% (sprinkler)	Ondulating plain	1 Intensity:1	16 (25%) 15 (43%) 11 (32%)		Mean: 8 Dom.: 480	• fragile2-fragile3$_{1961-1990}$ • fragile2-fragile3$_{2041-2050}$ • 120-150d$_{1961-1990}$ • 80-150d$_{2041-2050}$ • 50-100$_{1961-1990}$ • 50-100$_{2041-2050}$ • 0.664	Arable 4554.78 km^2 Grassland 836.43 km^2 Vine&Orch 165.91 km^2 **Cereals** 2634.19 km^2 W.wheat 50.97% Maize 27.76% **Oilseed** 1204.41 km^2 sunflower 82.0% oilseed rape 16.51% **Fallow** 11.1%
Crop farming dominated by cereal	Romania West	Timis	8696.7	10.7-10.9°C 580-630 mm 70-250 m	Medium soils with medium water storing capacity and poor drainage	No irrigation	Ondulating plain	1 Intensity:1	15 (45%) 11 (55%)		Mean: 3.83 Dom.: 600	• fragile2-critical2$_{1961-1990}$ • fragile3-critical2$_{2041-2050}$ • 80-200d$_{1961-1990}$ • 80-150d$_{2041-2050}$ • <50$_{1961-1990}$ • <50$_{2041-2050}$ • 0.922	Arable 4971.59 km^2 Grassland 1467.74 km^2 Vine&Orch 59.42 km^2 **Cereals** 3413.27 km^2 W.wheat 38.68% Maize 41.87% **Oilseed** 376.47 km^2 sunflower 88.35% soyabeans 10.59% **Fallow** 15.3%

Crop farming dominated by cereal	Romania North-East	Vaslui	5318.4	9.2-9.8°C 540-590 mm 40-415 m	Medium soils with medium water storing capacity and medium drainage; High intensity of soil water erosion	No irrigation	Ondulating plain, hills	1 Intensity:1	15 (25%) 11 (75%)		Mean: 3.28 Dom.: 3.19	• fragile3-critical1$_{1961-1990}$ • fragile3-critical3$_{2041-2050}$ • 60-200d$_{1961-1990}$ • 80-250d$_{2041-2050}$ • <50$_{1961-1990}$ • <50$_{2041-2050}$ • 0.922	Arable 2824.62 km^2 Grassland 833.25 km^2 Vine&Orch 146.72 km^2 **Cereals** 1922.1 km^2 W.wheat 30.1% Maize 65.7% **Oilseed** 518.75 km^2 sunflower 81.12% oilseed rape 12.85% **Fallow** 15.3%
Crop farming dominated by oilseed crops	Romania South-Muntenia	Calarasi	5087.9	10.4-11.3°C 450-550 mm 26-82 m	Medium soils with good water storing capacity, good drainage and medium soil mechanical resistance	No irrigation 90% Irrigation 10% (sprinkler)	Flat plain	3 Intensity:1	16 (10%) 15 (70%) 11 (20%)		Mean: 5.42 Dom.: 690	• fragile2-critical2$_{1961-1990}$ • fragile3-critical3$_{2041-2050}$ • 120-250d$_{1961-1990}$ • 150-300d$_{2041-2050}$ • 50-75$_{1961-1990}$ • 50-75$_{2041-2050}$ • 0.77	Arable 3727.77 km^2 Grassland 55.10 km^2 Vine&Orch 50.0 km^2 **Cereals** 2258.33 km^2 W.wheat 62.23% Maize 27.38% **Oilseed** 1025.37 km^2 sunflower 62.9% soyabeans 23.09% **Fallow** 4.34%
Crop farming dominated by oilseed crops	Romania South-Muntenia	Ialomita	4452.9	10.4-10.6°C 450-500 mm 30-137 m	Medium soils with good water storing capacity, good drainage and medium soil mechanical resistance	No irrigation	Flat plain	3 Intensity:1	15 (74%) 11 (26%)		Mean: 5.17 Dom.: 690	• fragile2$_{1961-1990}$ • fragile2$_{2041-2050}$ • 200-250d$_{1961-1990}$ • 250-300d$_{2041-2050}$ • 30-75$_{1961-1990}$ • 50-75$_{2041-2050}$ • 0.754	Arable 3374.22 km^2 Grassland 188.22 km^2 Vine&Orch 42.02 km^2 **Cereals** 1920.57 km^2 W.wheat 51.76% Maize 36.83% **Oilseed** 1043.76 km^2 sunflower 71.9% soyabeans 18.31% **Fallow** 2.12%

Crop farming dominated by oilseed crops	Romania South-East	Constanta	7071.3	10.9-11.3^{o}C 350-450 mm 0-207 m	Light and medium soils with good water capacity, good drainage and medium/low mechanical resistance	No irrigation 75% Irrigation 25% (sprinkler)	Ondulating plain	3 Intensity:1	16 (25%) 15 (43%) 11 (32%)		Mean: 8 Dom.: 480	• fragile2-fragile3$_{1961-1990}$ • fragile2-fragile3$_{2041-2050}$ • 120-150d$_{1961-1990}$ • 80-150d$_{2041-2050}$ • 50-100$_{1961-1990}$ • 50-100$_{2041-2050}$ • 0.664	Arable 4554.78 km^2 Grassland 836.43 km^2 Vine&Orch 165.91 km^2 **Cereals** 2634.19 km^2 W.wheat 50.97% Maize 27.76% **Oilseed** 1204.41 km^2 sunflower 82.0% oilseed rape 16.51% **Fallow** 11.1%

[1] Environmental Sensitive Area Index:

- Fragile: very sensitive areas to degradation under any change of delicate balance of climate and land use. Any change is likely to enhance reduction in biological potential. This area is threatened by higher rates of degradation under slight climate change and/or if the existing type of land use is changed (1- botoom level of fragility; 3: upper level of fragility)
- Critical: areas already higly degraded presenting a threat to the environment and surrounding areas

[2] Growing degree days: Number of days in an year with temperature over 5^{o}C and soil availbale water over half the potential evapotranspiration. Accoring with "Common biophysical criteria for defining areas which are less favourable for agriculture in Europe" – JRC 2007, a value less than 120 is limiting the agriculture potential.

[3] Bagnouls-Gaussen Aridity index: < 50 – no, 50-75 low, 75-100 – medium; 100-125: high; 125-150 – very high, > 150 critical aridity

Table 11.2. List of identified vulnerable regions to climate change in Romania and their main limitation and trends (expert assessment)

Dominating Agroeco-system	Geographic region	National name of region	Main limitations	Observed trends	Socio-economic conditions and problems	Main identified vulnerabilities to climate change
Crop farming dominated by cereal	Romania South-Muntenia	Arges	Heavy (vertic) soils inducing high mechanical resistance that reduces soil volume explored by roots Small intervals for optimum workability in spring Reduced number of growing days due to water shortage induced by reduced soil maximum available water Small farm sizes mainly in hilly region	No significant changes of the land use in the last 50 years Aggregation of very small farms and structural change to bigger farms Decreasing the number and increasing the age of rural population Land abandonment Cereals for grains area is 73.46% of arable. Cereals for grains structure is: Winter wheat: 50.44% Barley : 8.31% Oats: 5.61% Maize grains : 34.40%	Weak economic conditions Low level of education of persons involved in agriculture activities Small average area of parcels in agriculture explotation having less than 10 ha (59% of total) ranging from .14 ha for farms having .1-.3 ha to .94 ha for farms having 5-10 ha Very low level of subsidies Low level of farmers knowledge related to CAP including the poor level of consultancy provided by the official institutions	Drought on heavy soils Decreasing the time intervals for optimum soil workability Not enough flexibility to change management based on climate predictions (cultivar structure, sowing dates)
Crop farming dominated by cereal	Romania South-Muntenia	Calarasi	High water stress mainly in the most sensitive periods for the crop yield development (flowering, first stages of seed development) Cold waves during winter with no/low snow cover producing high demage to winter crops High crop yield variability from year to year (coefficient of variation for winter wheat yield 0.4 - 0.6, for maize : 0.6 - 0.8) induced by weather Even if the most of the agriculture area had irrigation facilities in case of severe drough no available water for irrigation is distributed by Water Administration	No significant changes of the land use in the last 50 years Decreasing area where irrigation is applied (from 90% in 1980's to about 10% in 2005) Increasing the number of extreme weather events (storms) in the last decade Decreasing the cereals for grain cultivated area in favour of oilseed crops (27.5% of arable) Cereals for grains area is 66.59% of arable. Cereals for grains structure is: Winter wheat: 62.23% Barley : 9.96% Oats: 0.29% Maize grains : 27.38%	Weak economic conditions High polarisation of agriculture explotations: very small farms dominate as number (30% of the number of agriculture explotations has less than .3 ha) large farms are dominating by area (76% of agriculture land has farms over 100 ha) Very low level of subsidies Low level of farmers knowledge related to CAP including the poor level of consultancy provided by the official institutions	Periods of severe droughts, heat waves and strong wind Increasing the probability of frost damage for winter crops due to the reduce snow cover and windows with warm weather starting vegetation during winter followed by very cold short periods Not enough flexibility to change management based on climate predictions (cultivar structure, sowing dates, tillage practices)

Crop farming dominated by cereal	Romania South-Muntenia	Ialomita	High water stress mainly in the most sensitive periods for the crop yield development (flowering, first stages of seed development) Cold waves during winter with no/low snow cover producing high demage to winter crops High crop yield variability from year to year (coefficient of variation for winter wheat yield 0.5 - 0.6, for maize : 0.6 - 0.7) induced by weather Even if the most of the agriculture area had irrigation facilities in case of severe drough no available water for irrigation is distributed by Water Administration	No significant changes of the land use in the last 50 years Decreasing area where irrigation is applied (from 90% in 1980's to less than 10% in 2005) Increasing the number of extreme weather events (storms) in the last decade Decreasing the cereals for grain cultivated area in favour of oilseed crops (31% of arable) Cereals for grains area is 59.93% of arable. Cereals for grains structure is: Winter wheat: 51.76% Barley : 10.27% Oats: 0.38% Maize grains : 36.83%	Weak economic conditions High polarisation of agriculture explotations: very small farms dominate as number (30% of the number of agriculture explotations has less than .1 ha) large farms are dominating by area (74% of agriculture land has farms over 100 ha) Very low level of subsidies Low level of farmers knowledge related to CAP including the poor level of consultancy provided by the official institutions	Periods of severe droughts, heat waves and strong wind Increasing the probability of frost damage for winter crops due to the reduce snow cover and windows with warm weather starting vegetation during winter followed by very cold short periods Not enough flexibility to change management based on climate predictions (cultivar structure, sowing dates, tillage practices)
Crop farming dominated by cereal	Romania South-Muntenia	Teleorman	High water stress mainly in the most sensitive periods for the crop yield development (flowering, first stages of seed development) Cold waves during winter with no/low snow cover producing high demage to winter crops Heavy soils inducing high mechanical resistance that reduces soil volume explored by roots Small intervals for optimum workability in spring Reduced number of growing days due to water shortage induced by reduced soil maximum available water	No significant changes of the land use in the last 50 years Relative low confidence in aggregation of land due to bad experience from the times of comunist co-operative farms High conservative atitude of farmers to management changes Cereals for grains area is 82.24% of arable. Cereals for grains structure is: Winter wheat: 64.78% Barley : 7.95% Oats: 0.78% Maize grains : 26.35%	Weak economic conditions Low level of education of persons involved in agriculture activities Small average area of parcels in agriculture explotation having less than 10 ha (51% of total) ranging from .11 ha for farms having .1-.3 ha to .94 ha for farms having 5-10 ha Very low level of subsidies Low level of farmers knowledge related to CAP including the poor level of consultancy provided by the official institutions	Drought on heavy soils Decreasing the time intervals for optimum soil workability Not enough flexibility to change management based on climate predictions (cultivar structure, sowing dates)

Crop farming dominated by cereal	Romania South-West Oltenia	Dolj	High water stress mainly in the most sensitive periods for the crop yield development (flowering, first stages of seed development) Cold waves during winter with no/low snow cover producing high demage to winter crops Heavy soils inducing high mechanical resistance that reduces soil volume explored by roots Small intervals for optimum workability in spring Sandy soils (in south) with low soil water and high wind erosion Reduced number of growing days due to water shortage induced by reduced soil maximum available water	No significant changes of the land use in the last 50 years High fragmentation of agriculture explotations High conservative atitude of farmers to management change Cereals for grains area is 77.21% of arable. Cereals for grains structure is: Winter wheat: 64.20% Rye: 0.95% Barley : 3.52% Oats: 0.94% Maize grains : 30.35%	Small farms (average farm size, dominant farm size based on area, dominant farm size based on number are in the range 3-4 ha) with weak economic conditions Very small agriculture parcels (from .15 ha in explotations withe area in the range .1-.3 ha, to .86 ha in explotations with area in the range 5-10 ha) Low level of education of persons involved in agriculture activities Very low level of subsidies Low level of farmers knowledge related to CAP including the poor level of consultancy provided by the official institutions	Drought mainly on light soils Heat waves Increasing wind erosion on sandy soils
Crop farming dominated by cereal	Romania South-West Oltenia	Olt	High water stress mainly in the most sensitive periods for the crop yield development (flowering, first stages of seed development) Cold waves during winter with no/low snow cover producing high demage to winter crops Heavy soils inducing high mechanical resistance that reduces soil volume explored by roots Small intervals for optimum workability in spring Reduced number of growing days due to water shortage induced by reduced soil maximum available water	No significant changes of the land use in the last 50 years High fragmentation of agriculture explotations High conservative atitude of farmers to management change Cereals for grains area is 76.03% of arable. Cereals for grains structure is: Winter wheat: 59.64% Barley : 5.88% Oats: 1.70% Maize grains : 32.71%	Small farms (average farm size, dominant farm size based on area, dominant farm size based on number are in the range 3-4 ha) with weak economic conditions Very small agriculture parcels (from .11 ha in explotations withe area in the range .1-.3 ha, to 1.8 ha in explotations with area in the range 10-20 ha) Low level of education of persons involved in agriculture activities Very low level of subsidies Low level of farmers knowledge related to CAP including the poor level of consultancy provided by the official institutions	Drought on heavy soils Decreasing the time intervals for optimum soil workability Not enough flexibility to change management based on climate predictions (cultivar structure, sowing dates)

Crop farming dominated by cereal	Romania South-East	Constanta	High water stress mainly in the most sensitive periods for the crop yield development (flowering, first stages of seed development) Cold waves during winter with no/low snow cover producing high demage to winter crops High crop yield variability from year to year (coefficient of variation for winter wheat yield 0.4 - 0.6, for maize : 0.6 - 0.8) induced by weather Even if the most of the agriculture area had irrigation facilities in case of severe drough no available water for irrigation is distributed by Water Administration	No significant changes of the land use in the last 50 years Decreasing area where irrigation is applied (from 90% in 1980's to about 25% in 2005) Increasing the number of extreme weather events (storms) in the last decade Decreasing the cereals for grain cultivated area in favour of oilseed crops (26% of arable) Cereals for grains area is 58.19% of arable. Cereals for grains structure is: Winter wheat: 50.97% Barley : 17.81% Oats: 3.29% Maize grains : 27.76%	Weak economic conditions in small farms High polarisation of agriculture explotations: very small farms dominate as number (23% of the number of agriculture explotations has less than .1 ha) large farms are dominating by area (73% of agriculture land has farms over 100 ha) Very low level of subsidies Low level of farmers knowledge related to CAP including the poor level of consultancy provided by the official institutions	Periods of severe droughts, heat waves and strong wind Increasing the probability of frost damage for winter crops due to the reduce snow cover and windows with warm weather starting vegetation during winter followed by very cold short periods Not enough flexibility to change management based on climate predictions (cultivar structure, sowing dates, tillage practices)
Crop farming dominated by cereal	Romania West	Timis	High water stress mainly in the most sensitive periods for the crop yield development (flowering, first stages of seed development) Cold waves during winter with no/low snow cover producing high demage to winter crops Alternate dry and wet periods. In wet years waterlogging on large areas and limitation of workability	No significant changes of the land use in the last 50 years Structural change to bigger farms After a sharp decrease of pig farms in 1990's there is now a trend of the increase of pig farms with the consequence of increasing area cultivated with maize Land abandonment Cereals for grains area is 69.16% of arable. Cereals for grains structure is: Winter wheat: 38.68% Barley : 13.11% Oats: 5.67% Maize grains : 41.87%	Weak economic conditions in small farms High polarisation of agriculture explotations: very small farms dominate as number (78% of the number of agriculture explotations has less than 5 ha) large farms are dominating by area (55% of agriculture land has farms over 100 ha) Very low level of subsidies	Increase extreme events (heat waves, drought and waterlogging periods even in the same agriculture season) New pest and diseases

Crop farming dominated by cereal	Romania North-East	Vaslui	Complex topography (hilly) with high water erosion Not working on contour levels due to downslope parcel structure High water stress mainly in the most sensitive periods for the crop yield development (flowering, first stages of seed development) Cold waves during winter with no/low snow cover producing high demage to winter crops Low available surface and groundwater resources	No significant changes of the land use in the last 50 years High fragmentation of agriculture explotations High conservative atitude of farmers to management change Cereals for grains area is 66.71% of arable. Cereals for grains structure is: Winter wheat: 30.10% Barley : 1.81% Oats: 2.08% Maize grains : 65.7%	Small farms (average farm size, dominant farm size based on area, dominant farm size based on number are in the range 3-4 ha) with weak economic conditions Very small agriculture parcels (from .11 ha in explotations withe area in the range .1-.3 ha, to 1.61 ha in explotations with area in the range 10-20 ha) Low level of education of persons involved in agriculture activities Very low level of subsidies Low level of farmers knowledge related to CAP including the poor level of consultancy provided by the official institutions	Drought Not enough flexibility to change management based on climate predictions (cultivar structure, sowing dates) Increase of soil erosion by water due to extreme weather events New pests and diseases
Crop farming dominated by oilseed crops	Romania South-Muntenia	Calarasi	High water stress mainly in the most sensitive periods for the crop yield development (flowering, first stages of seed development) Cold waves during winter with no/low snow cover producing high demage to winter crops High crop yield variability from year to year (coefficient of variation for winter oilseed rape yield 0.3 - 0.5, for sunflower : 0.5 - 0.7) induced by weather Even if the most of the agriculture area had irrigation facilities in case of severe drough no available water for irrigation is distributed by Water Administration	No significant changes of the land use in the last 50 years Decreasing area where irrigation is applied (from 90% in 1980's to about 10% in 2005) Increasing the number of extreme weather events (storms) in the last decade Increasing the area of oilseed crops (27.5% of arable) over the agronomic good practice recomandations for preventing pest and diseases (20%= 1 in 5 years). The highest increase is for winter oilseed rape Oilseed crop structure is: Sunflower: 62.97% Soyabeans : 23.09% Winer oilseed rape: 13.94%	Weak economic conditions High polarisation of agriculture explotations: very small farms dominate as number (30% of the number of agriculture explotations has less than .3 ha) large farms are dominating by area (76% of agriculture land has farms over 100 ha) Very low level of subsidies Low level of farmers knowledge related to CAP including the poor level of consultancy provided by the official institutions	Periods of severe droughts, heat waves and strong wind Increasing the probability of frost damage for winter crops due to the reduce snow cover and windows with warm weather starting vegetation during winter followed by very cold short periods Not enough flexibility to change management based on climate predictions (cultivar structure, sowing dates, tillage practices)

Crop farming dominated by oilseed crops	Romania South-Muntenia	Ialomita	High water stress mainly in the most sensitive periods for the crop yield development (flowering, first stages of seed development) Cold waves during winter with no/low snow cover producing high demage to winter crops High crop yield variability from year to year (coefficient of variation for winter oilseed rape yield 0.3 - 0.4, for sunflower : 0.5 - 0.6) induced by weather Even if the most of the agriculture area had irrigation facilities in case of severe drough no available water for irrigation is distributed by Water Administration	No significant changes of the land use in the last 50 years Decreasing area where irrigation is applied (from 90% in 1980's to less than 10% in 2005) Increasing the number of extreme weather events (storms) in the last decade Increasing the area of oilseed crops (30.93% of arable) over the agronomic good practice recomandations for preventing pest and diseases (20%= 1 in 5 years). The highest increase is for winter oilseed rape Oilseed crop structure is: Sunflower: 71.93% Soyabeans : 18.31% Winer oilseed rape: 9.76%	Weak economic conditions High polarisation of agriculture explotations: very small farms dominate as number (30% of the number of agriculture explotations has less than .1 ha) large farms are dominating by area (74% of agriculture land has farms over 100 ha) Very low level of subsidies Low level of farmers knowledge related to CAP including the poor level of consultancy provided by the official institutions	Periods of severe droughts, heat waves and strong wind Increasing the probability of frost damage for winter crops due to the reduce snow cover and windows with warm weather starting vegetation during winter followed by very cold short periods Not enough flexibility to change management based on climate predictions (cultivar structure, sowing dates, tillage practices)
Crop farming dominated by oilseed crops	Romania South-East	Constanta	High water stress mainly in the most sensitive periods for the crop yield development (flowering, first stages of seed development) Cold waves during winter with no/low snow cover producing high demage to winter crops High crop yield variability from year to year (coefficient of variation for winter oilseed rape yield 0.3 - 0.5, for sunflower : 0.5 - 0.7) induced by weather Even if the most of the agriculture area had irrigation facilities in case of severe drough no available water for irrigation is distributed by Water Administration	No significant changes of the land use in the last 50 years Decreasing area where irrigation is applied (from 90% in 1980's to 25% in 2005) Increasing the number of extreme weather events (storms) in the last decade Increasing the area of oilseed crops (26.44% of arable) over the agronomic good practice recomandations for preventing pest and diseases (20%= 1 in 5 years). The highest increase is for winter oilseed rape Oilseed crop structure is: Sunflower: 82.02% Soyabeans : 1.47% Winer oilseed rape: 16.51%	Weak economic conditions in small farms High polarisation of agriculture explotations: very small farms dominate as number (23% of the number of agriculture explotations has less than .1 ha) large farms are dominating by area (73% of agriculture land has farms over 100 ha) Very low level of subsidies Low level of farmers knowledge related to CAP including the poor level of consultancy provided by the official institutions	Periods of severe droughts, heat waves and strong wind Increasing the probability of frost damage for winter crops due to the reduce snow cover and windows with warm weather starting vegetation during winter followed by very cold short periods Not enough flexibility to change management based on climate predictions (cultivar structure, sowing dates, tillage practices)

Table 11.3. Summary table on identified adaptation options in vulnerable regions and production systems in Romania

Dominating Agroecosystem	Geographical region	National name of region	Agroecosystem, related to common agroclimatic etc. indicators	Observed trends in adaptations to climate change	Recommended feasible adaptation options to climate change Time horizon: 2020	Identified limitations for adaptation options to climate change	Uncertainties, cost/benefits, risks (including economic risks), opportunities of adaptation options	Mitigation effects (assessment)
Crop farming dominated by cereal	Romania South - Muntenia	Arges	**ESAI** • fragile1-2$_{1961-1990}$ • fragile2-3$_{2041-2050}$ **Growing Period Days** • 60-120d$_{1961-1990}$ • 80-150d$_{2041-2050}$ **BGI Aridity Index** • < 50$_{1961-1990}$ • < 50$_{2041-2050}$ **Rainfall/PET** • plain: 0.989 hills: 1.1	**Farm**: Shift of timetable for tillage operations **Region**: increase acreage for winter cereals (wheat, barley) and spring barley	Change timings of field operations Changing cultivar structure for spring crops (late cultivars to early ones; maize) Land aggregation from small to medium and large arable farms Increasing percentage of winter crops	Topographical limitations Heavy vertic soils	High yield variability from year to year Increasing costs of tillage operations High sensitivity to market prices	Negative: If grassland is changed to arable land Positive: Less compaction of soils due to increasing number of workable days
Crop farming dominated by cereal and oilseed	Romania South – Muntenia	Calarasi	**ESAI** • fragile2-critical2$_{1961-1990}$ • fragile3-critical3$_{2041-2050}$ **Growing Period Days** • 120-250d$_{1961-1990}$ • 150-300d$_{2041-2050}$ **BGI Aridity Index** • 50-75$_{1961-1990}$ • 50-75$_{2041-2050}$ **Rainfall/PET** • 0.77	**Farm**: Shift of timetable for tillage operations; Aggregation of small farms into larger ones **Region**: increase acreage for winter cereals (wheat, barley) and spring barley Reducing areas with sunflower due to water shortages vs. Increasing areas with winter oilseed rape Restarting irrigation systems	Change timings of field operations Introducing minimum tillage Rationale use of irrigation (pumping water uphill not more than 30 m height) Increaseing percentage of winter crops	Field elevation over irrigation water source (Danube)	Higher cost of machinery High yield variability from year to year Higher costs of irrigation up to becoming non profitable from an economic point of view Training of farmers for using minimum tillage system	Negative: If crop rotations restricts to 1-2 crops If oileed crops area is more than 25% Positive: Minimum tillage prevent soil compaction and increase carbon sequestratiuon in soils
Crop	Romania	Ialomita	**ESAI**	**Farm**: Shift of	Change timings of field	Field elevation over	Higher cost of	Negative:

farming dominated by cereal and oilseed	South – Muntenia		• fragile2$_{1961-1990}$ • fragile2$_{2041-2050}$ **Growing Period Days** • 200-250d$_{1961-1990}$ • 250-300d$_{2041-2050}$ **BGI Aridity Index** • 30-75$_{1961-1990}$ • 50-75$_{2041-2050}$ **Rainfall/PET** • 0.754	timetable for tillage operations; Aggregation of small farms into larger ones **Region**: increase acreage for winter cereals (wheat, barley) and spring barley Reducing areas with sunflower due to water shortages vs. Increasing areas with winter rape	operations Introducing minimum tillage Rationale use of irrigation (pumping water uphill not more than 30 m height) Introducing minimum tillage	irrigation water source (Danube)	machinery High yield variability from year to year Higher costs of irrigation up to becoming non profitable from an economic point of view Training of farmers for using minimum tillage system	If crop rotations restricts to 1-2 crops If oileed crops area is more than 25% Positive: Minimum tillage prevent soil compaction and increase carbon sequestratiuon in soils
Crop farming dominated by cereal	Romania South – Muntenia	Teleorman	**ESAI** • fragile1-fragile2$_{1961-1990}$ • fragile3$_{2041-2050}$ **Growing Period Days** • 80-250d$_{1961-1990}$ • 100-250d$_{2041-2050}$ **BGI Aridity Index** • <50$_{1961-1990}$ • 50-100$_{2041-2050}$ **Rainfall/PET** • 0.85	**Farm**: Shift of timetable for tillage operations **Region**: increase acreage for winter cereals (wheat, barley) and spring barley	Change timings of field operations Introducing minimum tillage Local irrigation systems Changing cultivar structure Aggregation of small farms in medium and large ones	-	Higher cost of machinery High yield variability from year to year Higher costs of irrigation Training of farmers for using minimum tillage system High sensitivity to market prices	Negative: If crop rotations restricts to 1-2 crops If oileed crops area is more than 25% Positive: Minimum tillage prevent soil compaction and increase carbon sequestratiuon in soils
Crop farming dominated by cereal	Romania South-West - Oltenia	Dolj	**ESAI** • fragile2-fragile3$_{1961-1990}$ • fragile3$_{2041-2050}$ **Growing Period Days** • 80-200d$_{1961-1990}$ • 100-250d$_{2041-2050}$ **BGI Aridity Index** • 30-75$_{1961-1990}$ • 50-100$_{2041-2050}$	**Farm**: Shift of timetable for tillage operations **Region**: increase acreage for winter cereals (wheat, barley)	Change timings of field operations Introducing minimum tillage Irrigation on sandy soils Changing cultivar structure	Field elevation over irrigation water source (Danube) Sandy soils	Higher cost of machinery High yield variability from year to year Higher costs of irrigation up to becoming non profitable from an economic point of view Training of farmers for	Negative: If crop rotations restricts to 1-2 crops If forest and wind belts are changed in arable increasing wind erosion Positive: Minimum tillage prevent soil compaction and increase carbon

			Rainfall/PET • 0.843				using minimum tillage	sequestratiuon in soils

APPENDIX B

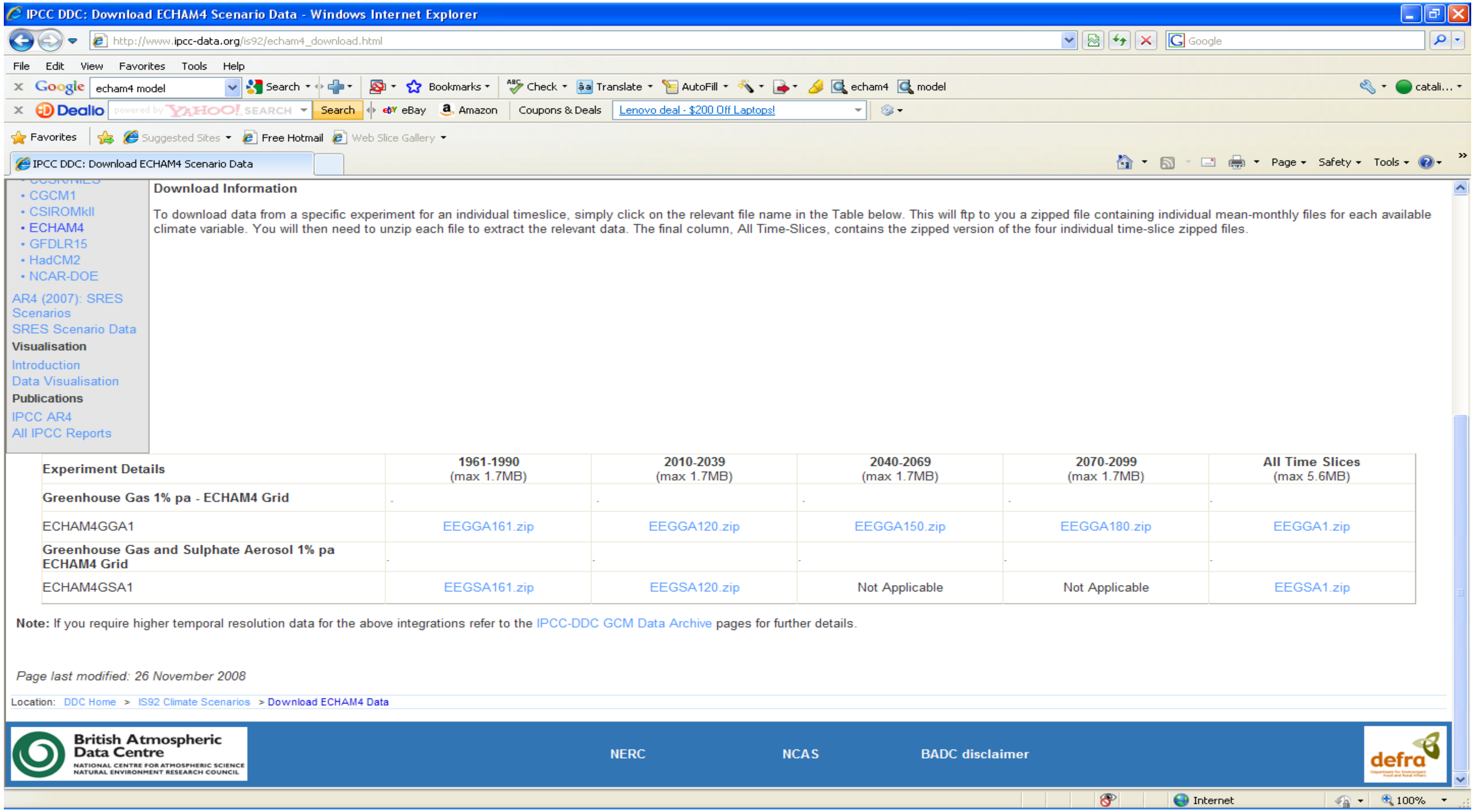
APPENDIX B – Selected agroclimatic indices over Europe describing changing agroecological conditions under climate change scenarios

(calculated and plotted by Catalin Simota, Romania)

Selected agroclimatological indices for assessment of agricultural production risks in Europe under various climate scenarios

Content

Data source for calculation of the indicators



IPCC DDC: Download ECHAM4 Scenario Data - Windows Internet Explorer

http://www.ipcc-data.org/is92/echam4_download.html

- CGCM1
- CSIROMkII
- ECHAM4
- GFDLR15
- HadCM2
- NCAR-DOE

AR4 (2007): SRES Scenarios

SRES Scenario Data

Visualisation

Introduction

Data Visualisation

Publications

IPCC AR4

All IPCC Reports

Download Information

To download data from a specific experiment for an individual timeslice, simply click on the relevant file name in the Table below. This will ftp to you a zipped file containing individual mean-monthly files for each available climate variable. You will then need to unzip each file to extract the relevant data. The final column, All Time-Slices, contains the zipped version of the four individual time-slice zipped files.

Experiment Details	1961-1990 (max 1.7MB)	2010-2039 (max 1.7MB)	2040-2069 (max 1.7MB)	2070-2099 (max 1.7MB)	All Time Slices (max 5.6MB)
Greenhouse Gas 1% pa - ECHAM4 Grid	.	.	.	.	.
ECHAM4GGA1	EEGGA161.zip	EEGGA120.zip	EEGGA150.zip	EEGGA180.zip	EEGGA1.zip
Greenhouse Gas and Sulphate Aerosol 1% pa ECHAM4 Grid	.	.	.	.	.
ECHAM4GSA1	EEGSA161.zip	EEGSA120.zip	Not Applicable	Not Applicable	EEGSA1.zip

Note: If you require higher temporal resolution data for the above integrations refer to the IPCC-DDC GCM Data Archive pages for further details.

Page last modified: 26 November 2008

Location: DDC Home > IS92 Climate Scenarios > Download ECHAM4 Data

British Atmospheric Data Centre

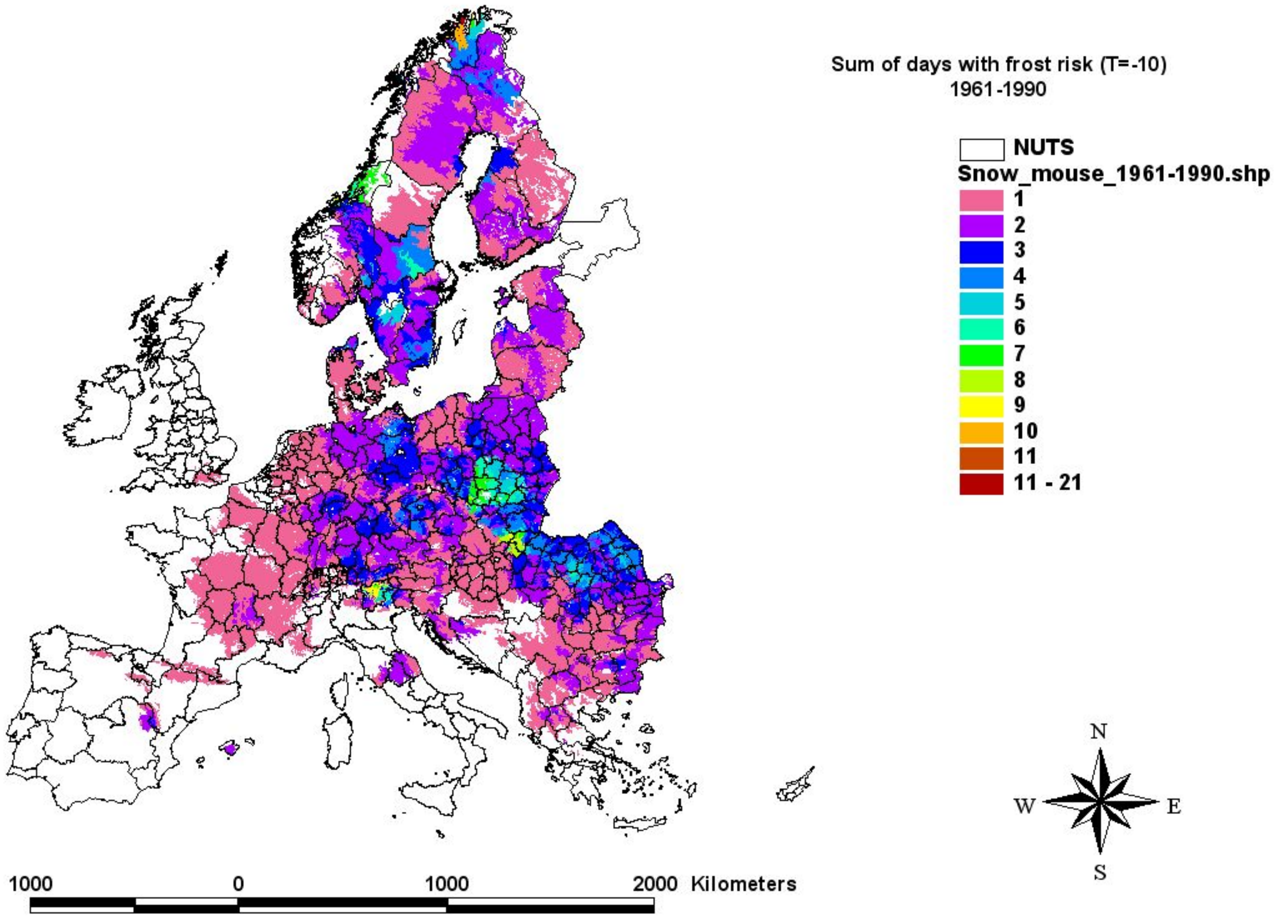
NERC NCAS BADC disclaimer

WINTER INDICATORS

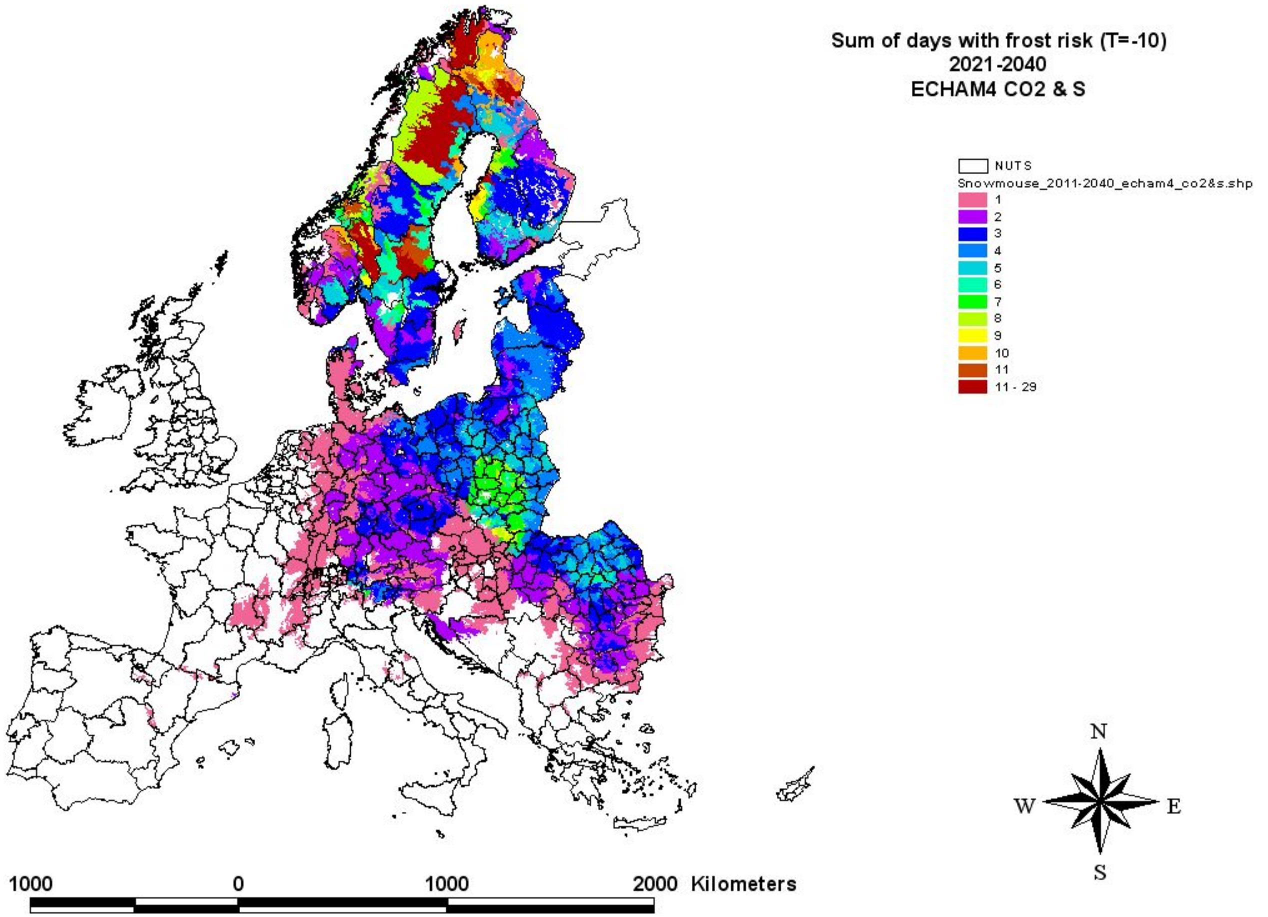
- Indicators based on SnowMouse:
  - sum of days with frost risk (Threshold temperature -10^{o}C)
  - number of snow cover days
  - sum of snow water
- Number of years with at least one early frost (a day with T_{min} less than -1^{o}C) in: september / october / november
- Number of years with at least one late frost in: march / april / may / june

