WMO RA VI WORKING GROUP ON CLIMATE AND HYDROLOGY

CLIMATE EXPERT GROUP

Task Team : Agrometeorology

Final Report (DRAFT)

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Overall aim: **Review of agrometeorological products/services to improve implementation and impact**

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Content

Work Plan

An overview on the team activities and the work plan is given in Table 1

Table 1: Terms of references, Tasks, proposed adapted deadlines, and status of the team activities

Term of reference / requirements	Action (Tasks)	Reporting Deadline (adapted)	Responsible persons (green) and contributors	Status (actual)	Comments on methods, studies, links to other TTgroups etc.
1) coordinate activities of TT AGM and cooperation with TT DM	A1.1 Conduct regular activity reports and gathering feedback from TT members (Josef Eitzinger)	Every 6 months;	*Eitzinger_Austria*	*3[rd] meeting March 12-14 2013, Helsinki*	
2) the economic impacts of agrometeorological information in Europe; document specific case studies on	A2.1 Survey on past studies and collecting available data on economic impact assessments	31.03.2013	*Eitzinger_Austria*	**Final Report**	Link to TT Drought (Climate Group).
	A2.2 Conduct own assessments (selected case studies)	31.03.2013	*Eitzinger_Austria* *Anastasiou_Greece*	**Final Report**	Case study 5
	A2.3 Recommend methods/standards for assessing economic impacts	31.03.2013	*Eitzinger_Austria* *Anastasiou_Greece*	**Final Report**	

Term of reference / requirements	Action (Tasks)	Reporting Deadline (adapted)	Responsible persons (green) and contributors	Status (actual)	Comments on methods, studies, links to other TTgroups etc.
3) improve the active collaboration between the farming community in Europe and agrometerological services; develop recommendations	A3.1 Gathering up to date information (on methods, experiences) from extension services / data providers (i.e. questionnaires)	31.03.2012	*Otte_Germany;* *Eitzinger_Austria*	**Final Report**	
	A3.2 Recommendations for increasing awareness and stakeholder implementation	31.03.2013	*Lalic_Serbia;* *Saylan_Turkey;* *Eitzinger_Austria*	**Final Report**	Comment 1
4) best practices for agrometorological products; review, evaluate and/or recommend	A4.1 Define region specific and stakeholder specific user requirements	31.12.2012	*Lalic_Serbia;* *Anastasiou_Greece* *Eckertsten_Sweden;*	**Final Report**	Case study 1;
	A4.2 Review, evaluate and/or recommend standards for agrometeorological products considering regional aspects, temporal/spatial scales, technology, etc.	31.03.2013	*Lalic_Serbia;* *Saylan_Turkey* *Mateescu_Romania*	**Final Report**	Comment 2; Link to TT WSD (Hydrology Group). Link to TT Drought (Climate Group).
	A4.3 Explore efficiency of seasonal and ensamble weather forecast for agrometeorological purposes	31.10.2012	*Lalic_Serbia* *Spirig_Switzerland*	**Final Report**	
5) new challenges or tasks for agrometeorological services and products related to ongoing climate change impacts; To identify and evaluate	A5.1 Identify new user needs regarding ongoing climate change impacts (i.e. literature survey, Questionnaires) considering regional aspects (agroecosystems, climate region, temporal/spatial scales, technology, etc.)	31.03.2013	*Eckertsten_Sweden;* *Frühauf_Germany* *Pietzsch_Germany;* *Eitzinger_Austria* *Kozyra_Poland* *Mateescu_Romania*	**Final Report**	Case study 2; Case study 3; Link to TT WSD (Hydrology Group).

Term of reference / requirements	Action (Tasks)	Reporting Deadline (adapted)	Responsible persons (green) and contributors	Status (actual)	Comments on methods, studies, links to other TTgroups etc.
	A5.2 Identification of the possibilities of satellite earth observations for monitoring of changes in biosphere related to climate change.	31.03.2013	*Struzik_Poland* *Spirig_Switzerland*	ongoing	Comment 3;
	A5.3 Develope recommendations triggering services/products for a better support to decision making on mitigation/adaptation options to climate change	31.03.2013	*Otte_Germany* *Frühauf_Germany* *Spirig_Switzerland* *Kozyra_Poland* *Mateescu_Romania*	**Final Report**	Case study 4;
	A5.4 Identify unsolved research tasks and problems in the field	31.03.2013	*Lalic_Serbia;* *Eitzinger_Austria*	**Final Report**	
6) use of climate and meteorological resources in the RA VI high-quality agricultural production chain; to review and access	A6.1 Identification of current strength and weakness in the agrometeorological support to the whole agro-food chain (input supply industry, farmers, agro-food industry and distribution systems).	31.03.2013	*Rossi_Italy,* *Mariani_Italy* *Anastasiou_Greece*	**Final Report**	Comment 4; Link to WMO-CAgM.
	A6.2 Identification of new tools potentially useful for the actors of the agro-food chain and suggestions for their implementations.	31.03.2013	*Rossi_Italy,* *Mariani_Italy* *Anastasiou_Greece*	**Final Report**	Link to WMO-CAgM.
	A6.3 Prepare a regional report of best agrometeorological practices to be adopted for a XXI Century European farming design	31.03.2013	*Rossi_Italy,* *Mariani_Italy* *Anastasiou_Greece*	**Final Report**	Link to WMO-CAgM.

Case study suggestions

Case Study 1: In the Baltic Compass project scenarios for nutrient load to the Baltic sea will be performed using the same models as currently are used by Stakeholders for strategic action plans for the Baltic Sea Region. A number of inputs of these models have the character of agroclimatic products, like calculation of sowing time, harvest time, dry/wet year etc. The inputs differ among models.
FOCUS: Agroclimatic indices providing inputs to nutrient load scenarios

Case Study 2: In a planned proposal to the Swedish Board of Agriculture:agroclimatic indices should provide information valuable for evaluating the risk of crop protection needs under climate change, The idea would be to make maps of indices and correlate them with maps of current protection needs, per crop, production level etc.
FOCUS: Agroclimatic indices relevant for evaluating future needs of crop protection.

Case Study 3: FOCUS: Implementation of an agromet-related Atlas.

Case Study 4: FOCUS: Combination of RCMs and Impact-Modells like AMBER.

Case Study 5: FOCUS: Stakeholder survey (questionnaires).

Comments

Comment 1: Saylan_Turkey: The importance of training of the educators within agrometeorological agenda is certainly rising. This can then be followed by the education of the users, decision makers, etc. Educational experience and knowledge can be acquired by a growing percentage of teaching group members.

Comment 2: Saylan_Turkey: Most of the data comes from climatological stations. While traditional data are acquired from many parts of Europe, many other less existing agrometeorological stations give the more important agrometeorological data like PAR, soil water content, etc. Hence; quality and quantity of the desired agrometeorological information (from raw data to theoretical knowledge) is to be increased. This can be done by establishing a connecting program between all research areas that requires building a related agrometeorological station net in frame of this action. This is especially necessary for the continued success of the improvement and implementation.

Comment 3: Struzik_Poland:. Recently we observe rapid development of satellite products related to analysis of energy and water balance at the earth surface. Sucha aproducts like: short wave radiation, long wave radiation, evapotranspiration, albedo, soil moisture (surface and root region) can be used for better etimation of water balance and actual soil conditions related to possible drought development. **Link to the needs of Drought Monitoring Task Team.**

Comment 4: Rossi, Mariani_Italy: We propose some addictions for the document, that are aimed to clarify the essential role of meteo-climatic variables as resources and limitations for agricultural activity in an advanced agricultural context, strongly integrated in a complex agro-food system. Our reflections, drawn taking into account the contents of the new Gamp (WMO n. 134), are referred to the introductory writing and the list of the Terms of Reference of the TT-AGM.
<u>Background:</u> The European approach to food production rapidly evolves towards the rational interaction of agriculture with input supply industry (seeds, agro-chemicals, energy, animal nutrition, etc.), agro-food industry (primary and secondary food processes) and distribution

systems (wholesale/retail). This new paradigm includes as corollaries (i) the full traceability of products along the agro-food chains, (ii) the evaluation of both consumers and farmers as primary entities in the agro-food chains and (iii) the full satisfaction of the expectance of consumers in a "farm to fork" perspective. This evolution of the European agro-food chain happens in a agricultural sector increasingly oriented towards schemes of sustainability, balanced use of resources, low environmental impact, multi-functionality, full meet of needs of food industry/consumers and rational evaluation of economic limitations. A relevant role in this scenario is played by atmospheric variables (solar radiation, temperature, humidity, precipitation, wind, etc.) because they are primary drivers for the agro-ecosystem. These variabiles, acting both as resources and limitations for agro-ecosystems, determine quantity and quality agricultural production of vegetal and animal origin. This justifies a relevant potential interest of all the actors of the agro-food chain for the space and time evolution of atmospheric variables and for the quantitative evaluation of their effects on agricultural productions. The above-described context opens a wide set of opportunities for meteorological and hydrological services able to produce high quality agrometeorological information by means of enhanced systems of measurement and modelling and to broadcast it to final users in a timely way. Agriculture, livestocks, forestry and fisheries activities may all take advantages by adopting such opportunities. Moreover it must be considered that an approach to agriculture in the light of atmospheric variables could represent a model for non European countries in order to improve the rational use of resources in a food security perspective.

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Results

Summary

The results of the Task teams are based mainly on expert assessments of the involved Task team members. Results from a questionnaire are further included but cannot be seen as representative source of information from European meteorological services due to weak feedbacks. The questionnaire contained questions from all Task teams (see example below) and was distributed to all RA VI countries through WMO office. 6 countries (Austria, Germany, Croatia, Hungary, Sweden, Slovakia) responded directly to the questionnaire. Some other countries are represented through Task team members (Romania, Greece, Italy, Poland, Slovenia, Serbia, Turkey, Switzerland). In total 14 RA VI countries therefore contributed to this report.
Some of the tasks still need more time to be completed in the next activity period (see below). An online questionnaire form was launched in December 2012 by Dimos Anastasiou (Greece), which is still active and could be reinforced in the second activity period. It can be accessed at: www.rainfed.com.
All deliverable deadlines for the final task reports were set till end of March 2013.

Comments to specific tasks:

TASK 2 : the economic impacts of agrometeorological information in Europe; document specific case studies on

Overall assessment:
This task is recommended to be extended in the next activity period. Economic studies and data are still rare and few ongoing studies can be used for further assessments. Preferably an economic expert should be involved in this task.

TASK 3 : improve the active collaboration between the farming community in Europe and agrometerological services; develop recommendations

Overall assessment:
Report finalzed.

TASK 4 : best practices for agrometorological products; review, evaluate and/or recommend

Overall assessment:
Report partly finalized.
Completion of task report is expected for the final report (remote sensing methods).

TASK 5 : new challenges or tasks for agrometeorological services and products related to ongoing climate change impacts; To identify and evaluate

Overall assessment: Current status of activities:
Report finalized. The task however is complex and needs further evaluation, therefore extension for the next activity period is recommended.

TASK 6 : use of climate and meteorological resources in the RA VI high-quality agricultural production chain; to review and access

Overall assessment: Current status of activities:
Report finalized. The task however is complex and needs further evaluation, therefore extension for the next activity period is recommended.

TASK OUTCOMES

Task A2

2) the economic impacts of agrometeorological information in Europe; document specific case studies on	A2.1 Survey on past studies and collecting available data on economic impact assessments A2.2 Conduct own assessments (selected case studies) A2.3 Recommend methods/standards for assessing economic impacts

Authors: Josef Eitzinger, Bernhard Pacher (Consultant), Luigi Mariani, Federica Rossi

Introduction

The knowledge on economic value or impact from the use and application of agrometeorological information is an important aspect for dissemination and user acceptance of agrometeorological information and products. According to Shivakumar (2006) most countries however do not assess the economic value of the information provided. His global review on the dissemination and communication of agrometeorological information reveals that especially developing countries lack of adequate interaction with the user community due to missing dissemination and communication procedures among others. There are many gaps however also in European countries in this aspect.

Several studies were carried out to estimate the economic impacts of weather forecasts (short and medium term) in agriculture and other agrometeorlogical information using different methods. For example, studies carried out in India (Rathore and Maini, 2008) and China (Shen et al., 2011) used stakeholder surveys and several indicators (such as crop yield, production costs, yield return (profitability) and others) for assessing economic value of weather forecast information for farmers and different crops. Other studies consider country wide and sectoral analysis (e.g. Leviäkangas et al., 2008).

On the applied methods in such studies, which could be recommended for further case studies, information is available. This can be demonstrated for example also on similar matters such as studies on economic value of adaptation options in agriculture to climate change or on the potential economic impacts of extreme weather events. This will be outlined in the following.

Methods of estimating economic value of agrometeorological information

In a report of the World bank (The World Bank, 2010) on the economic evaluation on adaptation options to climate variability and change a methodological approach can be described as “project economic analysis calls for defining the “baseline” or “without-project” scenario”. The problem of any approach is an inherent subjectivity caused by human decision making and depending on the scale of interest (e.g. a problem focused, stand alone project vs. more generalized projects). For example, in a stand alone adaptation assessment benefits and costs can be assessed relative to a no-project alternative where in the generalized or larger scales the comparison needs a business-as-usual scenario.

Additionally, economic co-benefits of any adaptation option (e.g. in our case farmers changed decisions based on weather forecasts or agrometeorological information) have to be considered. Especially for long term adaptation to climate variability socio-economic and ecological benefits will receive more importance through their relevance for sustainable options, and should be considered in this context as well.

Qualitative assessments of the economic evaluation of any intervention driven by the use of agrometeorological information can be carried out by surveys among stakeholders (farmers) using e.g. descriptive or numerical indicators. These were used in the past several times.
On the other hand, quantitative assessments need a clearly defined economic cost-benefit analysis, which may depend again on the spatial and time scale of interest. For a single farm. for example, the economic cost/benefit ratio of a specific intervention (e.g. if or when to irrigate) could be easily compared to a no-action scenario for a short term measure and is quite straightforward (also called “hard interventions”). For long term measures (e.g. in reaction to climate change) it is more complex, which needs the application of economic models or whole farm models, considering additionally market (cost and price) developments with a higher degree of uncertainty and considering additionally discount rates and non-economic aspects such as ecological impacts, for example. Assessments for larger scales (region, country) are most complex in both short and long term scales with a higher degree of uncertainty (also called “soft intervention”) and need specific tools such as Ricardian models and extended data bases.

Assessment of local macro and micro economic benefits of agrometeorological information can be made as a proxy variable prediction with the benefits of projects that emerged with the use of agrometeorological products.
For example, infrastructure or irrigation network development works and studies carried out, are made after expert recommendations and analysis of agrometeorological knowledge. For example, many infrastructures works or water management studies and projects for agriculture, are made after careful consideration of agrometeorological information which proves that: if for example, irrigation water was available, several productivity and socioeconomic benefits would emerge, and based on this agronomic expertise, agricultural investments are made. In this case, the economic impacts of agrometeorological information can be estimated as an auxiliary variable that guides decision maker opinion, towards investments and policy decisions.

Generally, estimating the economic impacts of agrometeorological information can be challenging, especially since in most cases is publicly available information as a public service from governments to the general public. And, as it is the case of many public goverment investments, the assessment of exact economic benefits is not the main goal during decision and planning; rather, the goal of such investments is the overall agricultural and socioeconomic benefit, for considerable time periods of a decade or much more. Also, such public domain investments such the agrometeorological information are made in combination with other services and investments. Therefore, it is a rather long term and multi-crtiteria complex procedure to estimate the exact economic benefits of agrometeorological information.
Qualitative criteria and analysis (i.e. SWOT analysis, Table A2.1-1) can be a first approach, at least in the first steps of an economic impact analysis, which gradually become more quantitative gathering input from the most important factors affected by information dissemination.
If, in estimating economic benefits one can limit the spatial and temporal scales of analysis and the local level and at a time period of a decade for example, then it could be possible to predict the benefits of a certain agricultural practice which was guided by agrometeorological information (such as an irrigation project, or the introduction of a new crop). NPV, IRR and generally discount models can easily apply to the local level, and then aggregated data can be used to combine results at the regional, country or EC level.

Table A2.1-1 presents an overview of methods recommended for the assessment of economical benefits of the use of agrometeorological information in the agricultural sector for short and long term assessments (based on literature survey).

Table A2.1-1.: Selected methods recommended for the assessment of economic benefits of the use of agrometeorological information in the agricultural sector for short and long term assessments.