Sum of days with frost risk
SnowMouse

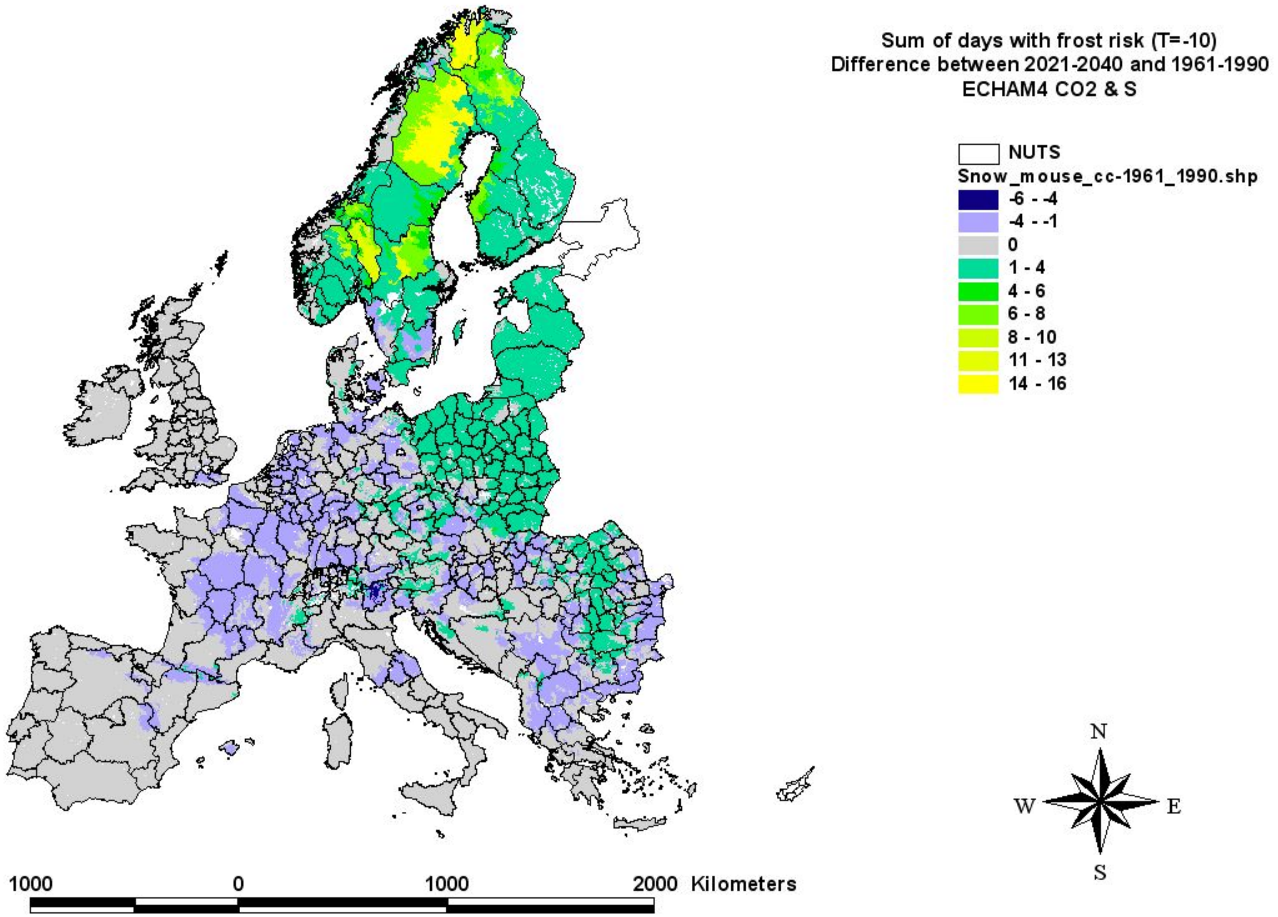
Sum of days with frost risk 1961-1990



Sum of days with frost risk
2011-2040 ECHAM4 CO2 & S

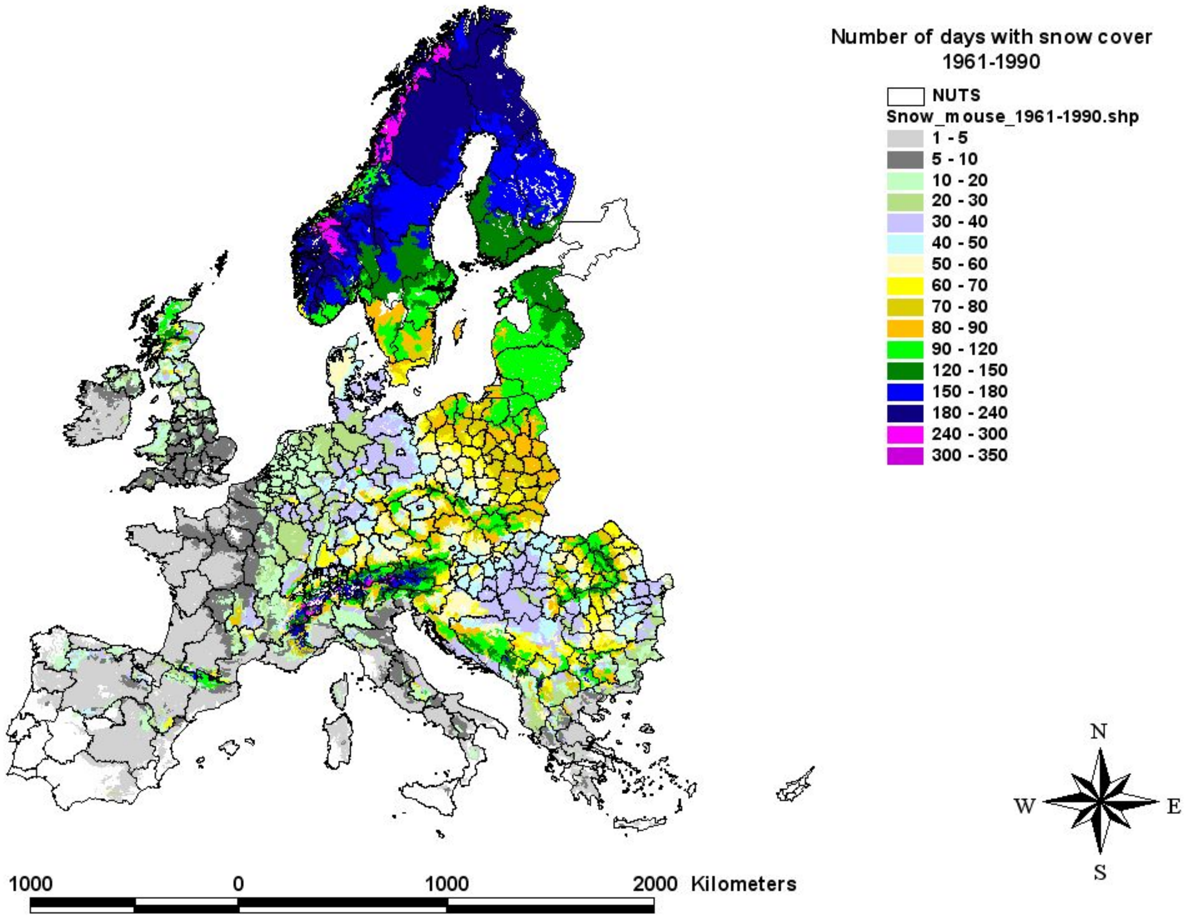


Difference of Sum of days with frost risk between 2011-2040 ECHAM4 CO2 & S and baseline (1961-1990)

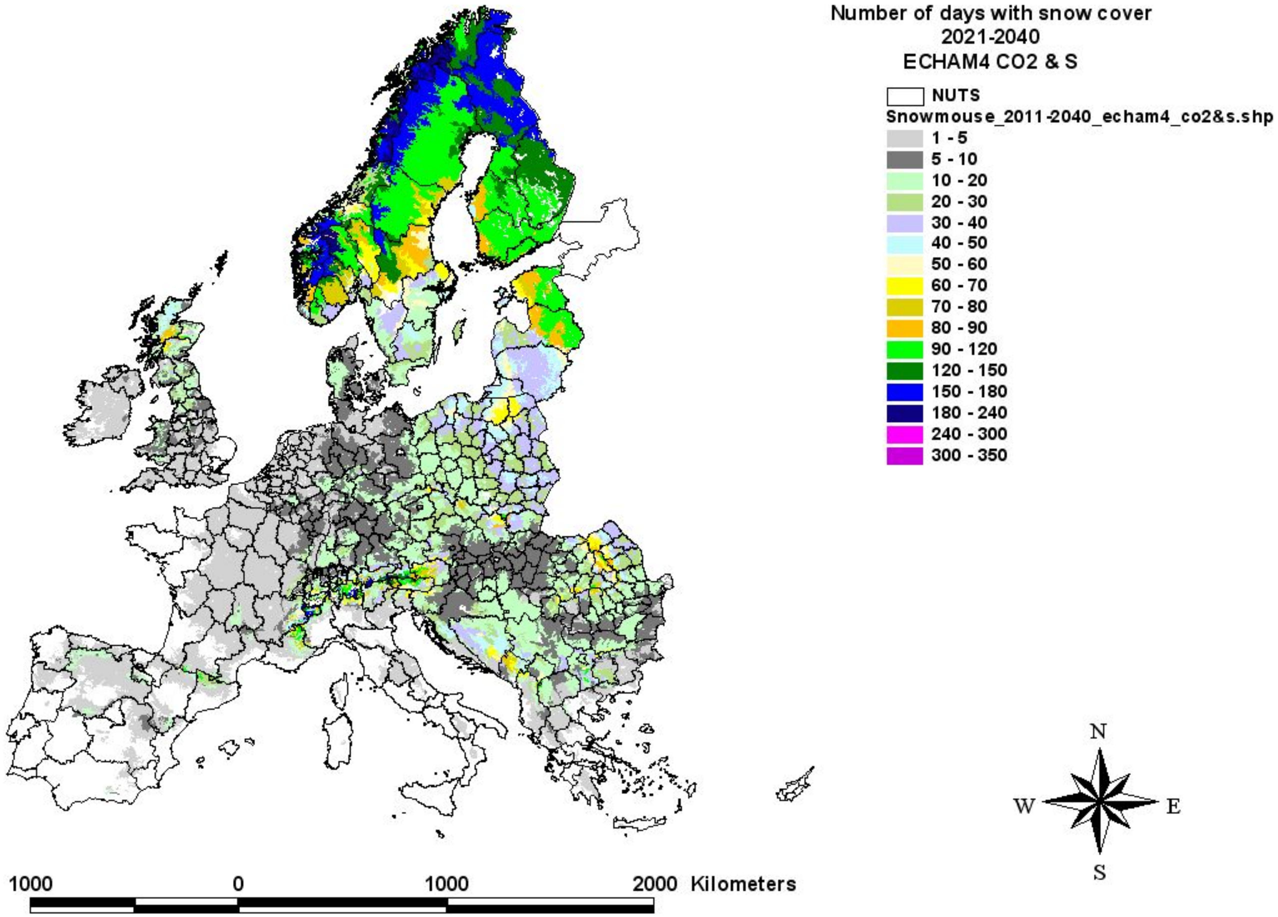


Number of snow cover days SnowMouse

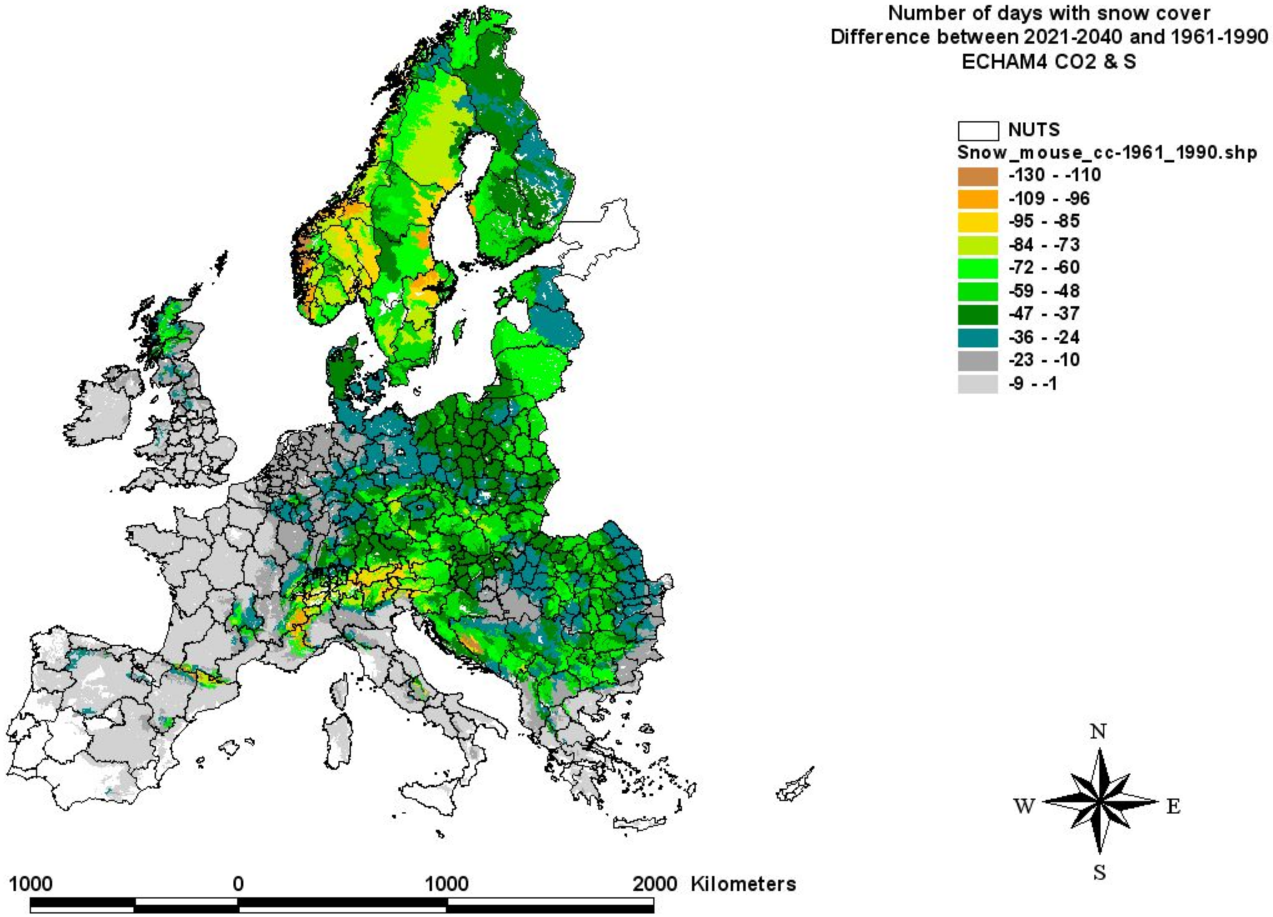
Number of days with snow cover
1961-1990



Number of days with snow cover
2011-2040 ECHAM4 CO2 & S

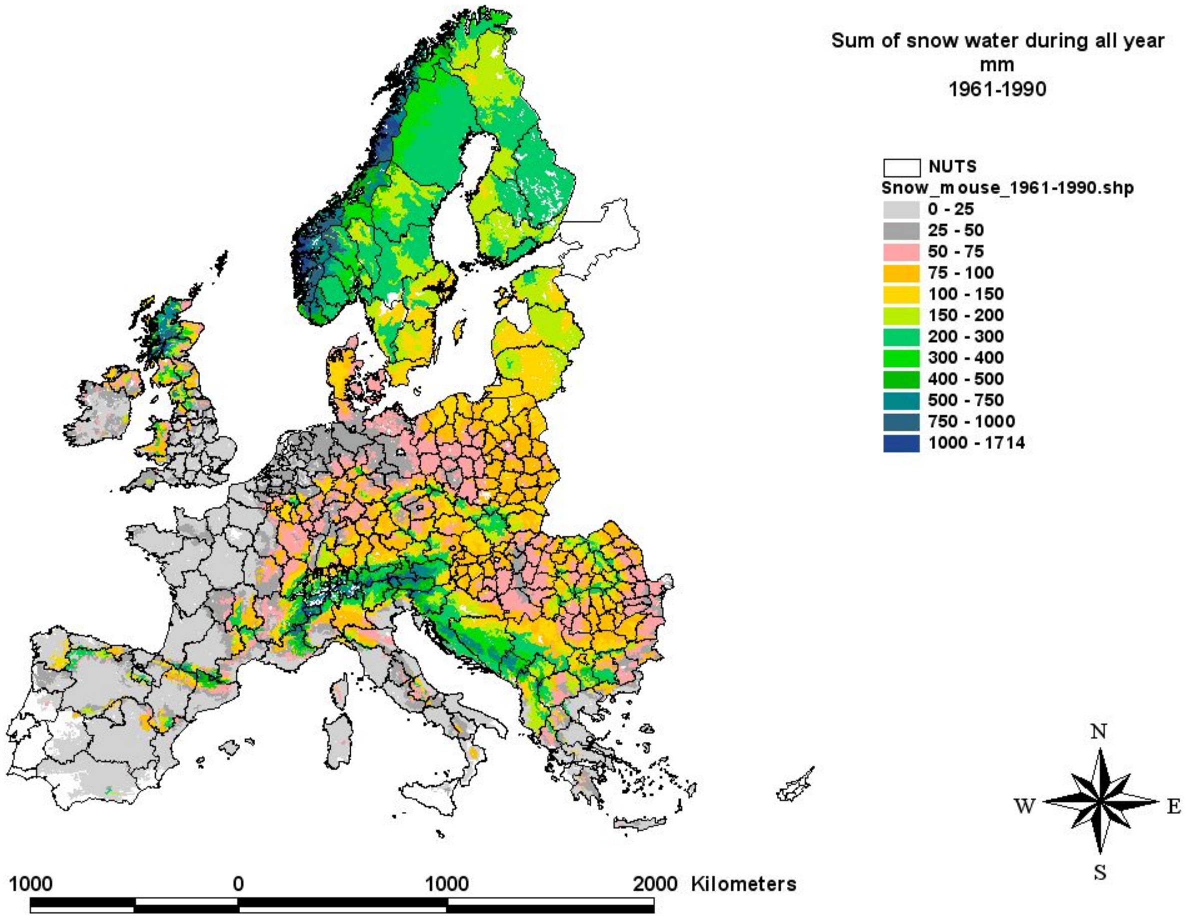


Difference of the number of days with snow cover between 2011-2040 ECHAM4 CO2 & S and baseline (1961-1990)

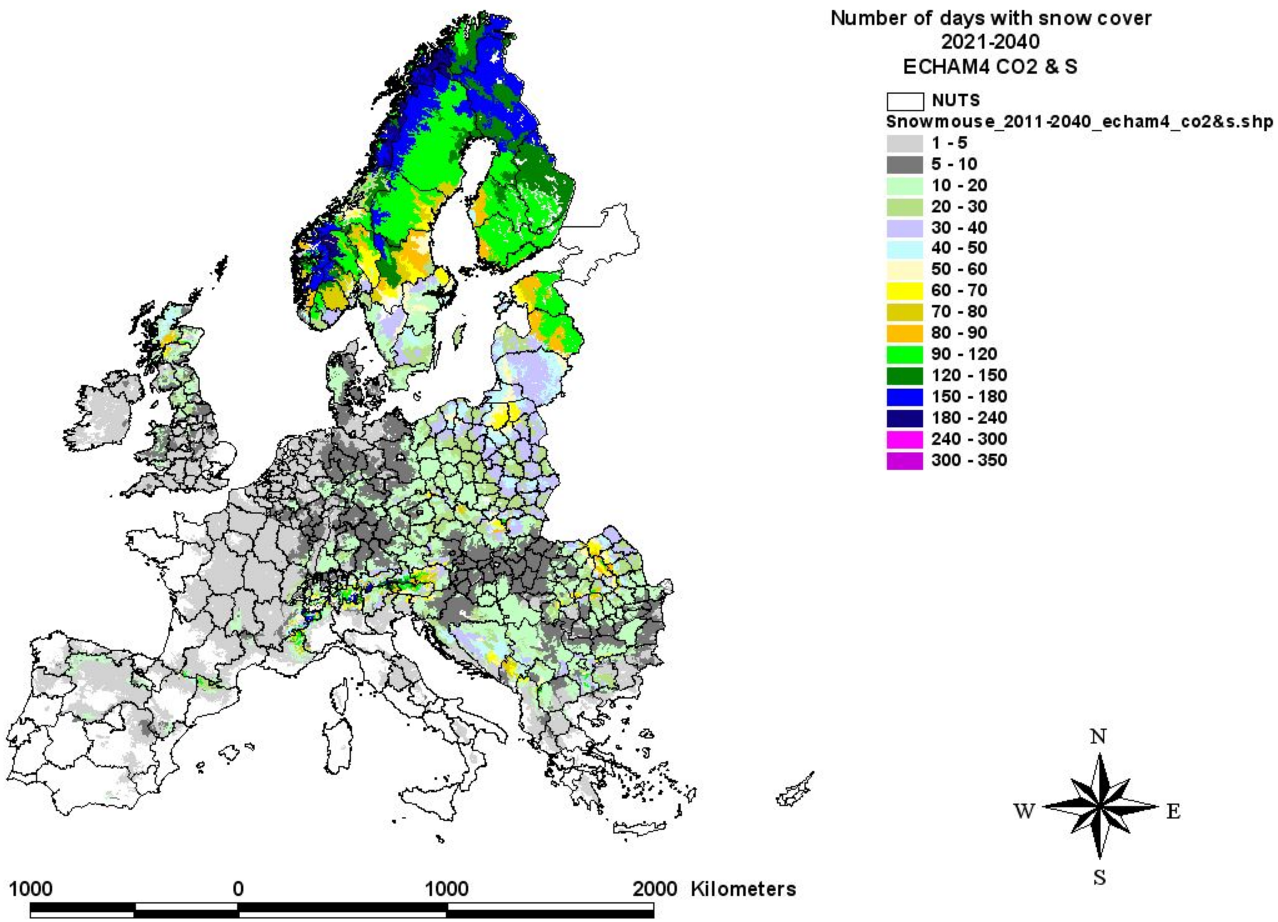


Sum of snow water during all year SnowMouse

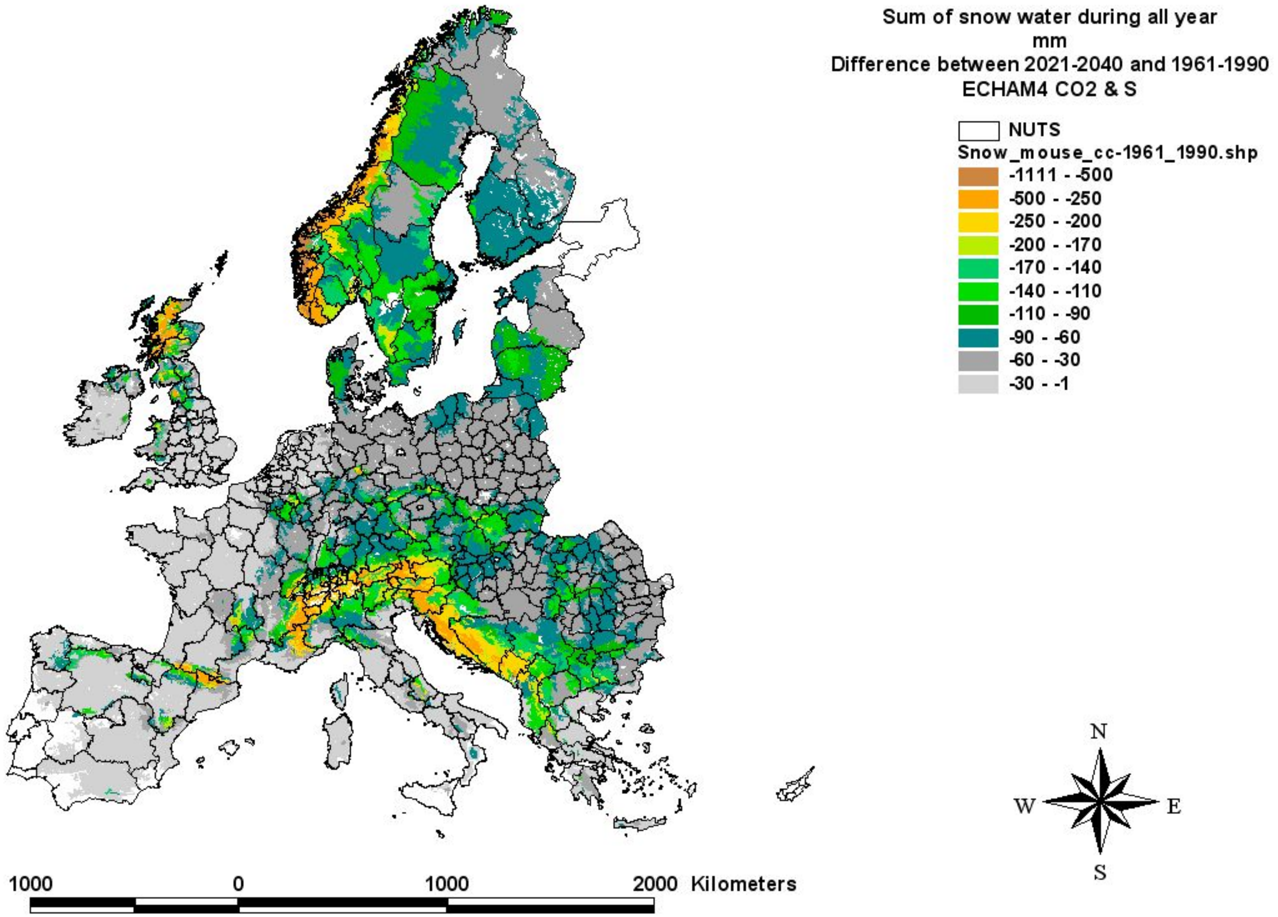
Sum of snow water during all year 1961-1990



Sum of snow water during all year 2011-2040 ECHAM4 CO2 & S

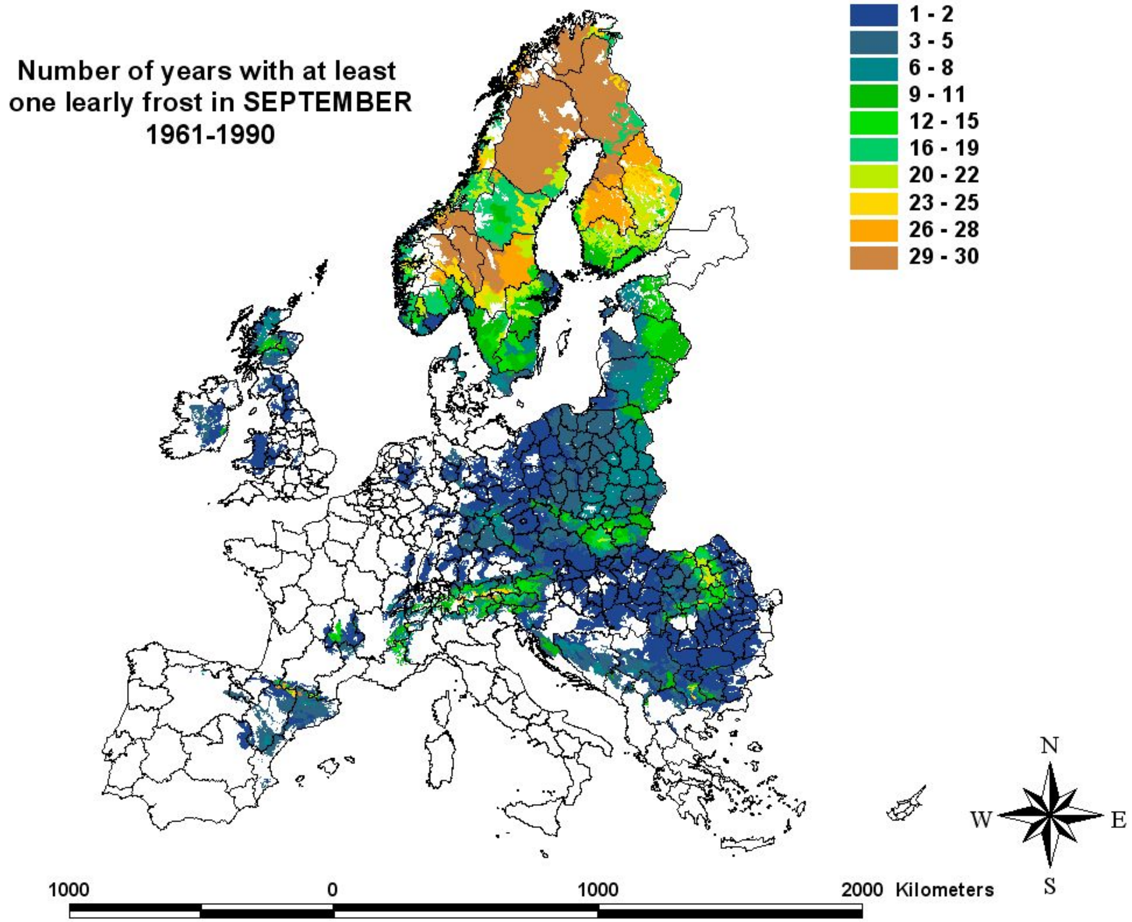


Difference of the Sum of snow water during all year between 2011-2040 ECHAM4 CO2 & S and baseline (1961-1990)

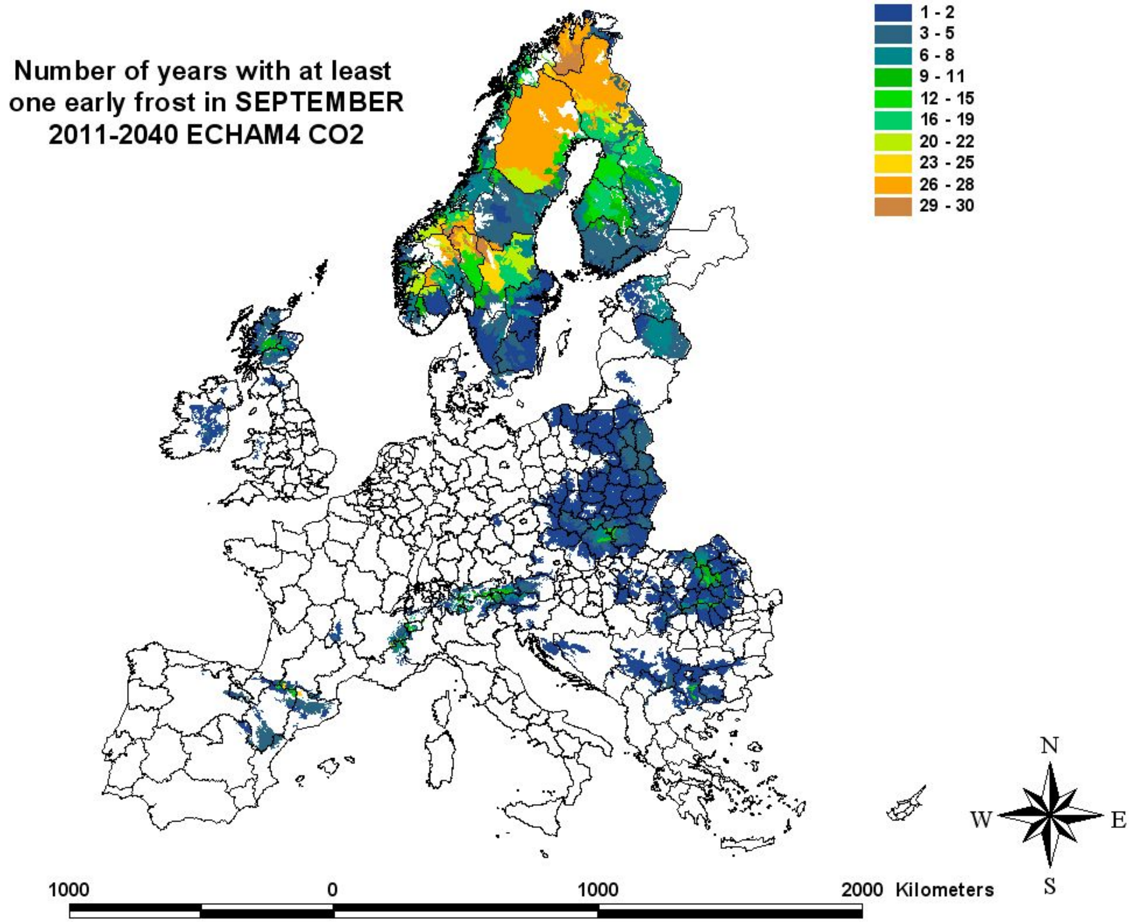


Number of years with at least one early frost in september / october / december

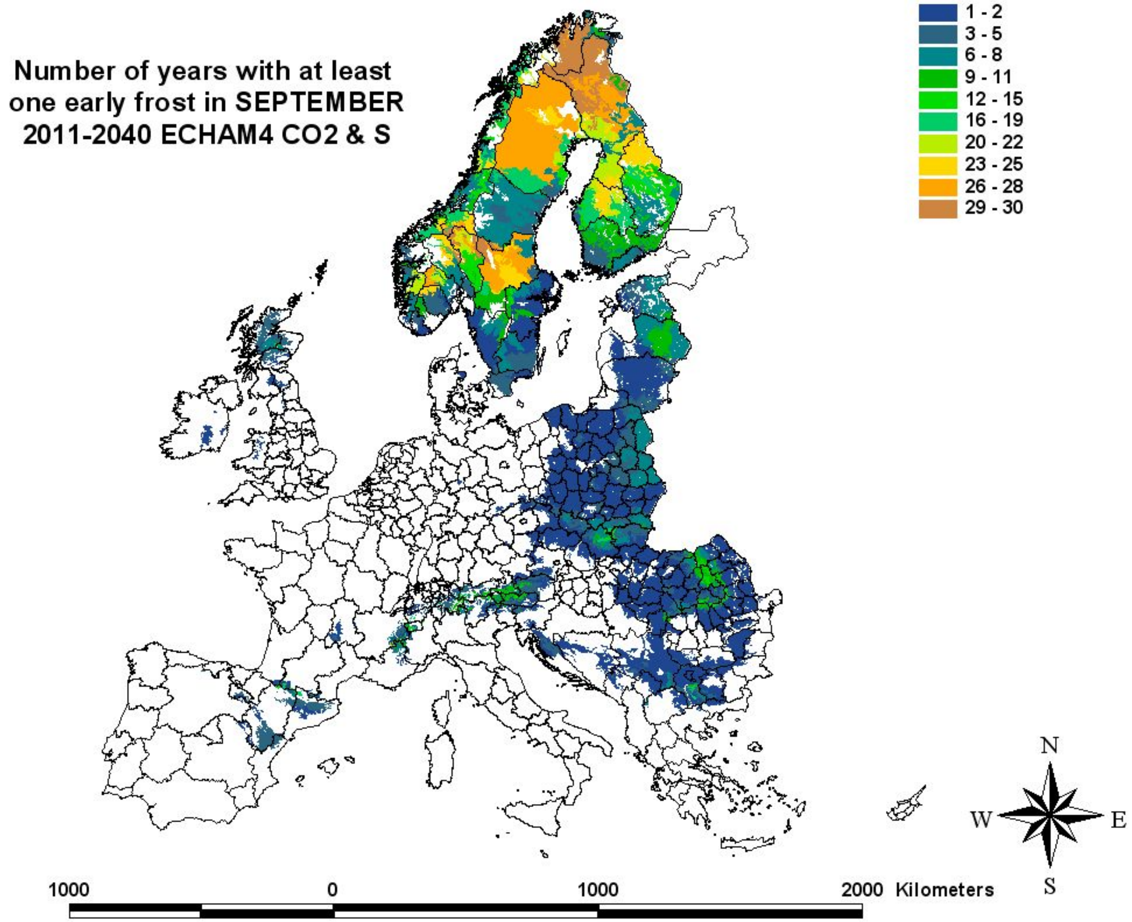
Number of years with at least one early frost in september 1961-1990



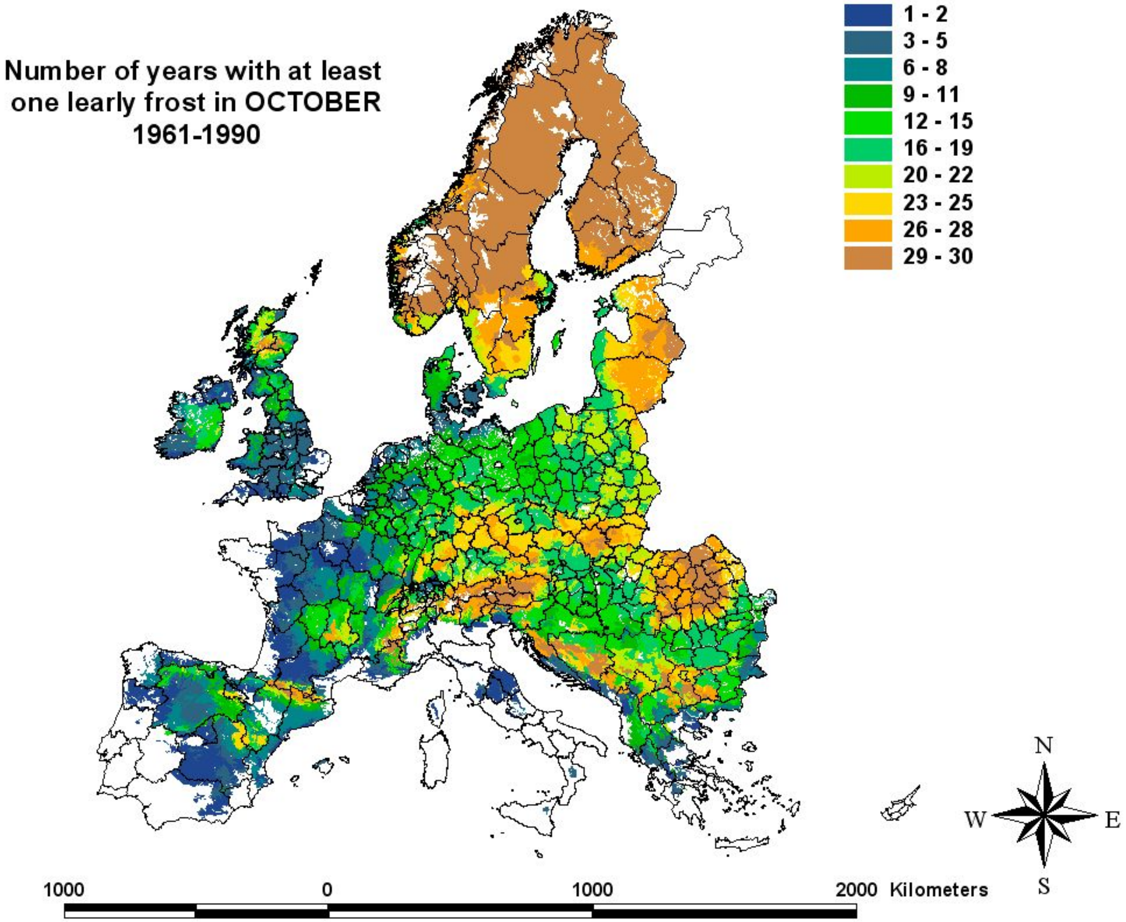
Number of years with at least one early frost in september 2011-2040 ECHAM4 CO_2



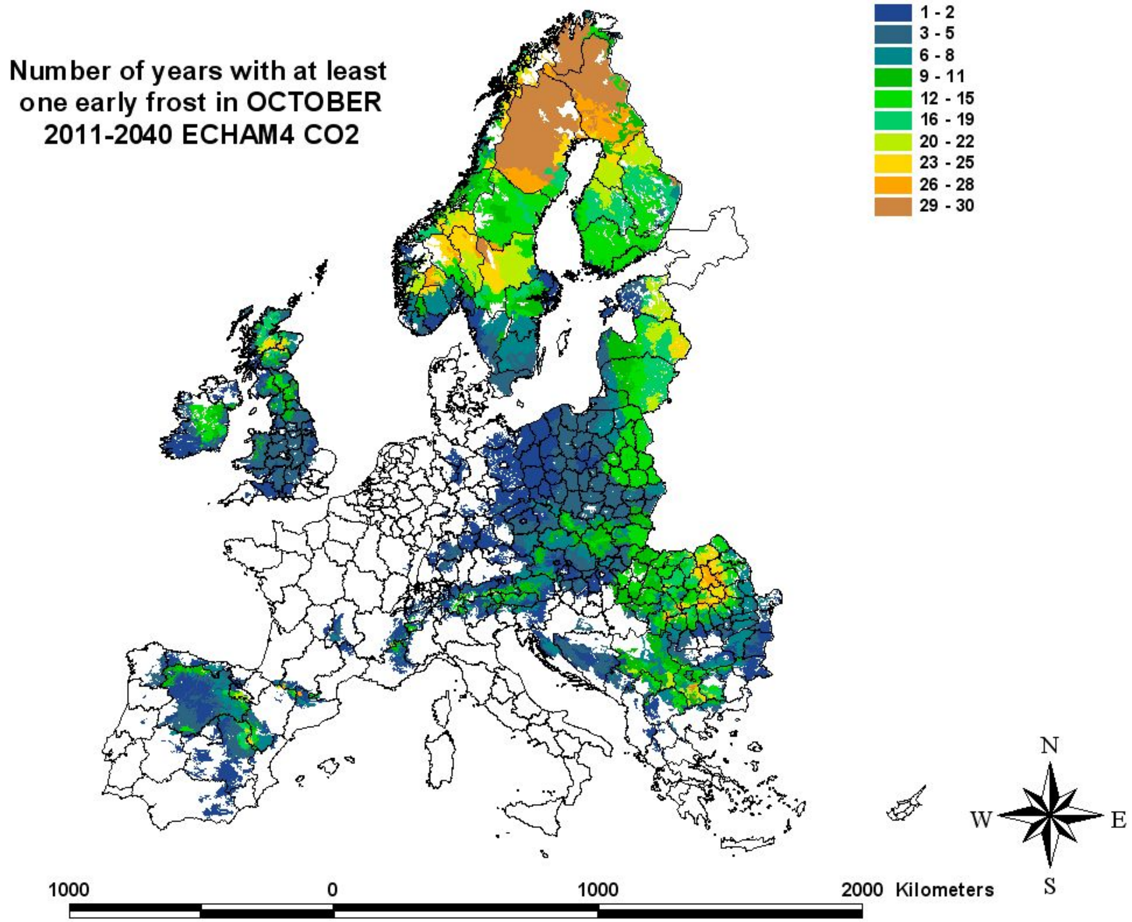
Number of years with at least one early frost in september 2011-2040 ECHAM4 CO2 & S



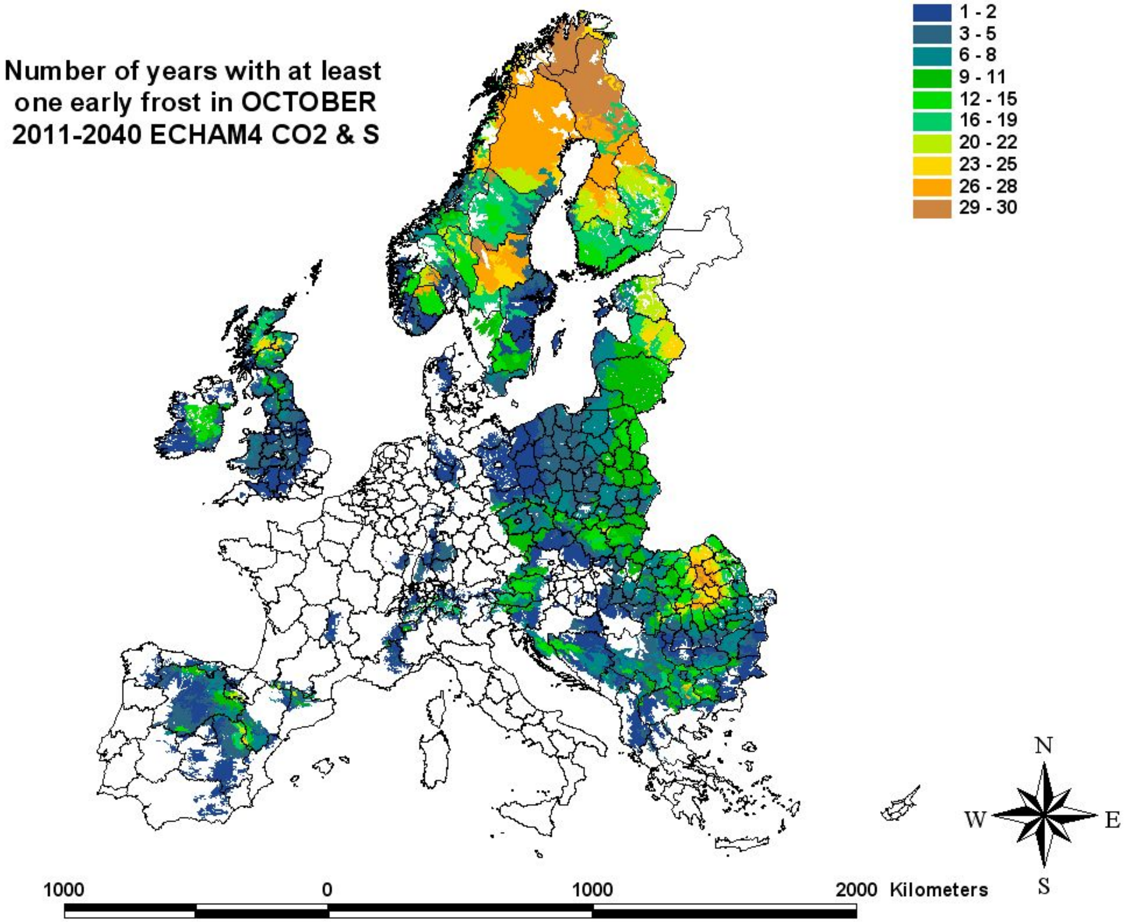
Number of years with at least one early frost in october 1961-1990



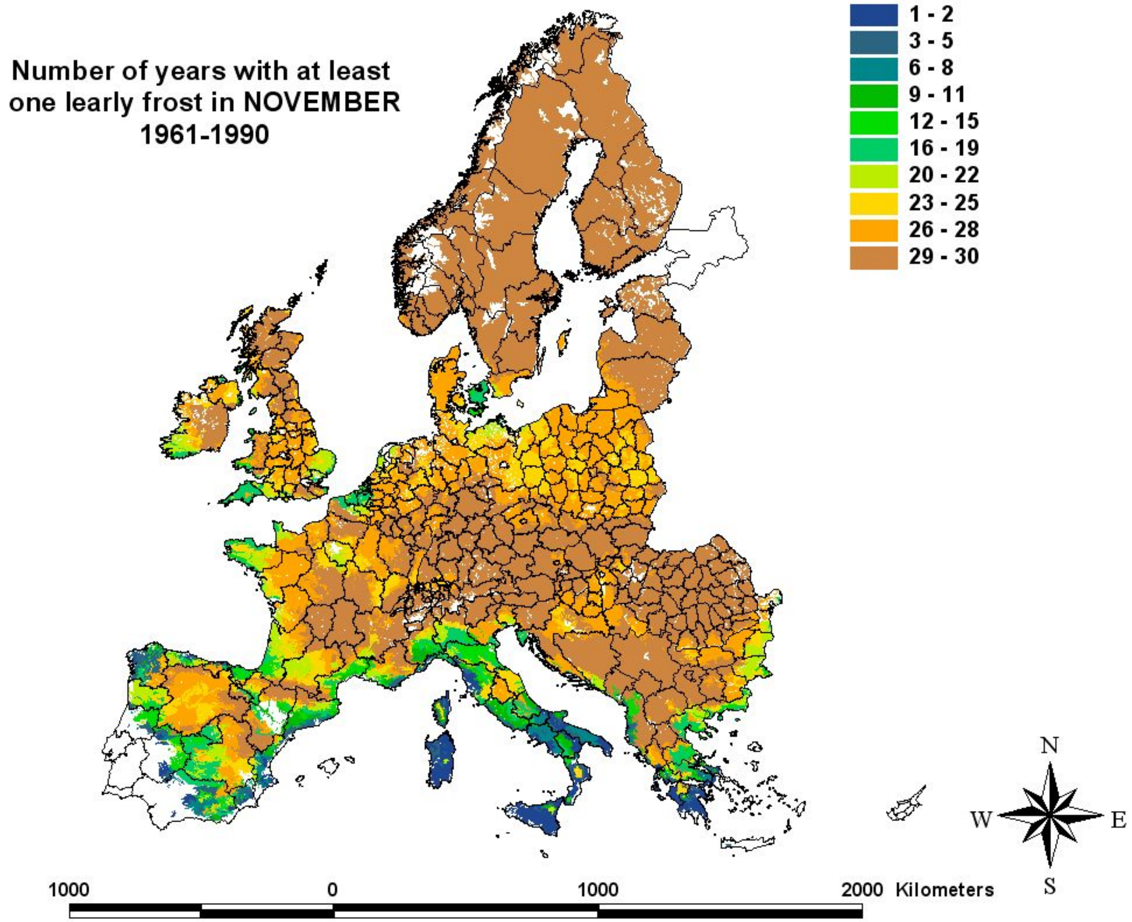
Number of years with at least one early frost in october
2011-2040 ECHAM4 CO2



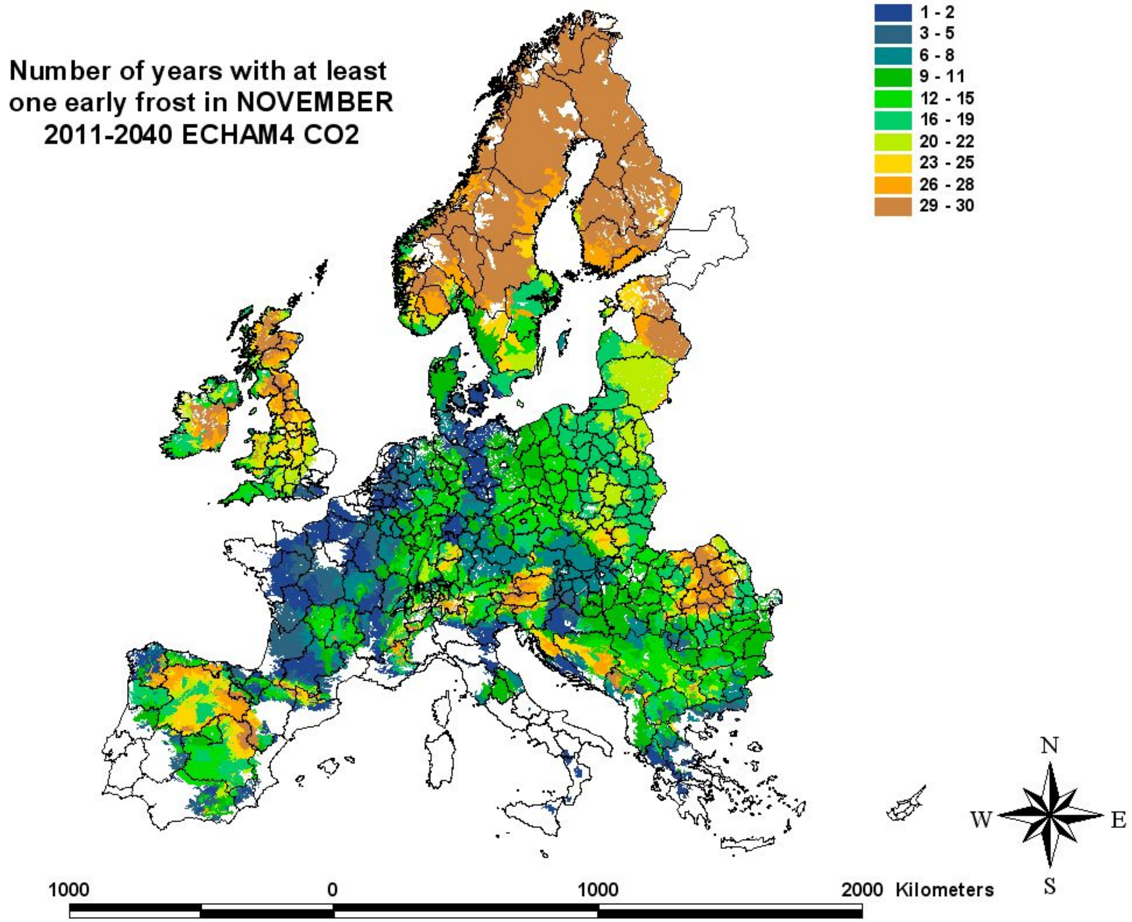
Number of years with at least one early frost in october 2011-2040 ECHAM4 CO2 & S



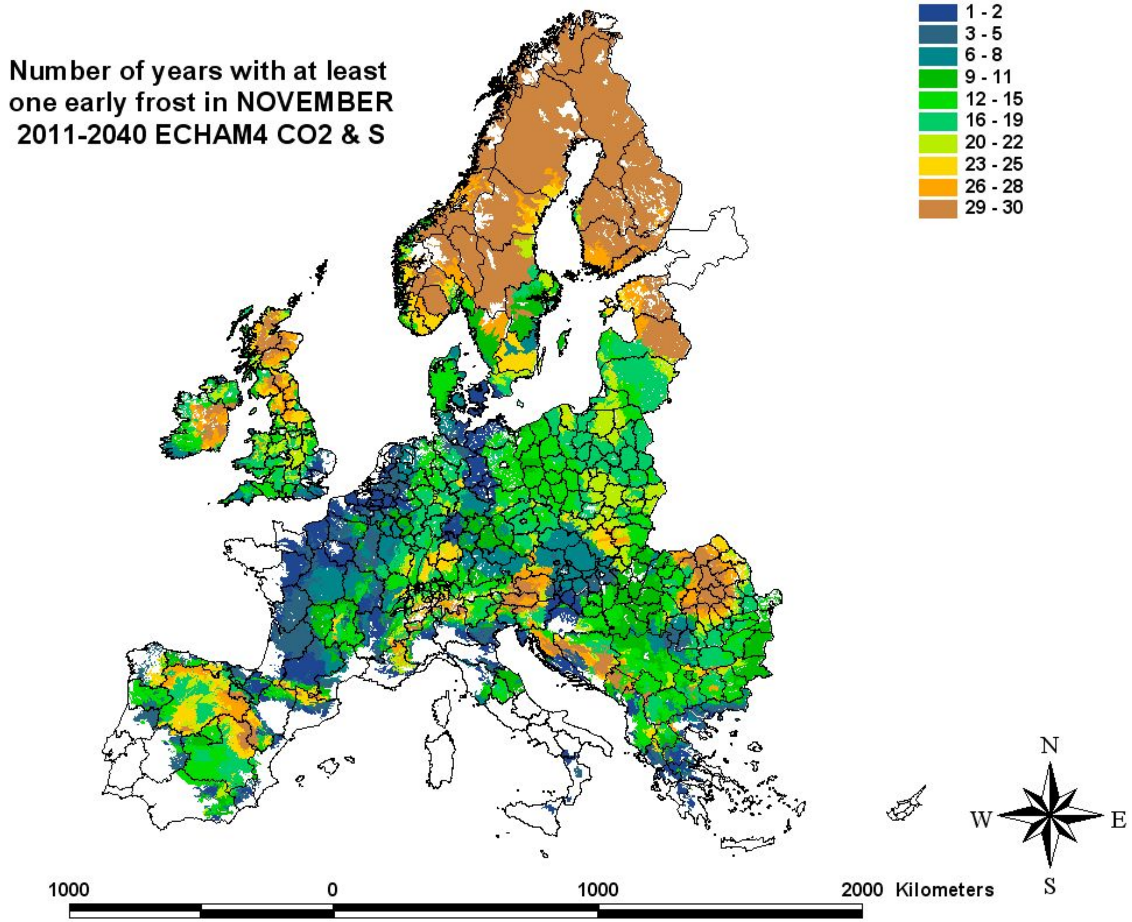
Number of years with at least one early frost in november 1961-1990



Number of years with at least one early frost in november
2011-2040 ECHAM4 CO2

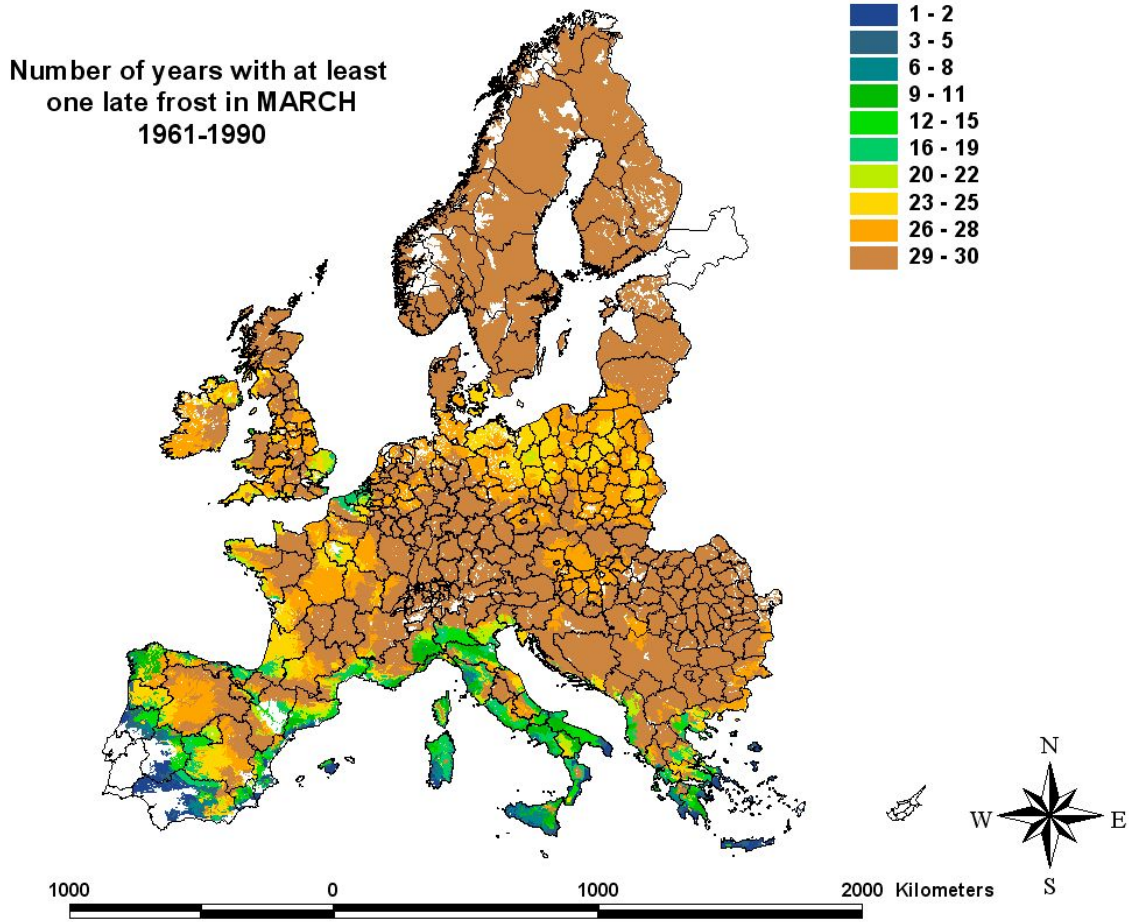


Number of years with at least one early frost in november
2011-2040 ECHAM4 CO2 & S

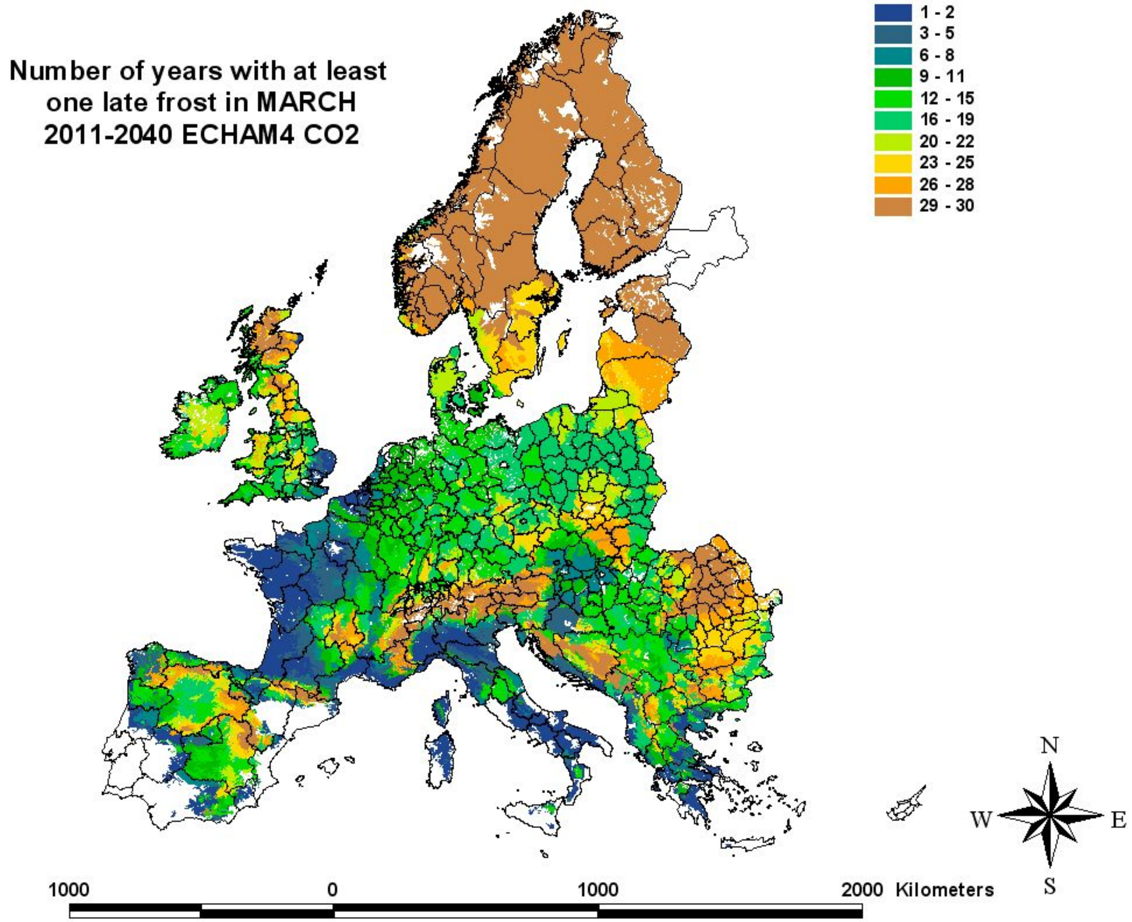


Number of years with at least one late frost in march / april / may / june

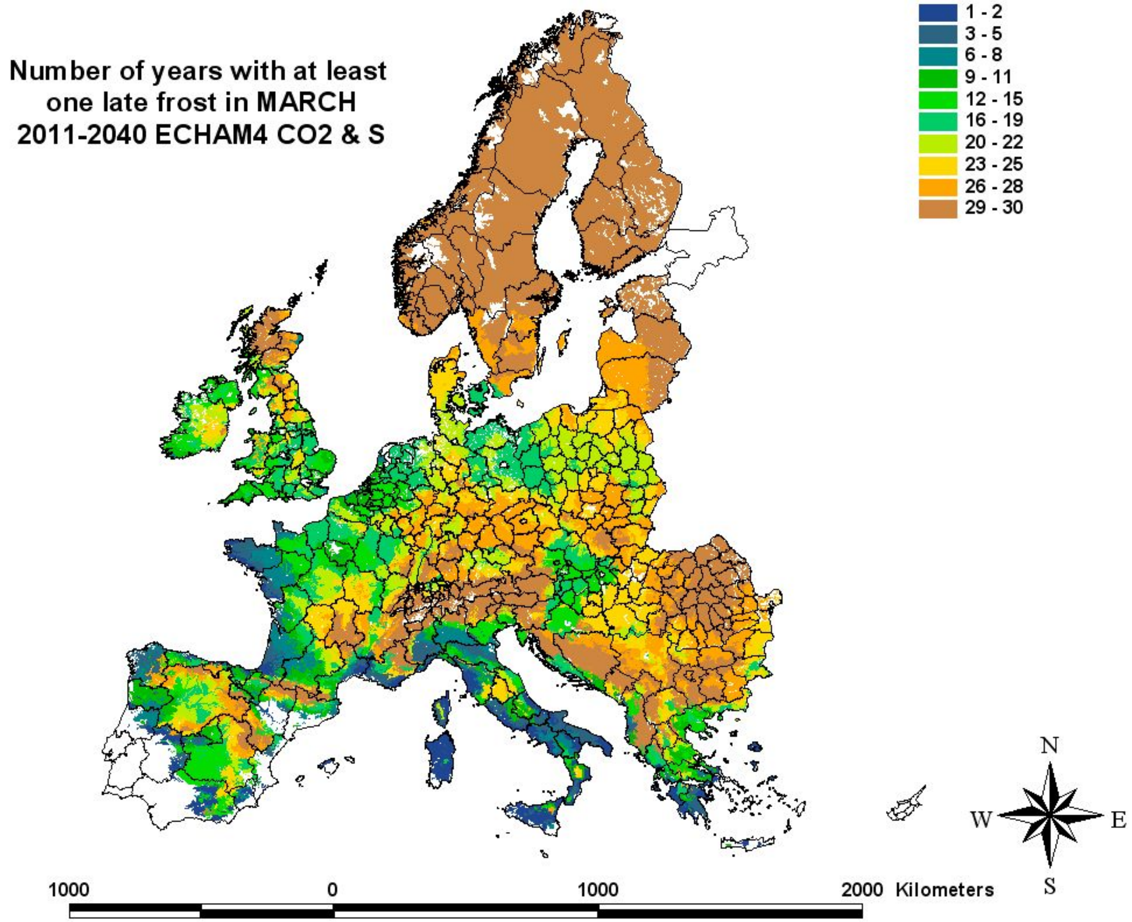
Number of years with at least one late frost in march 1961-1990



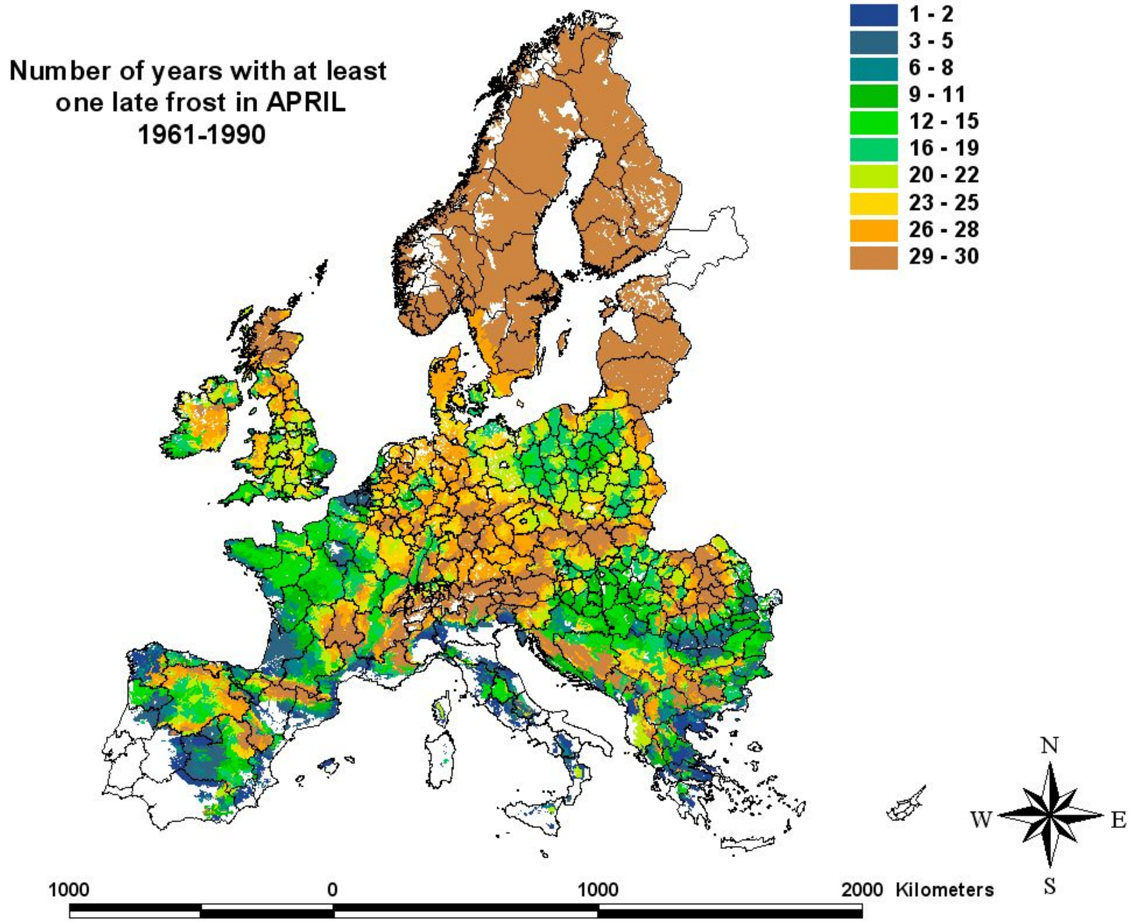
Number of years with at least one late frost in march
2011-2040 ECHAM4 CO2



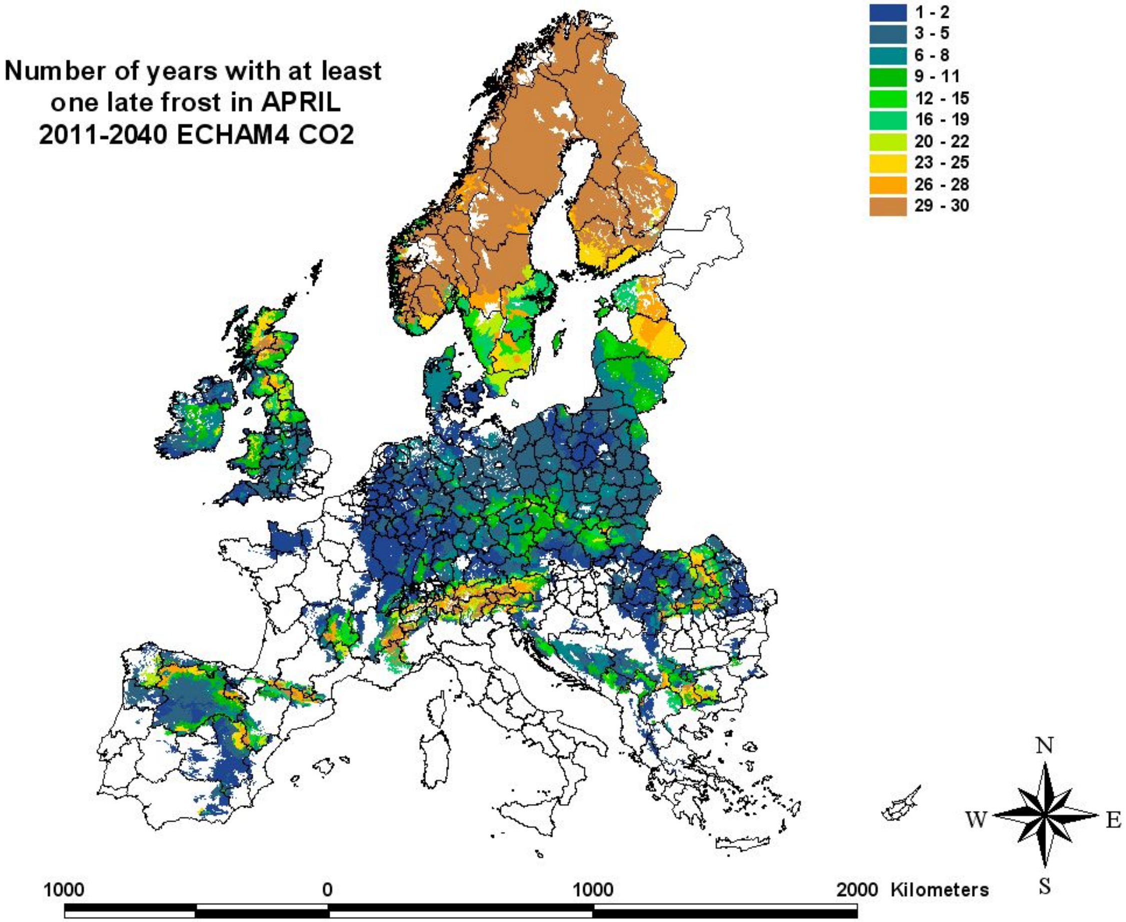
Number of years with at least one late frost in march 2011-2040 ECHAM4 CO2 & S



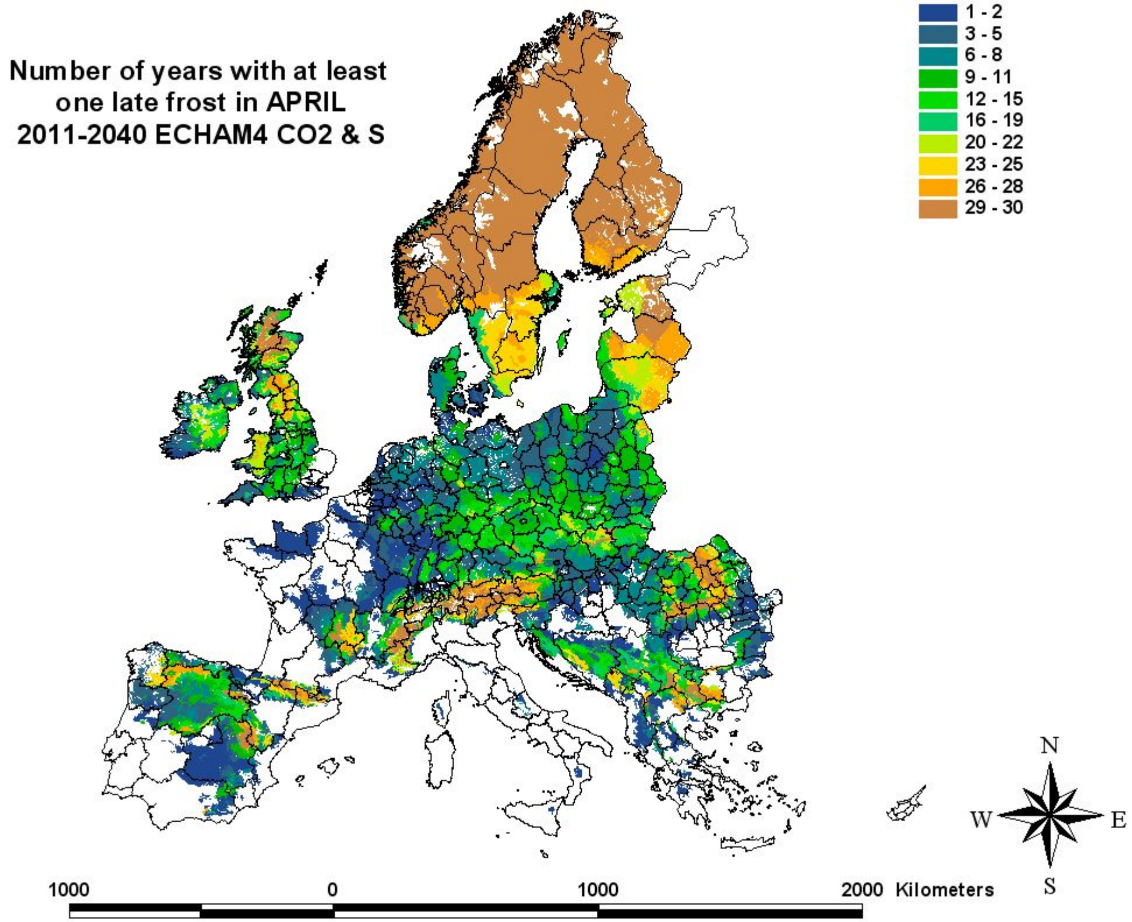
Number of years with at least one late frost in april 1961-1990



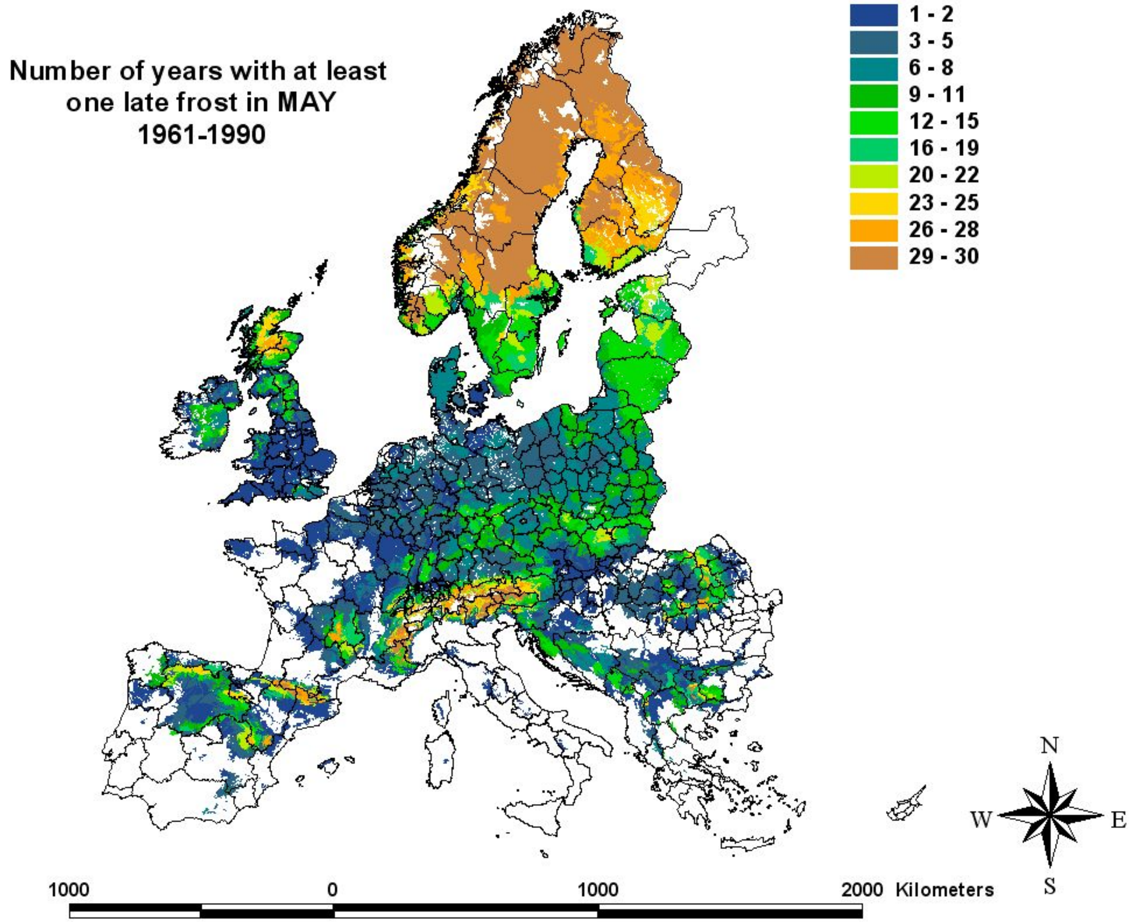
Number of years with at least one late frost in april 2011-2040 ECHAM4 CO2



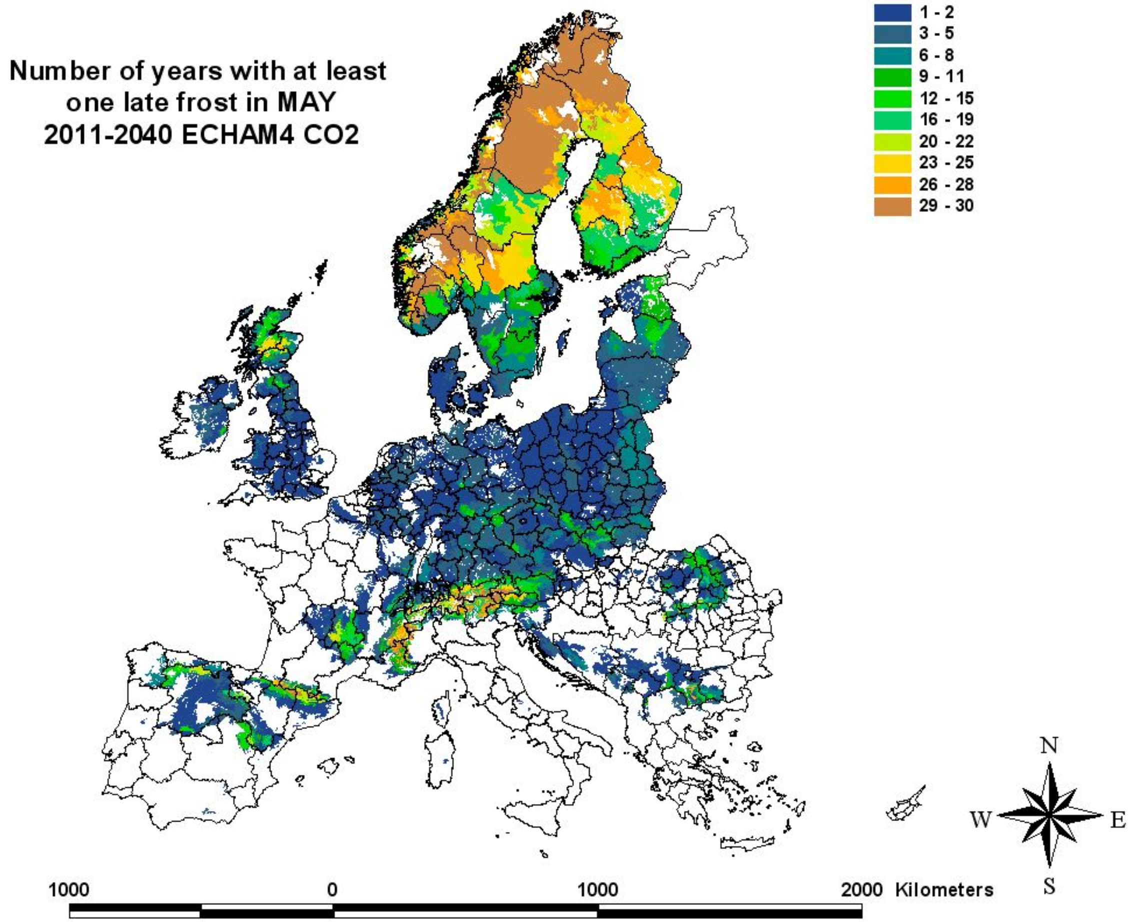
Number of years with at least one late frost in april 2011-2040 ECHAM4 CO2 & S



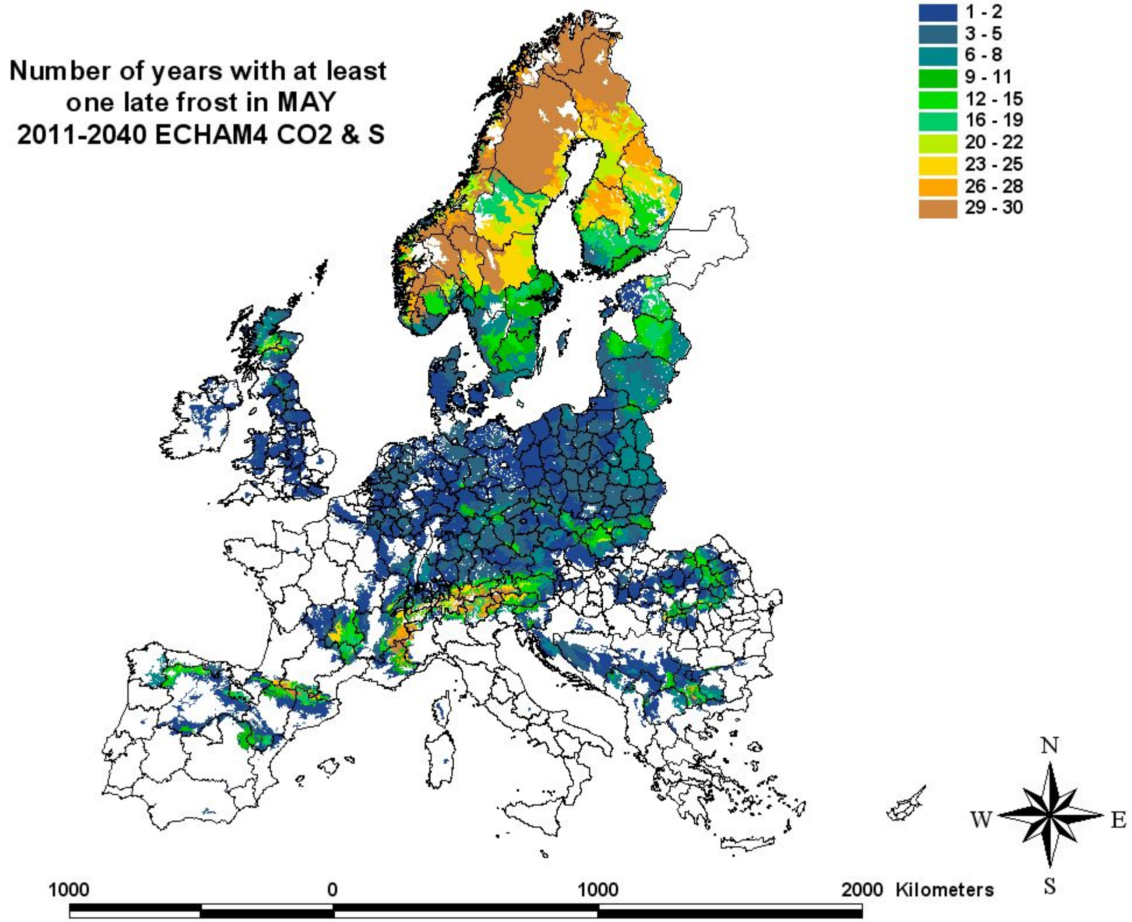
Number of years with at least one late frost in may
1961-1990