Method	**Characteristic**	**Applications**	**Advantage**	**Disadvantage**
Agronomic models (i.e. whole farm models, crop models, irrigation models, pest models etc..)	Estimating potential effects on specific crops / crop rotations	Short and long term: Climate change impacts; Irrigation; Sowing time; Cultivar effects; pest management	Detailed process analysis; Scenario optimization	High input data demand; Uncertainties from scenarios; needs experienced user
Ricardian[1] method	Comparative advantage (relative term)	Comparison of two regions/commodities based on labour content of products	Straightforward method	Focused on country trade, several limitations
Hedonic method[2]	Price of a marketed good is related to its characteristics, or the services it provides.	Most experience with housing price estimation.	Method is relatively straightforward, based on actual market prices and fairly easily measured data.	Relatively complex to implement and interpret, requiring a high degree of statistical expertise
Subjective methods (i.e. SWOT[3] analysis)	Survey / questionnaires /expert assessments	Preferably for short term scales and farm level	Low demand on specific data	Room for interpretation and related uncertainty
Cost-benefit analysis	Value based	Short and long term	Target focused	Complex multi-criteria analysis necessary

[1] The classic model of international trade introduced by David Ricardo to explain the pattern of, and the gains from, trade in terms of comparative advantage. It assumes perfect competition and a single factor of production, labor, with constant requirements of labor per unit of output that differ across countries. (Source: http://www.dictionarycentral.com/definition/ricardian-model.html)

[2] The hedonic pricing method is used to estimate economic values for ecosystem or environmental services that directly affect market prices. It is most commonly applied to variations in housing prices that reflect the value of local environmental attributes. (Source: http://www.ecosystemvaluation.org/hedonic_pricing.htm)

[3] SWOT is an acronym for Strengths, Weaknesses, Opportunities and Threats. By definition, Strengths (S) and Weaknesses (W) are considered to be internal factors over which you have some measure of control. Also, by definition, Opportunities (O) and Threats (T) are considered to be external factors over which you have essentially no control. SWOT Analysis is the most renowned tool for audit and analysis of the overall strategic position of the business and its environment. (Source: http://www.managementstudyguide.com/swot-analysis.htm)

Studies of estimation the economic impacts of agrometeorological information are rare, but a few examples, are described below.

Table A2.1-2 presents published studies carried out for the assessment of economic benefits of the use of agrometeorological information in the agricultural sector.

Table. A2.1-2.: Global studies for the assessment of the benefit of stakeholder intervention (adaptations) related to agrometeorological information and forecasts (based on literature survey).

Country	**Scale**	**Focus**	**Methods**	**Results**	**Reference**
China / Nanjiing	Farm level	Agromet. Services for grape farming	Questionnaire /shadow price method	90% satisfication; strong economic benefit value given.	Shen et al., 2011
Croatia	Country level	Agromet. Services for agriculture	Country comparison (based on Finland study below)	Current (2007) economic benefit of 5-10 mio. Euro/year with improving potential. Additional value by preventing potential of extreme weather impacts (app. 130 mio. Euros / year).	Leviäkangas et al., 2007
Finland	Regional level (southern Finland)	Agromet. Services for agriculture	Farmers survey / case study /expert assessment	Current (2006) economic benefit of tailored services of 34 mio. Euro/year.	Ansalehto et al., 1985; Leviäkangas et al., 2007
Australia	Region	Specialized service for cotton farmers.	Survey /case study	Benefit-Cost ratio of 12.6; potential additional benefits.	Anaman et al., 1997
India	Regions	Specialized service for rice farmers.	Survey / case study	Increase of net returns between 11-55 %.	Rathore and Maini, 2008.

REPORTED CASE STUDIES

Contribution to the "WMO RA VI CONFERENCE ON SOCIAL AND ECONOMIC BENEFITS OF WEATHER, CLIMATE AND WATER SERVICES", held in Lucerne, Switzerland, 3-4 October 2011.

The main purpose of the Conference was to stimulate socio-economical assessment among RA VI members on Weather Climate and Water Services.
Our contribution has presented the main Socio-economic benefits of irrigation advises to farmers and sustainable water use. Some rationale and activity results are following here:

Agriculture is now facing many urging pressure to provide food for an increasing population: the FAO estimations (2009) are to produce 70-100% more for an expected population of some nine billion by the middle of 20th century. Inequalities between industrialized and developing and least developed counties evidence malnutrition and food insecurity in the poorest parts of the globe and increased consumer purchasing power and improved dietary expectances in others. Environmental emergence, climate change and variability pressures, land use changes, large GHG emissions due to agro-food systems urge the agriculture to optimize productivity across a complex number of technical, socio-economic, environmental, rural development, sustainable use of resources (Perry et al, 2010).

NMHS data and services are vital and essential instruments to provide either scientific and technical instruments for a multi-functional agriculture, respectful of social and environmental priorities.
A recent study based on agroclimatic indices (Trnka et al, 2011) has provided for many European environmental zones marked needs for adaptive measurements to either increase water availability or drought resistance of crops. Rainfed agriculture is likely to face more climate-related risks and more proper management of irrigated crops and are urged to overcome economic uncertainties. Agriculture is currently accountable for 85% of the global water consumption, and irrigated areas are expected to rise by a factor of 1.9 by 2050, globally in the highest percentages where water-scarcity is most intense, namely South Europe Countries (Martindale, 2010). In many of them, crop irrigation has been practiced for centuries, and it is the basis of economic and social activity. Water allows to maximize yield and its inter-annual stability, and in many cases to improve the quality itself. The economic value assumed by water as an input to agro-ecosystems to produce commodities sums to the ecological and cultural values offered form the ecosystem themselves when their multifunctional aspects are considered and exploited (Tielborger, 2010).

Case study irrigation DSS - Italy

Irrigation water use decisions are often made at farm level, and at this scale the first economic impacts are manifest and the advices are essential, but in general the complex issue of improving water use efficiency -WUE- at catchment level requires strongly the highest level of interaction between NMHSs, research scientists, technical staff and policy makers. Proper strategic (short term) and tactical long-term adaptations may be consequently be adopted to drive towards increased sustainable, environmental respectful, equitable food production.
Best practices may be defined as practical, affordable approach to conserving water without sacrificing productivity, maximizing its use efficiency. An effort in this direction is represented by the DSS IRRINET PLUS, developed for Emilia Romagna region and now progressively developing towards the national IRRIFRAME system.
IRRINET-PLUS is an implementation of the irrigation advice service via IRRINET, that is a free-of-charge system managed by Consorzio di Bonifica per il Canale Emiliano Romagnolo (CER), aimed to support farmers with specific custom-built suggestions.
IRRINET has been established in its first version in 1984 by using public founding to test telematics in agriculture (Videotex), and evolved in a Web interface in 1999. GIS extensions were provided in 2002, and in 2003 Web plus SMS (IrriSMS) service firstly started. The software elaborates the irrigation advices for the main crops grown in the region on the basis of water balance, calculated utilizing meteorological data (rain and evapotranspiration) provided by the Regional Meteorological Service, soil data by Regional Geological Service and crop parameters collected by the CER technical service during over thirty years of local experimentation. The suggestion about water amount needed and proper timing of irrigation is also supported by graphs showing the trend of soil humidity from the beginning of the irrigation season.

Farmers register to become full-time users and archive their own farm data, that are definitely stored into the system, and are reached by easy advices on timing and amount of irrigation to the different crops via SMS or web.
So, far, the estimated water saving allowed by using IRRINET (registered users are more than 1000) is about 40-50 M cubic meters of water.
The innovation embedded into IRRINET-PLUS is aimed to offer to farmers an additional indication about economical opportunity deriving by any specific irrigation in a particular crop and at any phenological stage (yield response to water, based on FAO Paper 33). The cost of a single irrigation (water, energy, work, excluding mortgage of the irrigation system, that is considered as a cost at farm level) is calculated according to the indications given by the farmers to the system. The productive value of the same irrigation is computed based on the plausible yield increment consequent to that same irrigation (corresponding to the amount of

yield lost due to water stress and photosynthetic limitation related to missing irrigation). Economic convenience is then derived by fuzzy logic-based calculation.
Simple and easily perceived by farmers information is given. A green light means real advantage, a yellow light an uncertainty, while a red light evidences a clear disadvantage).
Approaches upscaling IRRINET PLUS at basin and catchment level are furthermore possible to obtain the economic evaluation of possible production losses due to increasing drought and lower water supply, economic evaluation of the rain events in given landscapes, economic evaluation of watertable, economic value given from of irrigation to a agricultural region.

Reported economic value of agrometeorological information in the field of plant protection (expert evaluations)

Three of the crops which are researched very well are potatoes, grapes and apples. For these high value crops a number of disease models are in use that have proven their efficiency in numerous field trials as well as in large scale application. Particularly in apples and potatoes the efforts of model development of the pathogen go back many decades and have resulted in algorithms that have found world wide distribution and acceptance, such as the Mills table for apple scab or the Ulrich-Schrodter model for potato late blight.

- Austria: Potato Late Blight
This first case study was conducted by the Austrian Federal Research Labs for Agriculture BFL, in cooperation with the Lower Austrian Machine Cooperative (Maschinenring) of Zwettl in the seasons of 1999 and 2000. Based on weather data collected by local weather stations 3 disease models were tested for their efficiency in predicting Late Blight outbreaks and providing timely recommendations. Amongst these where the German Simphyt Model, the Danisch NegFry model and the Ulrich-Schrodter model as implemented in the software by Austrian manufacturer Adcon Telemetry. All three models were performing fairly well. Compared with the standard treatment procedure an average reduction of sprays of almost 50% could be achieved. Given the average cost per spray of 35 to 40 Euros the achievable savings on a 50ha farm would pay back the investment into a weather station even within the first season.

- Austria: Grape Downy and Powdery Mildew
Since 1992 the Vintners association of the Lower Austrian Retz-Haugsdorf region has systematically built a network of 55 weather stations to feed an Adcon addVANTAGE decision support system running various models for downy and powdery mildew (Kast, Germany, and Gubler-Thomas, California). The stations cover an area of well over 1.500ha of predominantly white wine grapes (Gruener Veltliner) and a small percentage of red (Portugieser, Riesling). Data hosting, collection and processing is done by the local office of Austrias Chamber of Agriculture, whose staff sends out warnings by fax and email. Members pay a very low annual fee of only 10 Euros for this service.
Farm size is small, from 2 to 15 ha, which would usually not permit owners to purchase their own weather stations, computers and software, and to pay a consultant to perform assessments, issue recommendations, establish lists of chemicals, enter treatments into the software, etc. For this purpose the vintners have associated themselves in several larger groups and applied for subsidies towards the purchase of weather stations.
The experience of the last 16 years has shown that farmers using the service could achieve an average reduction of sprays of 35%. The number of treatments averages 5-6, and is in some low pressure years even as low as 3, while the standard treatment methods according to spray plan recommend 8 - 12 treatments per season. Even without the extremely low cost for the service due to the ongoing support by the Chamber of Agriculture the purchase of the equipment would have quickly paid back, as even a small 5ha farm could achieve an annual saving of approx. Euros 600 @ 200 Euros per spray, thus paying back for the station in less than 4 years.

-United Kingdom: intensive apple orchard farming

In 2008 the Fruitlink Producer Organisation in the Wisbech area, eastern UK, have commissioned two local advisory services, Agrovista and Plantsystems Ltd, to cover their growing area with 6 weather stations to feed data into a variety of disease models to control mildew and scab infections, and alert against Codling moth flight, egg deposition and larval emergence. Data (as in the two examples above) is automatically collected and transmitted every 15 minutes to a base station and to a central database, from where it is fed into Agrovistas GCI system. In addition to running a powdery mildew model, manual removal of primary mildew on affected blossoms and the application of potassium bicarbonate is also adding to the reduction of sprays. The combined efforts have led to a reduction in sprays in sufficient volume to pay back for the investment in equipment and consulting service.

-Europe: the fight against Erwinia amylovora ("Fire Blight")

In the last ten years Erwinia amylovora has become epidemic in most European countries, with particularly damaging appearances in Central Europe (Germany, Switzerland, Austria, Northern Italy, Slovenia), devastating large percentages of the regions apple and pear orchards. Being a bacterial disease there is currently only one proven way to treat infected trees (other than scouting and pruning affected parts of trees): the application of an antibiotic such as Streptomycin. However, spraying antibiotics is a highly controversial issue in Europe, particularly since excessive use has lead to the development of resistant bacteria in California, Oregon and Washington state, and since new methods of detection have found traces (albeit microscopic) of streptomycin in honey. This has resulted in an almost total ban in most countries, or in temporary authorizations under tough constraints. One such constraint, e.g. in Austria and Germany, was the condition to use an approved computer model such as "MaryBlyt", as developed by the University of Maryland, USA, or the Moltman Model from South Germany. These models require real time data from weather stations installed in the affected areas. The fact that in Austria´s major apple growing regions, Vorarlberg, the Tyrol, and the South-East of Styria, extensive networks of weather stations have been installed to fight apple scab and mildew, convinced Austria´s Ministry of Agriculture to authorize the application of streptomycin, limiting it to three sprays per season. A spray could only be applied after one of the above models had issued an alarm, generated by locally collected weather data. For farmers whose only alternative in the worst case of an infection would have been uprooting of the affected orchards the payback was a multiple of the investment.

-Greece: Report on the use of weather stations and warning systems for plant protection

Hellenic Ministry of Rural Development and Food

The Hellenic Ministry of Rural Development and Food operates Regional Centers of Plant Protection and Quality Control. These regional centers, among others publish bulletins and provide warnings and advisories for plant protection, operational guidelines and detailed directions on plant protection and treatment for farmers. The Ministry and its organizations and research directorates operate a series of weather stations which provide the data for further processing.

Specific works publihed by these centers can be found on the website of the Hellenic Ministry of Rural Development and Food, at the link: http://www.minagric.gr/index.php/el/for-farmer/agricultural-warnings.html

There are several centers reported at the specific webpage above, and specifically:
Regional Center of Plant Protection and Quality Control of Achaia (Western Greece)
Regional Center of Plant Protection and Quality Control of Irakleion (Crete)
Regional Center of Plant Protection and Quality Control of Thessaloniki (Northern Greece)
Regional Center of Plant Protection and Quality Control of Ioannina (North West Greece)
Regional Center of Plant Protection and Quality Control of Kavala (North Eastern Greece)

Regional Center of Plant Protection and Quality Control of Magnesia (Central Eastern Greece)
Regional Center of Plant Protection and Quality Control of Nauplion (Central West Greece)

Bulletins and warning are available on the web on the links provided above, and also another service to end users exist, which is receiving via email the Agricultural Warning bulletins.
The plants studied at the existing Agricultural Warnings are several, depending on the agricultural focus of each region, and cover annual, perennial, and tree crops. Some of the most widely mentioned are cotton, tomato, fruit tree orchards, and recommendations include from disease probability of occurrence based on expected weather conditions, symptoms, and agronomic and field treatments.

Recommendations

• Agrometeorological services and warning systems can be highly profitable in Europe, especially in the field of irrigation scheduling and pest and disease control. "Profitability" is in this context often closely related to increased efficient use of inputs and therefore contributes to sustainable production methods (i.e. use of less fertilizers, chemicals, water). However, local training and/or experienced extension services in combination with representative online monitoring tools (i.e. agrometeorological stations) and calibrated models is a precondition for successful application. For data providers such as weather services a close cooperation with extension services is recommended for developing reliable tools which can be applied locally (tailored services).

• The economic value of agrometeorological services and products is reported from several case studies, but are still mostly based on subjective methods than on scientific assessments (i.e. economic models). It is recommended that weather services should foster in cooperation with Universities and research Institutions studies on the economic impacts of regional agrometeorological services and products.

• A toolbox for economic impact studies should be developed, especially designed for application environmental services impacts.

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Task A3

3) improve the active collaboration between the farming community in Europe and agrometerological services; develop recommendations	A3.1 Gathering up to date information (on methods, experiences) from extension services / data providers (i.e. questionnaires) A3.2 Recommendations for increasing awareness and stakeholder implementation

Authors: Josef Eitzinger, Bernhard Pacher, Dimos Anastasiou

Introduction

In Europe the status of the use and needs of agrometeorological services and their products was evaluated in the past decade by several studies (e.g. Orlandini et al., 2008; Murphy and Holden, 2001). Dunkel (2002) and Eitzinger et al. (2008) described the institutional structure of agrometeorological services in Europe, where not only NMHSs are involved but in several cases also agricultural research and extension services and others. Similarly, Perarnaud (2004) outlined that the way of how agrometeorological information is developed and distributed in European countries depends on how different actors in the agricultural and food sector are organized and which interest the meteorological services show within this area. Increasing importance is obviously related to the private sector initiative (commercial, companies), which is also confirmed from other studies and surveys, such as from COST734 action (Nejedlik and Orlandini, 2008).