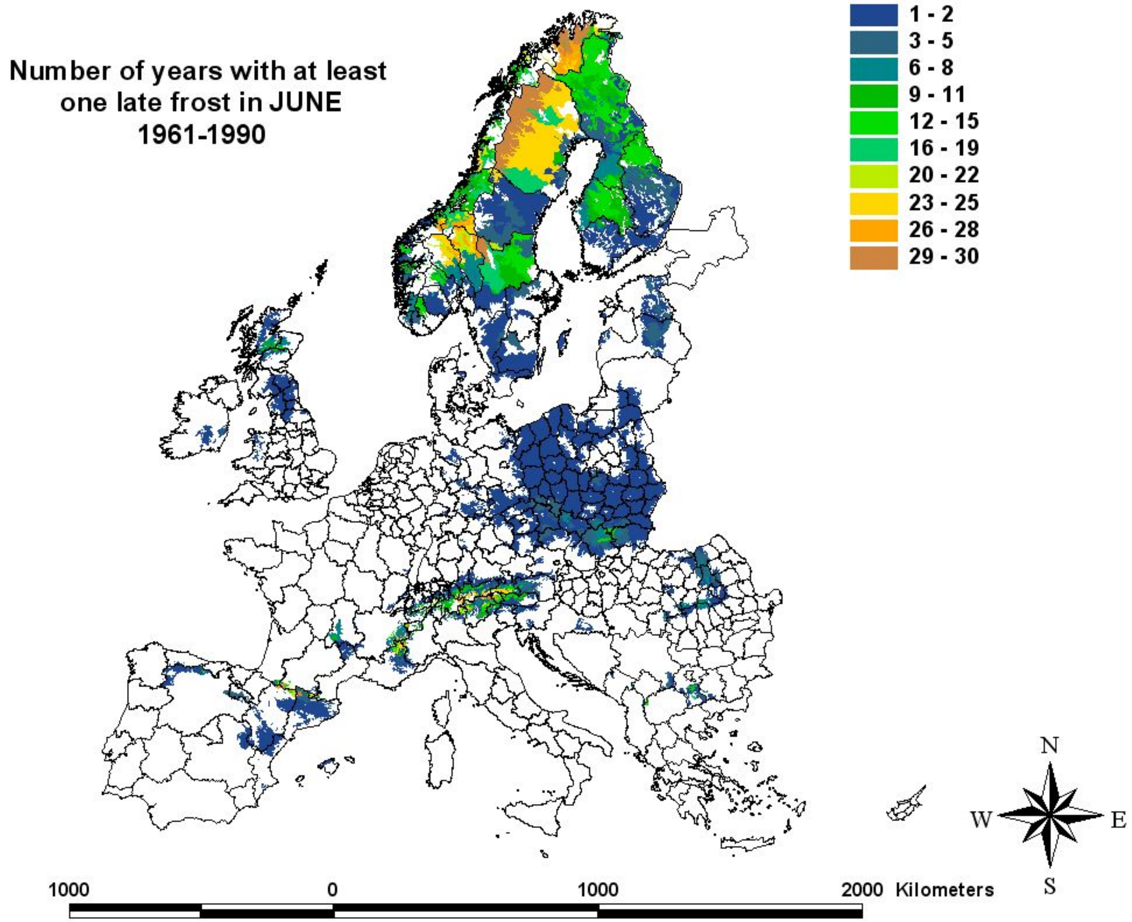
Number of years with at least one late frost in may 2011-2040 ECHAM4 CO2



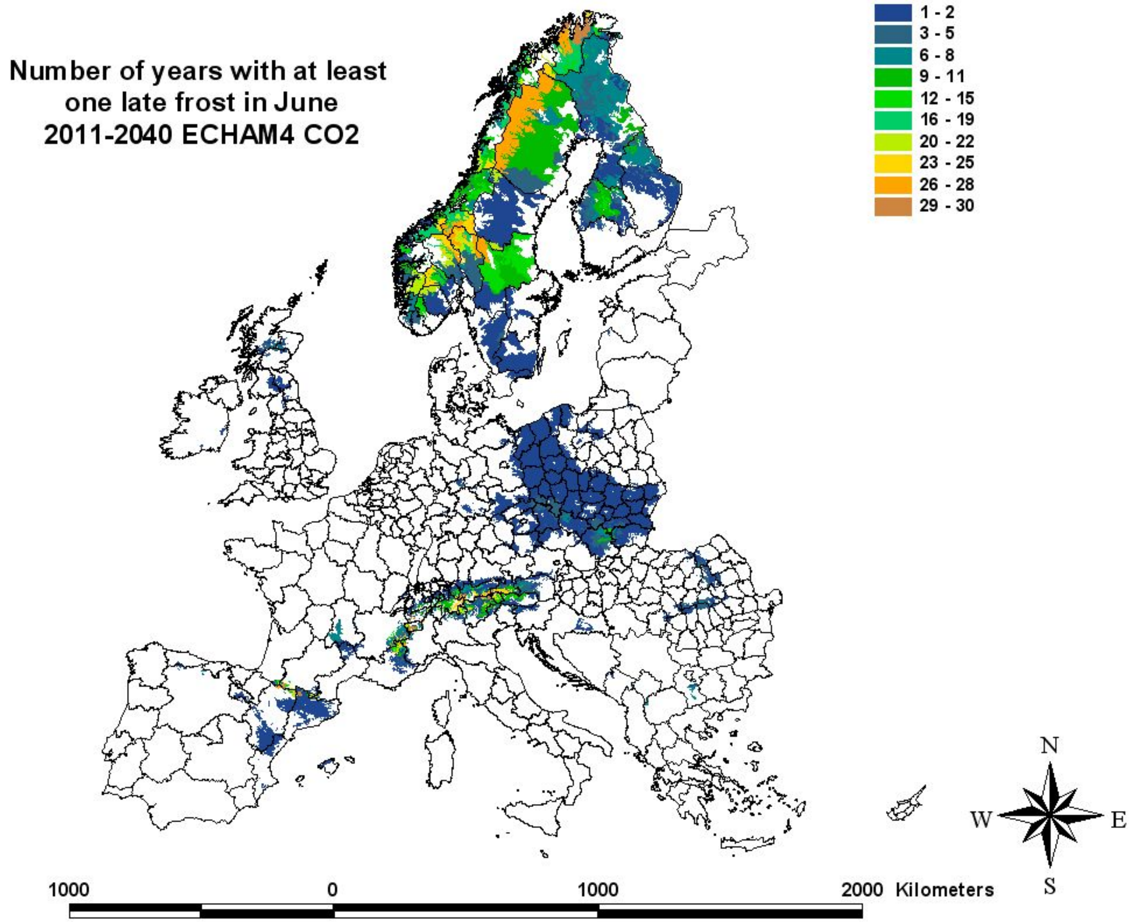
Number of years with at least one late frost in may 2011-2040 ECHAM4 CO2 & S



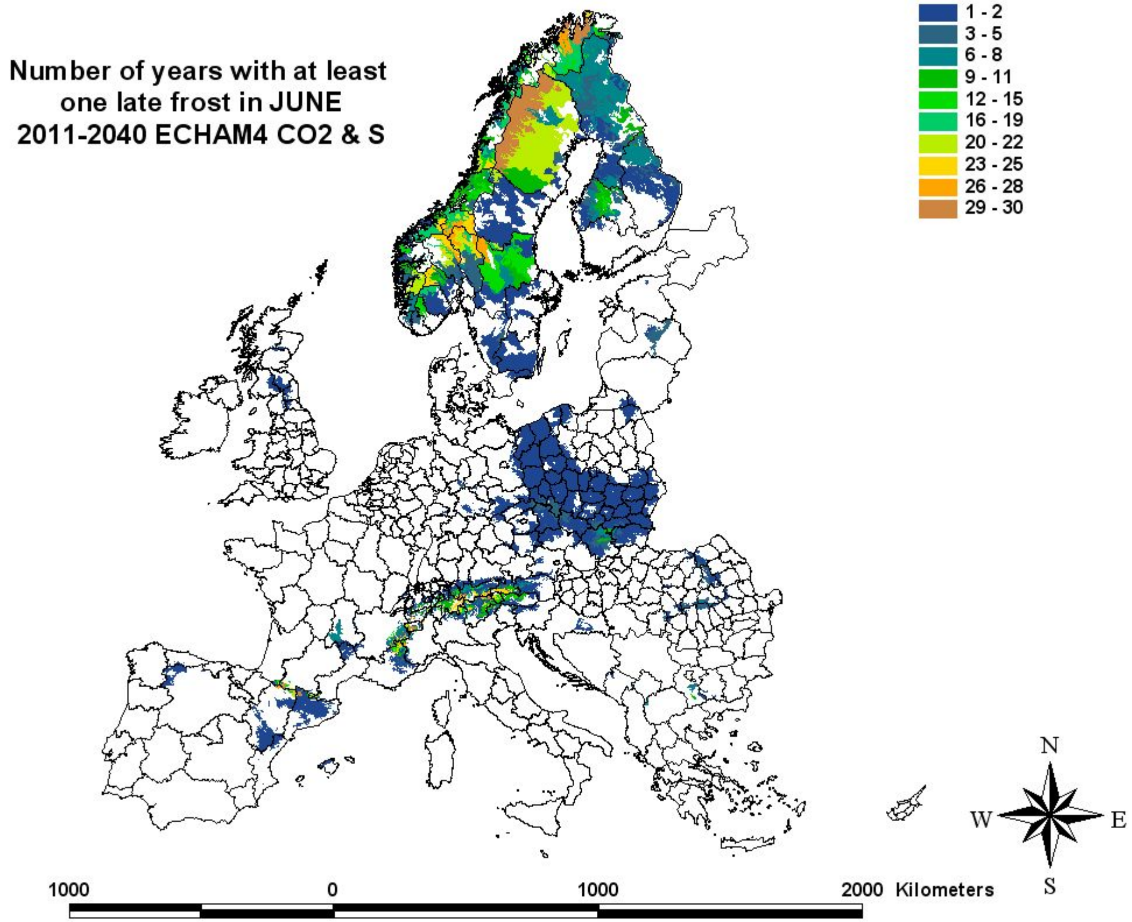
Number of years with at least one late frost in june 1961-1990



Number of years with at least one late frost in june
2011-2040 ECHAM4 CO2



Number of years with at least one late frost in june
2011-2040 ECHAM4 CO2 & S

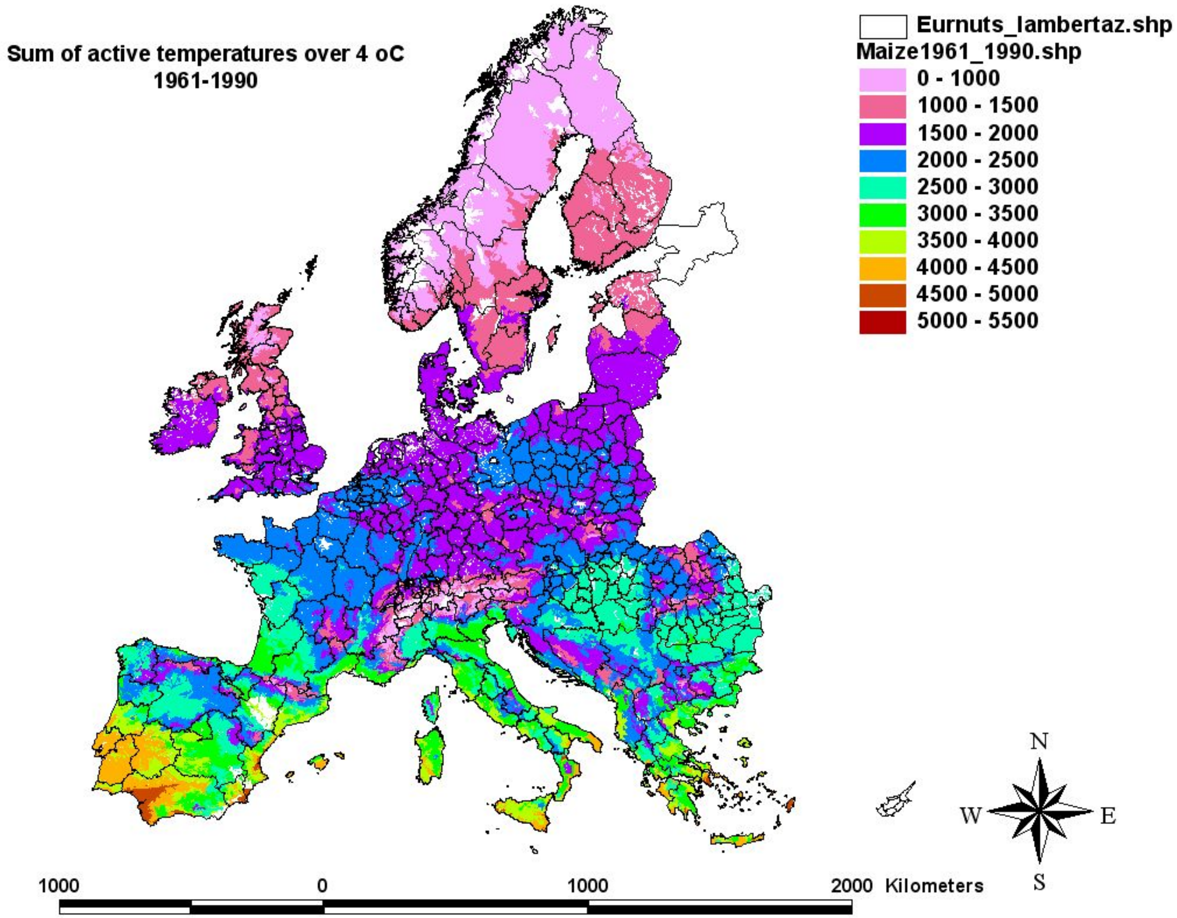


Crop independent indicators

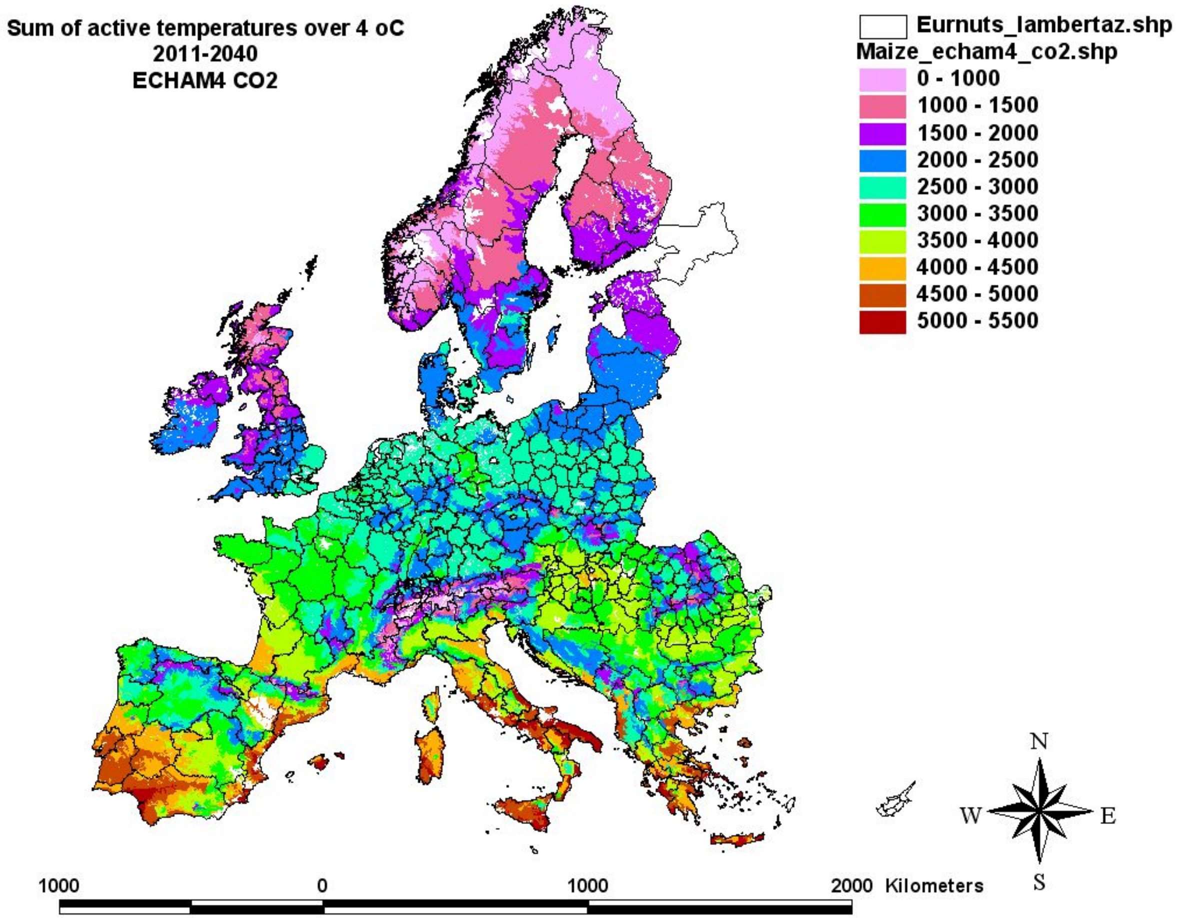
- Sum of active temperatures over 4^{o}C
- Sum of active temperatures over 10^{o}C
- Bagnouls-Gaussen Aridity Index
- Huglin Index
- UNESCO Water stress index
- Heat waves

Sum of active temperatures over 4°C

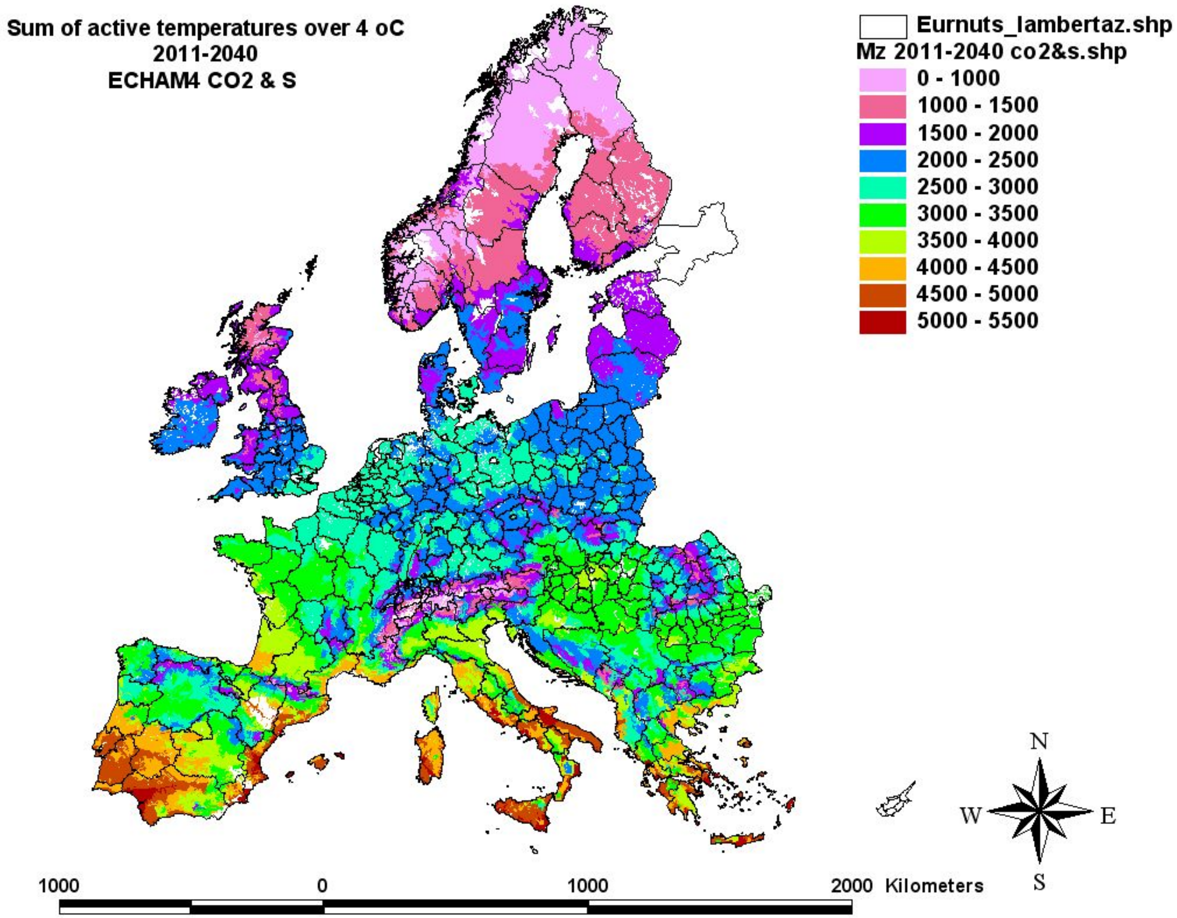
Sum of active temperatures over 4^{o}C 1961-1990



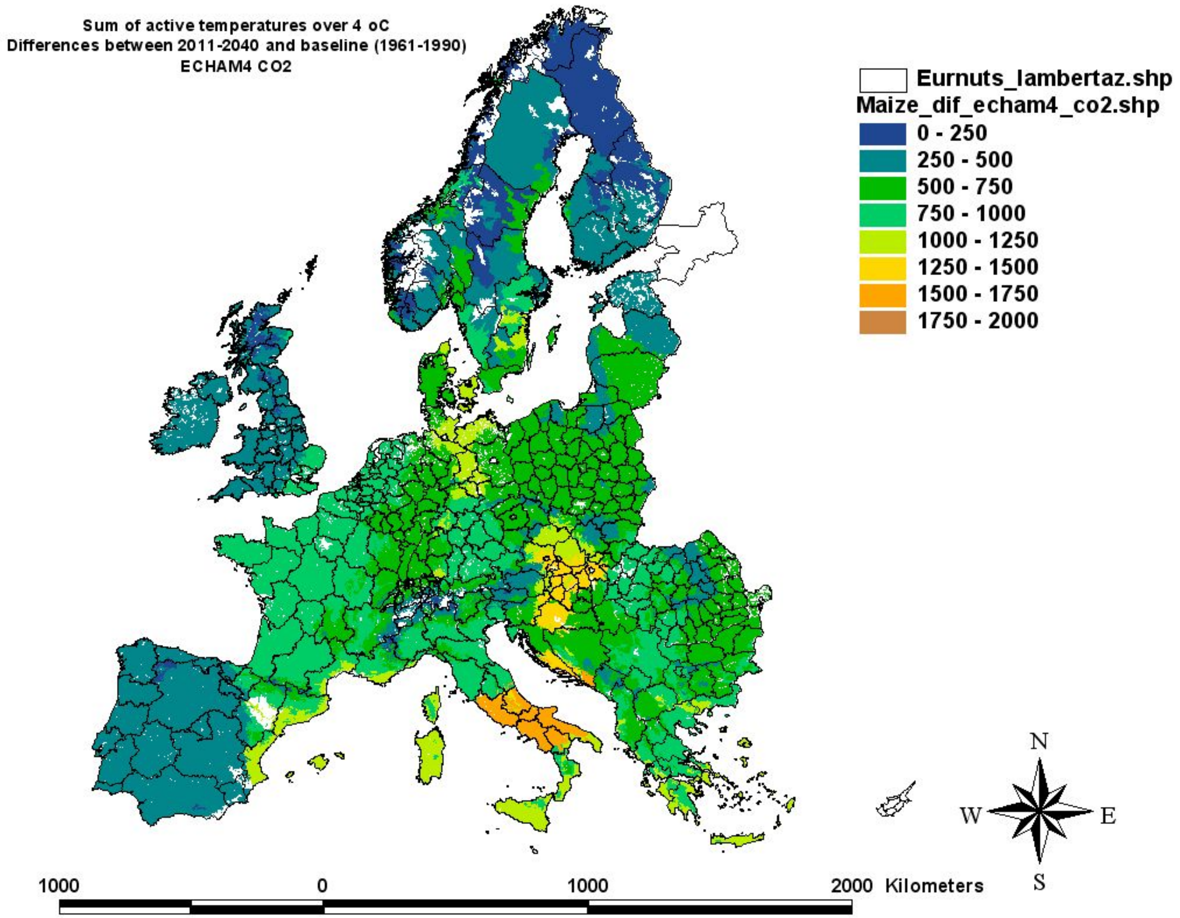
Sum of active temperatures over 4^{o}C
2011-2040 ECHAM4 CO2



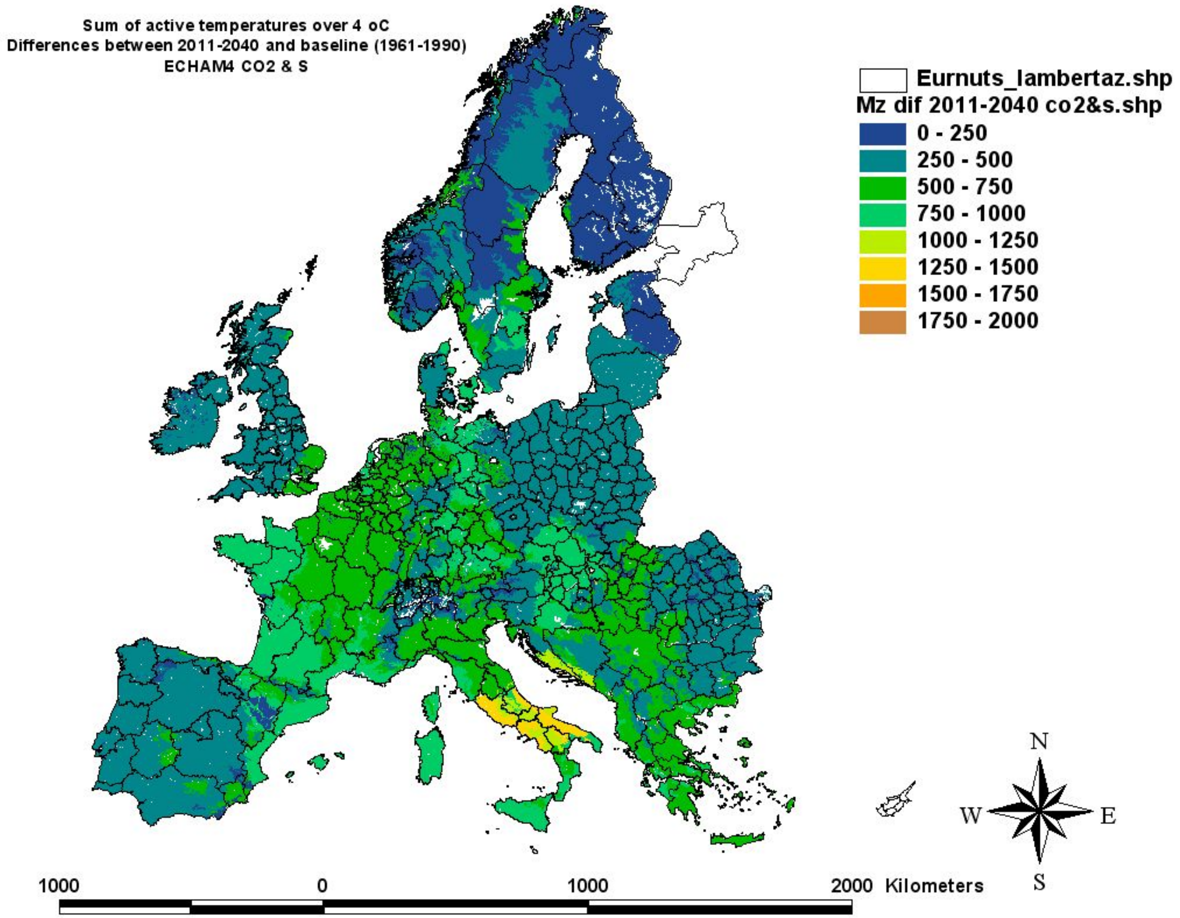
Sum of active temperatures over 4°C ECHAM4 CO2 & S



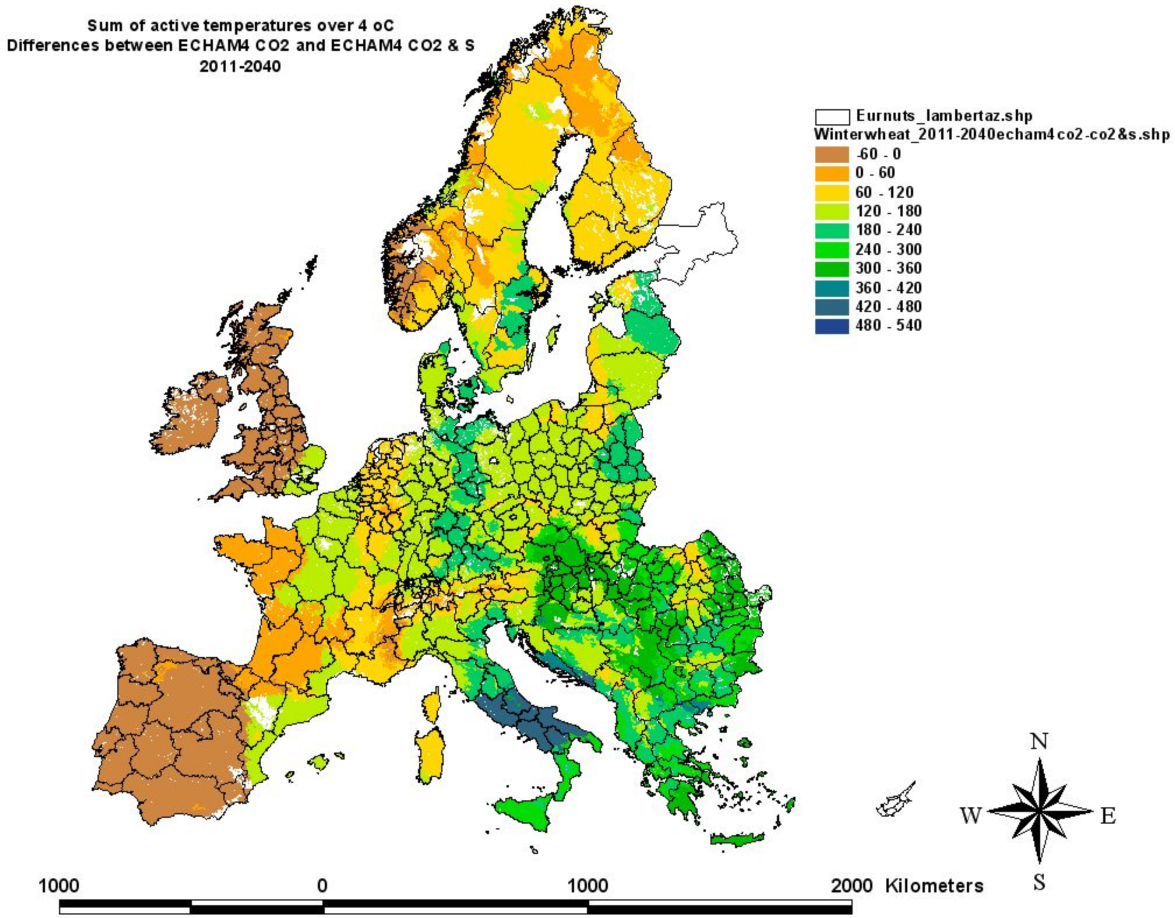
Difference of the Sum of active temperatures over 4°C between 2011-2040 ECHAM4 CO_2 and baseline (1961-1990)



Difference of the Sum of active temperatures over 4°C between 2011-2040 ECHAM4 CO_2 & S and baseline (1961-1990)

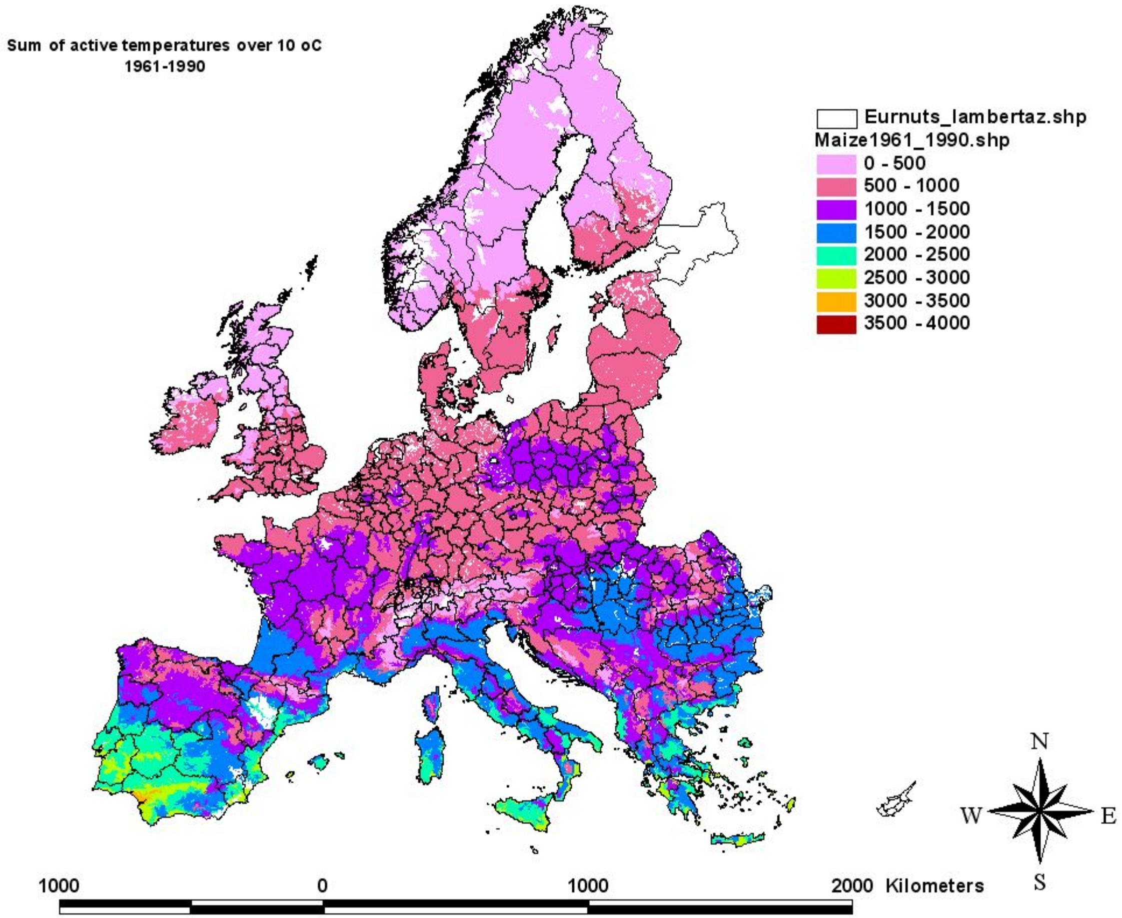


Difference of the Sum of active temperatures over 4°C between 2011-2040 ECHAM4 CO2 and 2011-2040 ECHAM4 CO2 & S

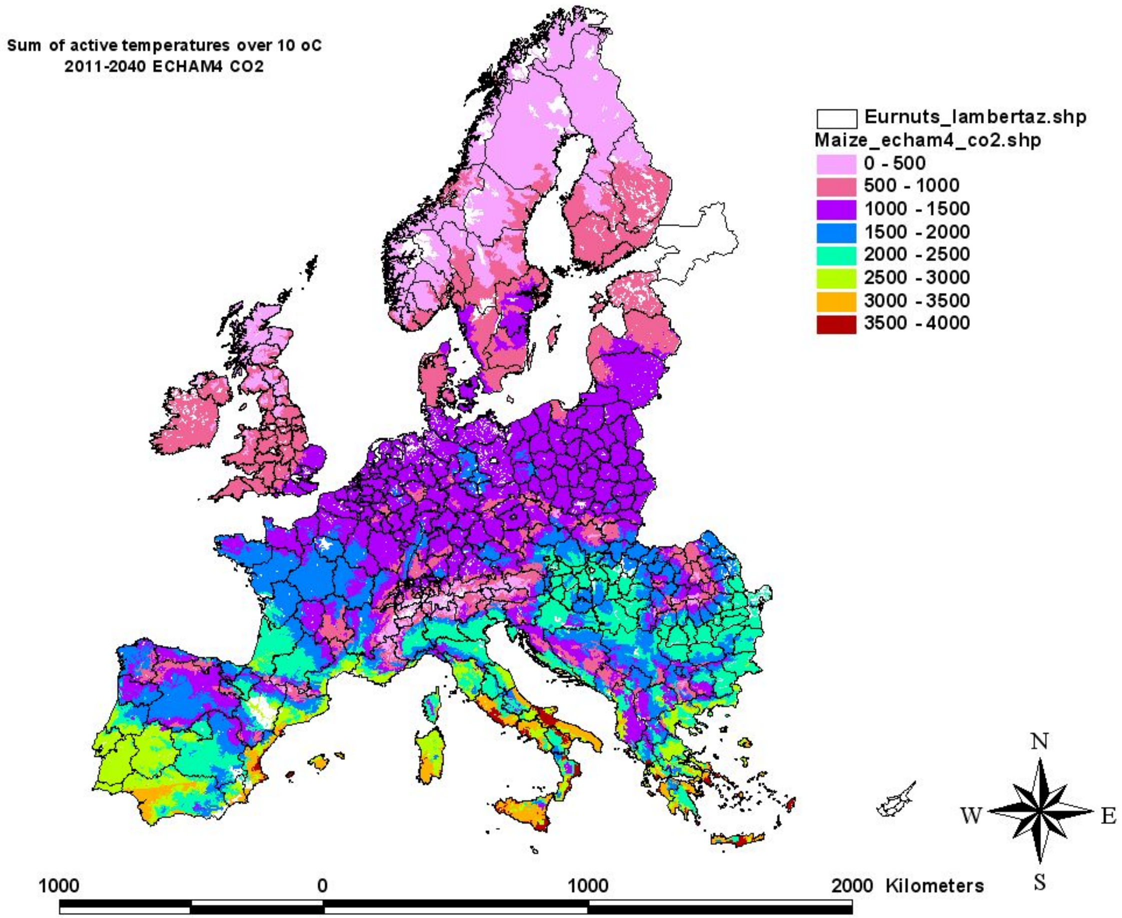


Sum of active temperatures over 10^{o}C

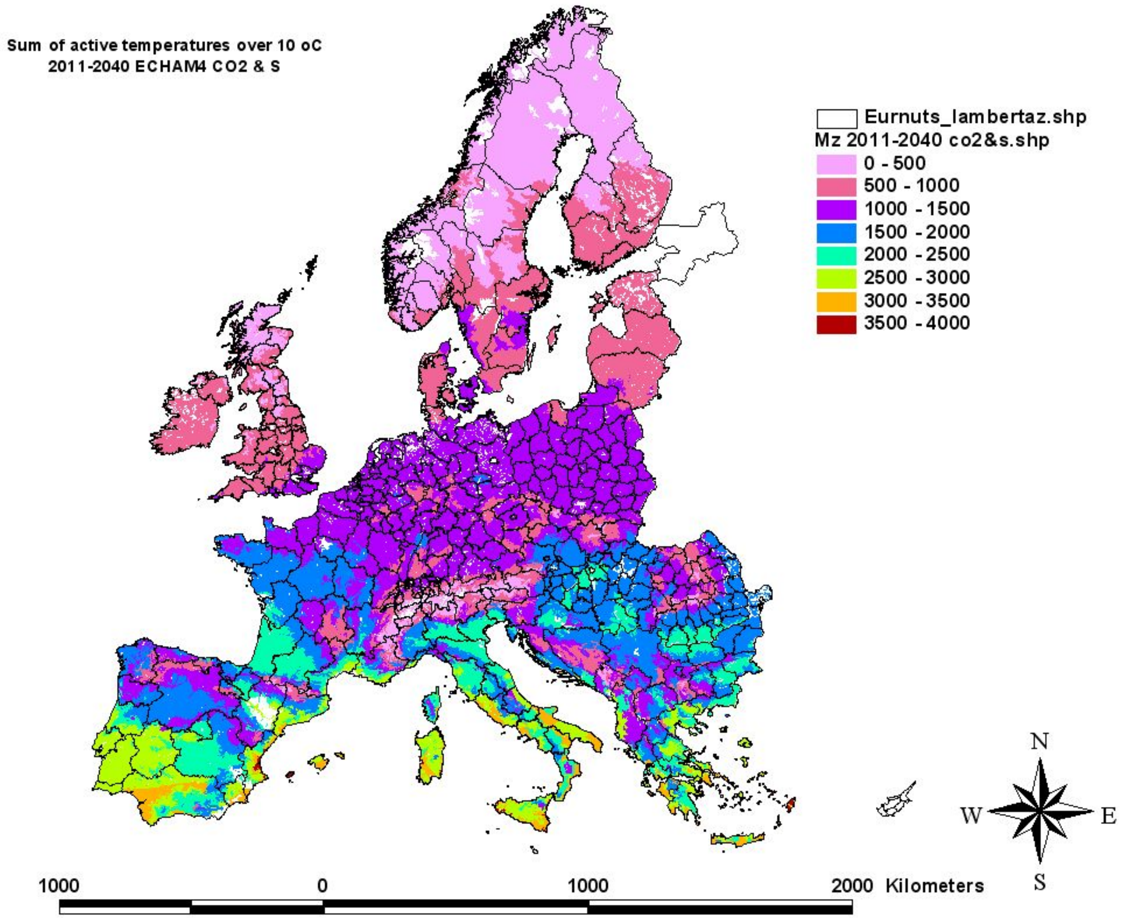
Sum of active temperatures over 10^{o}C 1961-1990



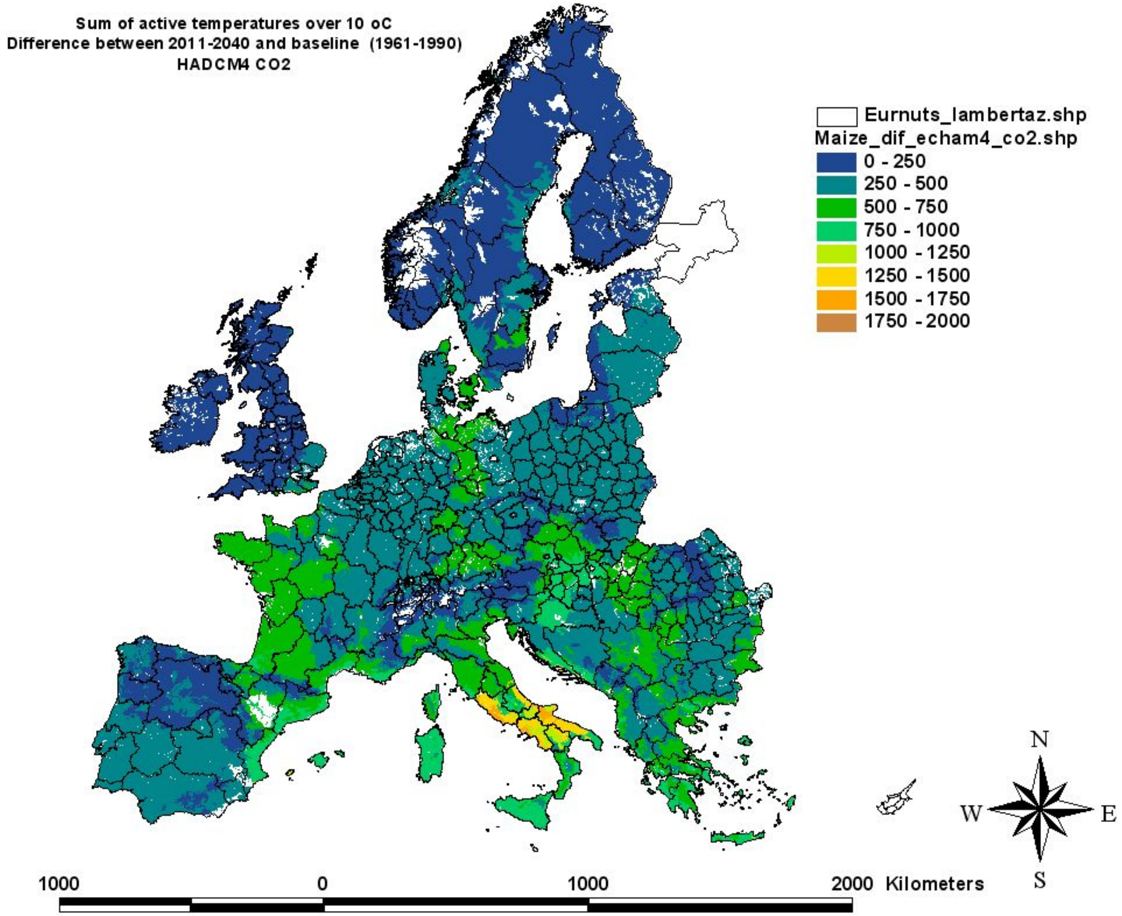
Sum of active temperatures over 10°C
ECHAM4 CO2



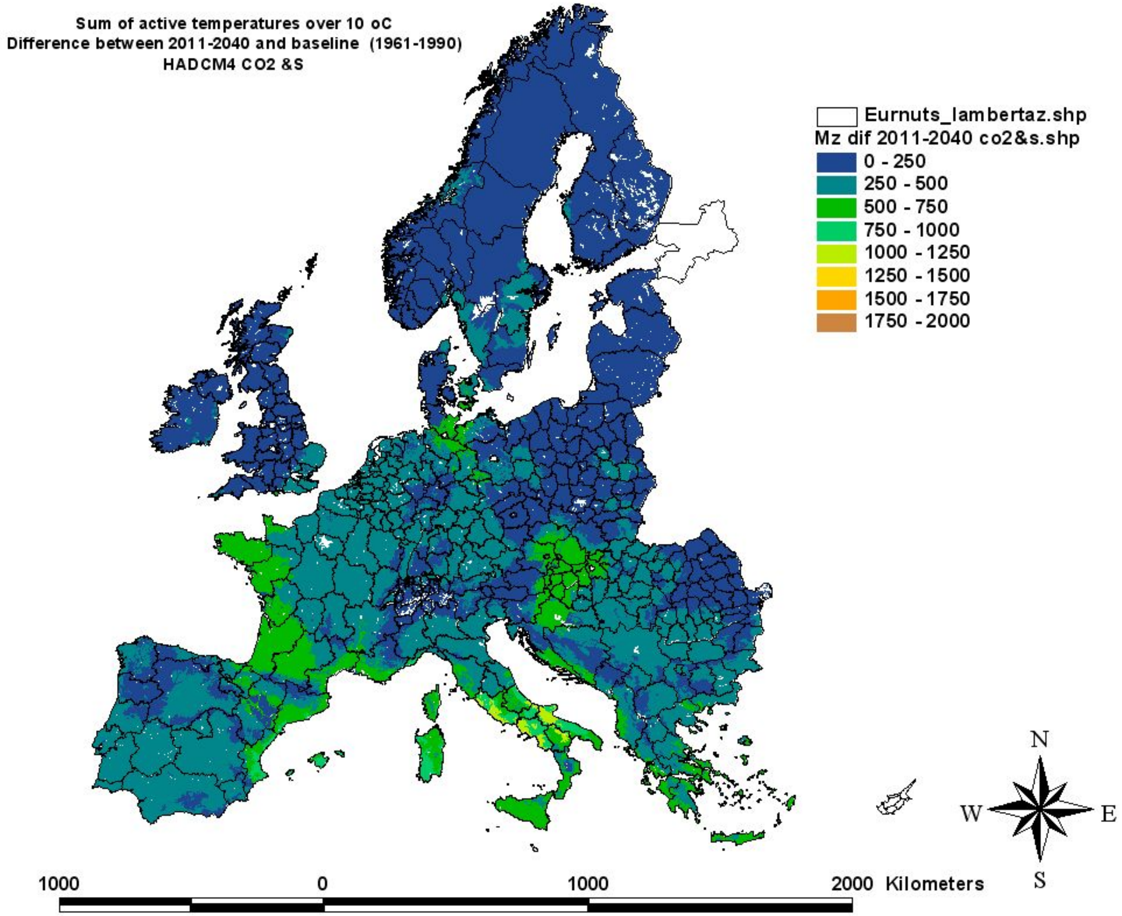
Sum of active temperatures over 10^{o}C ECHAM4 CO2 & S



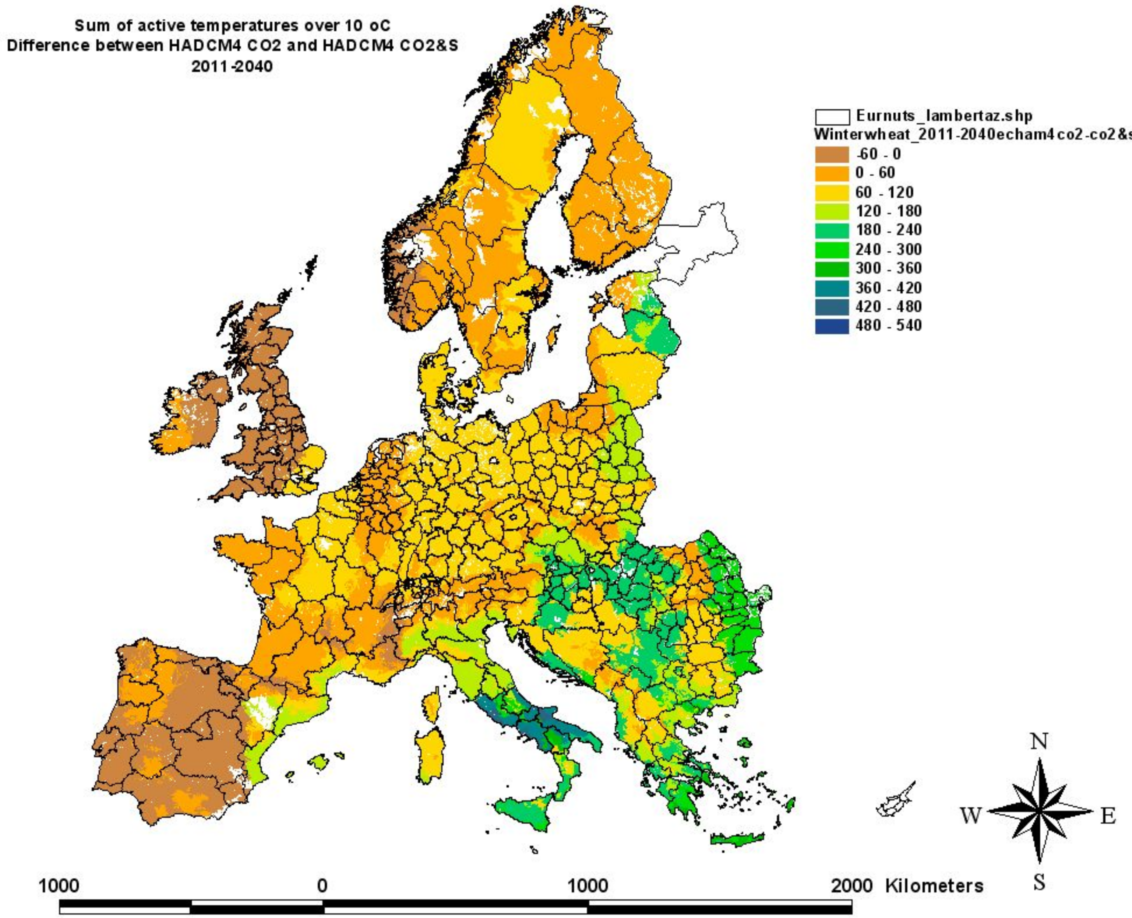
Difference of the Sum of active temperatures over 10°C between 2011-2040 ECHAM4 CO2 and baseline (1961-1990)



Difference of the Sum of active temperatures over 10^{o}C between 2011-2040 ECHAM4 CO2 & S and baseline (1961-1990)



Difference of the Sum of active temperatures over 10°C between 2011-2040 ECHAM4 CO2 and 2011-2040 ECHAM4 CO2 & S



Bagnouls-Gaussen Index

Originally, ESAs methodology considered the Bagnouls-Gaussen aridity index:

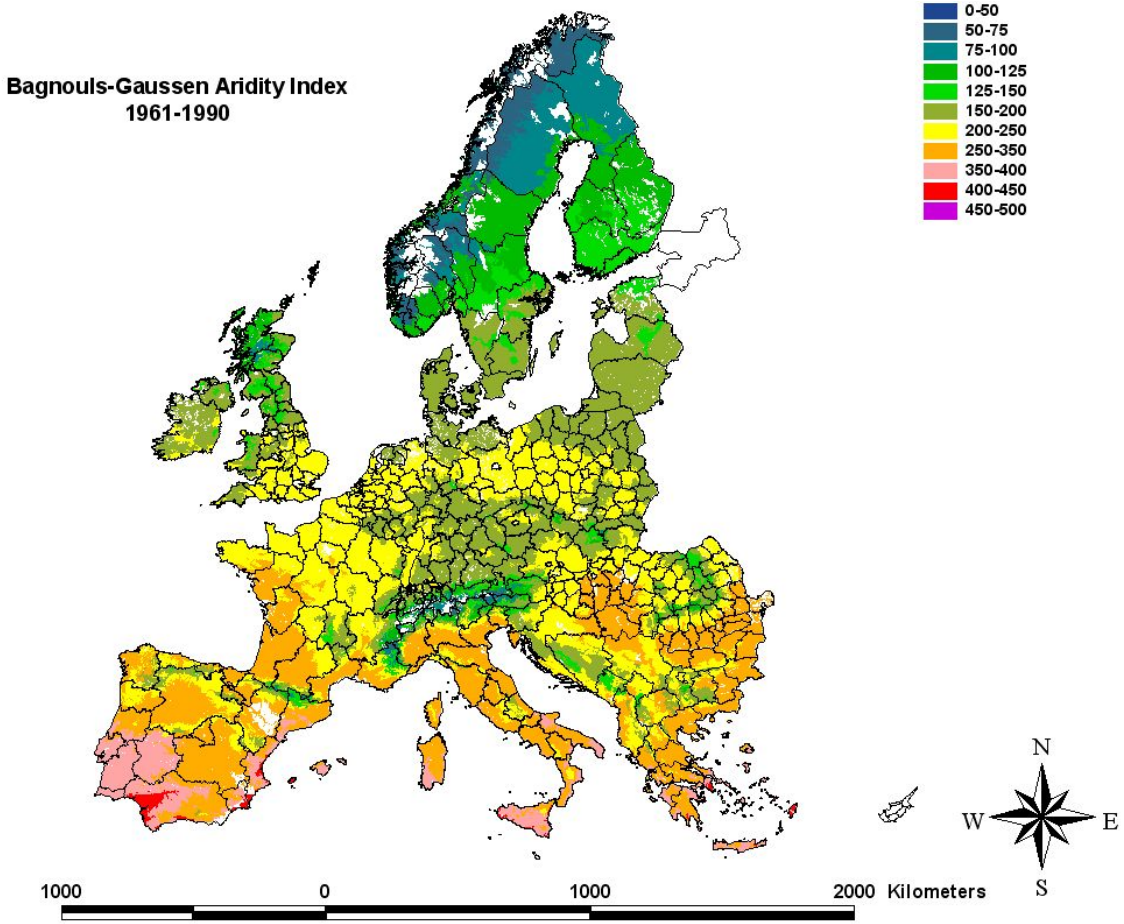
$$BGI = \sum_{i=1}^{n} (2Ti - Pi)\,k$$

where

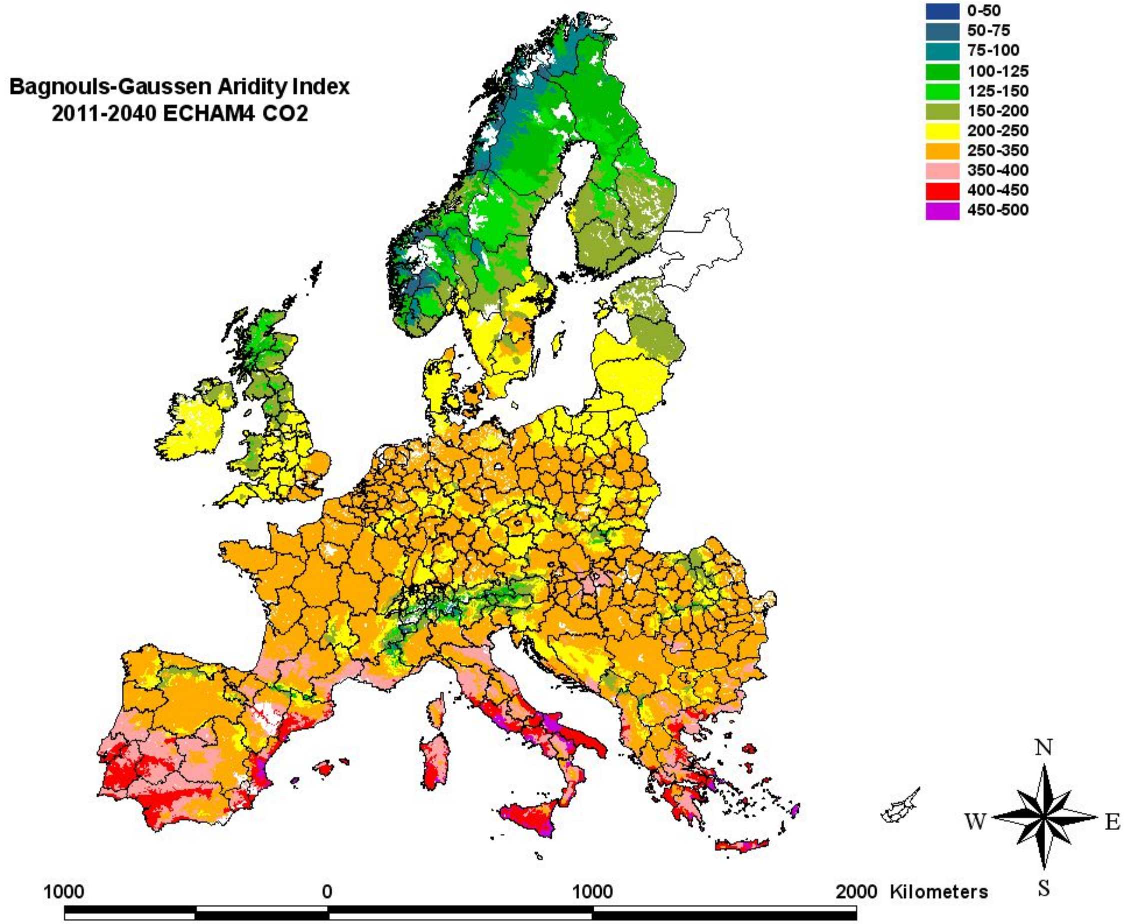
BGI = Bagnouls-Gaussen Index
Ti = Temperature of the i month (°C)
Pi = Total monthly precipitation of the month i (mm)
K = Frequency of the condition 2Ti-Pi>0 for the i month (%)

In this way, the soil component is not considered!

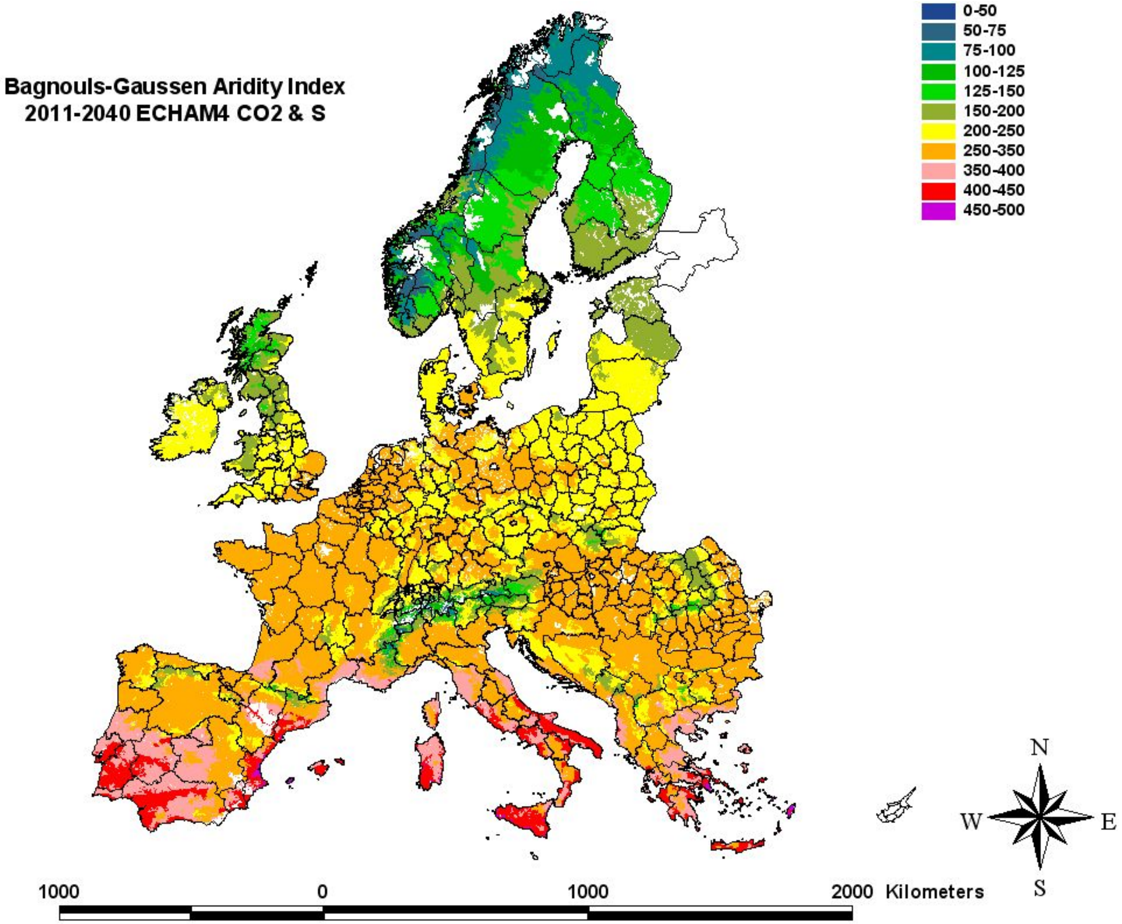
Bagnouls-Gaussen Aridity Index
1961-1990



Bagnouls-Gaussen Aridity Index
2011-2040 ECHAM4 CO2



Bagnouls-Gaussen Aridity Index
2011-2040 ECHAM4 CO2 & S

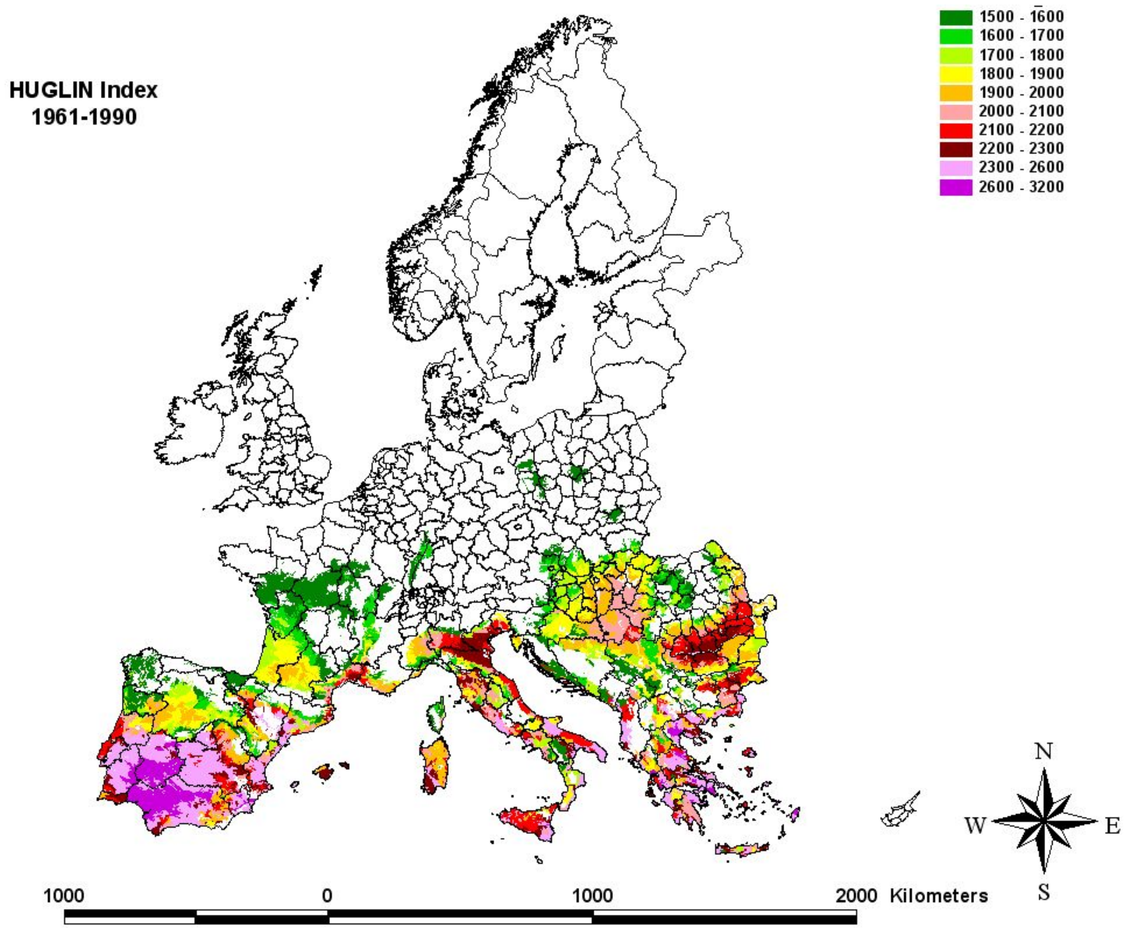


Huglin Index

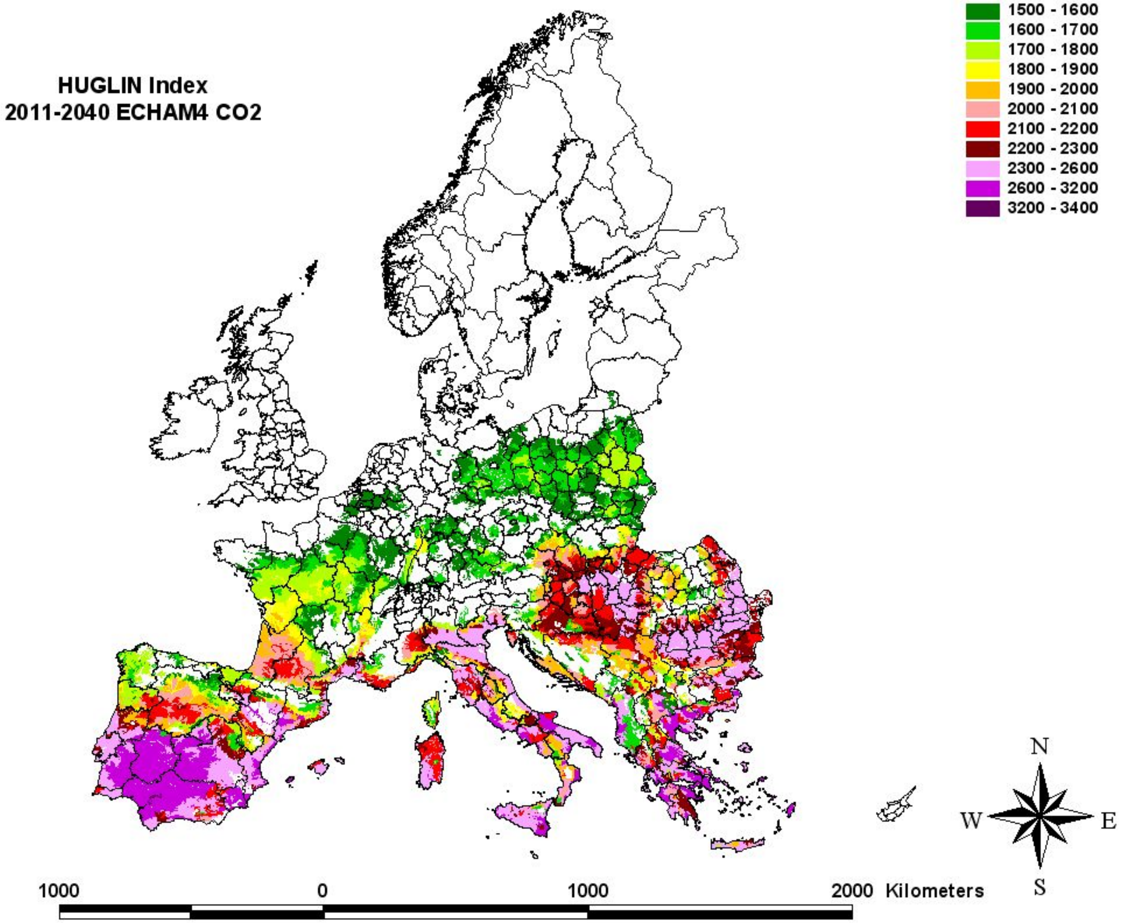
The Huglin index (HI) is calculated from April 1st to September 30th in the Northern hemisphere. This index enables different viticultural regions of the world to be classified in terms of the sum of temperatures required for vine development and grape ripening, (Huglin, 1978). Specifically, it is the sum of mean and maximum temperatures above +10°C – the thermal threshold for vine development. Different grape varieties are thus classified according to their minimal thermal requirement for grape ripening. For example, the HI is 1700 for Chardonnay and 2100 for Syrah. The minimal Huglin index for vine development is 1600.

Huglin P., 1978. Nouveau mode d’évaluation des possibilités héliothermiques d’un milieu viticole. Comptes Rendus de l’Académie d’Agriculture, France 1117-1126.

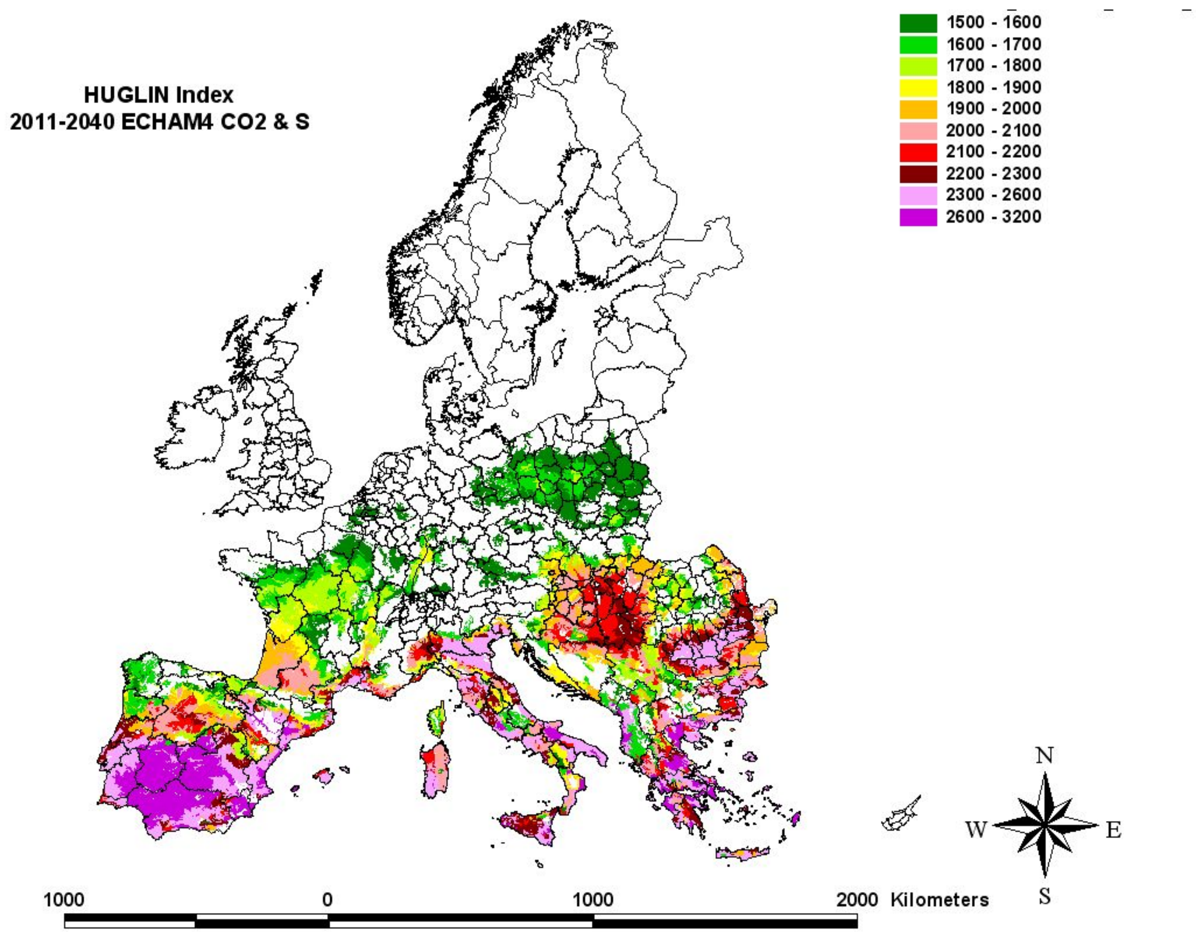
Huglin Index
1961-1990



Huglin Index
2011-2040 ECHAM4 CO2



Huglin Index
2011-2040 ECHAM4 CO2 & S



UNESCO Aridity Index

UNESCO aridity index
The UNESCO (1979) proposed a method for aridity mapping from the ratio of precipitation (P) to potential evapotranspiration (PET), i.e.,

$$AI = P / PET$$

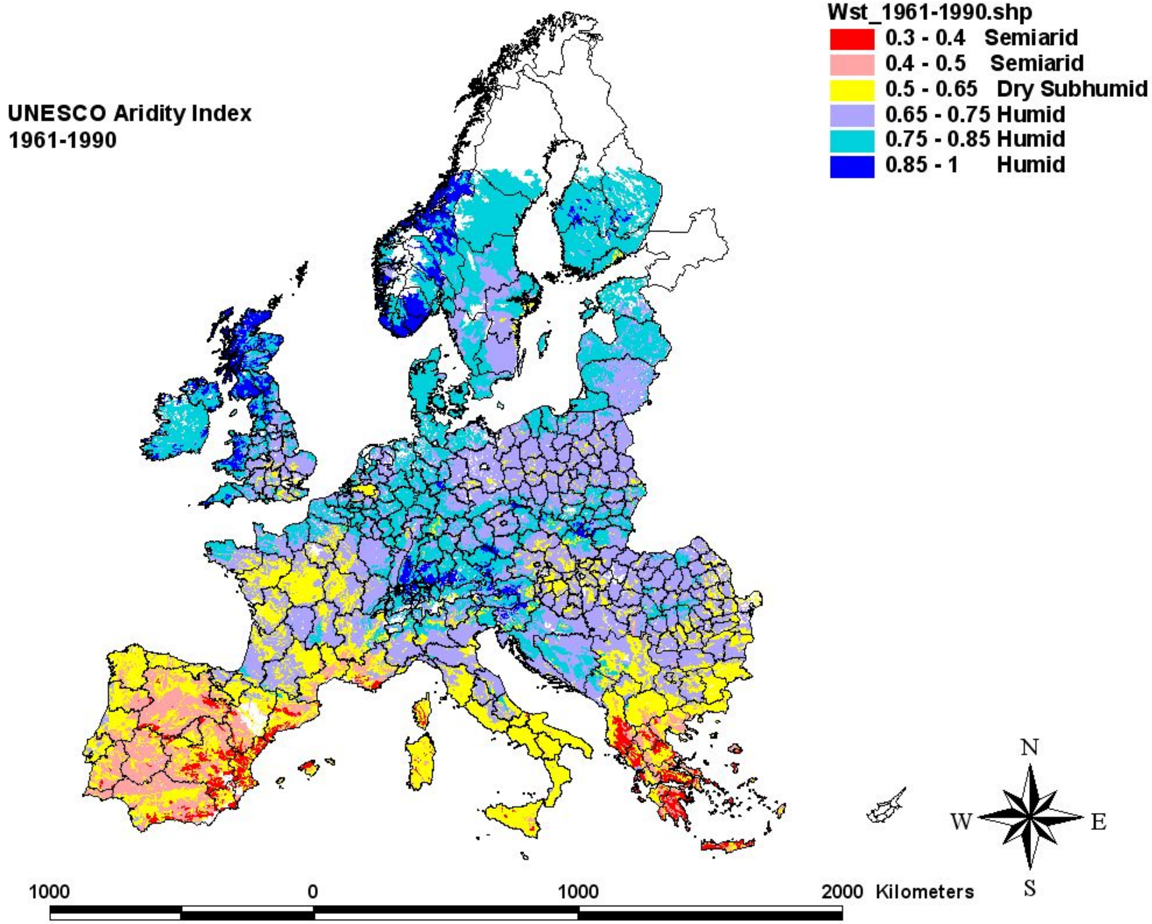
Where, PET is calculated by Penman's formula.

Based on the AI values, five climatic regions of aridity are proposed as given in Table 3.

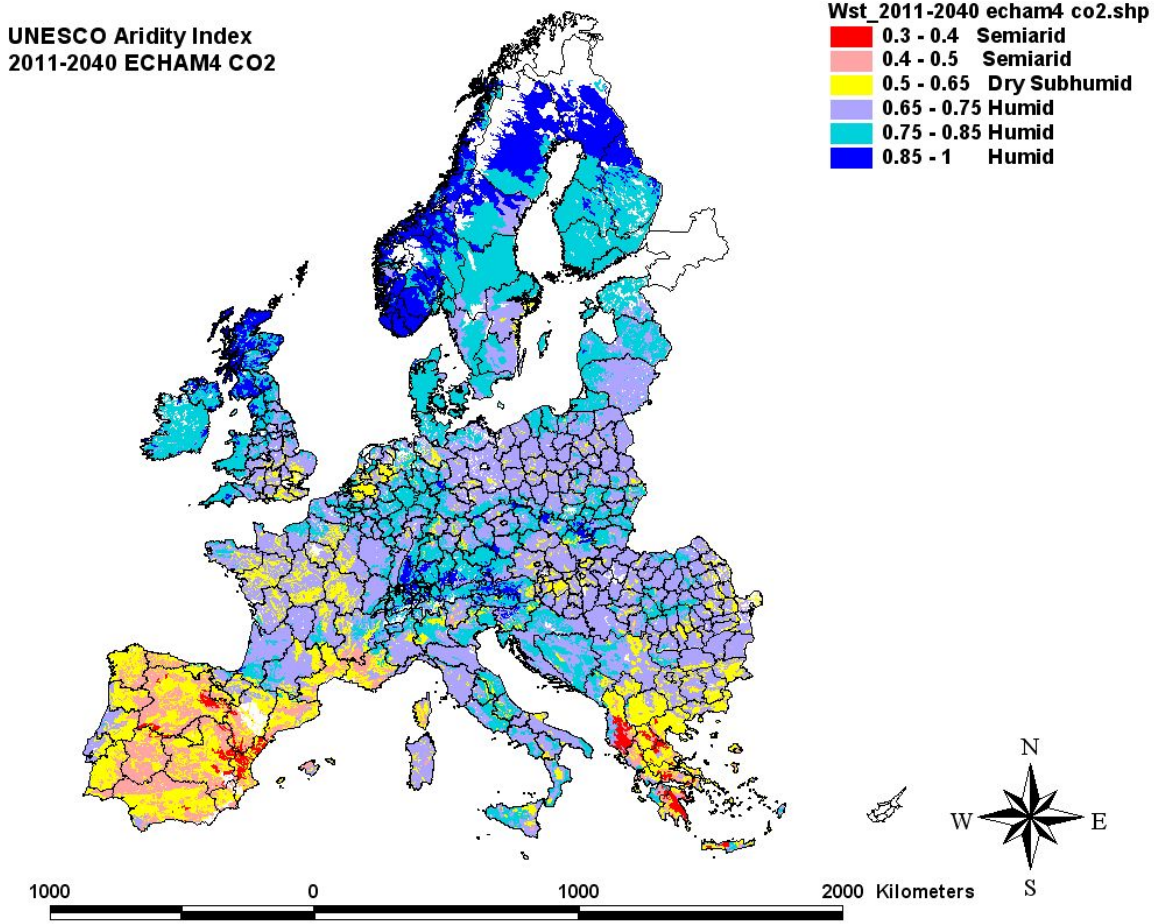
AI Value	Climate Class
≤ 0.03	Hyper Arid
0.03 – 0.2	Arid
0.2 – 0.5	Semi-arid
0.5 – 0.65	Dry sub-humid
> 0.65	Humid

Table 3: The classifications of the climate region based on UNESCO Aridity Index.