Organization structure of agrometeorological services across Europe

A recent survey across Europe has been carried out in the frame of COST734 (Nejedlik and Orlandini, 2008) in order to get the information on the present use of agrometeorological indices and about their providers.
Both agrometeorological monitoring and service is mostly operated by the national state bodies. In 12 European countries national meteorological and hydrometeorological institutes provide these services. Agricultural services act in some countries at national level but they run the most advisory services at the regional level. Commercial agrometeorological services are scattered and usually concentrate on some specific points of service like extreme weather warning service /in AT and NO/ or advisory services in case of plant protection against pests and diseases /in SK/. In Slovenia (SI) beside agrometeorological network at Meteorological Office another agro-meteorological network is applied under the authority of the Ministry of Agriculture, Forestry and Food (at present the Phytosanitary Administration of the Republic of Slovenia) which has been since 1998 used for public plant protection service and to minor extend also for irrigation. A complex information service for farmers including special weather forecast for farmers provided by a commercial company is organized in FI. In some cases companies selling chemicals or other materials and equipments to farmers include also some technical support and agrometeorological services and/or forecast as a part of their businesses. General agrometeorological information issued at the national level is mostly produced by national bodies e.g. meteorological services as they run the meteorological networks so that they are the owners of the databases. In many cases they cooperate with other national bodies providing them the data either free of charge or at the commercial base.

Applied methods for agrometeorological products/services

The COST734 survey enabled probably the most complete overview on the big number of models and indices currently used in Europe for different operational and scientific applications in agriculture. Due to their simplicity, agroclimatological indices are considered as valuable tools for research and operational applications. Particularly, the possibility of using wide temporal time steps (daily, weekly, monthly) makes these indices suitable for application with historical climatic series. There are few cases (e.g. drought indices, grapevine quality index), where indices also include thresholds describing the consequences of obtained values and recommended interventions needed to manage and to protect crops from climate related impacts. The results of the questionnaires pointed out their large use at European level for many purposes, spatial (regional, national) and temporal (nowcasting, past-casting, forecasting) scales. Especially for indices, it seems also to be clear, that there is a need of standardization and harmonization of applications in Europe in order to allow inter-comparison and to improve the interpretation of results.
The more complex approaches, namely process oriented models, are still very limited in operational applications (especially crop yield models), except for the more simple models (e.g. crop water balance models focusing on irrigation scheduling rather than on yield estimates), or widely applied models for pest and disease management. In research, however, process oriented crop models play a very important role in the assessment of global and climate change impacts on agriculture. A majority of these studies were carried out on a larger scale, neglecting the necessarily finer spatial resolution to be of relevance for local adaptation recommendations for farmers. One of the main difficulties for the spatial application of process oriented crop models in a high spatial resolution at the research level is often the lack of model input data (not available, high costs, expensive data management, etc.). On the other hand, new methods are currently being developed to overcome these problems by using GIS and integrating remote sensing data. Only very few examples exist for operational crop yield forecasting which integrate all these available tools, and they are only used at the expert level.
Beside the effects of climate change on crop productivity, which are the dominating studies till now, it is recommended that the modeling community should also have a closer look on other aspects such as soil fertility, and environmental issues like groundwater recharge and water quality, soil carbon stocks, erosion, trace gas emissions, etc., in the future. Integrated modeling approaches are thus required and should reflect the most relevant interactions in the soil-crop-atmosphere system. Furthermore, we should also try to combine our modeling of climate change impacts with ideas and experiences of sustainable production.

Case study Greece:

Agrometeorlogical knowledge dissemination and interaction with the local farming communities is made by several national, regional and local services of the Ministry of Rural Development and Food. Agrometeorological considerations are an inherent practice of agronomic decision making and practice in Greece.
Local and Regional authorities and directorates of Agriculture through their decentralized offices interact and can provide services to local farming communities. For example, the Agronomists of such services guarantee both an academic background in agrometeorology (through their Agronomic academic training) combined with local and regional experience of their geographic area of interest.

In Greece, there is also a special weather forecast provided by the National Meteorological Service and broadcasted by the National Television Network. The forecast also provides advisory information for new practices, products and has special issues for plant protection according to phenological stage and plant species. Except from the National Meteorological Service and the National Observatory of Athens, Universities and private or public institutes provide weather and agrometeorological information. This information is provided on user's request or published as results of research programs.

The Regional Centers of Plant Protection and Quality Control provide regional and local information services on plant diseases and agrometeorology (please refer to previous paragraphs of this report for more details).
The National Agricultural Reseach Foundation, through decentralized Offices and research stations can provide services to local community. Such services have a wide range of application to the agricultural practice.
The Hellenic National Meteorological Service, Universtities and Research Institutions, conduct own meteorological and/or agrometeorological reseach which then can be used by the local agricultural directorates and services.

Recommendations

• Careful evaluation is necessary on how to improve active collaboration between the farming community in Europe and agrometerological services. This may depend on the existing institutional structure of agrometeorological and extension services, the regional structure of agroecosystems and socio-economic conditions, which vary widely in the RA VI region.

• From several experiences a pure bottom up approach will not work, adoption is too slow. In case of suitable socio-economic conditions pioneer farmers adopt technology autonomously, all others need incentives or force - top down. Both bottom up and top down approached need to be combined depending on the regional agronomic conditions.

• A mix of specific actions is recommended:
- improve education of the next generation of farmers = revised study plans
- implement legislation as to the usage of meteorological data, e.g. implement EC Directive 128 in the strictest of senses, closely tying the application of pesticides to the availability of agrometeorological data
- offer better consulting services (Europe has a very low number of consultants per 1.000 farmers)
- provide easier access to raw and processed agrometeorological data (incl. soil data)
- implement a system of reward to those who best apply state-of-the-art technology, e.g. base the grant of subsidies on this.

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Task A4.1 & A4.2

4) best practices for agrometorological products; review, evaluate and/or recommend	A4.1Define region specific and stakeholder specific user requirements A4.2 Review, evaluate and/or recommend standards for agrometeorological products considering regional aspects, temporal/spatial scales, technology, etc.

Authors: Josef Eitzinger, Levent Saylan

Summary

A questionnaire was designed and sent out to agrometeorological services of the participating countries. Due to weak response and regional coverage for the RA VI region this task could not be fulfilled, regarding the evaluation of regional aspects.

From the existing feedbacks, often named problems of regional agrometeorological services are related to agrometeorological data availability and lack of qualitative data from measurement networks (e.g. soil water mesurements) for the development and application of operational products.
Especially in Eastern European Countries (i.e. Hungary, Croatia) there is a significant problem with decreasing financial budgets for operational agrometeorological services at institutional level. This has also consequences for the research area and the attractivity for young scientists, and there is an increasing gap of regional Know-How transfer to the next generation.

An example from a filled questionnaire (commercial company - Austria) is shown below as well as a case study description from Greece.

Example - Case study Greece:

Some of the agrometeorological services provided by the Regional and National Agricultural Authorities in Greece are given in the section A2-1. In the same spirit of these agricultural warnings, some proposals from stakeholders are made below.

Recommendations and proposals

End users and farmers can best utilize a ready to use guidance document, which shows a brief weather forecast and crop/locality specific agrometeorologic recommendation. An example of such service can be the Agricultural Warnings Service mentioned at a previous paragraph of this report.
The temporal scale of such warnings can follow the one of the already existing meteorological forecasts. Special attention can be given to time periods of importance for the farming community:
For example, in the case of cereals, it is very important to know meteorological conditions during fall and early winter in order to adjust the seeding dates. Agrometeorology condition

forecast is extremely important, in order farmers to be able to sow and after that there should be a period wet enough for plants to germinate and grow.
The above is higly correlated with the spatial scale of agrometeo forecasts, which can be as high resolution as possible in order to provide local forecasts. NWP products of high resolution for example can serve this propose at a local level.
Customization of local forecasts to the crops used locally: the forecasts should adapt to local crop variability and provide custom recommendations for the area of interest.

Examples of agrometeorological and meteorological products are given on next pages of the report (and on section A4.2 for agricultural warnings for diseases/pests/agrometeo)

Example

Questionnaire - Agrometeorlogical products and services, experiences of company ADCON

WMO – RA VI; Task team Agrometeorology

Questionnaire – related to TOR 4 (see file TT-Agromet_Workplan_Final.doc)

(prepared by Levent Saylan, Turkey)

Your service (name, organization): ADCON, commercial company (weather stations and service for farmers), Austria

Topic	**Question**	**Answer (*If necessary you can use additional pages for the answer).**
1.) Agrometeorological Services	What are the components (products) of your agrometeorological services? Who uses these services, for Which purposes and how?	Components: -Weather stations -Soil Sensors (Moisture, Conductivity, Temp. -Pest&Disease Models -ETo and ETc Models -Irrigation Models -Generic Statistics -Alarms -Valve control Users: -Governments -Cooperatives -Chambers of agriculture -Corporate Growers -Food Processors -Agro-Chem Companies -Consultants -International Relief Organisations (FAO, WFP, Oxfam, etc.) -Research/Universities Purposes:

		-Better timing of ag-chem application (disease risk, wind drift, temperature,...) -Improving irrigation practice - reduce water, energy and fertilizer usage - avoid salinization -documentation/ traceability -index insurance How: -in most cases experienced consultants evaluate the data and distribute recommendations by fax or mail or phone call.. Depending on the size of the farm the consultant is either an employee of the grower (corporate farms), the government, the chamber of agriculture, or a private consultant -in some cases only generic data is made available to farmers who ned to draw their own conclusions -insurance companies assess weather phenomena during and after the growing season to determine payouts - government use data to calculate yield and make decisions regarding food imports
2.) Needs for agrometeorological information (services)	Are the quantity and quality of the presented/serviced agrometeorological information compatible with the agrometeorological needs of farmers?	This varies largely from user to user, and depends a lot on the farmers education (=ag-met related knowhow), their farm size, their level of mechanization, their way of operating their farm (conventional vs. organic; full-time vs. part-time), on the type of customers they have for their crop; general observation: farmers on average have ways too little knowhow of application and benefit of agromet data and equipment
3.) Studies/works until now in order to increase the usage efficiency of agrometeorological information (products).	What kinds of studies/works have been done by your organizations in order to increase the usage efficiency of agrometeorological services (information) by farmers/users?	Continuous interviews with users to find out which kind of services they want, how this information is to be presented, how the usability can be improved. In addition workshops are offered to various topics, not only to familiarize farmers with the use of the equipment, but alos to increase their knowledge; participation in national and international conferences as presenter/ speaker to raise awareness; lobbying with law-makers to educate them on the current state-of-.the art and make its usage compulsary
4.) Studies to	Do some study plans exist	An extensive customer survey will need

be planned for an enhanced usage efficiency of agrometeorological data.	to satisfy the need given in item 4 in the future? If yes, please explain what they are and when they can become fact?	to answer the question why farmers are so reluctant on making more and better use of agro-met data and its derivatives. Experience shows that the large majority of farmers don't want to learn how to use agromet data and related software. They want processed data to be readily and easily available. The study will have to see what kind of "push services" to improve data delivery are desired by farmers, on which platforms (iPad, iPhone, SmartPhone, etc.), in which frequency and at which cost. This is an ongoing process that ahs already started.
5.) Studies being conducted for an enhanced usage efficiency of agrometeorological data.	Please explain briefly whether a relevant method is in use of your institution? If yes, what is the related application?	Overlap with Q4 No specific methods other than systematic interviews are applied.
6.) Possible feedbacks of the studies being conducted for an enhanced usage efficiency of agrometeorological data.	What are the results obtained and being obtained through the relevant activities (educational, etc.)?	-Such data has to be presented in a simple and very easy way to understand -clear recommendations, not just raw data -comprehensive overviews of the season -delivery without the need to log onto a website -push service to cell phones preferred - Fax is a very much desired delivery method
7.) Introducing the present status of the studies to be conducted for an enhanced usage efficiency of agrometeorological data.	Do the relevant results of a possible survey study exist in your institution? If yes, please send the results as well as your opinion on it's general aspect.	Surveys conducted amongst Austrian users (farmers, consultants, research) show a very fragmented usage of data: - Farmers: only to an extremely small extent (less than 10%) are farmers interested in raw meteorological data. They are not willing to take efforts to retrieve such data, but expect processed data to actively be delivered to them, preferably by fax or mobile phone. - Consultants of the Chambers of Agriculture: daily users. However, a continuous reduction in manpower and resources has led to a less than optimum usage, with microclimatic data being interpolated for large regions, and site specific recommednations and services being avoided. - Research: currently the only efficient

		users of ag-met data
8.) Suggestions for an enhanced usage efficiency of agrometeorological data.	From your point of view; what are the necessary future studies should be done in that area?	
9.) Existence of a possible agrometeorological measurement net	Is there an agrometeorological measurement (stations) net and/or a related research center dependent to your institution? If not, do you have any plan on establishing it/them in the future?	There are several networks in Austria, which can be accessed by BOKU. Two, consisting of a total of 30 stations, are operated by the University, and serve research purposes regarding plant protection, irrigation, and the influence of climate and soil on the quality of whine. The other 8 networks are privately owned, but operated by the Chamber of Agriculture. They consist of a total of approx. 300 weather stations, which are predominatly used for plant protection purposes.
10) (If the answer to the question of item 10 is "yes") Usage of the WMO standards in the agrometeorological measurements and observations	Are the properties of your existing/planned net (or system (sensors)) compatible with WMO standards? Have the WMO criteria for the selection of stations been applied? Were the concerning opinions of the responsible institution taken? Have they been applied?	"Terroir Burgenland" - Equipment is compliant, measuring methods are compliant, timing is not - measuring intervals are not based on WMO standards, but on standardized and common 15-minute intervals. All other networks consist of a mix of equipment, which is - depending on its age/date of installation - partially WMO compliant, partially not. Site selection in agriculture was never done in accordance with WMO criteria, but always in accordance with the requirements of the respective plant protection models that are operated with the stations data. WMO rules are often in conflict with a disease models' requirements, which has led to the preference of model vs. WMO.
11.) Institutions collecting agrometeorological data	Are the collected data of your net (system) kept together in a main organization? If not; do you experience some related difficulties?	There are two main entities collecting agro-meteorological data in Austria: 1) The Chambers of Agriculture, which make the data avilable to the interested public (= to farmers as members of the organization) and for research purposes. 2) University data is partially collected by the University through its own infrastructure, partially ("Terroir" network) hosted by a third party and transferred to BOKU. An NDA secures data confidentiality.
13.) Taking advantage of	Were any academic help (universities) of the	Consulting with experts from ZAMG with respect to the selection of sensors, the

experts in agrometeorology	domestic experts in related areas (e.g. sensors) taken for your existing/planned net ? If yes; have these opinions been carried into effect? Are you in continuous cooperation with these experts for ongoing progresses and future plans?	implementation of proper measuring methods and the check of sensor data regarding plausibility; cooperation with experts for plant protection regarding the improvement of data processing (disease models) In general there are several conflicts that need to be considered when talking to experts: - Sensor selection is based on 3 criteria: quality, robustness, budget, each of which can lead to compromises with the other. Main motto: “fit for the job” - good price-performance ratio and long lifetime under agricultural conditions. . Site selection: agri-cultural requirements dominate over meteorological requirements - Maintenance: only too often data quality is compromised by a lack of maintenance, caused by a lack of budget. This is more dangerous to the quality of data than improper selction of components or installation sites
14.) Improving the present agrometeorological database.	Please specify the types of the new (additional) agrometeorological data, which should be measured and observed continuously by your institution.	- Soil moisture, temp. and conductivity on various levels - Air temperature and rel.H. on additional levels - PAR - Precipitation at a much higher density of instruments

Task A4.3

4) Best practices for agrometeorological products; review, evaluate and/or recommend	A4.3 Explore efficiency of seasonal and ensemble weather forecast for agrometeorological purposes

Authors: Branislava Lalic

Introduction

As a result of joint efforts of interdisciplinary scientific community, with meteorologists in the "leading role", a vast number of sophisticated meteorological products are available now. Short range weather forecast (with 10 km spatial resolution), ensemble forecast, monthly and seasonal forecasts and climate model simulations are result of continuous work on improvement of all aspects of numerical weather prediction (NWP). Accuracy of some NWP simulations is not satisfactory yet; however, their testing and non-operational use offers a wide range of possibilities (see case studies in Annex 2-3).
The review of NWP application-related papers and services shows that end-users community is not well informed about features, applicability and ways of use of different NWP products. From the point of view of agrometeorological community all above indicated kinds of NWP are very important.
The main goal of this task is to explore the efficiency of seasonal (long range weather forecast-LRF) and ensemble weather forecast application for agrometeorological purposes.