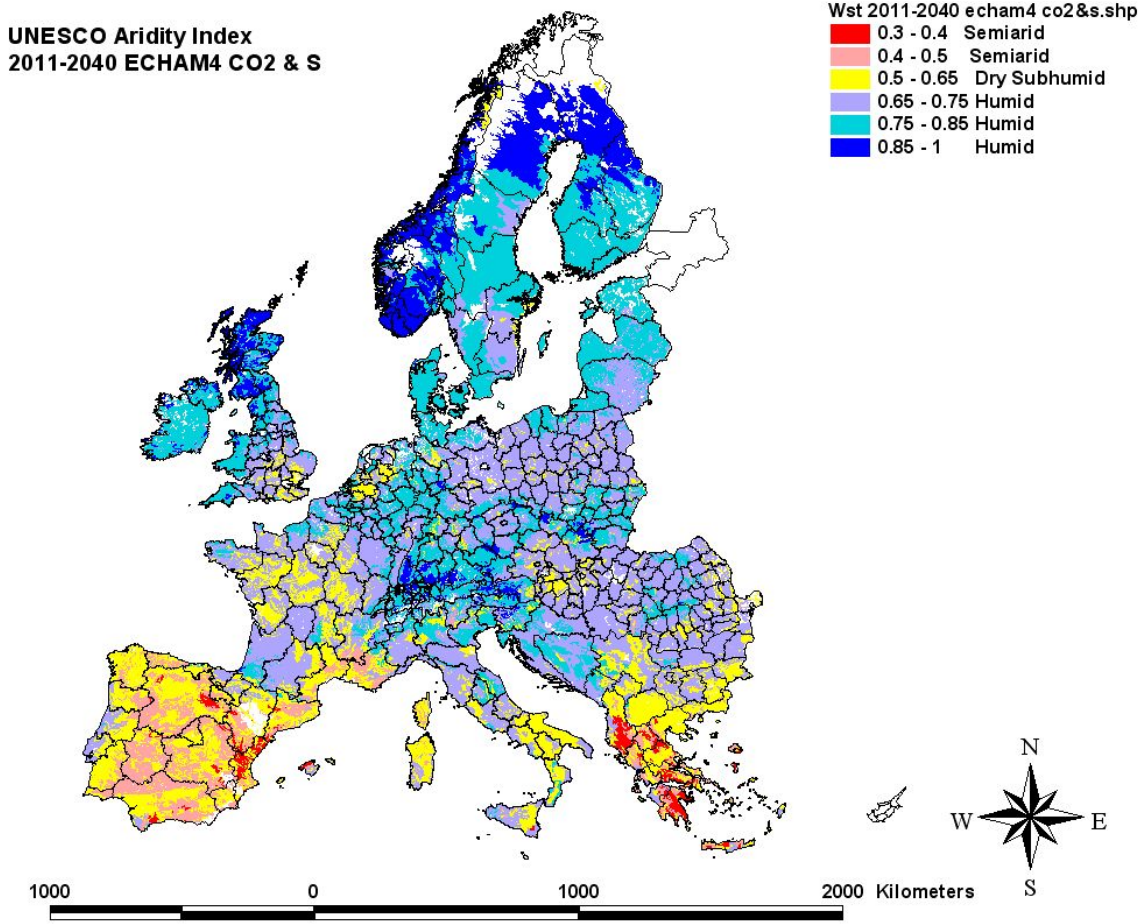
UNESCO Aridity Index
1961-1990



UNESCO Aridity Index
2011-2040 ECHAM4 CO2



UNESCO Aridity Index
2011-2040 ECHAM4 CO2 & S



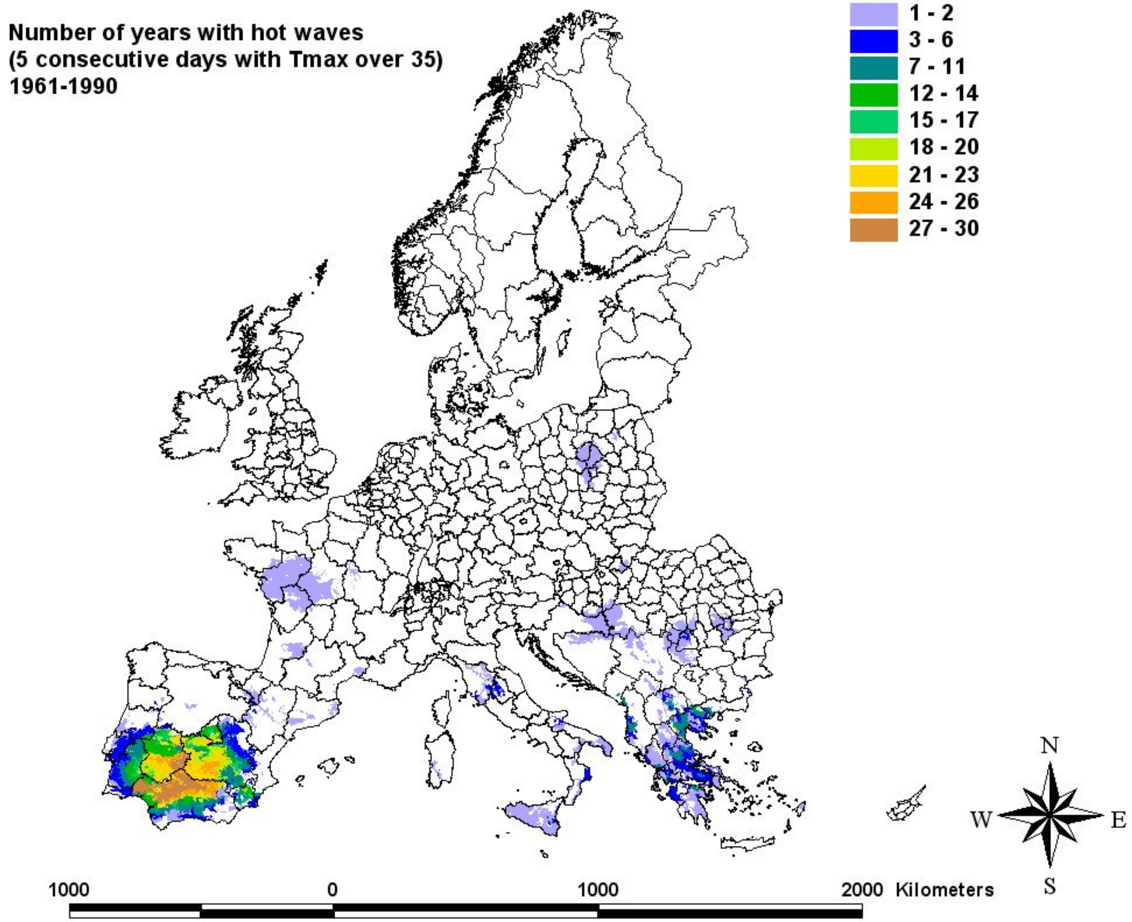
Number of years with “Heat waves”

Heat wave: consecutive 5 (or 10) days with maximum air temperature over 35^0C

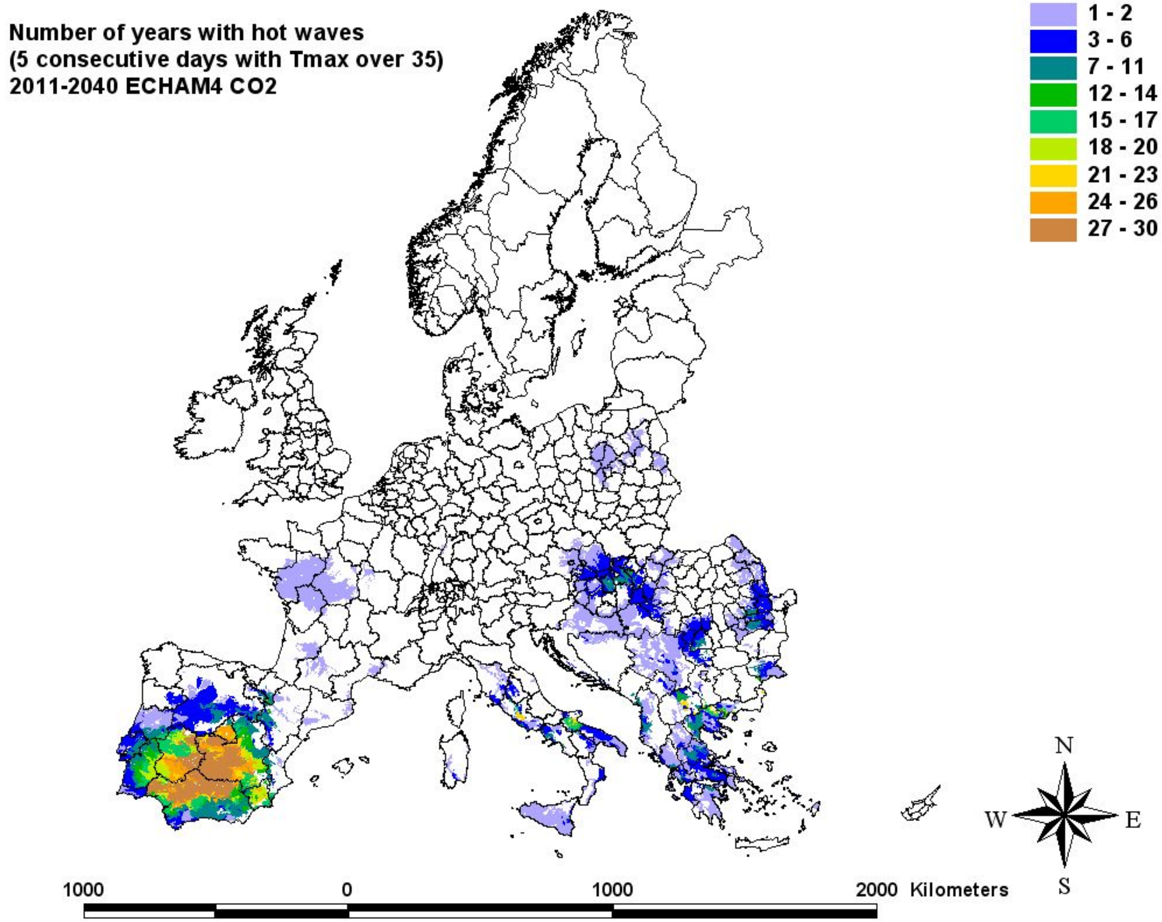
Heat waves

At least 5 consecutive days with $T_{max} > 35^oC$

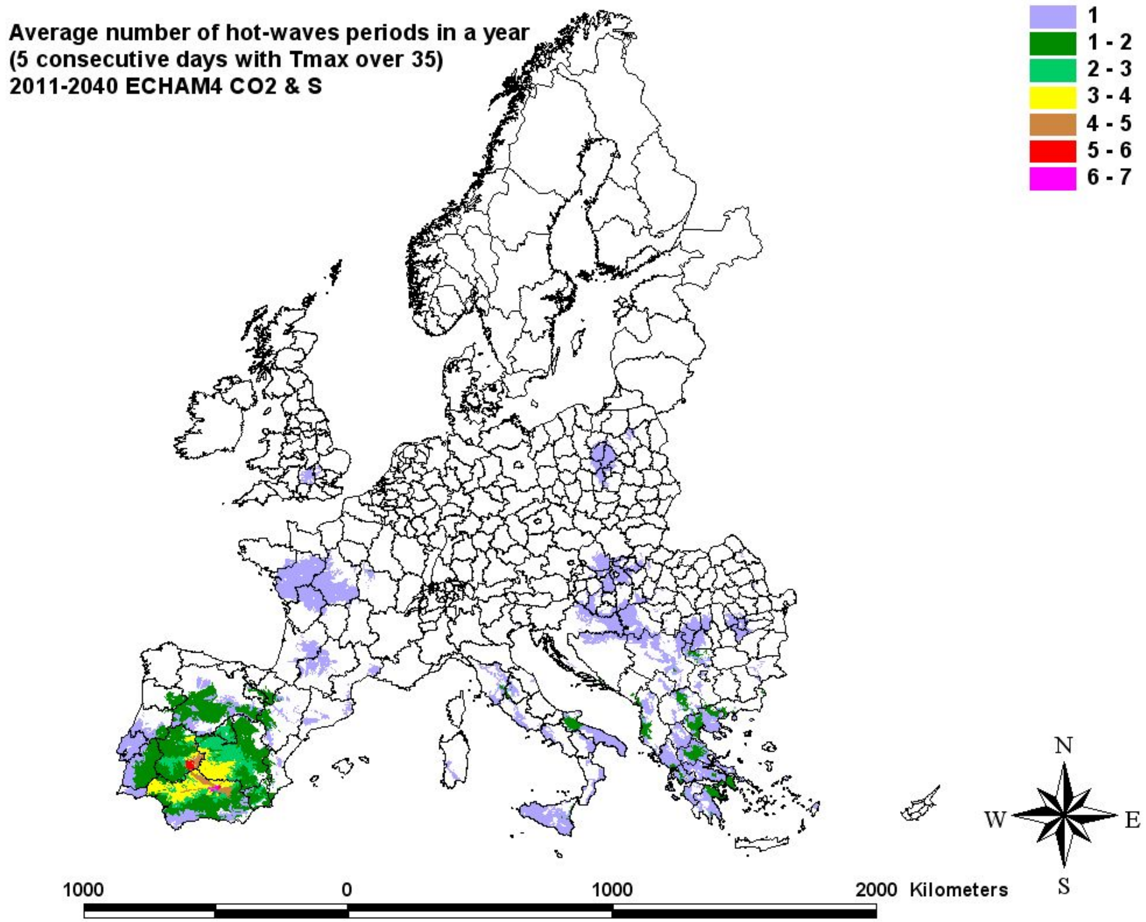
Number of years with 5-day heat waves
1961-1990



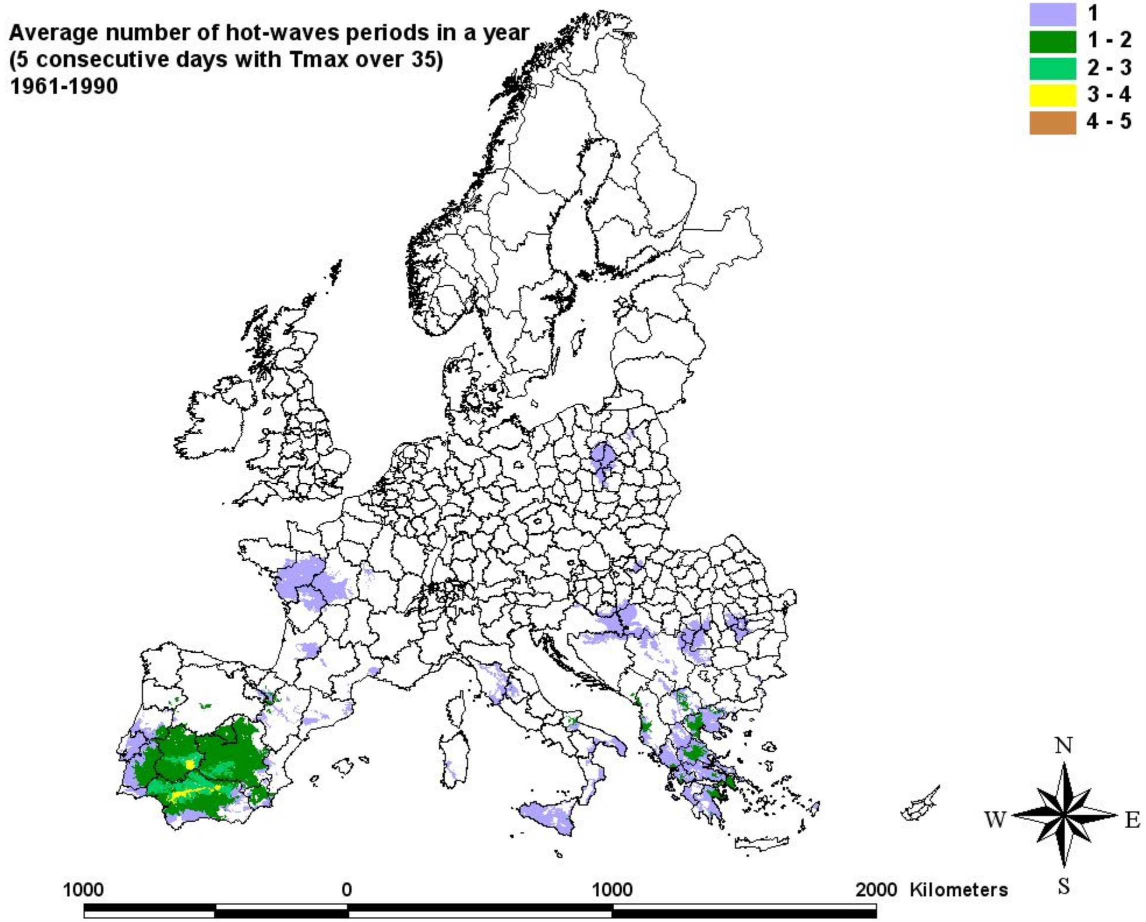
Number of years with 5-day heat waves 2011-2040 ECHAM4 CO2



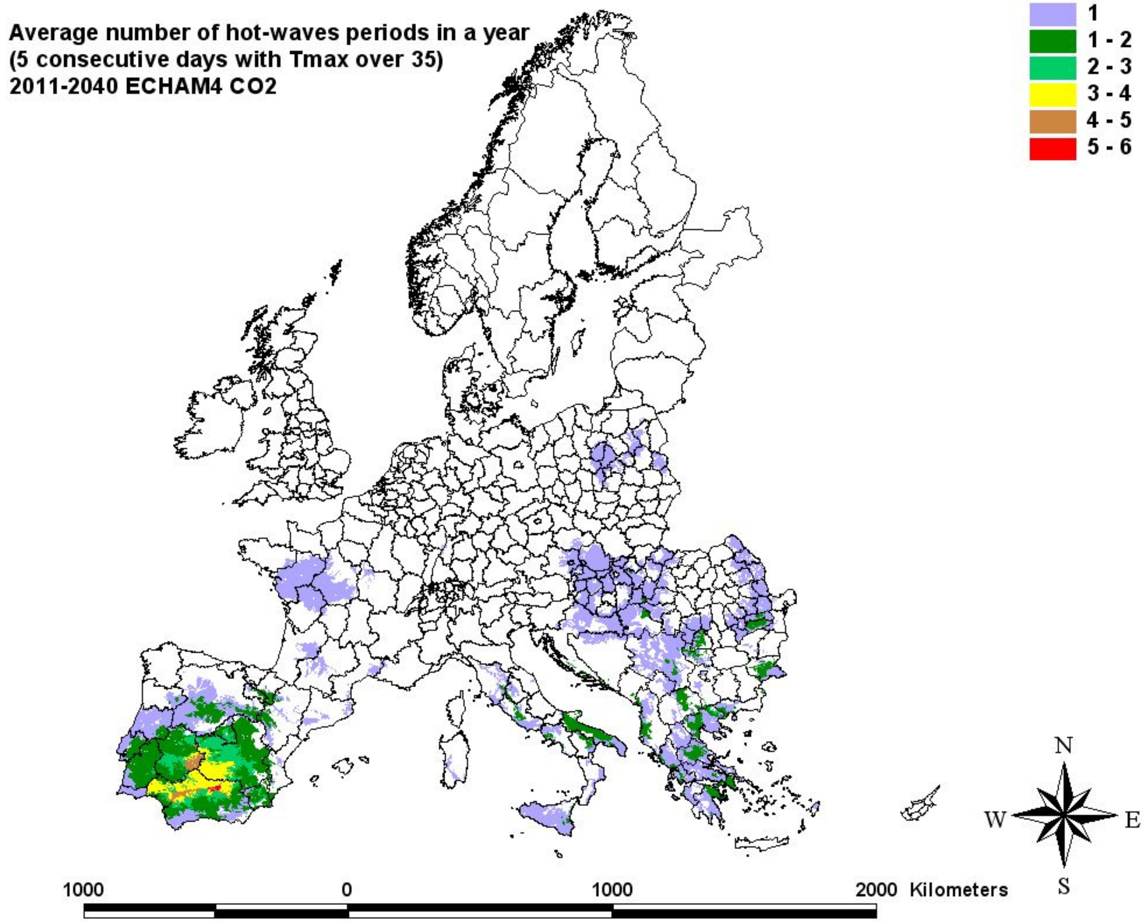
Number of years with 5-day heat waves 2011-2040 ECHAM4 CO2&S



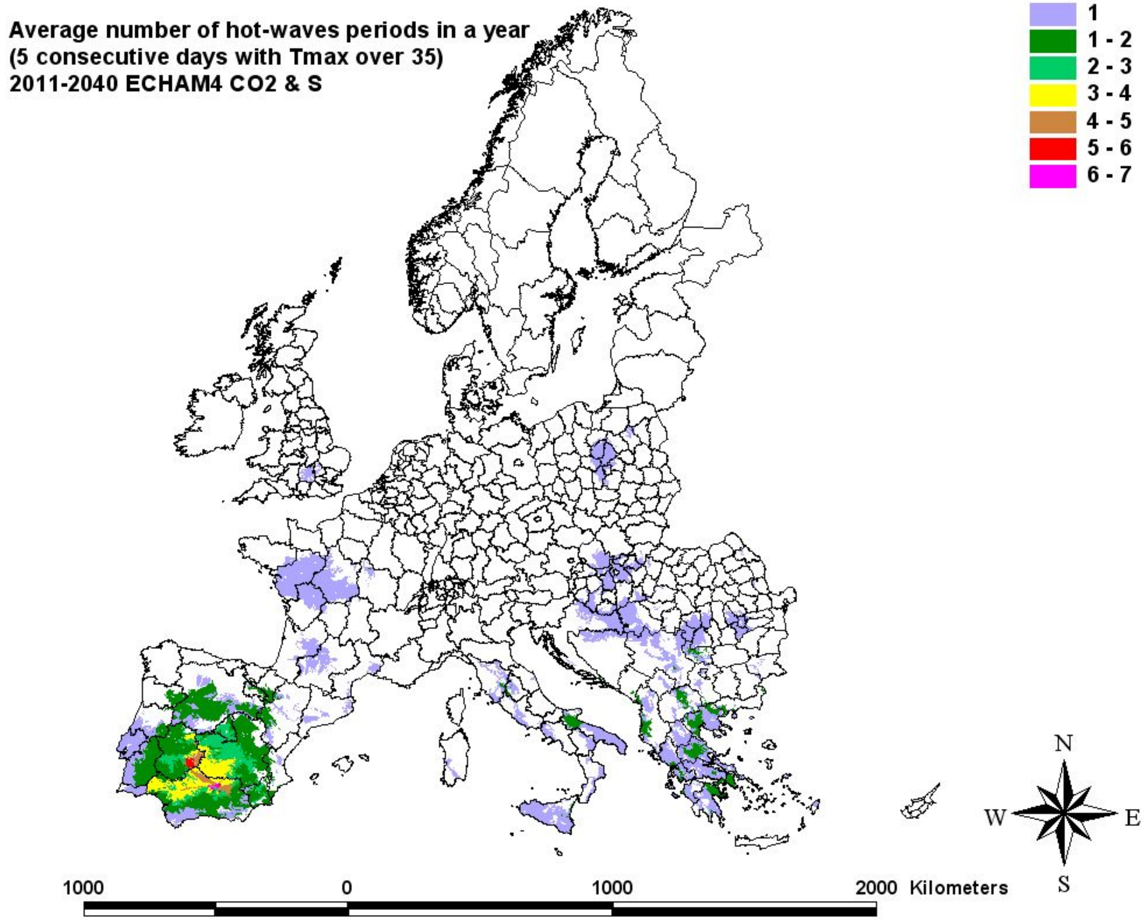
Average number of heat-waves (5 day T_{max}>35^{o}C) in a year 1961-1990



Average number of heat-waves (5 day T_{max}>35ºC) in a year 2011-2040 ECHAM4 CO2



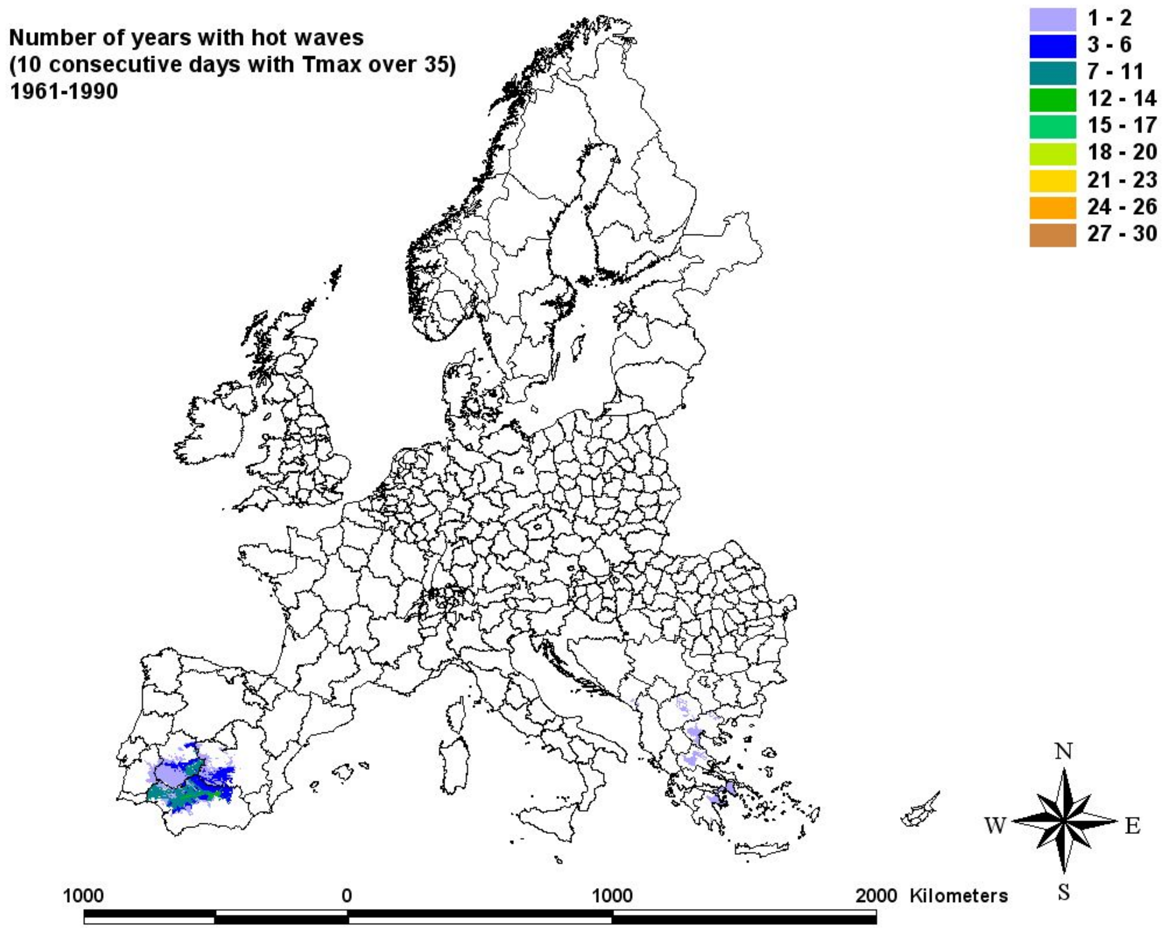
Average number of heat-waves (5 day T_{max}>35°C) in a year
2011-2040 ECHAM4 CO2 & S



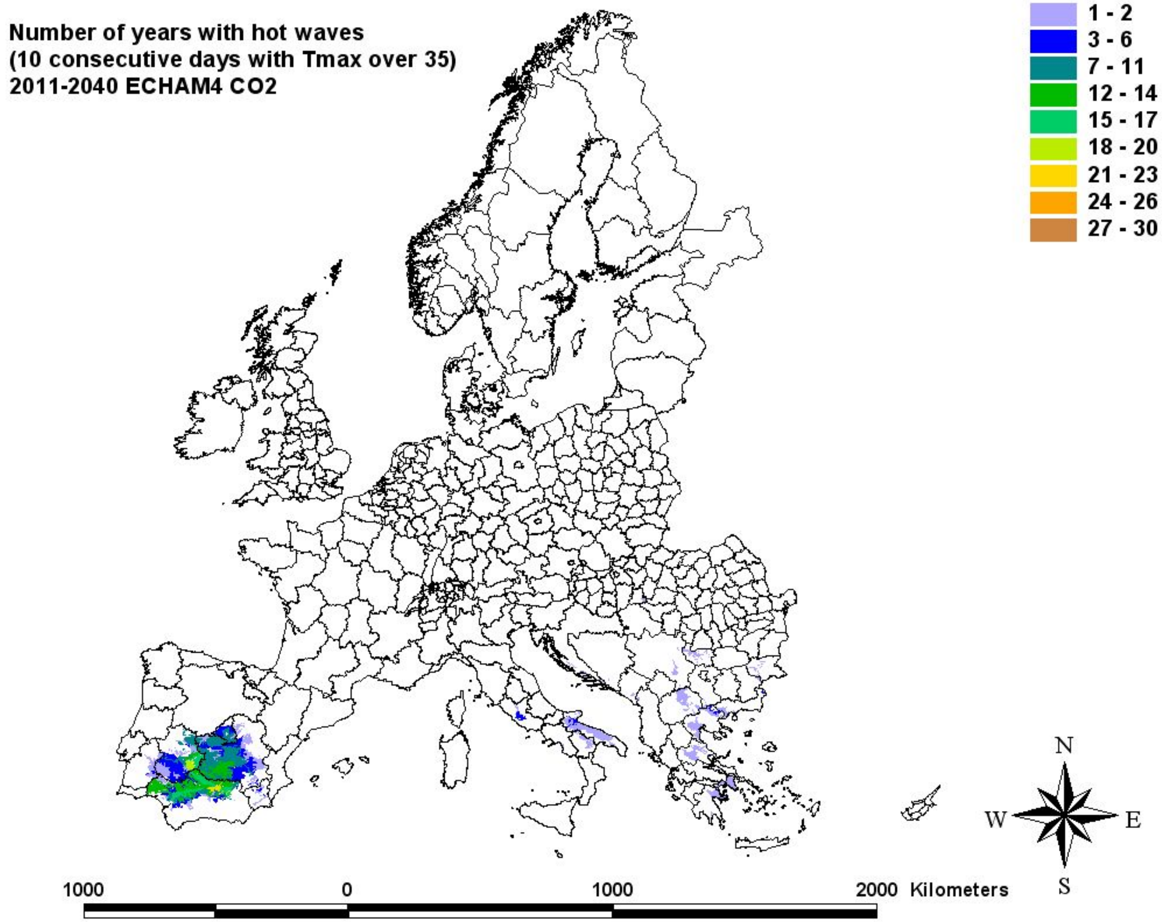
Heat waves

At least 10 consecutive days with $T_{max} > 35^oC$

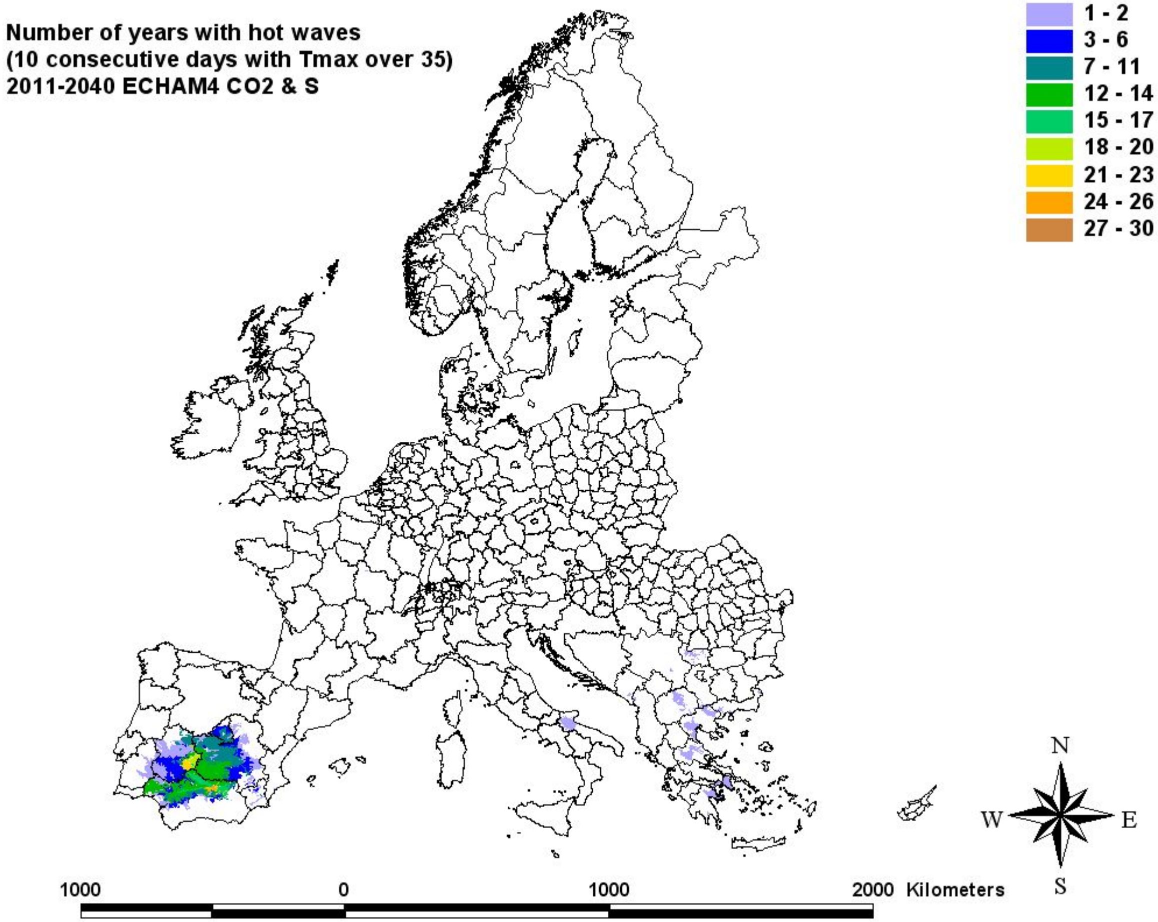
Number of years with 10-day heat waves 1961-1990



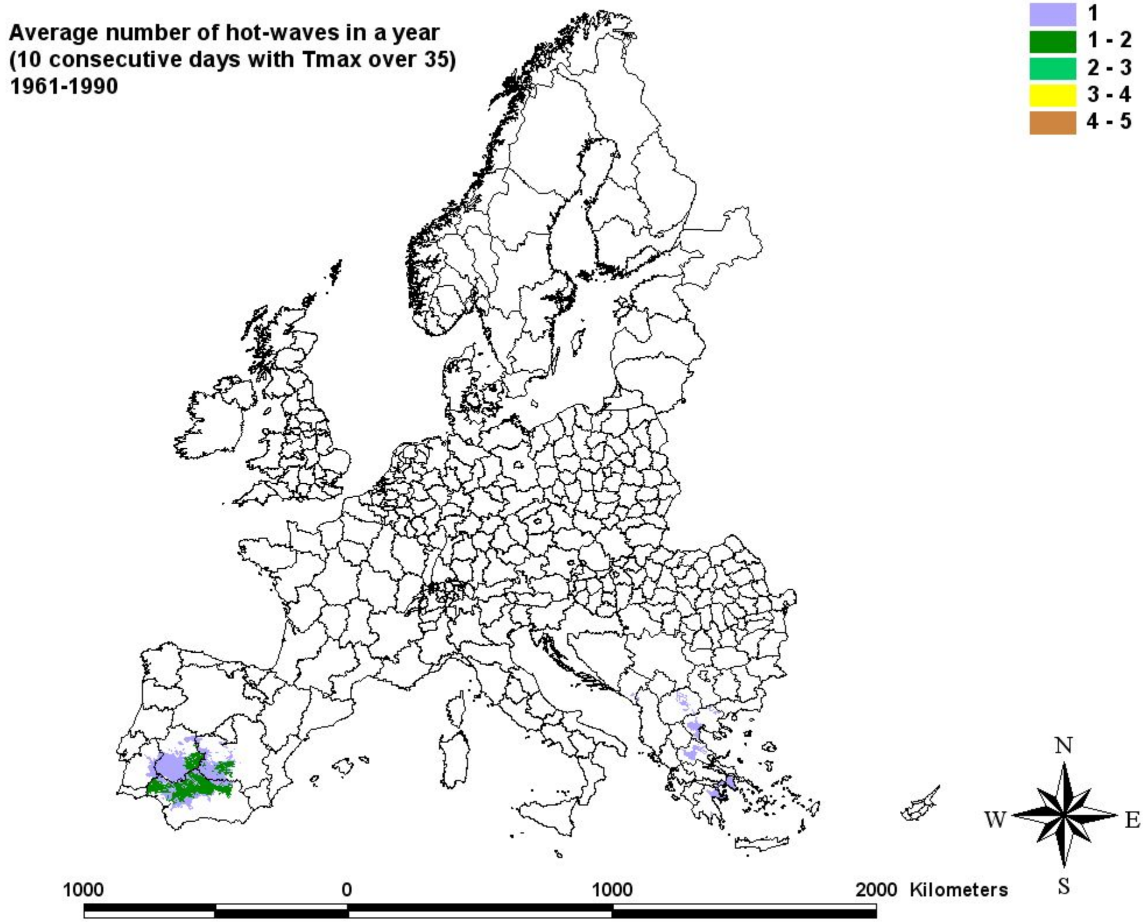
Number of years with 10-day heat waves
2011-2040 ECHAM4 CO2



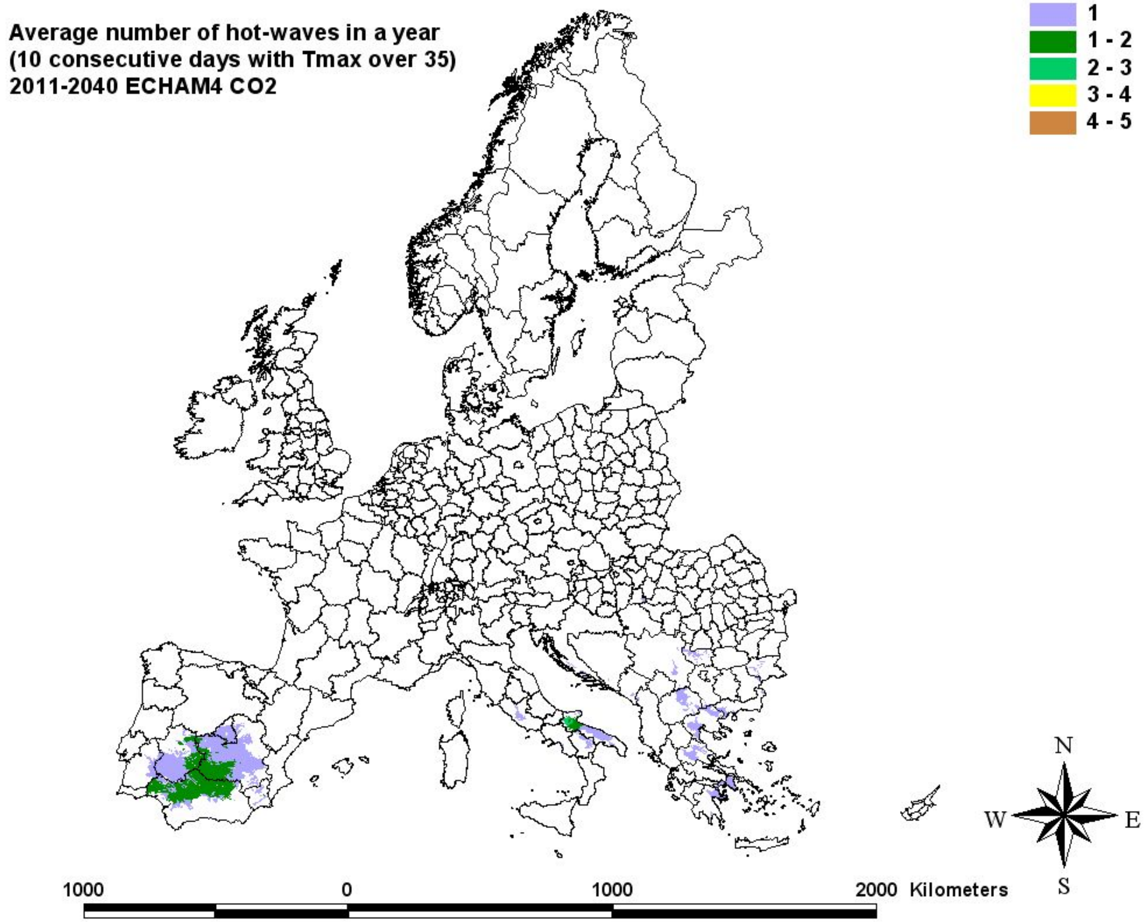
Number of years with 10-day heat waves 2011-2040 ECHAM4 CO2&S



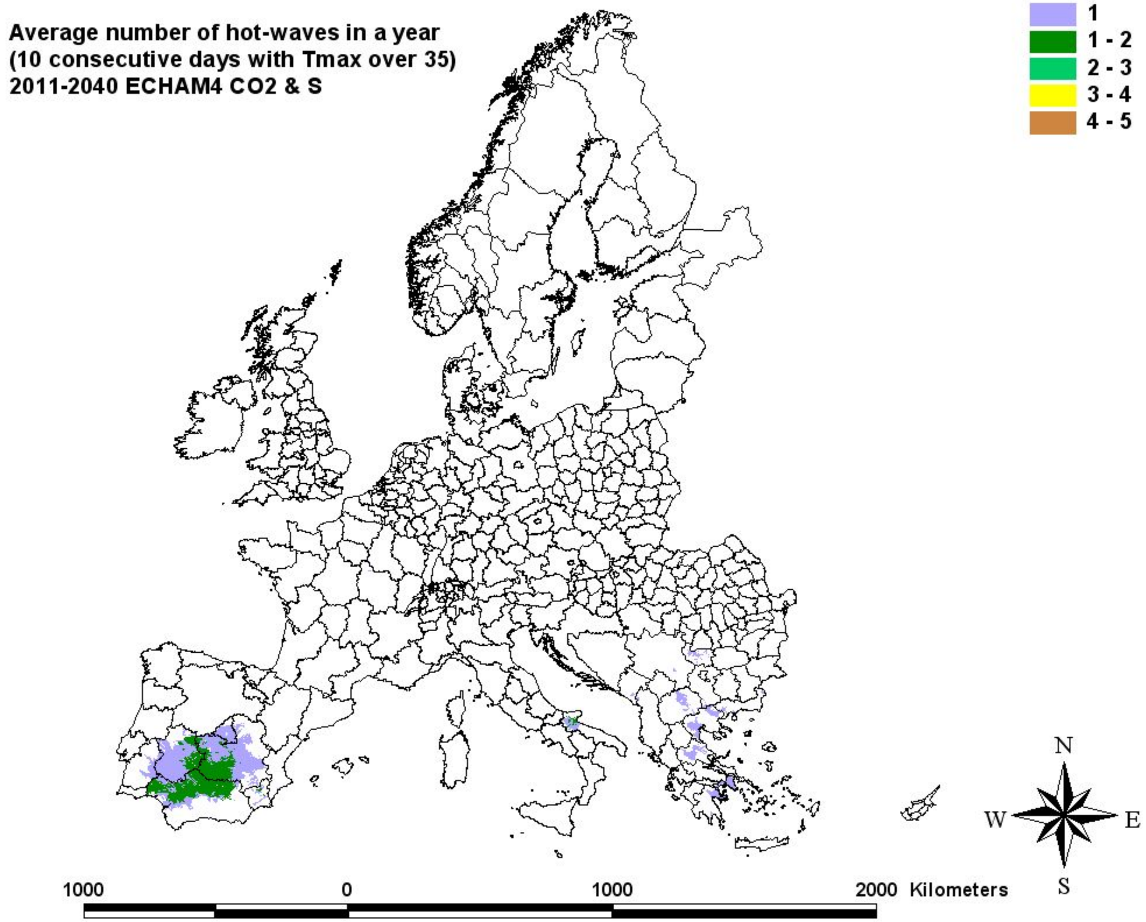
Average number of heat-waves (10 day T_{max}>35°C) in a year 1961-1990



Average number of heat-waves (10 day T_{max}>35°C) in a year 2011-2040 ECHAM4 CO2



Average number of heat-waves (10 day T_{max}>35°C) in a year
2011-2040 ECHAM4 CO2 & S

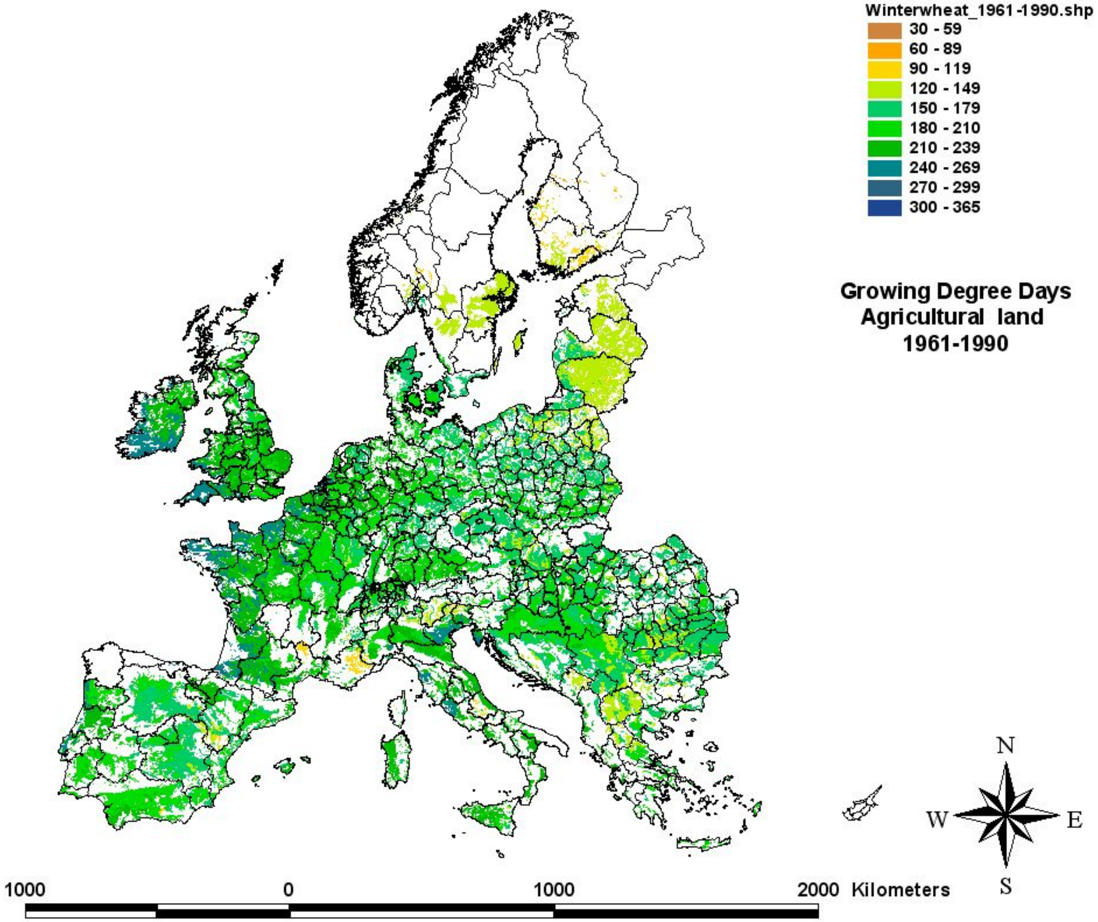


Crop dependent indicators

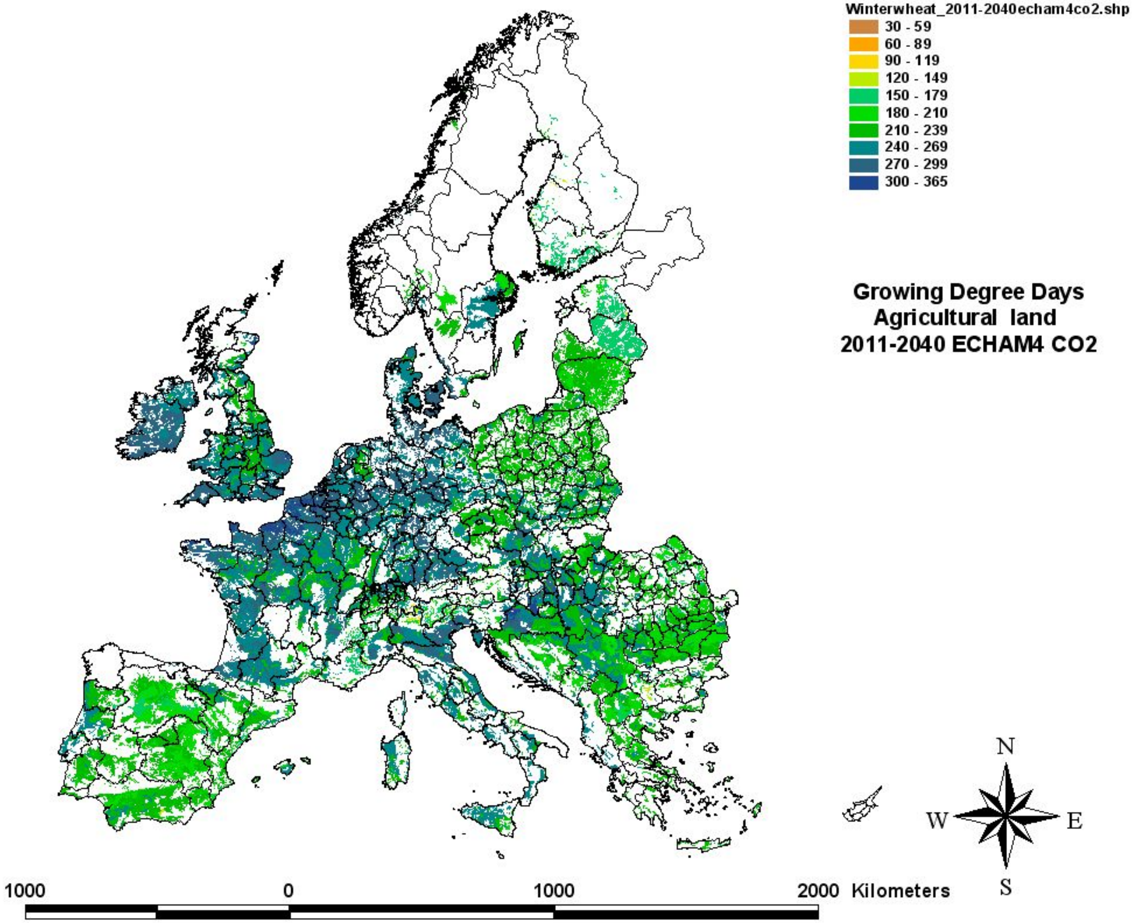
- Number of growing days
  - days with T>4^{o}C and ratio of actual to potential evapotranspiration over 0.5
  - calculated for
    - winter crops (reference crop: winter wheat)
    - early-spring crops (reference crop: spring wheat)
    - late spring crops (reference crop: maize)
- Number of years with alarm criteria during sensible developement stages (flowering, grain filling, harvesting)