Questionnaire results (see Annex 1)

The main aim of this questionnaire is to examine factors affecting the use of LRF by agrometeorological and agricultural experts and producers. Especially important is information related to level of understanding of available LRF, appropriate format of presentation of LRF and attitude of targeted group regarding the usefulness of LRF and consequent indicators of future weather and agrometeorological conditions. Similar studies were conducted in many regions especially in those with agriculture vulnerable to extreme weather events.

<u>According to results obtained from our questionnaire (Annex 1) it can be concluded that:</u>

- In some countries (Croatia for example) LRF has been used for agrometeorological forecasting purposes for different users (farmers, wine and olive growers). There is also group of countries in which, for the purpose of agrometeorological advice services, national weather service makes no use of seasonal weather forecasts. In Germany, for example, the agricultural community has shown no need for this, neither those responsible for consulting the farmers nor the farmers' associations and agricultural policy-makers.
The availability of monthly and seasonal forecasts (on the basis of ECMWF predictions) and their usability for policy-makers and associations have been brought up to discussion at various occasions, but without satisfying response. The reasons for this are manifold. The main aspect, however, is the hesitant attitude towards the spatial and temporal resolution of seasonal forecasts, in particular that of precipitation forecasts, which continues to be considered as insufficient. As far as we know, none of the other agricultural consulting institutions in Germany uses seasonal forecasts.

- Some of the main limitations of LRF are low horizontal resolution and skill. Therefore only the probabilistic approach could have some benefit.

- First results of monthly forecast applications in Serbia and Austria indicate its high skill in crop modelling and irrigation management application. On the other hand its use for plant protection management is very limited since pest and disease application forecast assumes high skill of short range weather forecast and site representative data.

Literature review results

According to literature review current status of LRF application for agricultural purposes indicate moderate to low level.

Scientific level: During the last decades, a significant effort was invested in defining principles of providing information about growing season characteristics and crop model input data in advance of the season. For that purpose LRFs were assimilated either from ensembles of atmospheric models run with the same initial and boundary conditions or from ensembles obtained using the one atmospheric model which was run with perturbated initial and boundary conditions.
An new method for supplying seasonal forecast information to crop simulation models was offered by Cantelaube and Terres (2005). It consisted in running a crop model from each individual downscaled member output of climate models and then deriving the probability distribution function (PDF) through an ensemble of crop yields. PDFs of wheat yield provides information on both the yield anomaly and the reliability of the forecast. However, significant contribution to this research field comes from the DEMETER project consisted to test ensemble of seasonal climate forecasts potential for crop yield forecasting (Palmer et al., 2004; Marletto et al., 2005).
Conceptually different, but also useful, method was proposed by Hansen and Indeje (2004) for linking crop models with dynamic seasonal climate forecasts which includes classification and selection of historic analogs, stochastic disaggregation, direct statistical prediction, probability-weighted historic analogs, and use of corrected daily model output.
Special attention to LRF was devoted in case of regions affected by the ENSO phenomenon (Meinke and Stone, 2005; Mulen, 2007; Subbiah and Kishore, 2001) and in some parts of world which are especially vulnerable to extreme weather events and climate change (Huda et al., 2004; Jones et al., 2000; Harrison et al., 2007; Marletto et al., 2005).

Planning and Food supply chain: Advance warning of such events as drought, flooding, hot/cold spells, etc. through LRF can minimize various socio-economic problems which are often associated with such events. Advance warning of impending extreme climate events, especially within time scales of one to six months, would provide vital information which could be used for sustainable agricultural production (Fraisse et al., 2004; Ferrari, 2010; Hansen, 2005; Hansen et al., 2006; Ogalloa et al., 2000; Andre et al., 2010; Das et al., 2010). However, LRF can significantly affect the supply process through impacts on growing operations (planting/harvesting timing, fertilizer/pesticide acquisition and use, irrigation, crop selection, seed purchase), crop growth rate, storage and transport requirements (i.e. cooling chain), insurance, marketing and consumer demand (sales) (Davey and Brookshaw, 2011).
From the point of view of agricultural planning (strategic or tactical), significance of seasonal forecast is manifested through its potential to: minimise business risk, optimize the potential for reducing production costs through improved planning, optimize the marketing opportunity to meet consumer demand and optimize environmental care (Andre et al., 2010).

Decision support systems: Agriculture decision support system based on fully integrated NWP model outputs of different rage with process-based agricultural models is powerful tool of modern agriculture. The agricultural advantages derived from LRF can be, in general, summarized through the principle of providing information about growing season characteristics in advance of the season (Calanca et al., 2011; Fraisse et al., 2004; Schneider and Garbrecht, 2002; Das et al., 2010). Model-based "discussion support system" contribute to learning and farmer–researcher dialogue but it has limited role in efforts to support climate risk management in agriculture (Hansen, 2005).

Conclusions

The main goal of this task was to explore efficiency of seasonal and ensemble weather forecast application for agrometeorological purposes. In order to access these tasks the following activities were carried out:
a) a questionnaire was designed in order to explore availability and use of monthly and seasonal weather forecast;
b) case study, based on ECMWF monthly forecast for two selected locations, has been performed in order to assess applicability of this type of forecast for agrometeorological purposes.
According to results obtained from questionnaire it can be concluded that:

• In some countries (Croatia for example) LRF has been used for agrometeorological forecasting purposes for different users (farmers, wine and olive growers). There is also group of countries in which, for the purpose of agrometeorological advice services, national weather service makes no use of seasonal weather forecasts.
• Some of the main limitations of LRF are low horizontal resolution and skill. Therefore only the probabilistic approach could have some benefit.
• First results of monthly forecast applications in Serbia and Austria indicate its high skill in crop modelling and irrigation management application. On the other hand its use for plant protection management is very limited since pest and disease application forecast assumes high skill of short range weather forecast and site representative data.

Recommendations

• In order to strengthen the use of LRF for promising applications (e.g. food chain management – cooling, transport, storage conditions) an information campaign and expert training especially for Agricultural Ministeries, Insurances, Extensions services is recommended.

• One of the most important limiting factors in application of LRF is end-user availability of data. If national weather services as a members of ECMWF are ready to make LRF easy available in ASCII format through their own web pages, it can improve wider application of LRF.

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ANNEX Task A4.3

Annex 1

Questionnaire - interim results (answers)

Question	Country	Data supplier	Answer
Do you/your Institution use seasonal weather forecast information?	Croatia	Visnja Vucetic	Yes. For agrometeorological forecast purpose for different users (farmers, wine and olive growers) two months ahead.
	Germany	Ulrich Otte	For the provision of its agrometeorological advice services, the Deutscher Wetterdienst makes no use of seasonal weather forecasts. So far, the agricultural community has shown no need for this, neither those responsible for consulting the farmers nor the farmers' associations and agricultural policy-makers. The availability of monthly and seasonal forecasts (on the basis of ECMWF predictions) and their usability for policy-makers and associations have been brought up to discussion at various occasions, but without satisfying response. The reasons for this are manifold. The main aspect, however, is the hesitant attitude towards the spatial and temporal resolution of seasonal forecasts, in particular that of precipitation forecasts, which continues to be considered as insufficient. As far as we know, none of the other agricultural consulting institutions in Germany uses seasonal forecasts. In the medium future, Agrometeorology at the DWD will deal with the issue of yield modelling. Then, the question about the usability of seasonal forecasts will come again to the fore. As the national meteorological service of Germany, the Deutscher Wetterdienst does provide monthly and seasonal forecasts (that are based on the predictions of the ECMWF). The users of these are the German energy industry, the tourism sector as well as the beverage and textile industries.
	Hungary	Sandor Szalai	No.
	Serbia	Branislava Lalic	Yes.
Do you use seasonal weather forecast in qualitative/descriptive form (maps, diagrams etc.)?	Croatia	Visnja Vucetic	Yes. We use the ECMFW maps and diagrams of predicted deviation of monthly mean of air pressure, air temperature and precipitation over Europe and Croatia two months ahead. The horizontal resolution of ECMWF maps is 0.25°×0.25° and temporal resolution is monthly, six months ahead.
	Hungary	Sandor Szalai	No.

	Serbia	Branislava Lalic	Yes.
Do you use seasonal weather forecast in quantitative form (specific values related to, for example, maximum daily temperature)?	Croatia	Visnja Vucetic	No. However, we would like to apply quantitative values of ECMFW seasonal weather forecast (T_{max}, $T_{min,}$ RAD and PREC) for crop forecast using crop model in near future.
	Hungary	Sandor Szalai	No.
	Serbia	Branislava Lalic	Yes. For scientfic purposes only.
Do you/your Institution use ensemble/monthly weather forecast information? If yes, for which purpose	Croatia	Visnja Vucetic	Yes. For agrometeorological forecast purpose for different users (farmers, wine and olive growers)
	Hungary	Sandor Szalai	No.
	Serbia	Branislava Lalic	Yes. For scientfic purposes only.
Do you use ensemble/monthly weather forecast in qualitative/descriptive form (maps, diagrams etc.)?	Croatia	Visnja Vucetic	Yes. We use the ECMFW maps of mean weekly air temperature and weekly precipitation amount over Croatia a month ahead
	Hungary	Sandor Szalai	
	Serbia	Branislava Lalic	Yes. For scientfic purposes only.
Do you use ensemble/monthly weather forecast in quantitative form (specific values related to, for example, maximum daily temperature)?	Croatia	Visnja Vucetic	No.
	Hungary	Sandor Szalai	No.
	Serbia	Branislava Lalic	Yes. For scientfic purposes only.
Please indicate the main limitations/problems in seasonal weather forecast use/application:	Croatia	Visnja Vucetic	The main limitation in seasonal weather forecast is that monthly maps and diagrams are only available for agrometeorological forecast. We also need daily predicted meteorological values as maximal and minimal air temperature, precipitation and solar radiation for example for crop modeling purposes. However, the low horizontal resolution of global circulation model could be one of limitations in application of seasonal forecast for crop modeling purpose. Other limitation is lack in human resource in the Agrometeorological Department because there are not any young scientists. There are only two

			senior scientists and a senior expert. They cover the all agrometeorological researches (climate change, extreme events, crop modelling, wildland fire risk and phenology) and activities (agrometeorological bulletin, agrometeorological forecast for TV, radio, SMS, newspapers, weekly and monthly magazine and agrometeorological information for different users). Insufficient support of informatics in agrometeorology is also problem due to lack in human resource in the Department of Informatics. It is similarly for monthly weather forecast for agrometeorological purpose. The mean weekly air temperature and weekly precipitation maps over Croatia are only available a month ahead but we need predicted daily data, too. For agrometeorological forecast there are daily maximal and minimal temperature, 3-hourly of air and soil temperatures, air pressure, relative air humidity, soil moisture, precipitation, evaporation, insolation duration and solar radiation ten days ahead. But sometimes it is not enough long predicted time series of meteorological data. Limitation is also lack of human resource.
	Hungary	Sandor Szalai	The skill is too low, therefore only the probabilistic approach could have some benefit. For this purpose, a large capacity building project would be necessary, The internal sources are not comparable with the request of such a project. The role of the (hydro)met. service is doubtless. Unfortunately, the Hungarian Met. Service has several other problems and does not pay attention to this topic.
	Serbia	Branislava Lalic	Use of seasonal forecast in this phase of application in Serbia assumes a lot of testing and identification of limits of application.
Please indicate the main limitations/problems in ensamble /monthly weather forecast use/application:	Croatia	Visnja Vucetic	It is similarly for monthly weather forecast for agrometeorological purpose. The mean weekly air temperature and weekly precipitation maps over Croatia are only available a month ahead but we need predicted daily data, too. For agrometeorological forecast there are daily

			maximal and minimal temperature, 3-hourly of air and soil temperatures, air pressure, relative air humidity, soil moisture, precipitation, evaporation, insolation duration and solar radiation ten days ahead. But sometimes it is not enough long predicted time series of meteorological data. Limitation is also lack of human resource.
	Serbia	Branislava Lalic	First results of monthly forecast application indicate its high skill in crop modeling and irrigation management application. On the other hand its use for plant protection management is very limited since pest and diseas application forecast asumes high skill of short range weather forecast.
	Hungary	Sandor Szalai	The skill is too low, therefore only the probabilistic approach could have some benefit. For this purpose, a large capacity building project would be necessary, The internal sources are not comparable with the request of such a project. The role of the (hydro)met. service is doubtless. Unfortunately, the Hungarian Met. Service has several other problems and does not pay attention to this topic.

Annex 2

Case study: Efficiency of monthly forecast application for agrometeorological purposes

Method:

- Ensemble forecasting system for time range up to 30 days is operational in ECMWF (European Centre for Medium range Weather Forecast) since October 2004. Monthly forecast is short enough to keep some information from the initial state and long enough that the ocean variability can impact atmospheric circulation. Coupled model consists of the ECMWF atmospheric model and ocean general circulation model which is a version of the Hamburg Ocean Primitive Equation model (HOPE).
Every Thursday the coupled model is integrated forward to make a 32 day forecast with 51 different initial conditions, in order to create a 51-member ensemble. The first 10 days performed with a TL399L62 resolution forced by persisted SST anomalies (updated every 24 hours). After day 10, the model is coupled to the ocean model and has a resolution of TL255L62.
Monthly EPS products are available once a week in GRIB format with the horizontal resolution 0.5° x 0.5° in latitude-longitude grid and 11 standard pressure levels. Depending of requirements it is possible to use raw forecast data as well as weekly means.Our efforts were directed in two courses. The first was to use raw ensemble products applying simple statistical approach; the other was using ECMWF monthly forecast products as a boundary conditions for WRF NMM model run.
Downscaling was developed using WRF NMM model 3.3 version with horizontal resolution of about 20 km. Problems appeared in spatial distribution of precipitation and monthly amount of precipitation. That leads to question of adequacy of using monthly products for boundary conditions.

- From the monthly weather forecast variable list were select those variables which are required for agrometeorological purposes: maximum and minimum daily temperature, daily amount of precipitation, daily sum of global radiation, daily average of relative humidity and wind speed.

- At first step all calculations were made using ECMWF 50 x 50 km resolution.

-One representative data set (for 2005 season from March to July) of past weather was established based on monthly weather forecast asimilated from control run only. This data set contains daily data of sunshine radiation, temperature, air humidity, precipitation and wind.

- Agrometeorological indices calculated using observed data were compared with indices obtained using representative data set. All results can be find below:

NWP products of interest in agrometeorology

- Short-range weather forecast (out to 5 days)
- Medium-range weather forecast (out to 15 days)
- Monthly forecast (10 to 30 days)

- Seasonal forecast (out to 7 months)
- Climate model simulations (decades)

In forthcoming text denotations GS – Groß-Enzersdorf (Austria) & NS – Novi Sad (Serbia) were used for two stations in Austria and Serbia for which all calculations were made while obs and month are shortages used for observed and monthly weather data.