Number of growing days
Winter crops

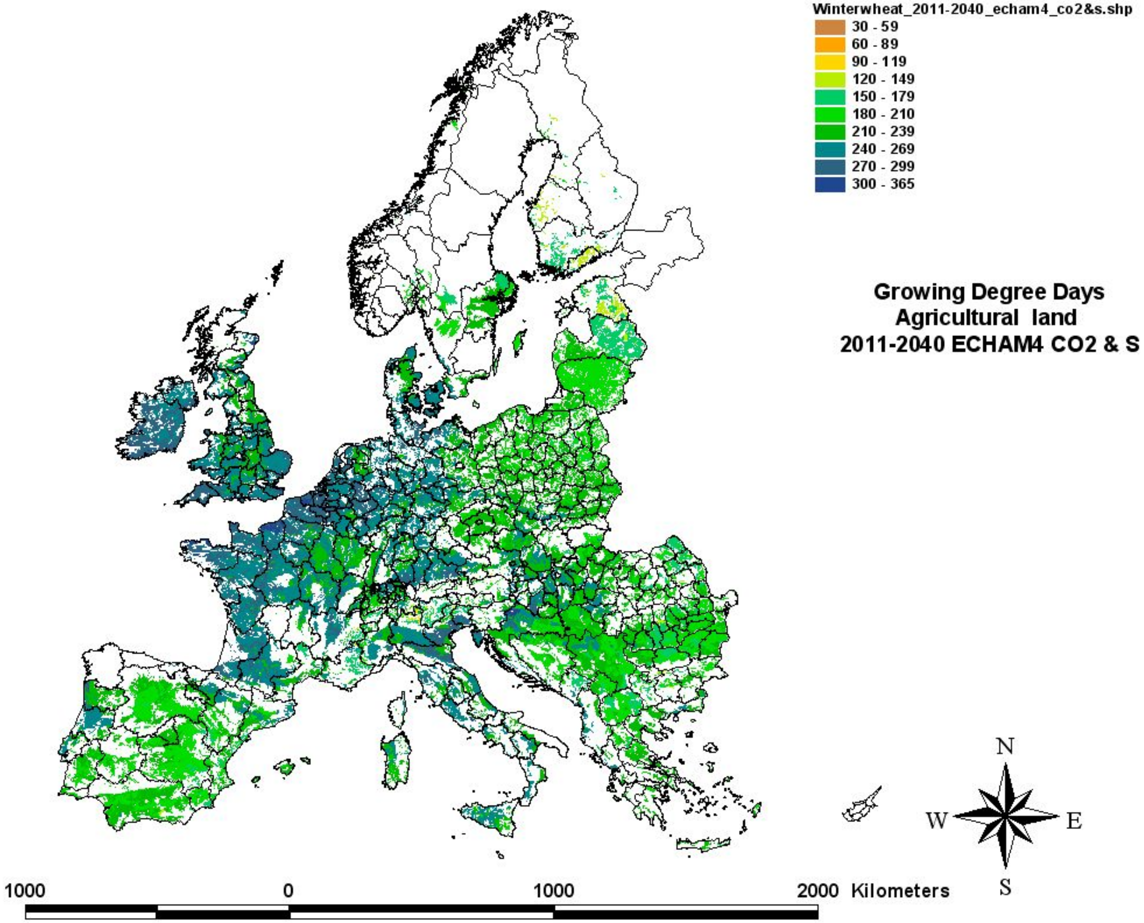
Growing Days – Winter crops
1961-1990



Growing days – Winter crops
2011-2040 ECHAM4 CO2

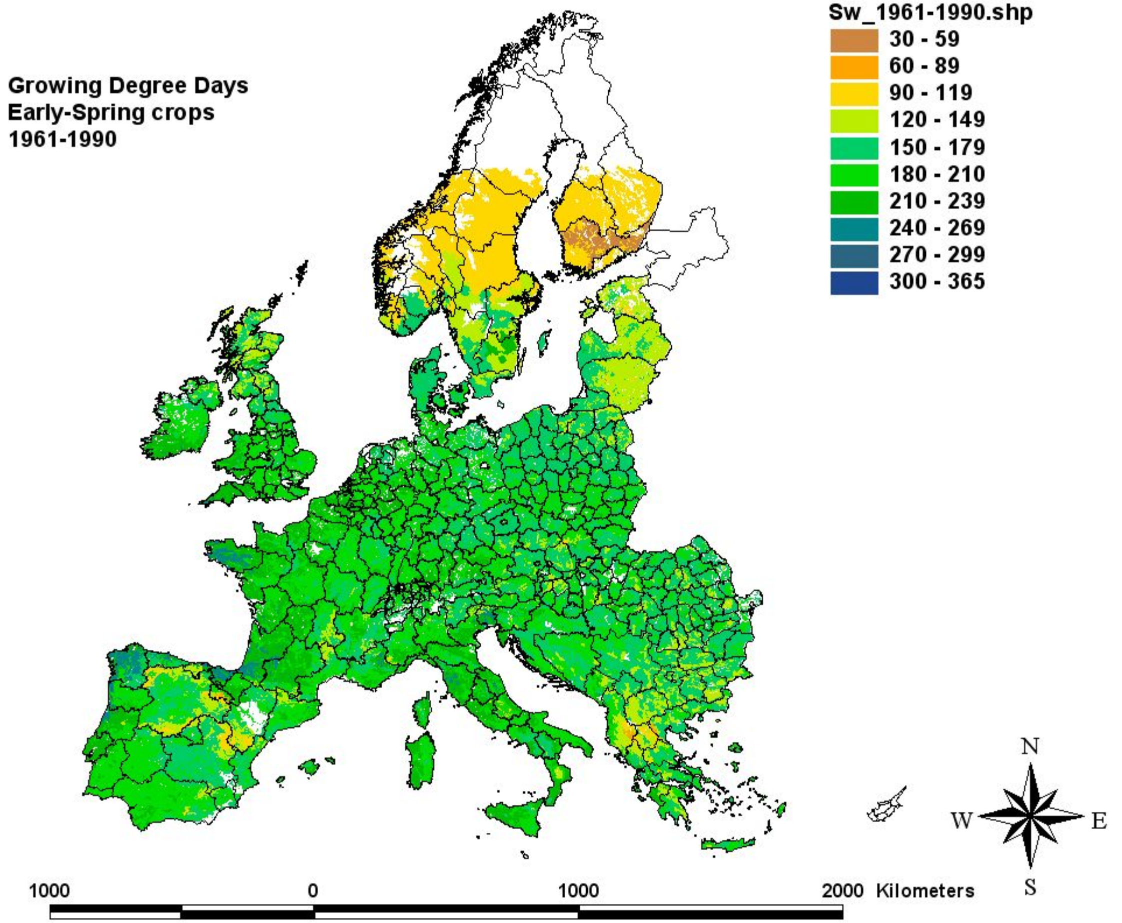


Growing days - Winter crops
2011-2040 ECHAM4 CO2 & S

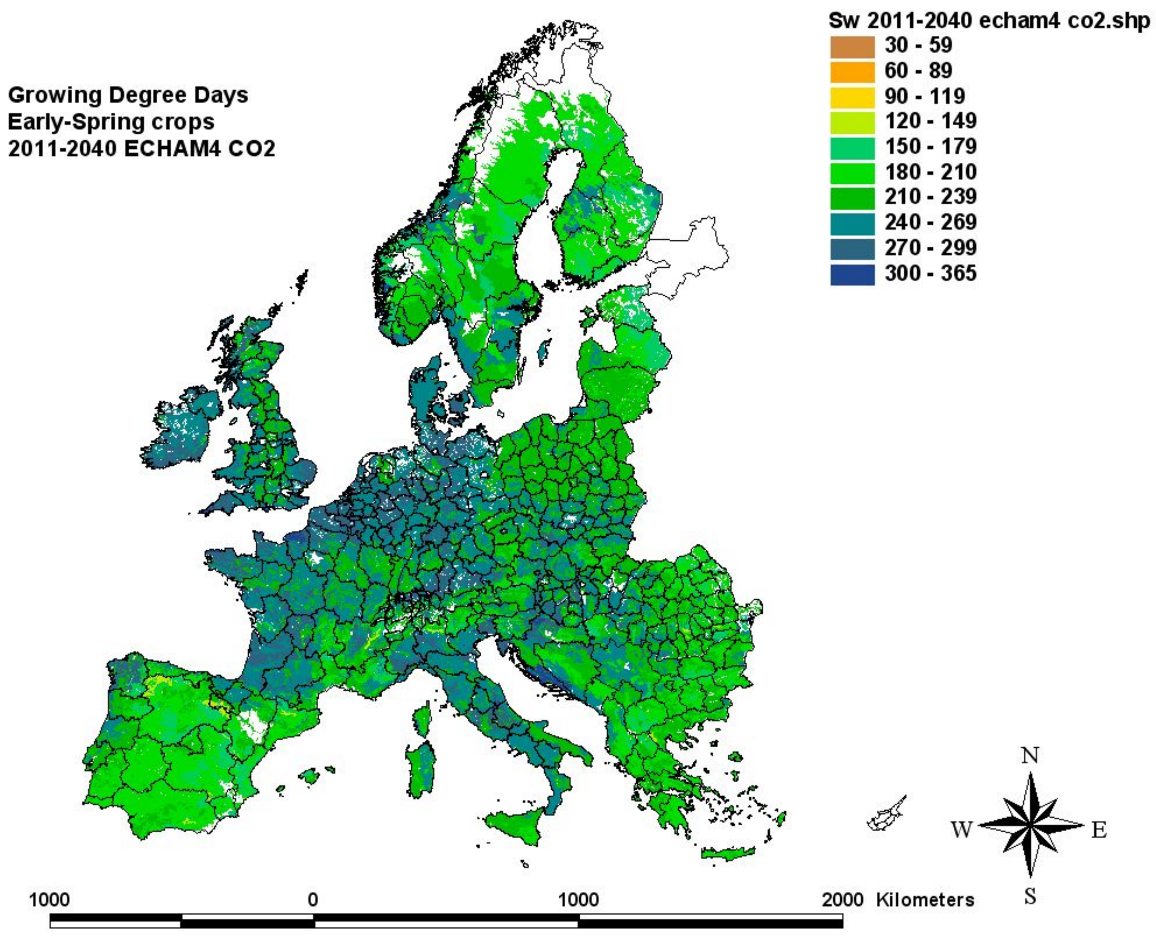


Number of growing days
Early-spring crops

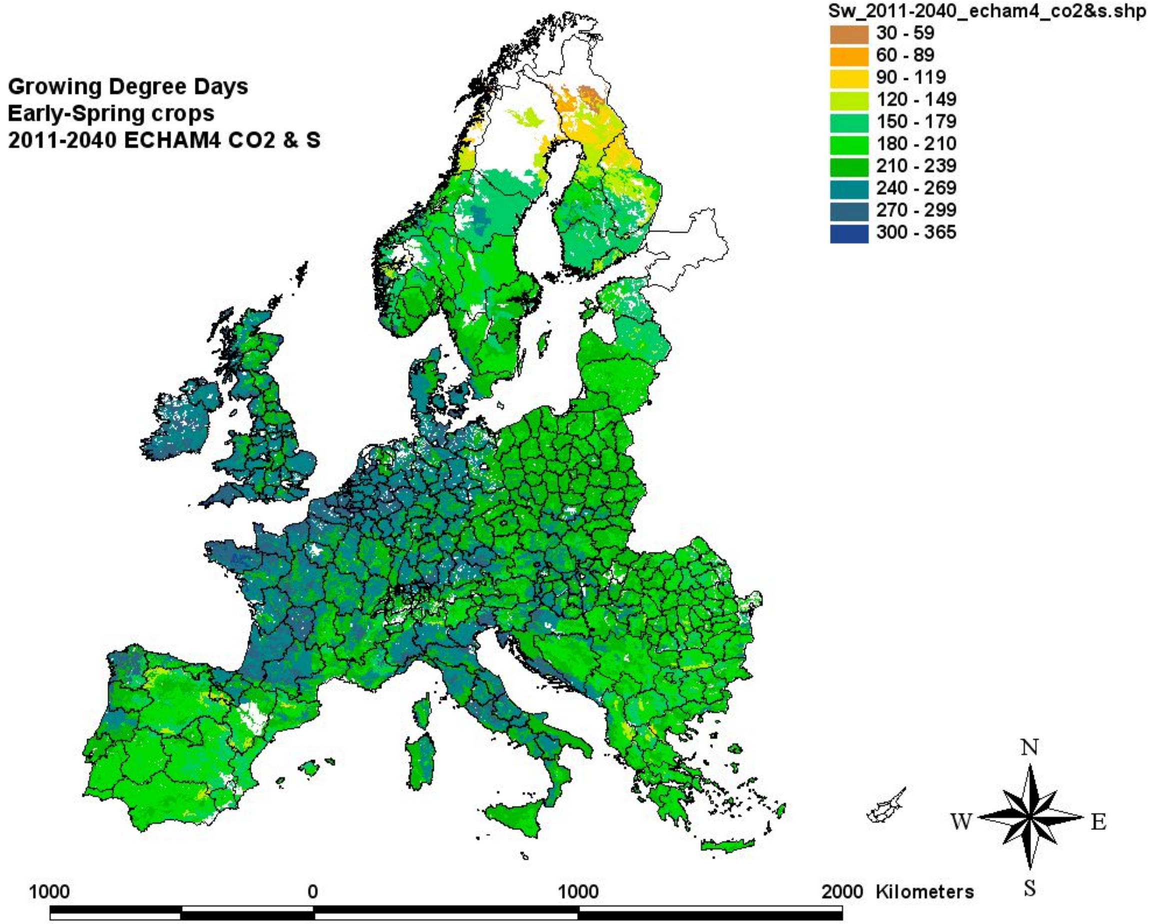
Growing Days – Early spring crops 1961-1990



Growing days – Early-spring crops
2011-2040 ECHAM4 CO2

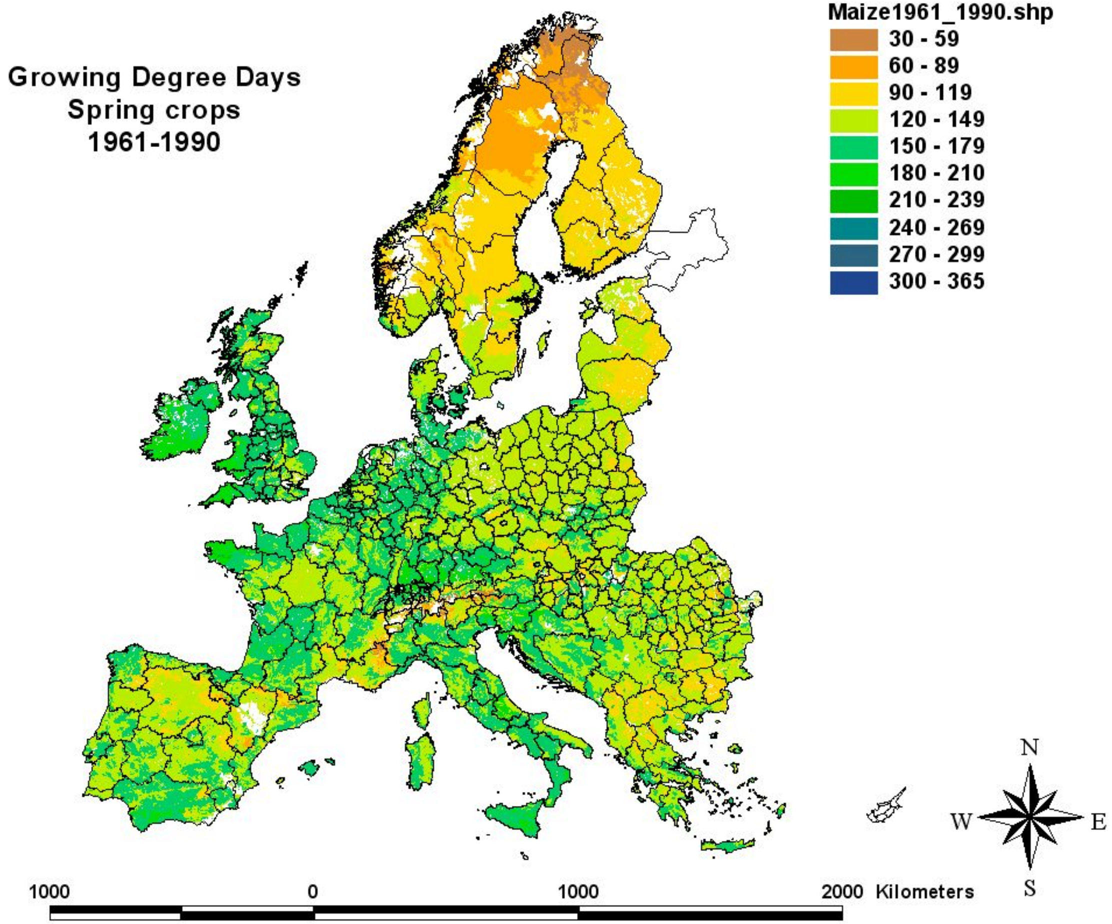


Growing days - Early-spring crops
2011-2040 ECHAM4 CO2 & S

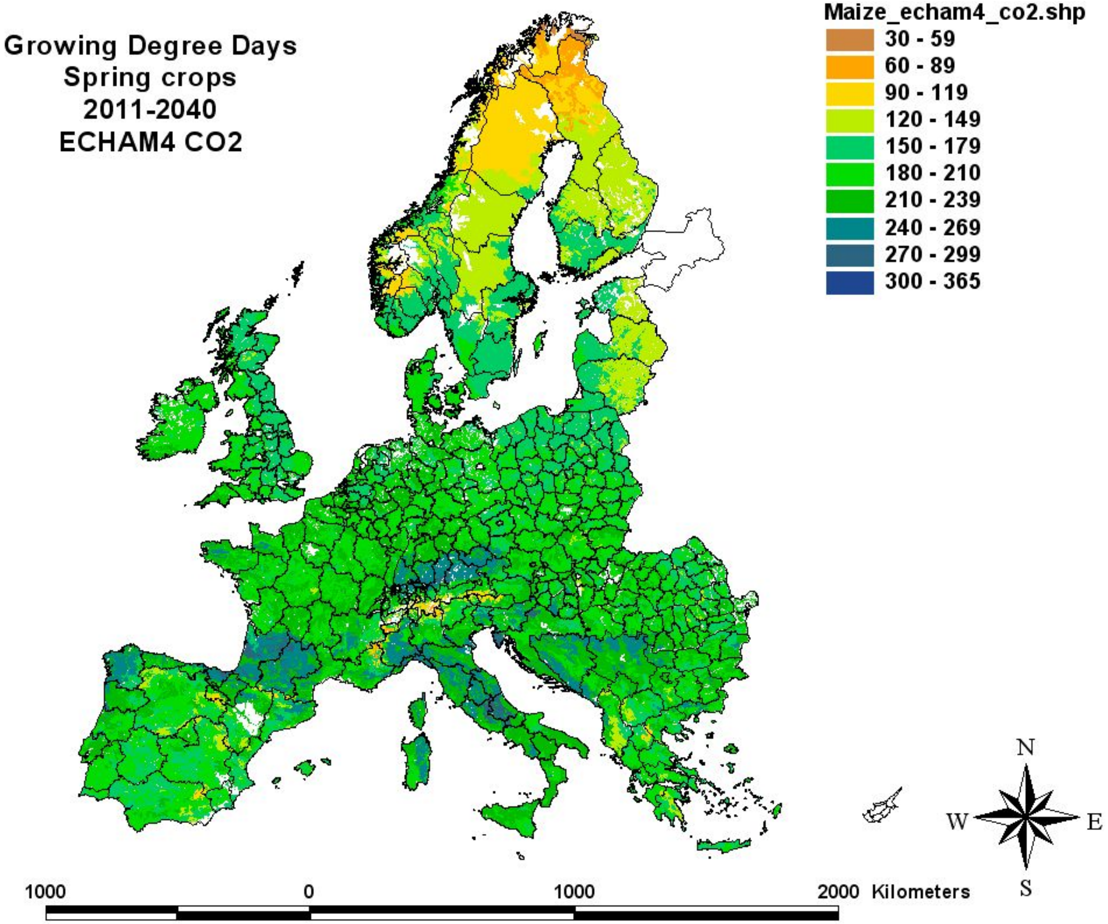


Number of growing days
Late-spring crops

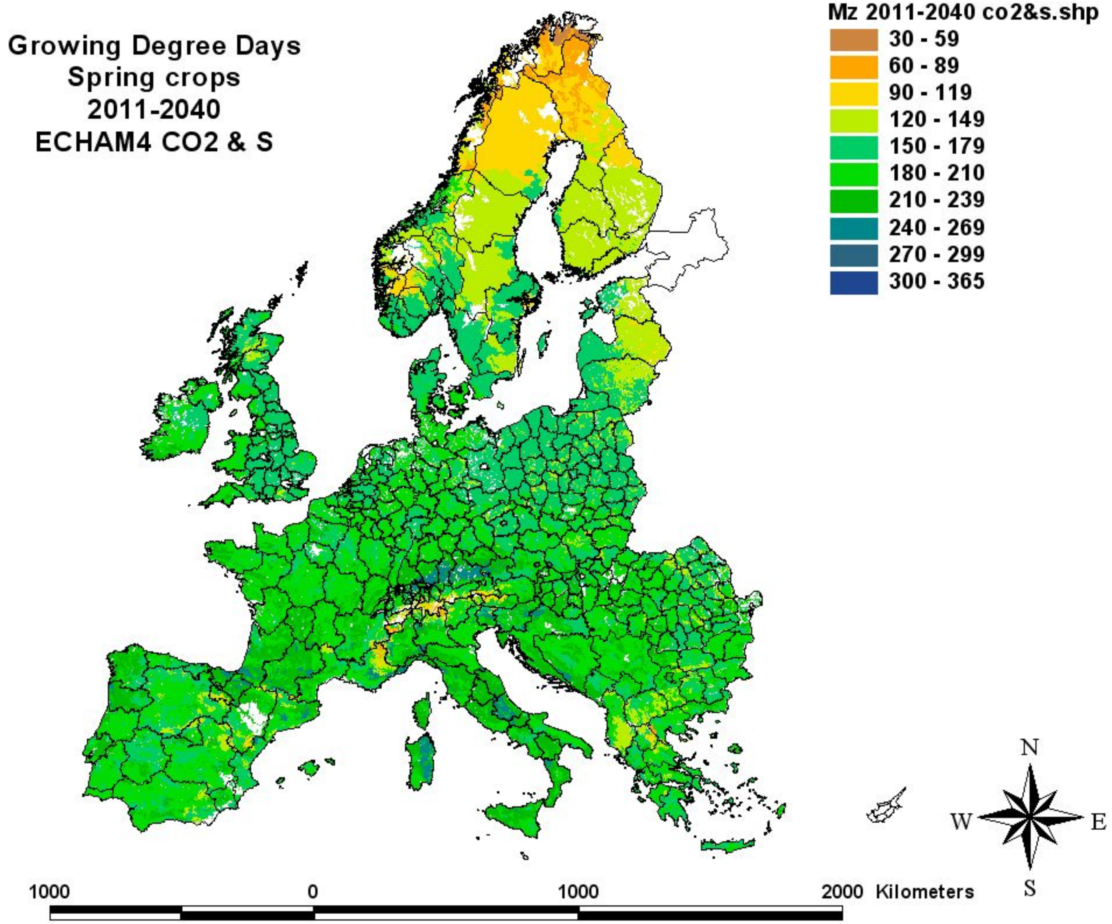
Growing Days – Late spring crops 1961-1990



Growing days – Late-spring crops 2011-2040 ECHAM4 CO2



Growing days - Late-spring crops 2011-2040 ECHAM4 CO2 & S



Number of years with alarm criteria during:

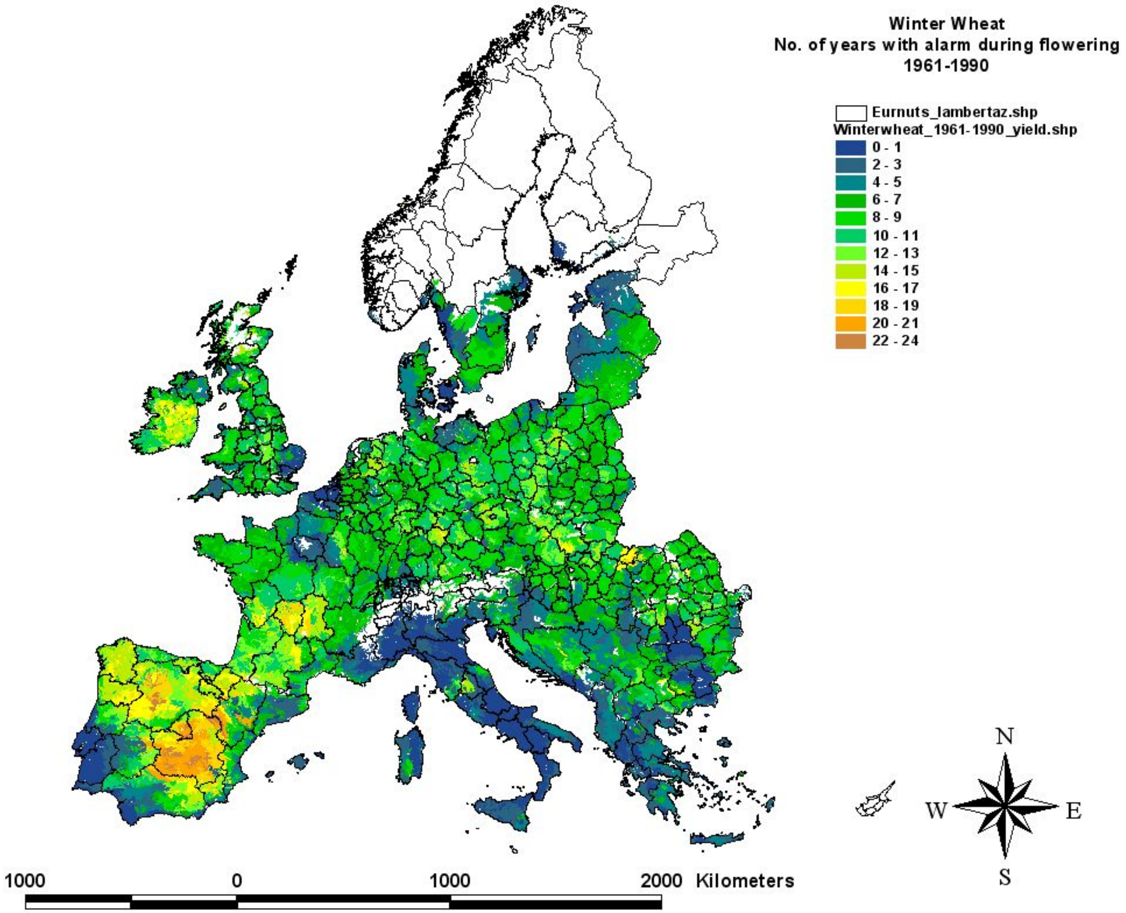
- flowering
- grain filling
- harvesting

Crops:
- winter wheat
- spring wheat
- maize

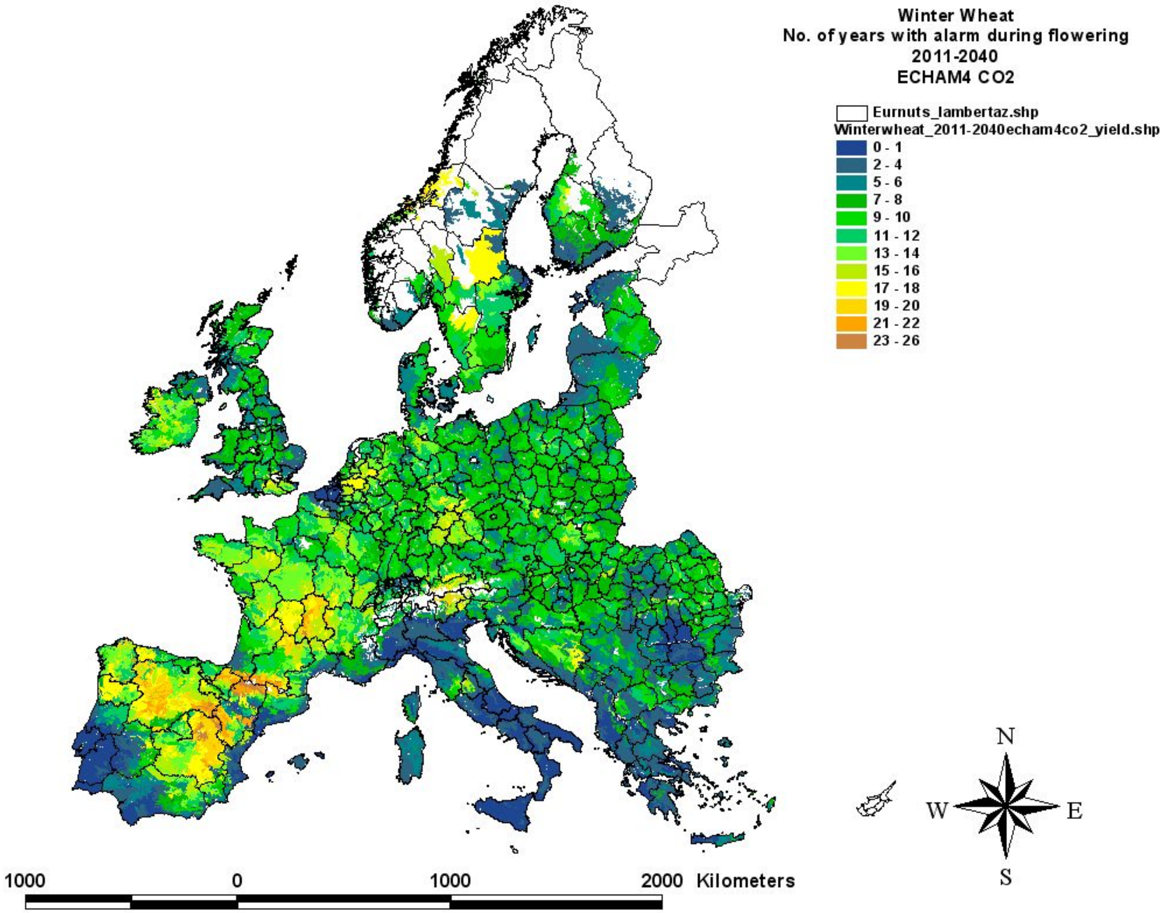
ALARM criteria during winter wheat flowering

- **IF** one weak before anthesis the minimum temperature is less than –4^{o} C **OR** the maximum temperature is higher than 30^{o}C **THEN** the final crop yield is reduced with 15%.

Winter wheat
Number of years with alarm criteria during flowering
1961-1990



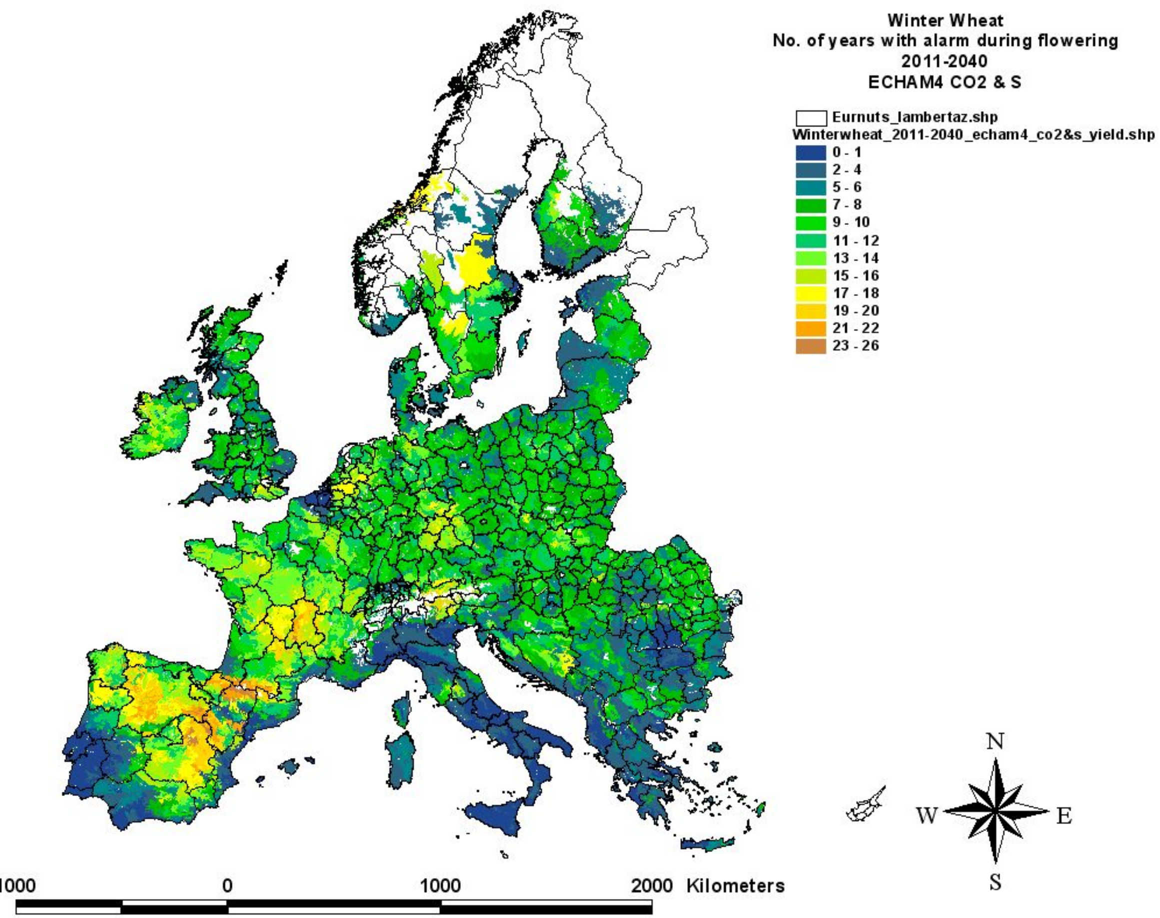
Winter wheat
Number of years with alarm criteria during flowering
2011-2040 ECHAM4 CO2



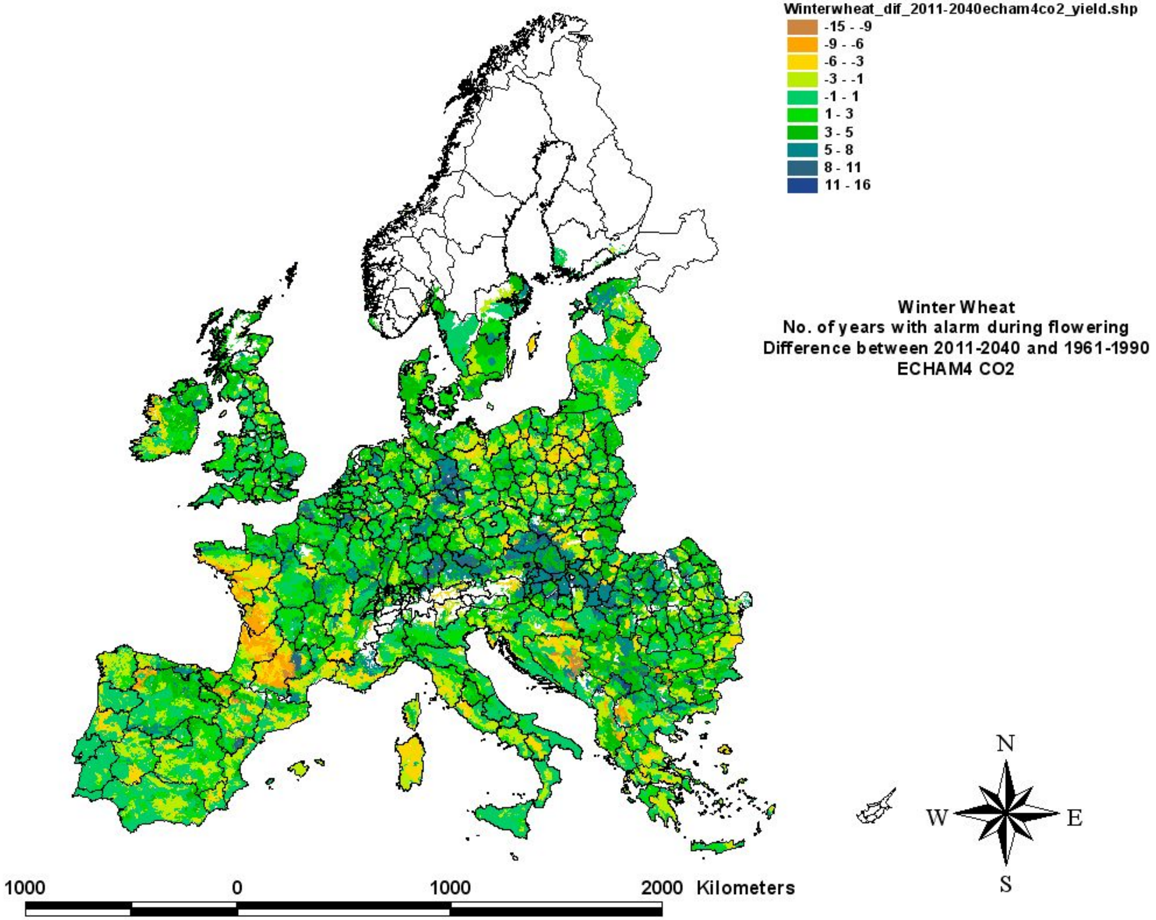
Winter wheat

Number of years with alarm criteria during flowering

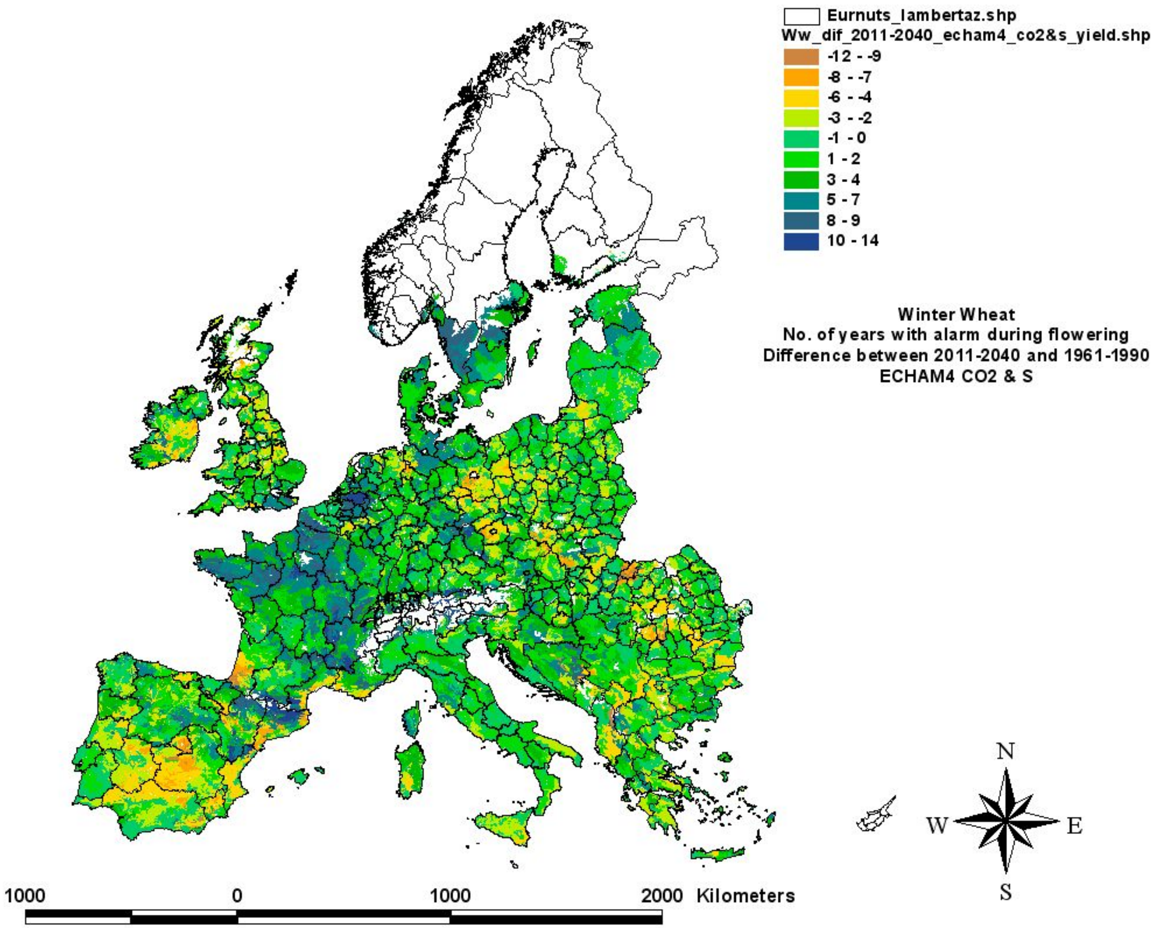
ECHAM4 CO2 & S



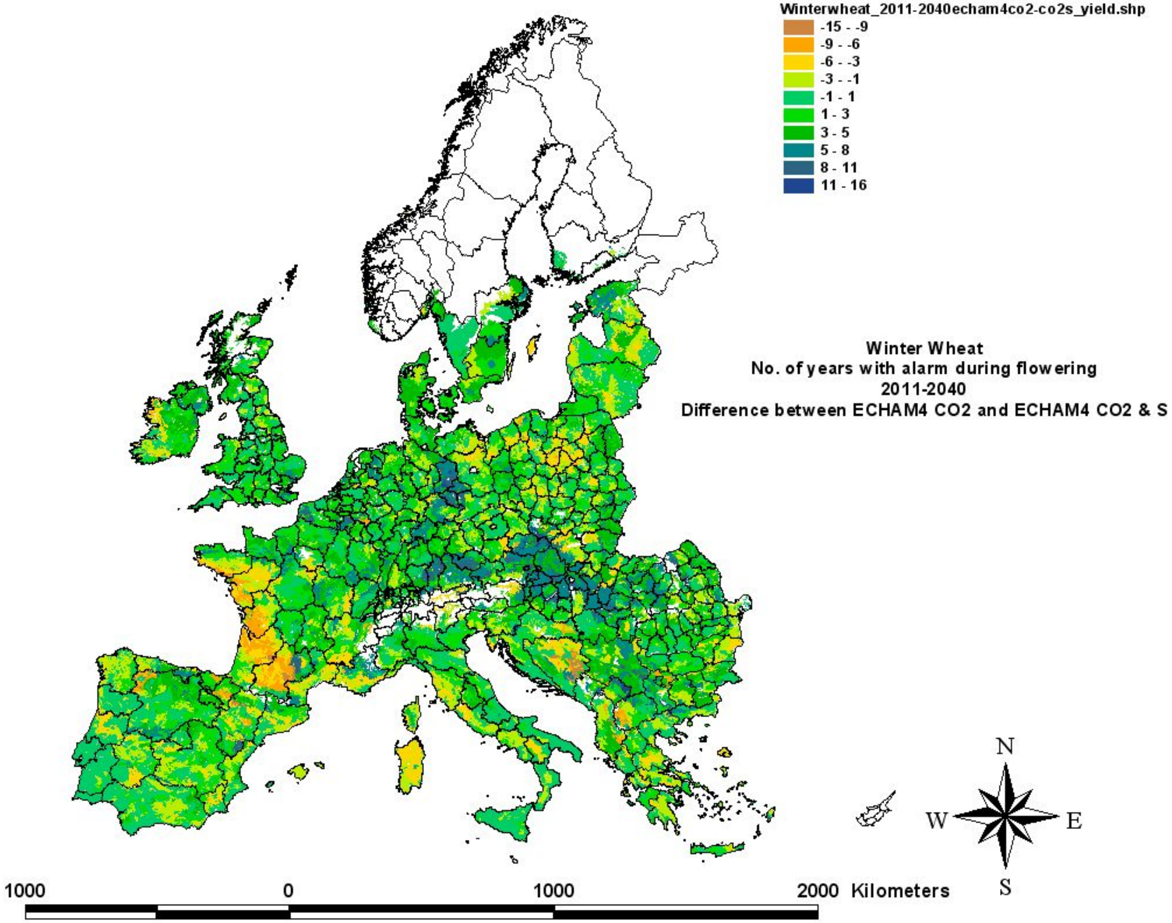
Winter wheat
Difference of Number of years with alarm criteria during flowering between 2011-2040 ECHAM4 CO2 and 1961-1990