Monthly forecast application – **agrometeorological conditions March – June 2005**

		March		April		May			June		
	Year	FrostDay	FreezDay	FrostDay	FreezDay	TropDay	SumDay	TropNig	TropDay	SumDay	TropNig
GS obs	2005	13	5	4	0	3	10	0	2	19	0
GS month	2005	23	6	4	0	1	4	0	6	17	1
NS obs	2005	15	2	1	0	4	12	0	3	18	0
NS month	2005	17	0	4	0	2	8	2	11	21	3

				Tmean		Rain		Water balance		Effective temperature				FrostStress	
	Year	LateFrost	HeatStress	AMJ	MAM	AMJ	MAM	AMJ	MAM	SumT_0	SumT_5	Sum_10	Sum_15	T_10Ex	T_10
GS obs	2005	23.04.	0	15.30	10.7	144.1	100	-181	-151	1611.7	1027.8	430.5	123.4	1431	1
GS month	2005	13.04.	0	14.3	7.9	182.5	176	-330	-162	1392.6	882.7	460.8	160.4	1177	1
NS obs	2005	02.04.	0	16.0	11.5	206.9	99	-128	-158	1695.3	1103.5	252.1	137.1	1604	0
NS month	2005	14.04.	0	16.2	9.9	122.2	160	-482	-235	1596.9	1083.5	635.1	197.3	1521	0

SPRING CROPS

	Year	Dry start		Dry intensive		Dry extreme		Dry very extreme		Dry complete		DryRat	Sowing		Harvest
		AMJ	MAM	AMJ	MAM	AMJ	MAM	AMJ	MAM	AMJ	MAM	AMJ	pring_ea	pring_lat	Jun
GS obs	2005	44	40	34	33	18	25	9	17	0	0	0.51	32	14	22
GS month	2005	57	37	45	28	32	22	13	13	0	0	0.42	11	10	25
NS obs	2005	38	36	24	29	13	21	5	13	0	0	0.58	29	14	22
NS month	2005	72	42	54	26	41	21	26	15	0	0	0.35	16	11	25

WINTER CROPS

	Year	Dry start		Dry intensive		Dry extreme		Dry very extreme		Dry complete		DryRat	Sowing		Harvest
		AMJ	MAM	AMJ	MAM	AMJ	MAM	AMJ	MAM	AMJ	MAM	AMJ	Spring_early	Spring_late	Jun
GS obs	2005	80	57	51	33	11	1	1	0	0	0	0.39	32	14	22
GS month	2005	60	30	46	16	34	4	19	0	5	0	0.36	11	11	25
NS obs	2005	69	52	40	26	12	2	2	0	0	0	0.45	29	14	22
NS month	2005	81	51	63	33	44	14	30	1	12	0	0.26	16	11	25

BLIGHT OF GRAPEVINE

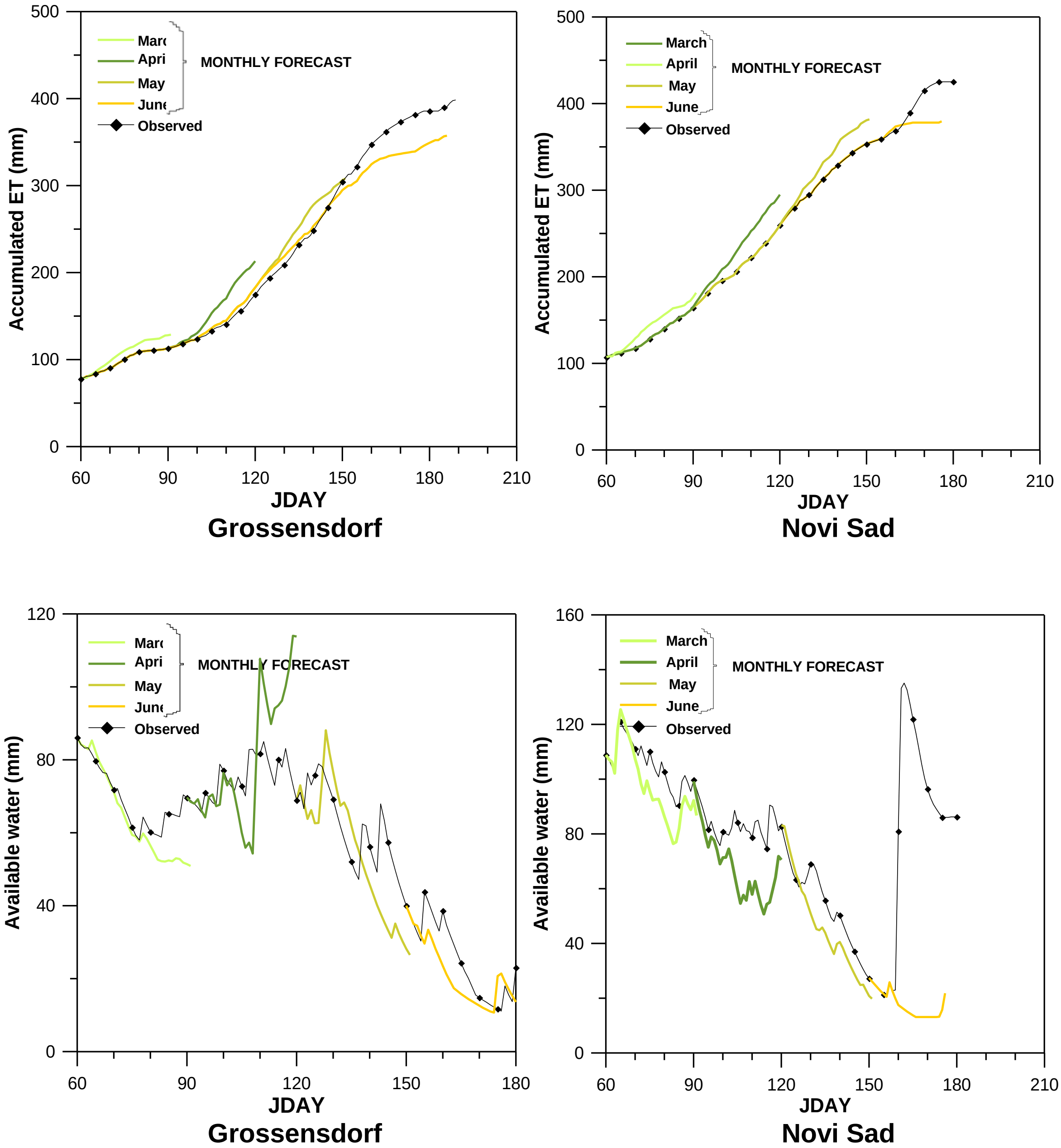
Grossensdorf - no conditions for accurence of infection

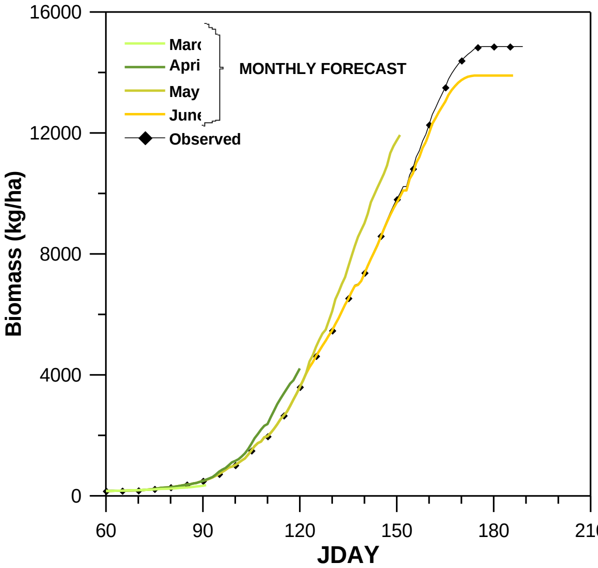
Novi Sad

	Observed	Control run			
Start of IP	117	135	140	142	177
End of IP	124	140	145	146	179
Duration	7	5	5	4	2
No. IP	1	4			

IP – incubation period

SIRIUS: WINTER WHEAT





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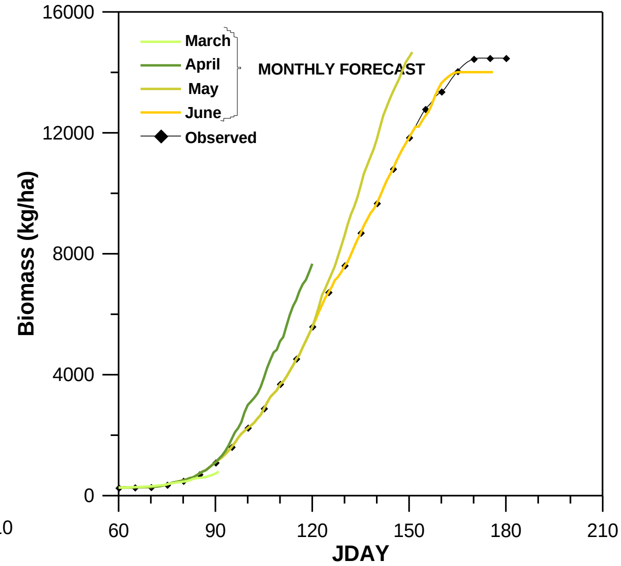

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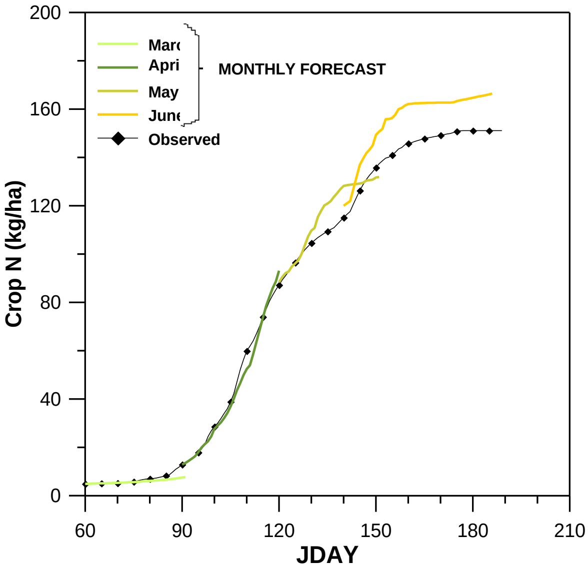

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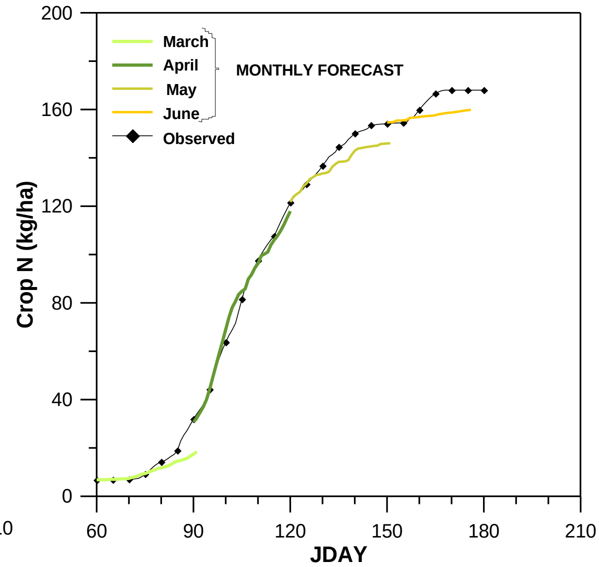

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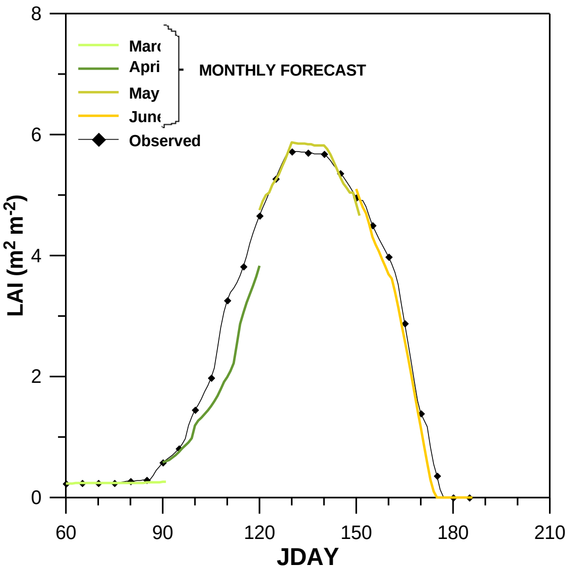

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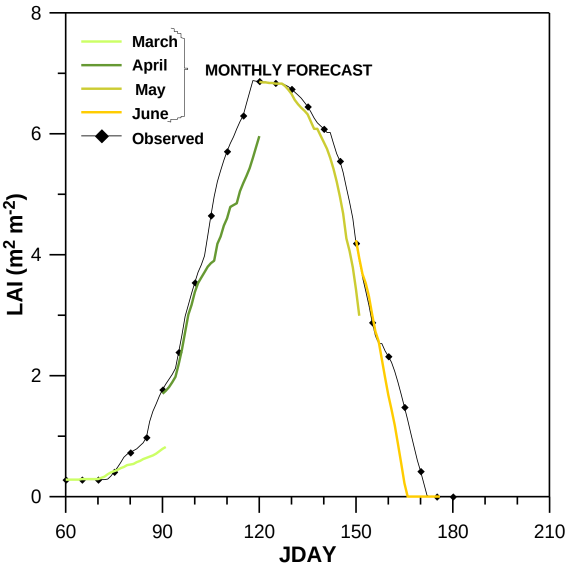

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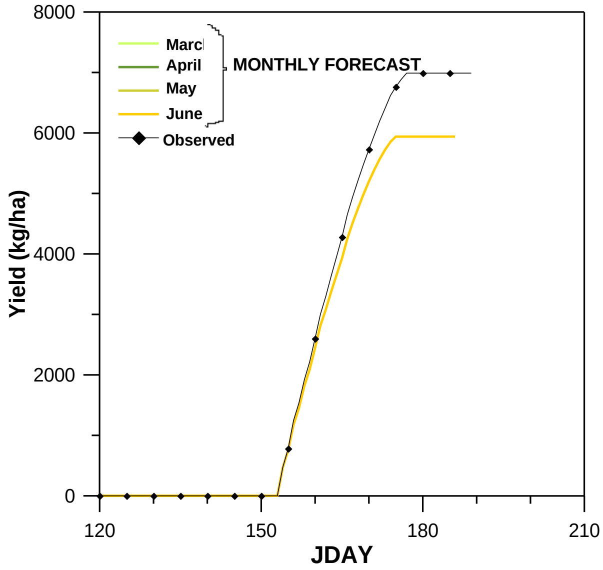

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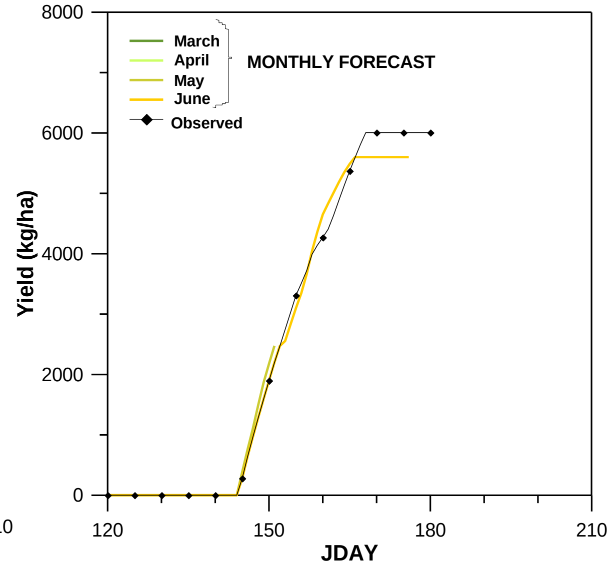

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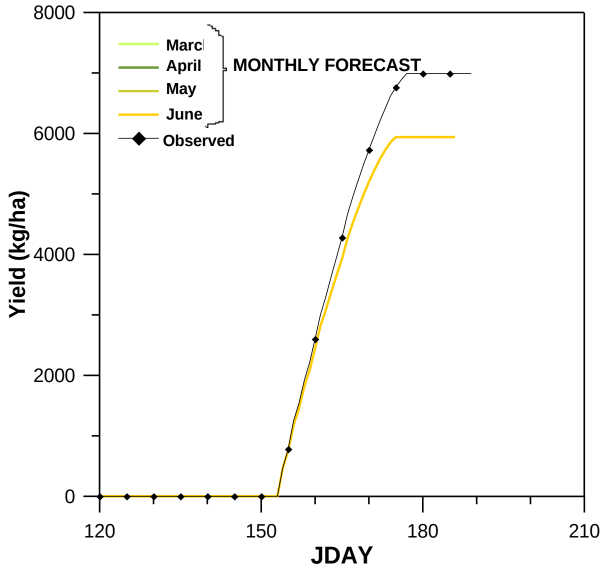

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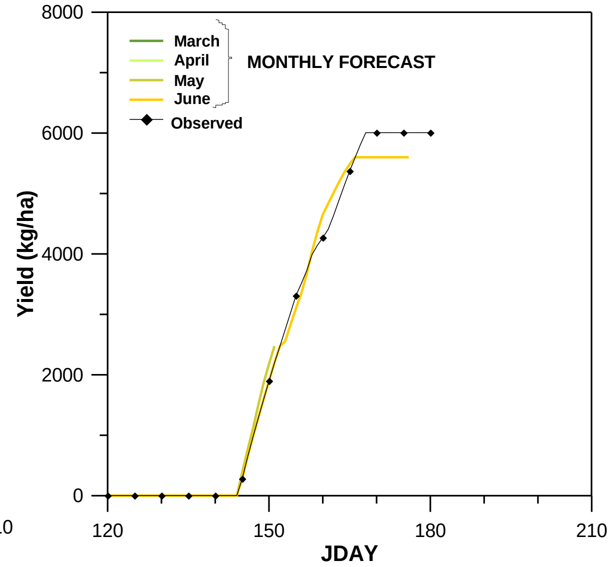


Novi Sad

	ET (mm)	Max def. (mm)	Anthesis day	Maturity day	Biomass at anth. (kg/ha)	Biomass (kg/ha)	Yield (kg/ha)	CropN (kg/ha)
GS obs	395	187	149	190	9597	14859	6989	151
Gs month	355	145	149	187	9505	13899	5940	166
NS obs	425	136	139	181	9487	14473	6006	168
NS month	379	143	139	179	9904	14478	5920	160

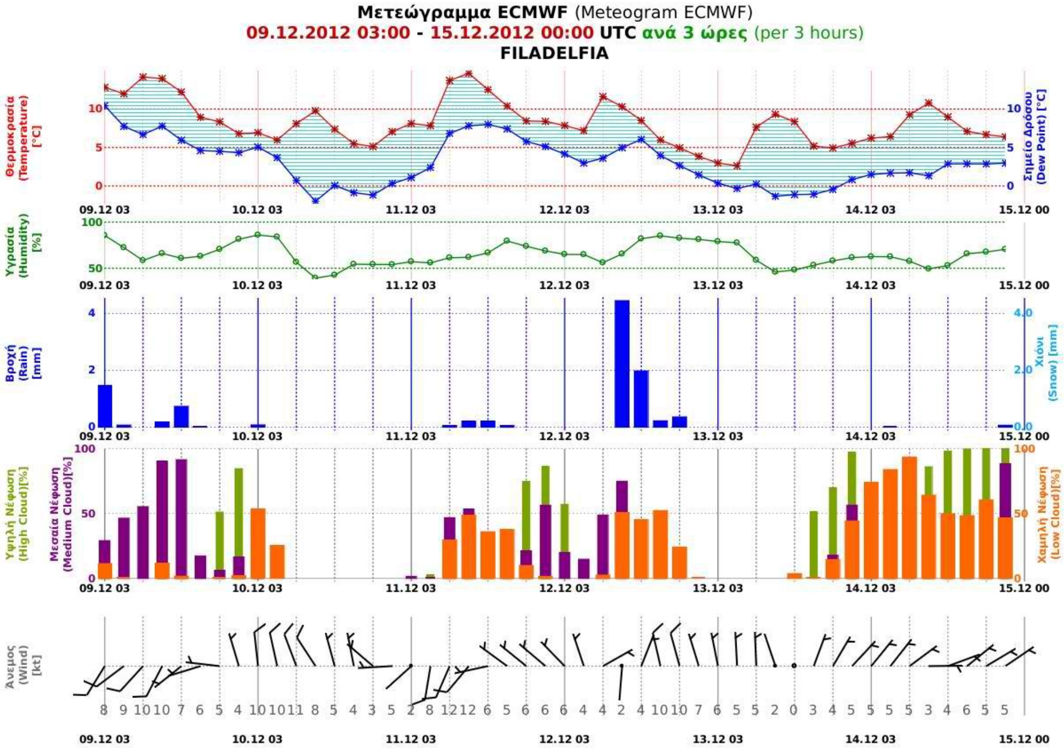
Annex 3 - Greece

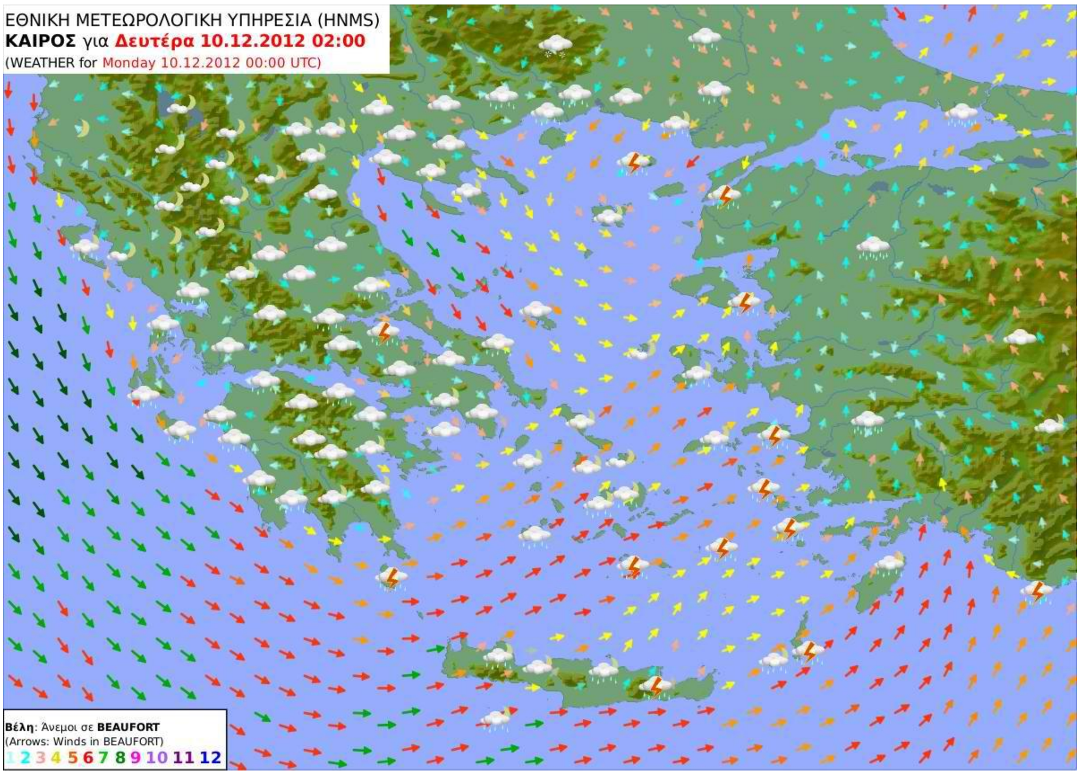
Case studies on weather forecast and meteorological products (including NWP products)

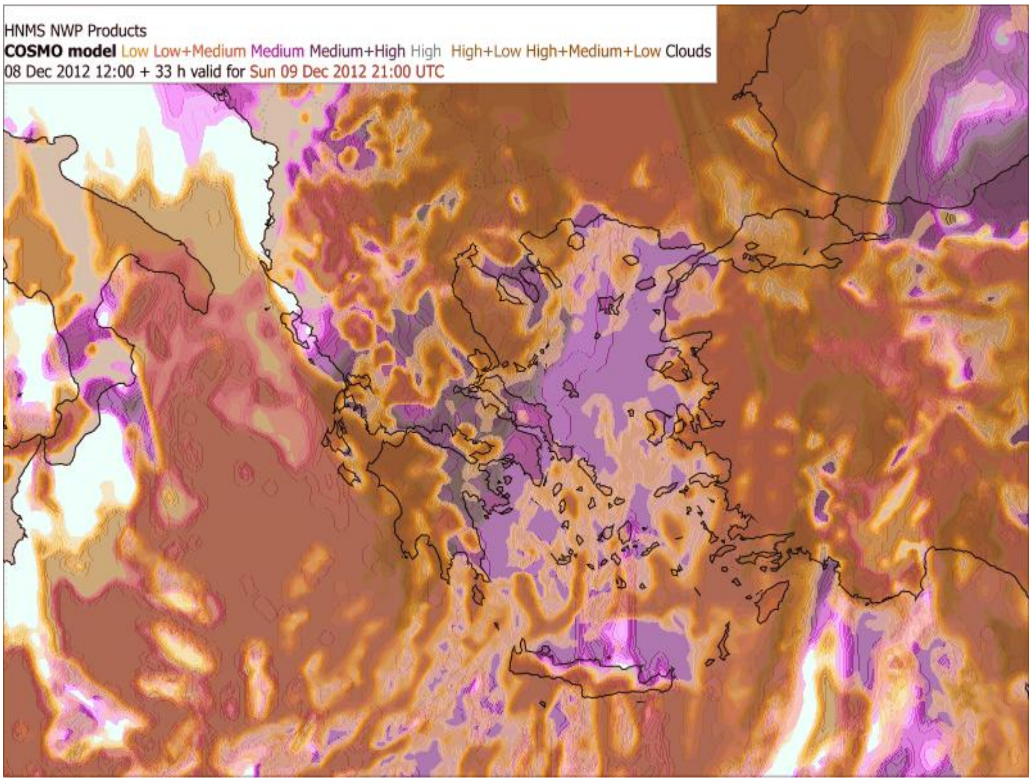
The National Meteorological Service provides weather forecasts at the national level (providing information at the national, regional and local levels), and disseminates information though the Mass Media (National Television Network) and its website, www.hnms.gr.
The HNM Service is a provider of meteorological and climatological data to other national or local public bodies. In addition to the broadcasting weather forecasts, the Service was providing a TV weather forecast specifically for farmers.
National Observatory of Athens, Institute for Environmental Research and Sustainable Development is also a National Institution providing weather forecast data, which is published at the website of www.meteo.gr , which can be also of interest for the agrometeorology and the farming community.
Universities and research institutes conduct and publish research for agrometeorology, and certain studies are provided in the bibliography. In general, at the national level public bodies analyze and provide weather forecasts and data, while there are various other services provided from private or local government agencies which are oriented towards a specific region of interest. In addition to that, there are several websites and private bodies which disseminate weather forecast information.
Also, in the market there are services that provide hardware solutions which aim to inform farmers for soil moisture levels and thus regulate their irrigation needs.

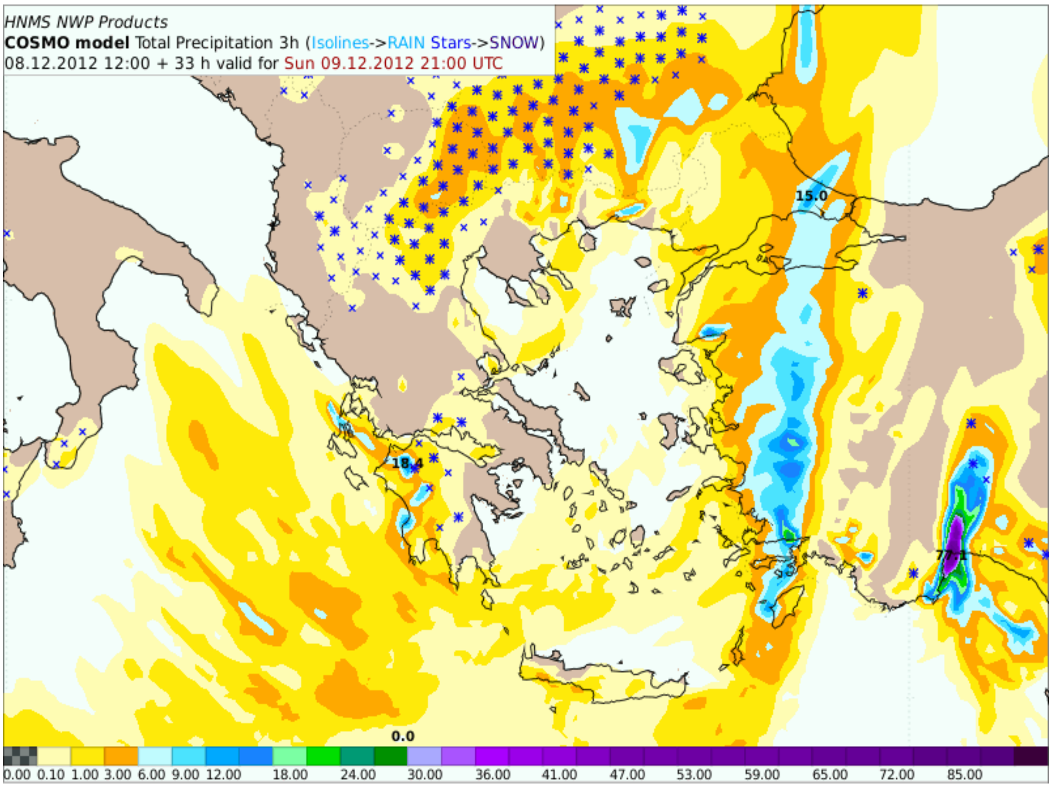
HNMS COSMO model and additional forecasting services of possible interest to agrometeo

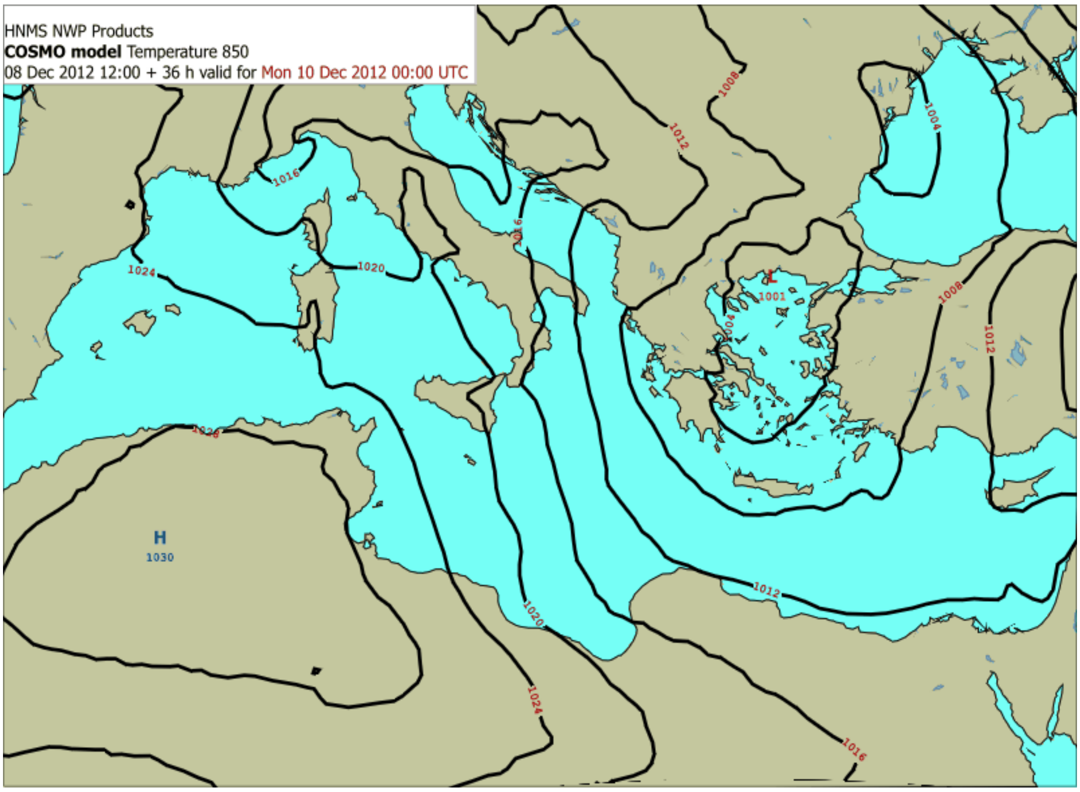
HNMS operates the COSMO Model and provides several NWP products which are of interest to agrometeorology. The HNMS website provides access to forecasts and to NWP products maps.
COSMO Model NWP product examples of Hellenic Meteorological Service

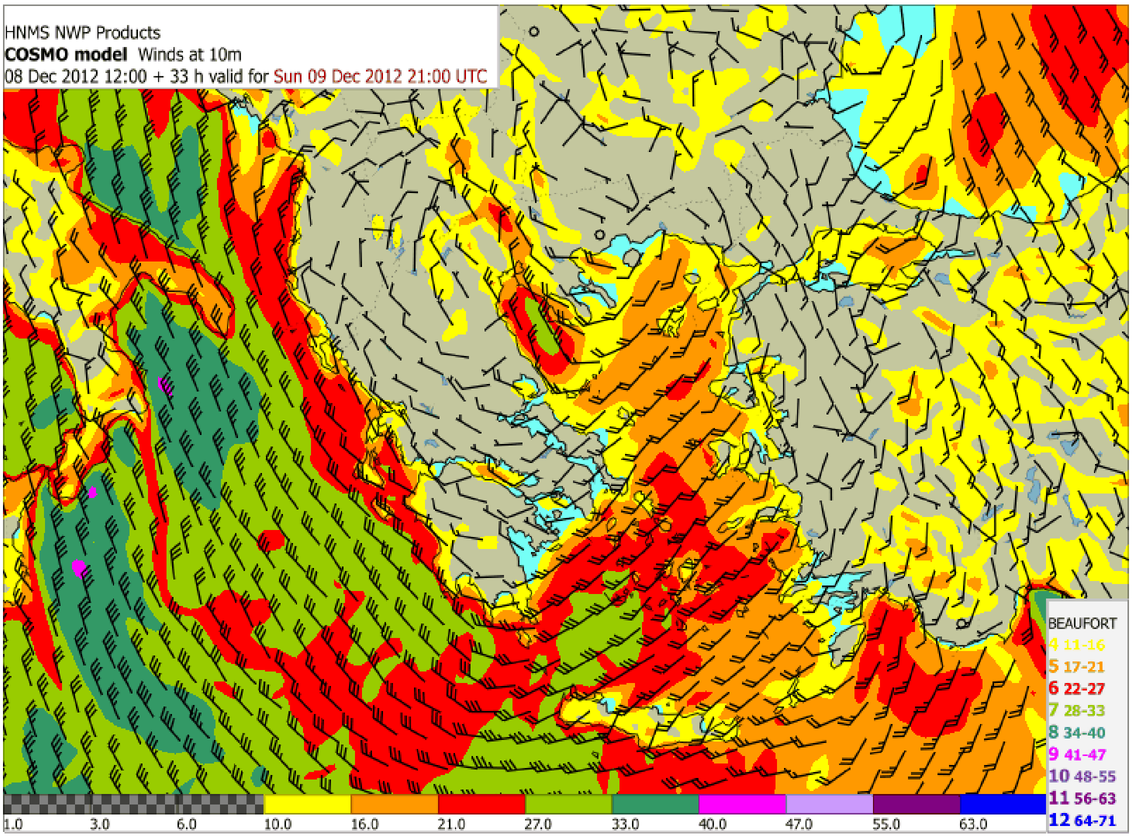

Μετεώγραμμα ECMWF (Meteogram ECMWF)
09.12.2012 03:00 - 15.12.2012 00:00 UTC ανά 3 ώρες (per 3 hours)
FILADELFIA
Θερμοκρασία (Temperature) [°C]
Σημείο Δρόσου (Dew Point) [°C]
Υγρασία (Humidity) [%]
Βροχή (Rain) [mm]
Χιόνι (Snow) [mm]
Υψηλή Νέφωση (High Cloud)[%]
Μεσαία Νέφωση (Medium Cloud)[%]
Χαμηλή Νέφωση (Low Cloud)[%]
Άνεμος (Wind) [kt]
09.12 03
10.12 03
11.12 03
12.12 03
13.12 03
14.12 03
15.12 00