Winter wheat
Difference of Number of years with alarm criteria during flowering between 2011-2040 ECHAM4 CO2 & S and 1961-1990



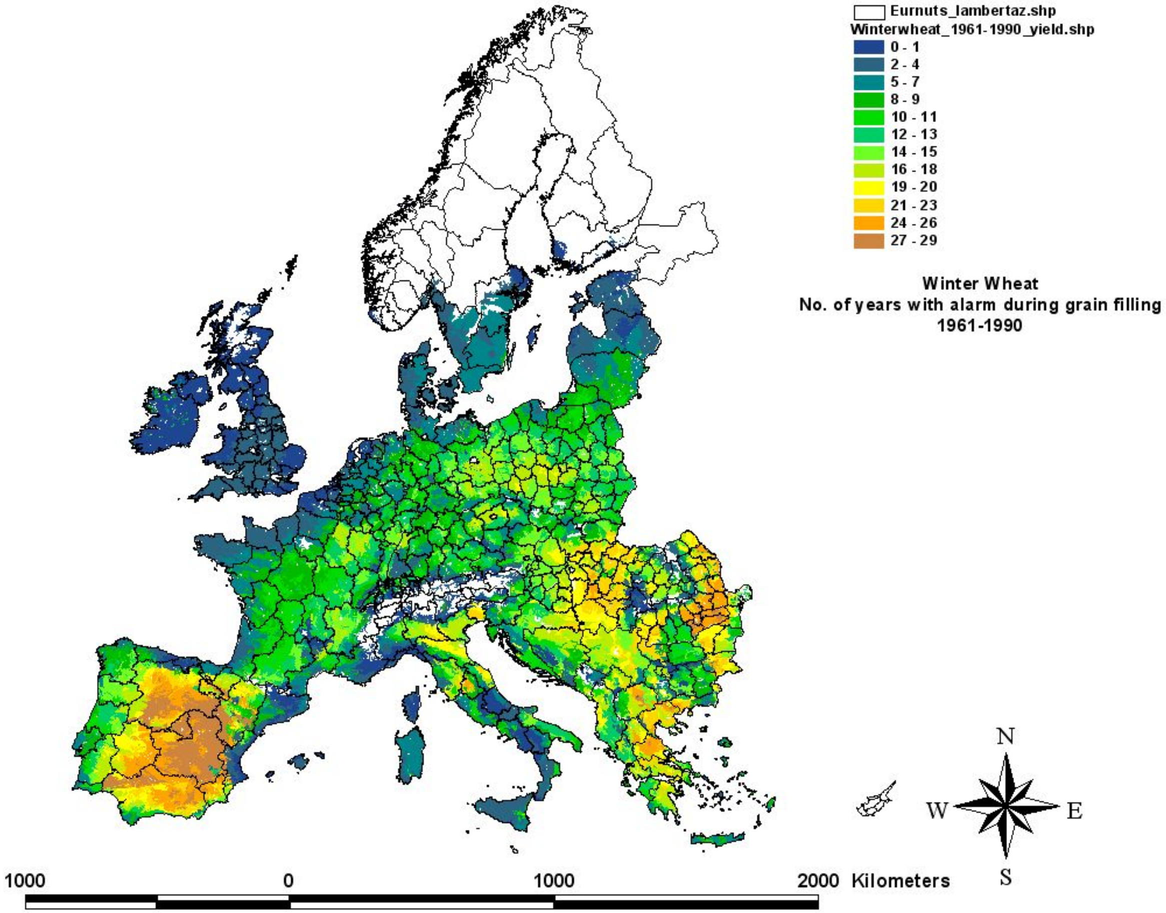
Winter wheat
Difference of Number of years with alarm criteria during flowering between 2011-2040 ECHAM4 CO2 and 2011-2040 ECHAM4 CO2 & S



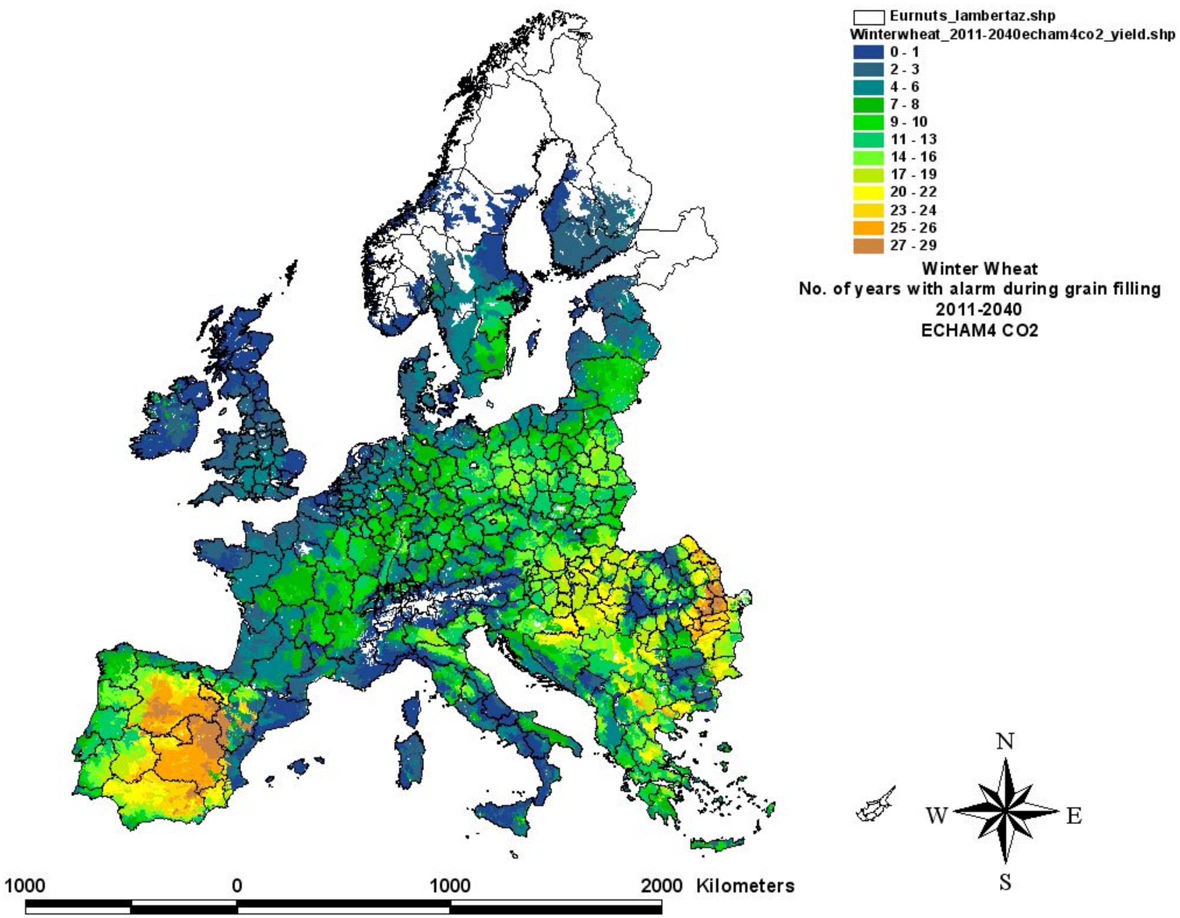
ALARM criteria during winter wheat grain filling

- **IF** maximum temperature is higher than 30º C for 3 consecutive days during the grain filling period **THEN** the final yield decreases with 15%.

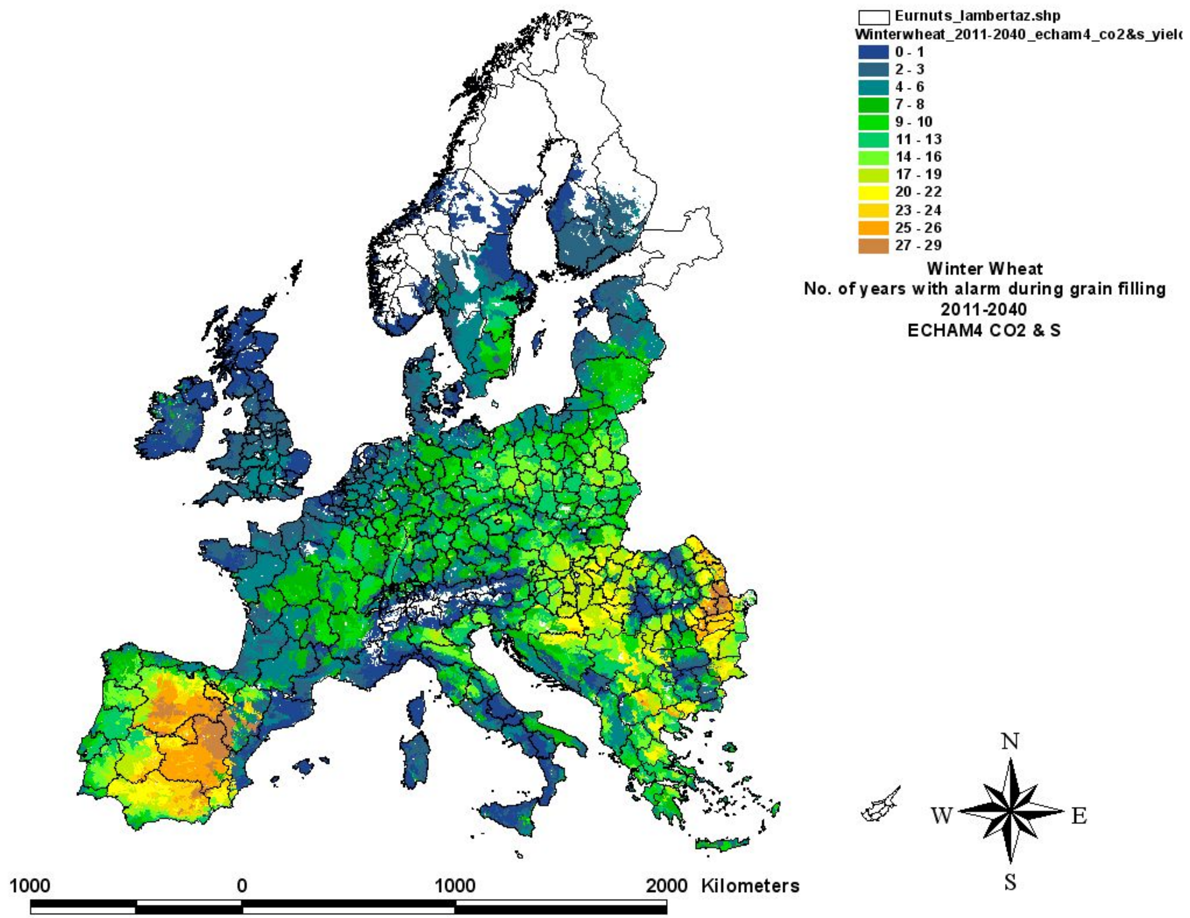
Winter wheat
Number of years with alarm criteria during grain filling
1961-1990



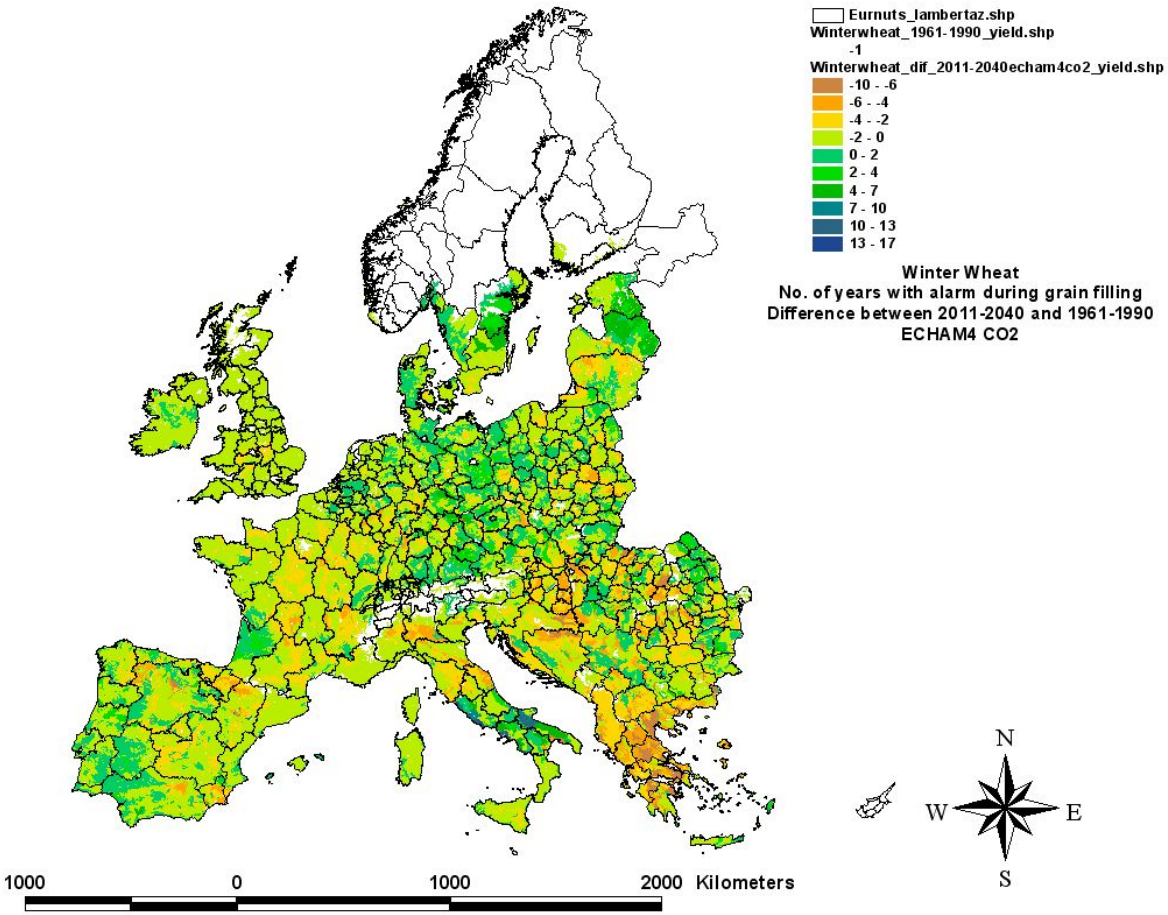
Winter wheat
Number of years with alarm criteria during grain filling
2011-2040 ECHAM4 CO2



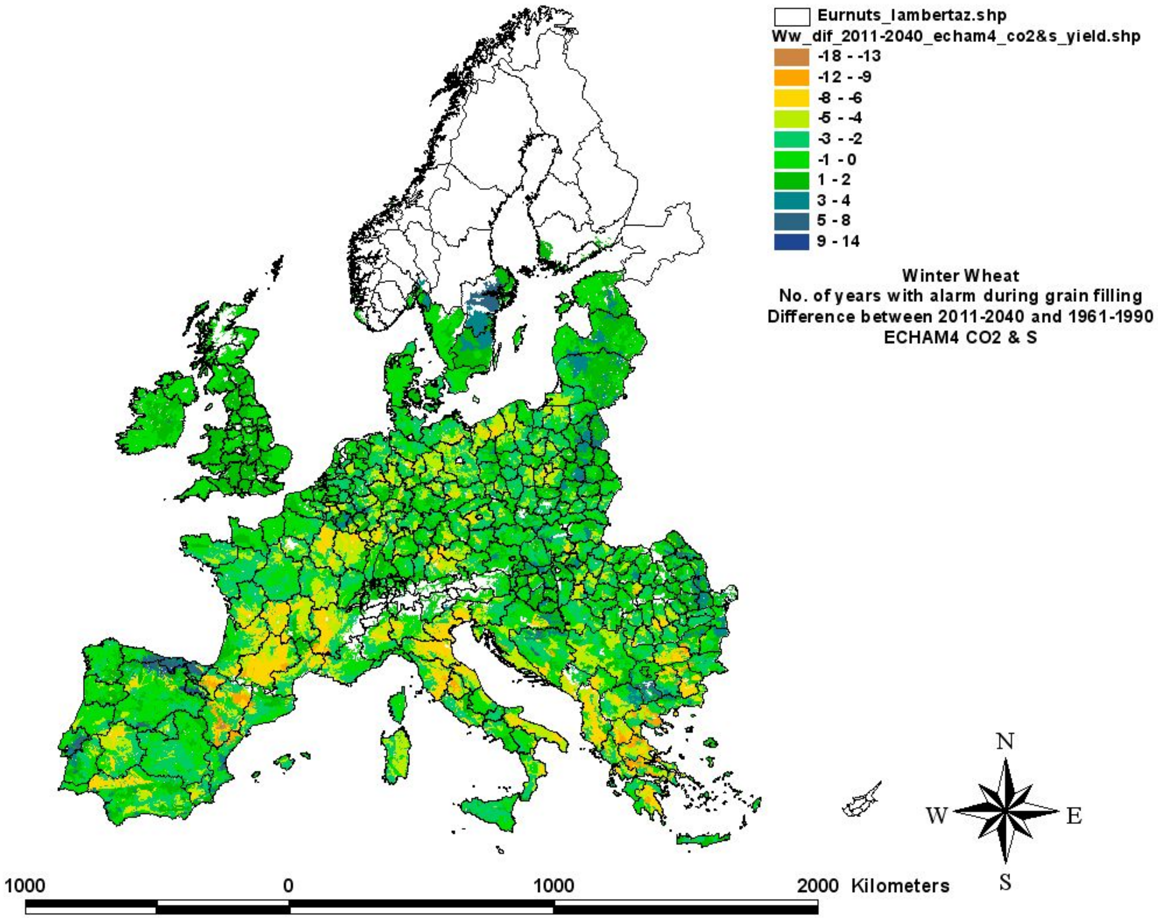
Winter wheat
Number of years with alarm criteria during grain filling
ECHAM4 CO2 & S



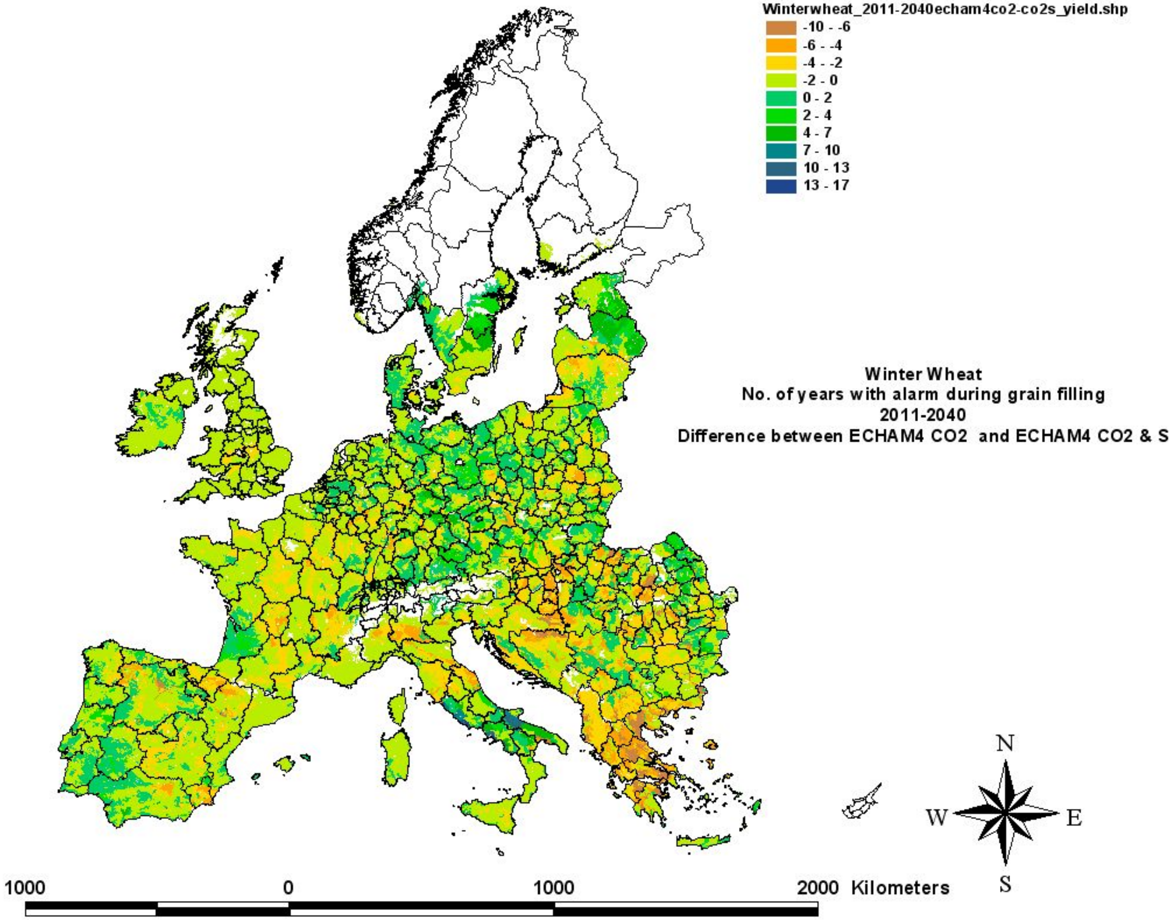
Winter wheat
Difference of Number of years with alarm criteria during grain filling between 2011-2040 ECHAM4 CO2 and 1961-1990



Winter wheat
Difference of Number of years with alarm criteria during grain filling between 2011-2040 ECHAM4 CO2 & S and 1961-1990



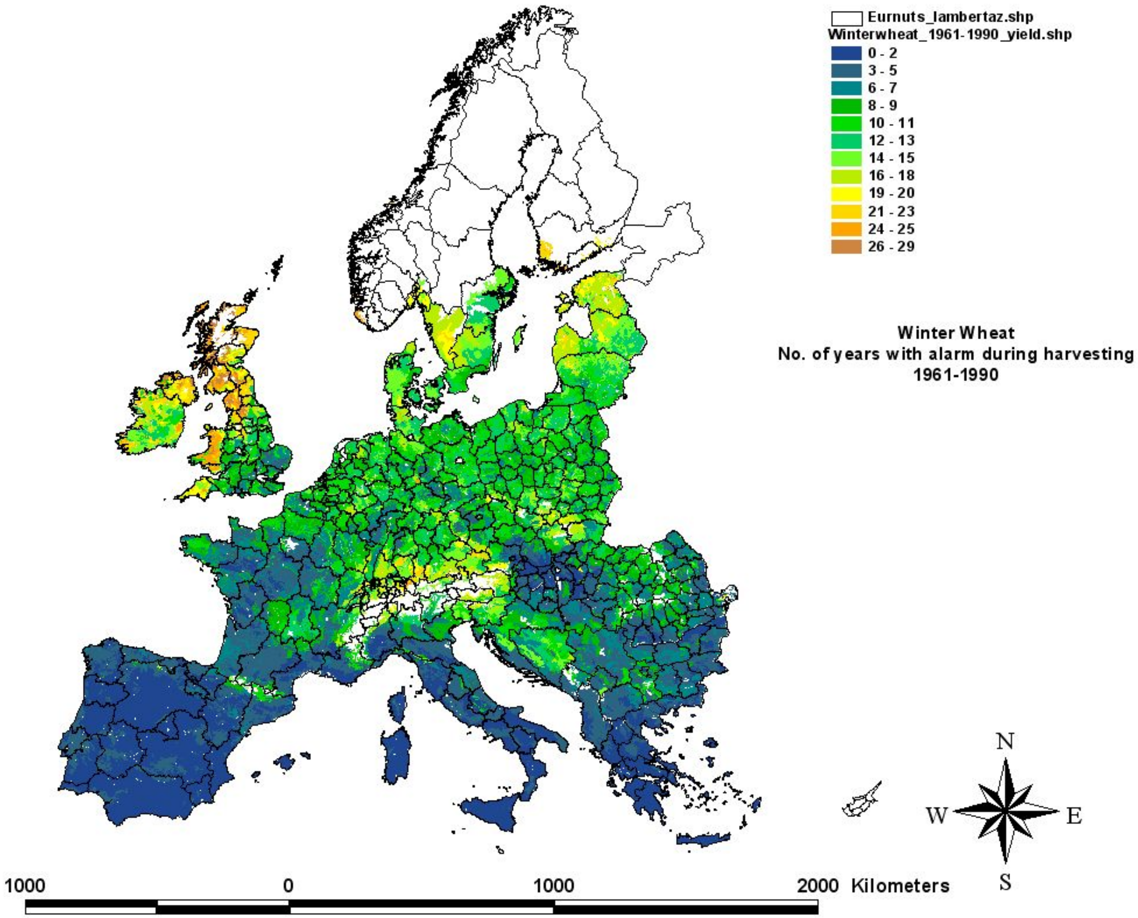
Winter wheat
Difference of Number of years with alarm criteria during grain filling between 2011-2040 ECHAM4 CO2 and 2011-2040 ECHAM4 CO2 & S



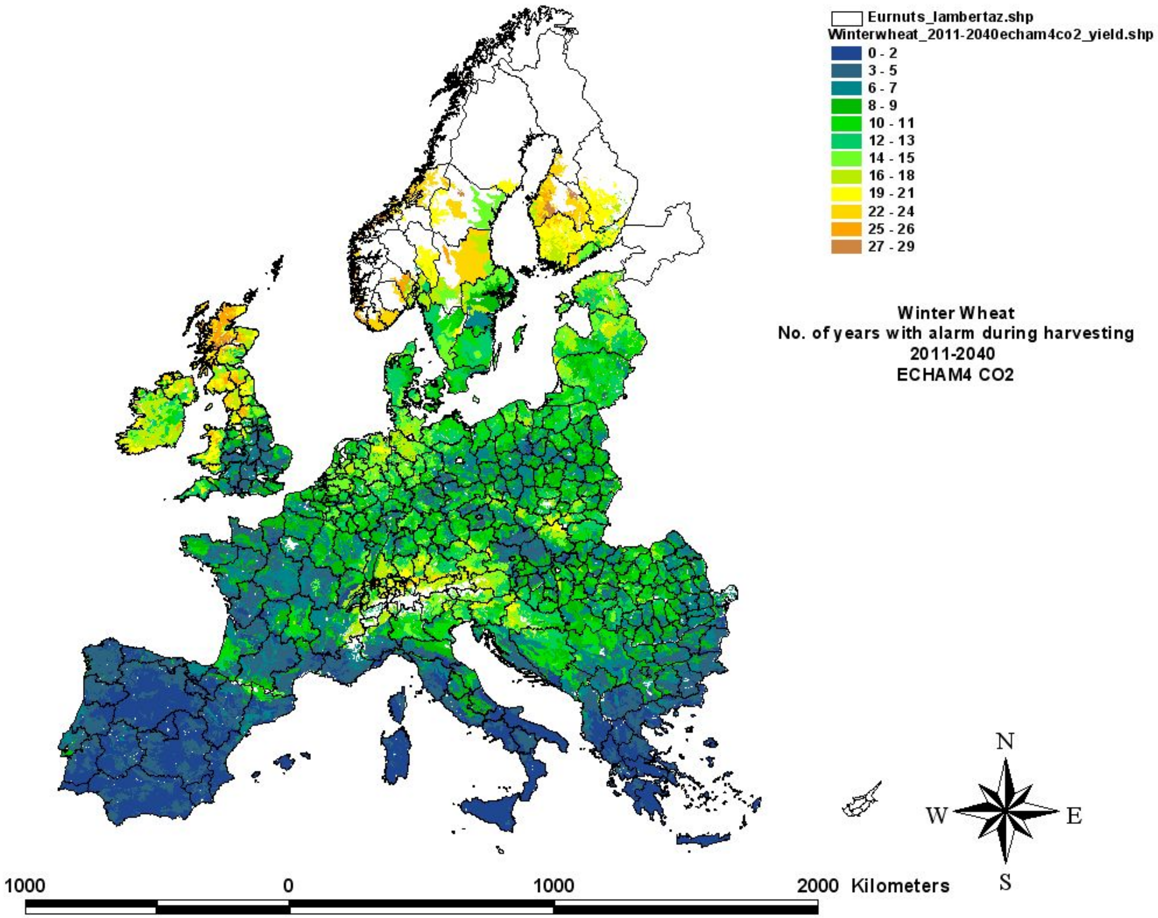
ALARM criteria during winter wheat harvesting

- **IF** in the next 10 days after maturity there are less than 4 workable days **THEN** the crop yield is reduced with 10%.

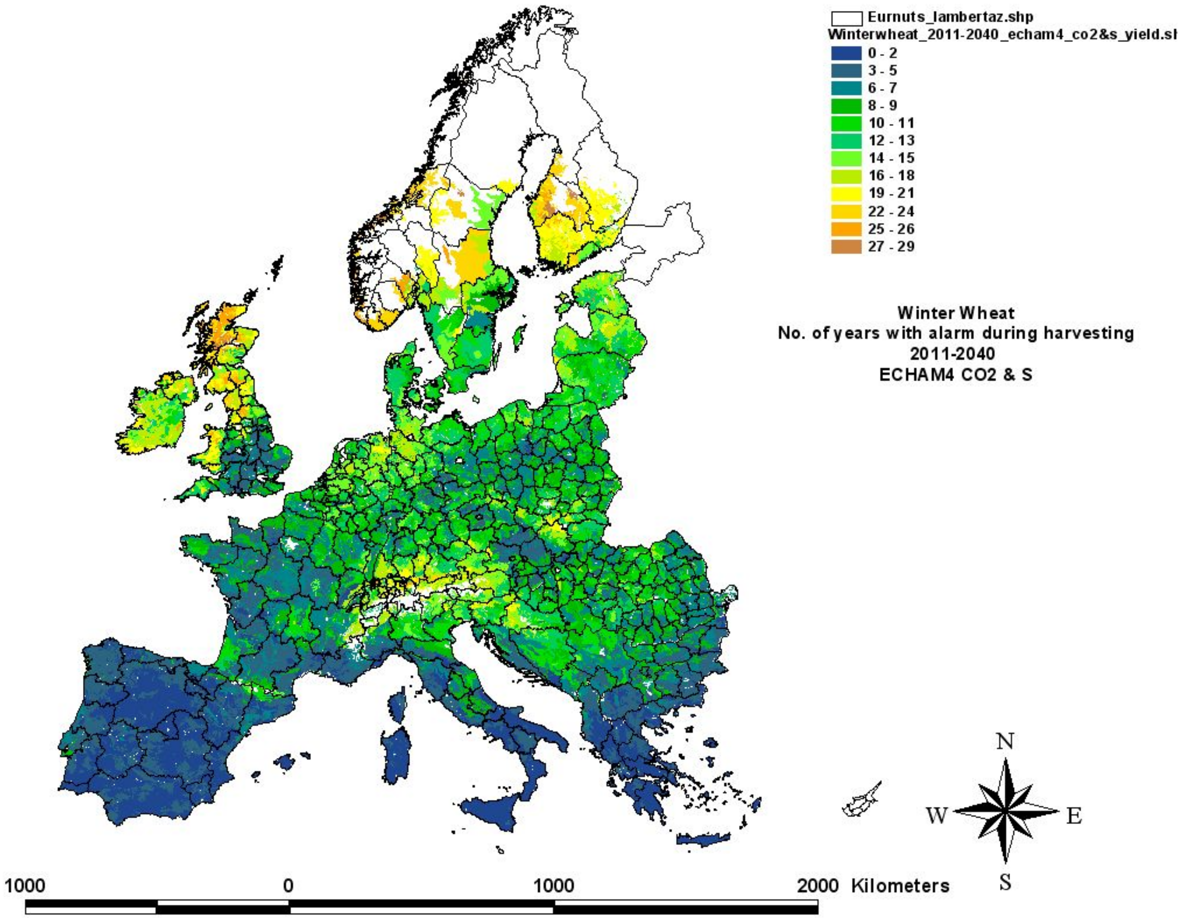
Winter wheat
Number of years with alarm criteria during harvesting
1961-1990



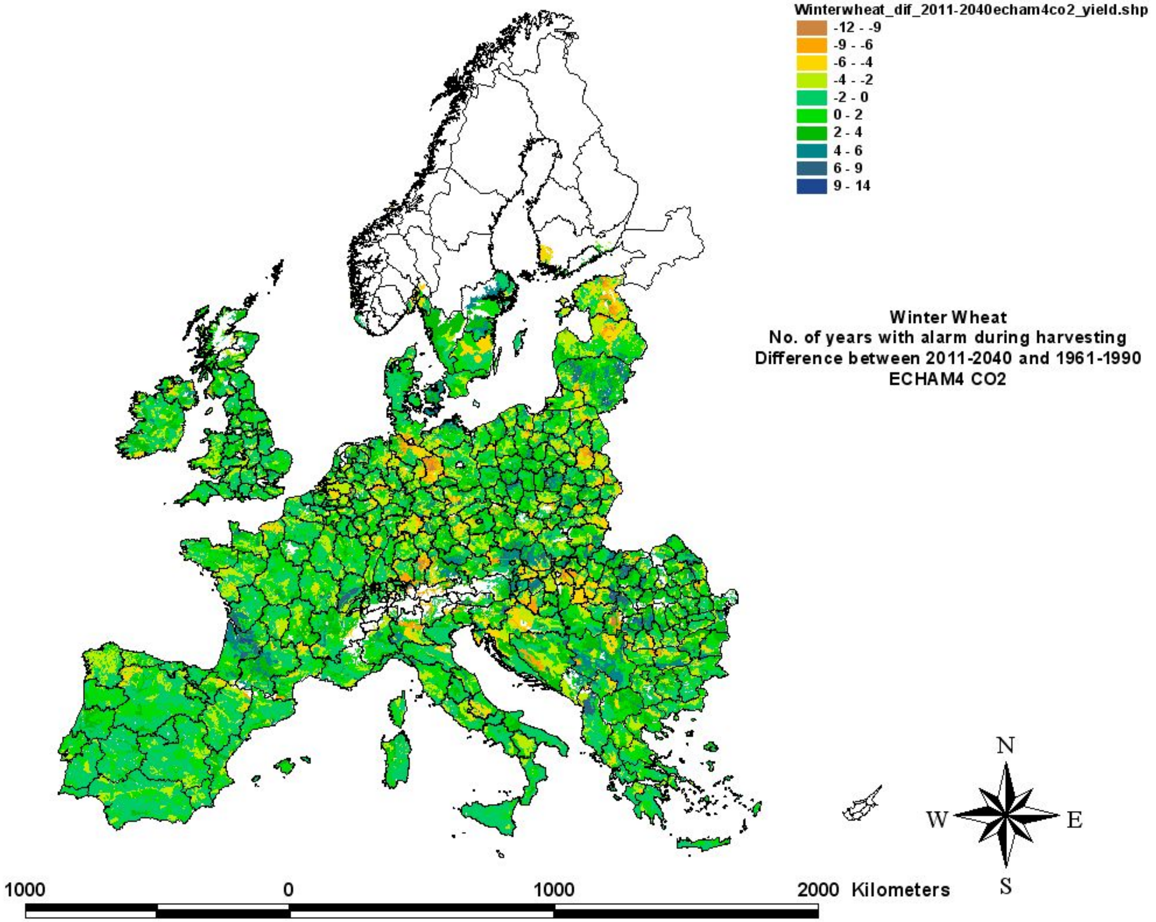
Winter wheat
Number of years with alarm criteria during harvesting
2011-2040 ECHAM4 CO2



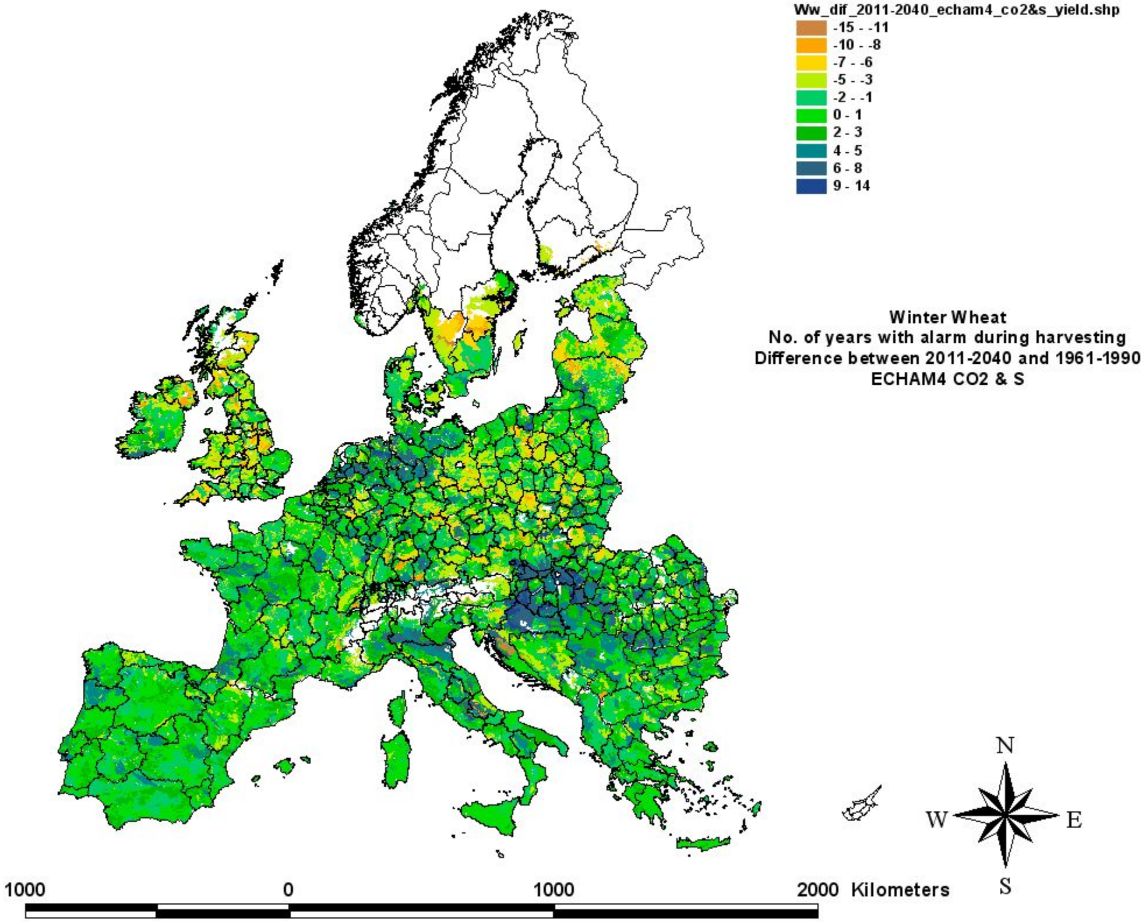
Winter wheat
Number of years with alarm criteria during harvesting
ECHAM4 CO2 & S



Winter wheat
Difference of Number of years with alarm criteria during harvesting between 2011-2040 ECHAM4 CO2 and 1961-1990



Winter wheat
Difference of Number of years with alarm criteria during harvesting between 2011-2040 ECHAM4 CO2 & S and 1961-1990



Winter wheat
Difference of Number of years with alarm criteria during harvesting between 2011-2040 ECHAM4 CO2 and 2011-2040 ECHAM4 CO2 & S