ΕΘΝΙΚΗ ΜΕΤΕΩΡΟΛΟΓΙΚΗ ΥΠΗΡΕΣΙΑ (HNMS)
ΚΑΙΡΟΣ για Δευτέρα 10.12.2012 02:00
(WEATHER for Monday 10.12.2012 00:00 UTC)
Βέλη: Άνεμοι σε BEAUFORT
(Arrows: Winds in BEAUFORT)
1 2 3 4 5 6 7 8 9 10 11 12


HNMS NWP Products
COSMO model Low Low+Medium Medium Medium+High High High+Low High+Medium+Low Clouds
08 Dec 2012 12:00 + 33 h valid for Sun 09 Dec 2012 21:00 UTC


HNMS NWP Products
COSMO model Total Precipitation 3h (Isolines->RAIN Stars->SNOW)
08.12.2012 12:00 + 33 h valid for Sun 09.12.2012 21:00 UTC
15.0
18.4
0.0
0.00 0.10 1.00 3.00 6.00 9.00 12.00 18.00 24.00 30.00 36.00 41.00 47.00 53.00 59.00 65.00 72.00 85.00


HNMS NWP Products
COSMO model Temperature 850
08 Dec 2012 12:00 + 36 h valid for Mon 10 Dec 2012 00:00 UTC
H
1030
1024
1020
1016
1012
1008
1004
1001


HNMS NWP Products
COSMO model Winds at 10m
08 Dec 2012 12:00 + 33 h valid for Sun 09 Dec 2012 21:00 UTC
BEAUFORT
4 11-16
5 17-21
6 22-27
7 28-33
8 34-40
9 41-47
10 48-55
11 56-63
12 64-71
1.0
3.0
6.0
10.0
16.0
21.0
27.0
33.0
40.0
47.0
55.0
63.0

Case Study on Hydrological-Meteorological products

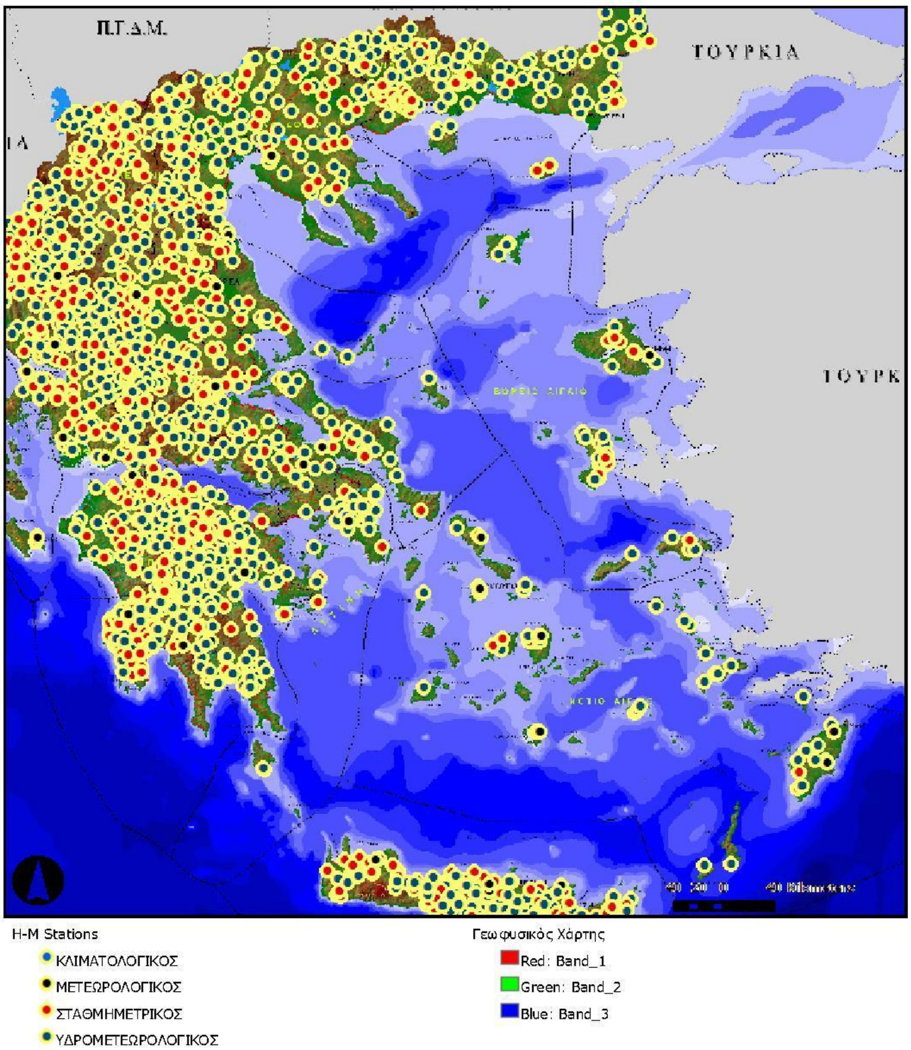
National Database of Hydrological and Meteorological Information

A project of the Ministry of Environment, Energy and Climate Change, hosts among others data, spatial and other information on hydrology and meteorology. The specific database is related to the WFD implementation in Greece. Results of numerous scientific studies, meterological station archive from various agencies, are contents of the database and can be of interest to agrometeorology. More information can be assessed from the website of the project, at http://www.hydroscope.gr/project.html

Map of the Hydrological – Meteorological Stations registered in the National Database of Greece (colored points - map derived from the website of the project http://www.hydroscope.gr/project.html)

Map http://thyamis.itia.ntua.gr/aspnet_client/ESRI/WebADF/PrintTaskLayou...

Map



Task A5.1

5) New challenges or tasks for agrometeorological services and products related to ongoing climate change impacts; To identify and evaluate	A5.1 Identify new user needs regarding ongoing climate change impacts (i.e. literature survey, Questionnaires) considering regional aspects (agroecosystems, climate region, temporal/spatial scales, technology, etc.)

Authors: Elena Mateescu, Henrik Eckertsten, Cathleen Frühauf, Ulrich Otte

Introduction

The results presented below reflect gathered examples of national experiences on the topic.

Case study 1 (Romania)

Referring to the climate change impact at spatial/temporal scales it is necessary to identify the common/different issues within sectors or among sectors including regional/local aspects (i.e. dynamic variability and temporal scales, observed changes and projected perspectives, magnitude of impact, etc). Analysis and synthesis of historical data can identify the most vulnerable areas to climate change, especially to extreme events, in order to develop the response options and specific recommendations for adaptation in agricultural sector at regional/local level. In this context, is important to align the scales (spatial/temporal and sectoral/regional level) and reliability of the information with the scale and nature of the decision. For example, short-term climate adaptation by farmers may be accomplished by taking into account local climate trends and projected climate changes, or climate forecasting at scales from daily to monthly and annual period.

As the face of agriculture changes, early warning systems will have to change to cope with the greater variety of crops, the greater scale at which the information is available and a greater focus on accurately reflecting the needs of small-scale farmers. Also, the first step to develop an adaptation plan at any territorial level is to study the potential impacts of climate change under various scenarios and understanding the probabilities of such events. While uncertainties prevail, a list of impacts at regional level needs to be prepared at appropriate territorial level. It is highly recommended to start from the expected climatic impacts, those are:

- changes in average temperature in the seasons and expected increase in temperature extremes;
- changes in precipitation patterns;
- changes in snow cover;
- changes in water systems: river flow changes (flood and drought risks); groundwater level changes;
- coastal region impacts: sea level rise and flood risks;

National Meteorological Administration of Romania can provide a synthesis related on the review of known impact projections and regional effects with focus on adaptation measures in agriculture obtained in various national/european projects. Also, the Agrometeorological Laboratory from NMA propose to develop new product, respectively agrometeorological diagnosis and forecast at regional level based on various climate forecasts indices – heat index, drought index, etc).

In addition, in order to evaluate the importance of climate products for specific users the study "Advancing Adaptation through CLIMATE INFORMATION SERVICES – Results of a global survey on the information requirements of the financial sector", published in 2011 by the Sustainable Business Institute (SBI) and the United Nations Environment Programme Finance Initiative (UNEP FI), underlines the importance of developing climate information services in international networks. This will only be possible through cooperation between the research community, the finance industry, and other private- and public-sector institutions. This study can be useful as a contribution to the Global Framework for Climate Services" including a "Global Climate Observing System", following the World Climate Conference 3 "Better climate information for a better future". The framework will link science-based predictions and information on climate change with the management of related risks and opportunities in order to support adaptation to climate change. The current report is a contribution towards the development of such climate information services and a respective framework.

Referring to the sectoral aspects, agriculture and the energy stand out as the sectors that need information the most. Also, the results at the regional/local scale show a large information gap for continents with a high number of developing countries, but the demand for better climate information refers to all macro-regions of the world, not only those where information infrastructure is less developed. It is, therefore, crucial that climate information systems are structured spatially down to sub-country level for information. The survey confirms also, that location plays an important role; not only with regards to the factual predictions required of physical climate change impacts at the local level, but also in terms of the subjective perception of climate change risks by companies. In part, this can be explained by differences in the extent to which climate change is already apparent in different parts of the world.

The further improvements of information services can thus build on co-operation between partners with different experience and knowledge. The respondents (62 of 65) expressed a broad and strong interest to collaborate with weather and climate data and information providers, research institutes, and other partners regarding the (further) development of various information services and formats:

- sectoral analyses (54)
- regional scenarios (40)
- project databases (e.g. for renewable energy projects) (39)
- databases on weather/extreme events (26)
- loss and catastrophe models (24)
- loss databases (21)

In terms of the format for information, again survey respondents are interested in a wide range of media, as:

- Periodical reports about the effects of climate change on certain sectors and companies (61)
- Best practice cases on tackling risks and opportunities in the financial services industry (60)
- Periodical reports about the effects of climate change on certain regions (51)
- Further training (seminars / conferences) (33)
- Periodical reports about the state of the art in climate science (27)
- Online services (FAQ etc.) (27)
- Ad hoc statements / Expert opinions (27)

The survey it is available at http://www.unepfi.org/fileadmin/documents/advancing_adaptation.pdf.

Case study 2a (Sweden)

A base for strategic evaluations of the need of crop protection in the future Swedish Agriculture due to a changing climate is developed in an ongoing project. The base that should be given is the assessed change in crop development and yield of a number of crops currently used, and potentially used, in the typical agricultural districts of Sweden for the climate change scenarios given by the Swedish Hydrological and Meteorological Institute (SMHI). The work will provide a matrix of crop yield and development over space and time, so that the future projections of a certain location can be compared with today situations at other locations. This would provide information asked for by the division for crop protection of the Swedish Board of Agriculture (JBV). Crop yield and development models used in practical agriculture and research, and monitoring data from JBV, and cultivar trial data from the Swedish University of Agriculture (SLU), are used to make these assessments. The work is ongoing and planned to be ready by November 2011.

The work is ready and published in:

Eckersten, H.; Kornher, A., 2012. Klimatförändringars effekter på jordbrukets växtproduktion i Sverige – scenarier och beräkningssystem. (Climate change impacts on crop production in Sweden – scenarios and computational framework). Report No 14, Department of Crop Production Ecology, Swedish University of Agricultural Sciences, Uppsala, Sweden. 62 pp (In Swedish with English summary). http://pub.epsilon.slu.se/8590/1/eckersten_h_120208.pdf

This report has been one of the bases for a report published by the Swedish board of Agriculture:

Berg G. (Ed.) 2012. Vässa växtskyddet för framtidens klimat (Improve crop protection to adapt to future climate). Rapport 2012:10. 77pp (In Swedish with English summary). (www.jorbruksverket.se)

Case study 2b (Sweden, Finland, Denmark, Poland)

This study tried to answer the question on whether agriculture around the Baltic Sea can reduce its phosphorus (P) and nitrogen (N) losses to the sea, in the near and far future, and still be productive. The answer was based on quantitative assessments of losses and crop production of four catchments located in Sweden, Finland, Denmark and Polen, respectively, applying agricultural practices as proposed by local stakeholders. This work was performed as a part of the Baltic Compass project (2013) and reported by Blombäck et al. (2013).

As a base for the assessments were used locally applied nutrient load models that have been tested against observations. We called those applications the Current situation (for periods centred on ca year 2005). Then, Future scenarios were created by introducing expected changes to the inputs of the Current situation. These changes concern climate change, land use and obligatory agricultural measures and were regarded “unavoidable” in the future from the perspective of the local stakeholder’s missions and influence. Based on the results of the Future scenarios the stakeholders proposed agricultural measures that could reduce the nutrient losses to the targets set by environmental directives in the new “unavoidable“ situation. The proposed measures were interpreted by the modellers in terms of changing inputs of the Future scenario. The new scenarios were called the Adaptation scenarios, which then mimicked what the local stakeholders find possible for each local catchment. The scenarios were made for several year periods centred on ca 2020 and 2050, respectively.

The study used a methodology for stakeholder-modeller interactions of which Important components were (i) an input/output group facilitating the communication between stakeholders and modellers, (ii) locally used models and modellers capable of interpreting the stakeholder proposals and translating the proposals in terms of changed inputs to the locally used models, and

(iii) stakeholders quite familiar with the functioning of nutrient dynamics in soil and plant and well aware with agricultural practice in the area concerned. The stakeholder-modeller interactions could be regarded a role-play where the stakeholders represent the society in terms of proposing agricultural practice, and the modellers represent nature in terms of model assessments (Fig. 1).

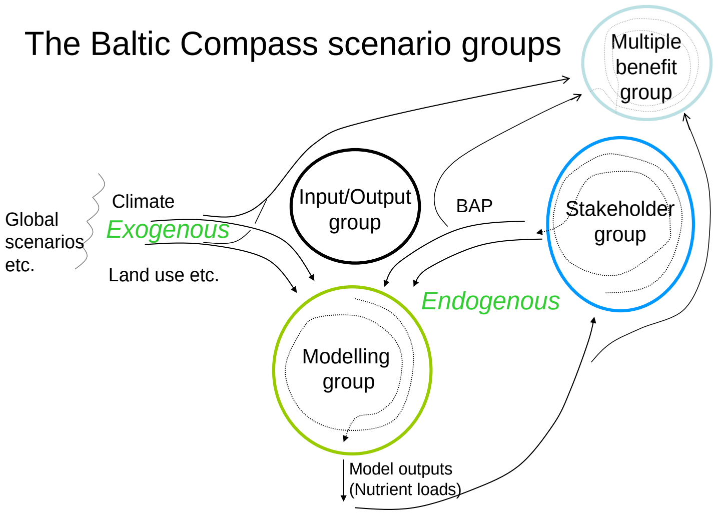


Fig.1. Flow of information between groups in the scenario work of the Baltic Compass project (2013; *Henrik Eckersten, Staffan Lund, Uppsala 2011-09-30). BAP refers to best available practice measures to reduce nutrient leaching. After Collentine et al. (2013)*

Shortly, the answer to the question on whether agriculture around the Baltic Sea can reduce its nutrient losses to the sea in the future, and still be productive, was yes in some cases, and no in most cases. In the Swedish forest dominated catchment the production increased and the reductions of nutrients were larger than needed to reach the targets. In the Finish hot spot catchment, the production was unchanged and nutrient losses reduced to targets in 2050, but not in 2020. In the Danish intensive agriculture dominated catchment the yield increased in 2020, but also N leaching, although to a minor extent. In 2050 the N reduction target was reached but this was accompanied by reduced yield primarily due to climate change effects and changed crop rotations and 20% reduction in N fertilization. In the Polish low input agricultural dominated catchment the nutrient losses increased by 2050, although yields slightly decreased.

The next question to be answered by a joint study (Collentine et al, 2013) was then whether the measures adopted to reduce N and P losses improve or impair multiple benefits of agriculture. The question was only answered for the Swedish catchment. Agricultural production was to a large extent considered in the nutrient loss scenarios, whereas effects on other ecosystem services were not evaluated. Hence, the nutrient loss scenarios were evaluated for six multiple benefit (MB) categories: greenhouse gas (GHG) emissions, biosecurity, biodiversity, cost effectiveness, soil quality and water protection. The MB-categories were evaluated in terms of an index between zero, five and ten, defined within each MB-category as very negative, no change and very positive effect, respectively, compared with the Current situation. Inputs to the MB evaluations (made by a multiple benefit group consisting of experts of the disciplines, Fig.1) were inputs of the nutrient load scenarios on future crop choice, biomass yields, sowing and harvest dates and climate change, and the adaptation measures to reduce the N and P leaching, as provided by the stakeholder group. The adapted measures to be evaluated were specific values for reduced fertilisation, spring cultivation instead of autumn cultivation, catch crop, buffer-zones, structural liming, constructed wetlands, sedimentation ponds and liming in drains. Also, although to a minor extent except for GHG emissions, scenario output factors on N and P leaching, and N mineralisation were used in the MB evaluations.

The answer to the question whether the measures adopted to reduce N and P losses from agricultural fields improved or impaired multiple benefits of agriculture, seems to be: improved. The biosecurity was positively influenced by most measures (6 out of 9) and soil quality the next (5 out of 9), and most of the adaptation measures had a positive influence on most of the MB categories, the clearest exception being liming in drains which only improved the cost effectiveness. Current trends and climate change suggested increased yields which in turn suggested increased fertilisation, which was evaluated to increase GHG emissions. The only adaptation measure that mitigated that effect was reduced N fertilisation, which thus provided further arguments for reduced fertilisation than only reduced leaching.

A number of questions raised by this study address the needs of future work. (i) Is it feasible to implement the proposed adaptation measures? (ii) Can we develop scenarios that fully reach both the loss reduction and production targets? (iii) What is the implication of these case studies for assessments of nutrient loads to the whole Baltic Sea? (iv) How certain are these scenarios and do we need more research? And, (v) why is this scenario development methodology not used in operative management of the Baltic Sea quality? Concerning the last question, the stakeholder's ability to utilise the models for decision support in this study was strongly facilitated by their earlier experience from model applications, suggesting that stakeholders would benefit from being trained in this methodology, and even better if already in basic courses in agronomy.

References

Baltic Compass project, 2012. www.balticcompass.org

Blombäck K., Duus Børgesen C., Eckersten H., Gielczewskid M., Piniewskid M., Sundin S., Tattari S., Väisänen S., Eds. Productive agriculture adapted to reduced nutrient losses in future climate - Model and stakeholder based scenarios of Baltic Sea catchments. ca 177 pp. To be submitted to the Finnish Environment Institute (SYKE) Report series:

Collentine D., Eckersten H., Norman Haldén A., Ryd Ottoson J., Salomon E., Sundin S., Tattari S, Braun J., Kuussaari, M., 2013, Consequences of future nutrient load scenarios on multiple benefits of agricultural production. To be published in; Department of Crop Production Ecology, Report XX, Swedish University of Agricultural Sciences. 69 pp

Case study 3 (Germany)

Introduction

The Braunschweig Agrometeorological Research Centre (ZAMF) of the Deutscher Wetterdienst (DWD) has extensive and specialised agrometeorological know-how which combines climate and weather issues with the needs of agriculture and is successfully used to advise customers. One focus of activity of the ZAMF is the development and application of models for agricultural production, soil climate and soil moisture regime as well as the agroclimatological evaluation of extreme events. Users are interested in information about the regional distinctions of meteorological and agrometeorological parameters. With the ongoing climate change every drought or other difference from the mean is discussed. Maps are the best way to display the spatial distribution.

Results

The DWD's most recent climate consultancy product is the German Climate Atlas (available online www.deutscher-klimaatlas.de; in German), which presents an overview of the development of certain agriculturally important parameters over the past decades, the current situation as well as the expected developments until 2100.
The available meteorological parameters are:

- temperature
- number of ice days (maximum temperature < 0°C)
- number of frost days (minimum temperature < 0°C)
- number of summer days (maximum temperature ≥ 25°C)

- number of hot days (maximum temperature ≥ 30°C)
- number of tropical nights (minimum temperature ≥ 20°C)
- precipitation

With the agrometeorological software package AMBER additional parameter are calculated:

- start of the vegetation period
- beginning of blossom of rape
- number of days with changing frost
- soil moisture under winter wheat, sandy soil
- soil moisture under sugar beet, heavy soil
- maize ripeness
- yield of maize
- yield of grassland (first cut)

All parameters are displayed as maps (see Fig. 1). The mean values (1961-1990) are on the left side. The absolute values and the deviation for the actual year can be selected in the middle. For temperature, precipitation and both soil moistures maps exist for every month, season and the whole year since 2009. The results of 21 regional models are displayed as percentiles for the future scenarios at the right side. Additional the curse of the mean for Germany is at the bottom part (see Fig. 2).

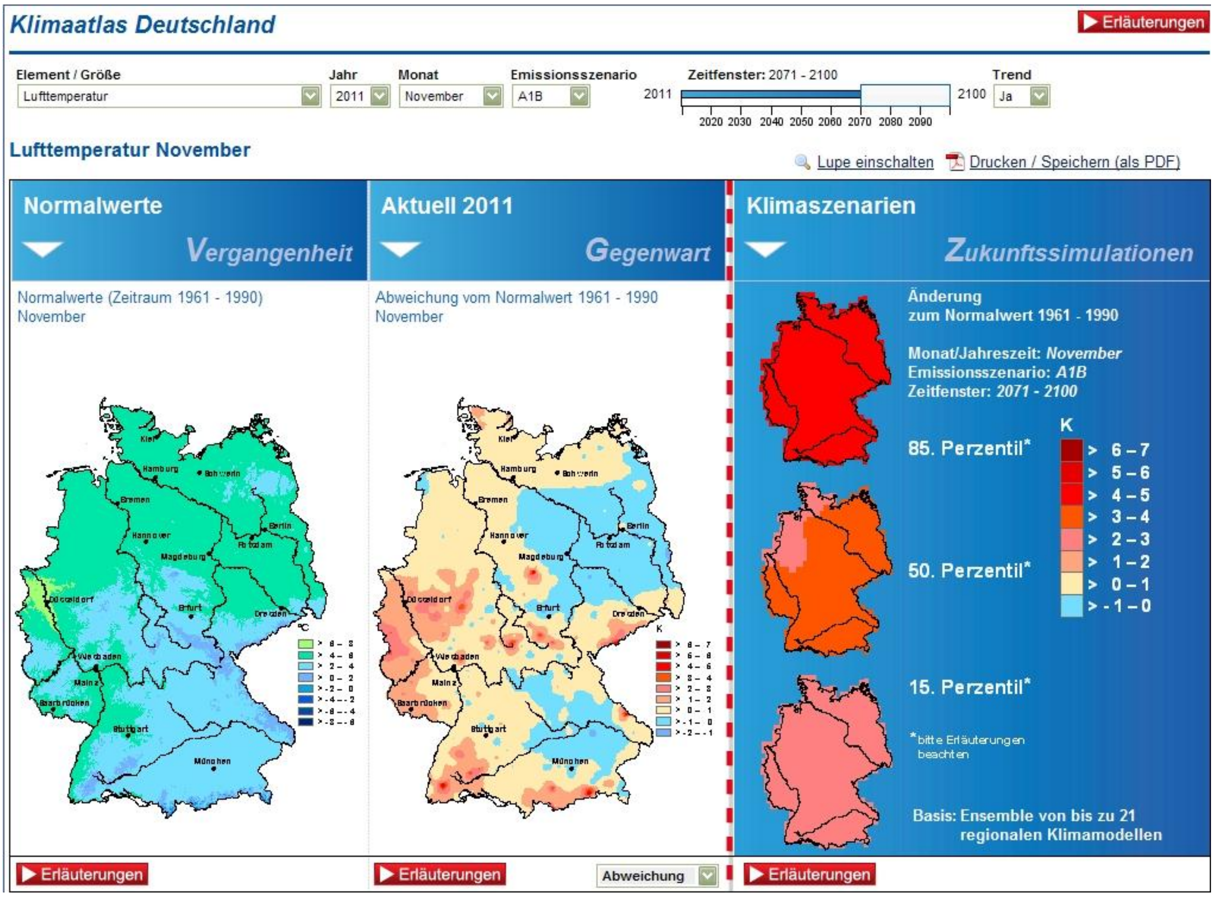


Fig. 1: The past (left, mean 1961-1990), present (middle) and future (right) of the parameter air temperature for the month November.

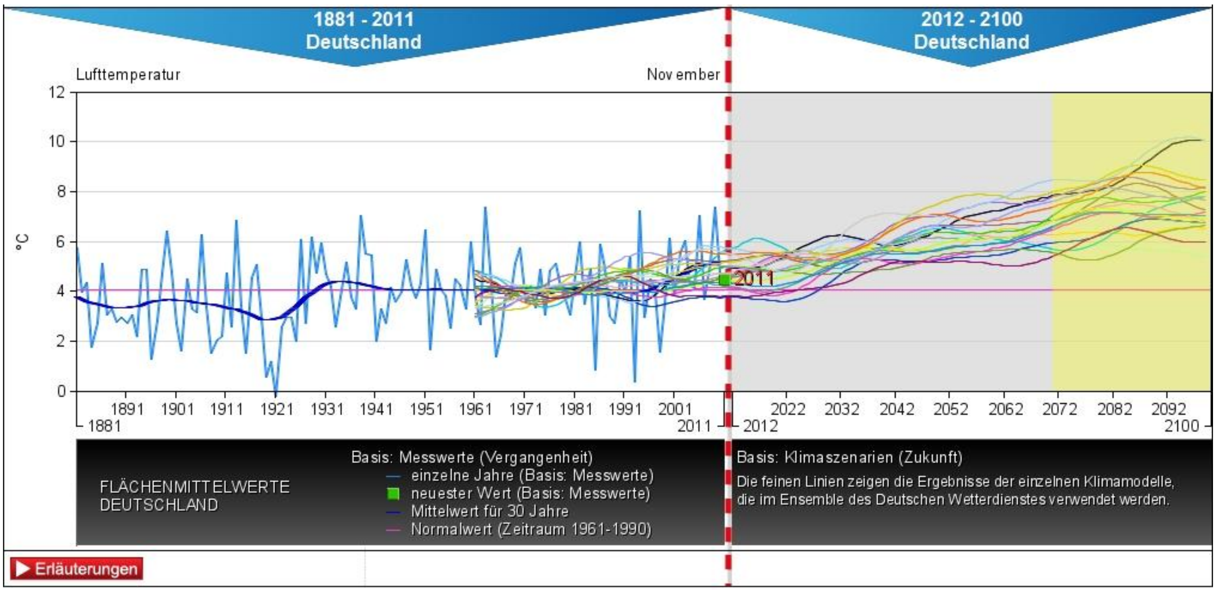


Fig. 2: Course of the mean for Germany for the parameter air temperature November. 1881-2011: blue – measured values; dark blue – measured values (Gaussian low-pass filter); 1961-2100: different colours – results of 21 different regional models (Gaussian low-pass filter)

The Standardized Precipitation Index (SPI) is one of the most common climatological precipitation indices used for the identification of drought and rain-surplus periods. The monthly precipitation frequencies are used to calculate the probability of occurrence, which is indicated by the SPI. In order to present the effect of longer time periods (longer than a month, e.g. 3- or 6-month precipitation totals, etc.) on the evolution of SPI, moving averages over 3, 6 or more months are calculated. Taking different time scales into account provides information on agriculturally or hydrologically relevant droughts (time scale ≤ 6 months or time scale > 6 months, respectively).
The Standardized Temperature Index (STI) expresses the temperature anomaly for a month as a multiple of the standard deviation from the long-term mean. The statistical classification of each month relies on the monthly means and standard deviations of the reference period 1961-1990. The frequency of the monthly mean temperature is calculated from the cumulative standard normal distribution. Both indices were computed for one, three, six and twelve month and can be used internally.

New user needs in the agricultural production chain regarding ongoing climate change impacts – Summary

• Risk indices with regional relevance should be developed for various stakeholder groups for current climate variability and climate change scenarios. These indices should be well evaluated, optimized regarding spatial and temporal scale and addressed to specific regional vulnerable targets (such as specific crops, production systems). It may include heat risk, soil erosion risk, troposheric ozone, water scarcity,flood risk, leaching risk, etc..

• Early warning systems for extreme weather events will have to change to cope with the greater variety of crops, the greater scale at which the information is available and a greater focus on accurately reflecting the needs of small-scale farmers.

• Multiple effects of long term adaptation options for agriculture to climate change needs better regional evaluation and research (including environmental impacts, mitigation effects, economic effects, sustainability aspects, etc.).

• In some cases international cooperation is crucial, especially when adaptation options are directed to environmental protection (e.g. nutrient loads from agriculture into water bodies). Regional management directives should be developed for stakeholder groups in such cases.

Task A5.2

5) New challenges or tasks for agrometeorological services and products related to ongoing climate change impacts; To identify and evaluate	A5.2 Identification of the possibilities of satellite earth observations for monitoring of changes in biosphere related to climate change.

Status: Interim report

Authors: Piotr Struzik, Josef Eitzinger, Christof Spring

Report on activities performed

The purpose of this task was to define possible satellite missions and parameters derived from satellite data available for long time and thus suitable to monitor changes in biosphere related to climate change. During the reporting period were defined structure of report and started preparation of individual chapters.

Realisation of this task is based on authors publications and available other published material. Structure of report was defined as follows:

1. Available satellite long term datasets suitable for biosphere monitoring – definition of satellite data sets which are available in long term periods (>10 and >20 years), have suitable channels for determination of indices related to biosphere condition, are available for public use, will have continuation in future.
2. Parameters which can be derived from satellite data characterising vegetation condition – description of various indices which can be retrieved from satellite data (eg. NDVI, VCI, TCI, VHI, etc). Examples of indices and long term anomalies related to vegetation stress.
3. Benefits of satellite data for monitoring of changes in biosphere – examples of different studies on long term changes in vegetation season duration, peeks, volcanic ash influence, desertification, insects plague influence etc .
4. Limitations of satellite observations of biosphere conditions – analysis of limiting factors regarding to: cloudiness, changing spectral response of sensors, changing observation time, degradation of sensors.
5. Recommended applications and services presenting actual anomalies vs. long term observations available in public services.
6. Future possibilities according to already scheduled satellite missions in years 2012-2030.

The basic material (see publication list below) was already selected and actually are investigated possible updates of available methods and datasets from recent publications. Points 1-2 of report structure were already prepared, chapters 3 and 4 are actually updated. Chapter 5 and 6 will be prepared in scheduled time.

Used material for preparation of report:

1. Struzik P., Stancalie G., Danson F.M., Toulios L., Dunkel Z., Tsiros E. – Study on Satellite Data Availability and their Resolution in Time and Space, for the Assessment of Climate Change and Variability Impact on Agriculture, Satellite Data Availability, Methods and Challenges for the

Assessment of Climate Change and Variability Impacts on Agriculture, European Science Foundation, COST Office 2010.
2. Leonidas Toulios, Gheorghe Stancalie, Elena Savin, F Mark Danson, Piotr Struzik, Zoltán Dunkel And János Mika, “Satellite-derived NDVI for monitoring climate impacts on European agriculture” Időjárás, Hungary, 2010.
3. P. Struzik, L. Toulios, G. Stancalie, M. Danson, J. Mika, C. Domenikiotis „Satellite Remore Sensing as a Tool for Monitoring Climate and its Impact on the Environment – Possibilities and Limitations”, Survey of Agrometeorological Practices and Applications in Europe Regarding Climate Change Impacts, COST, European Space Foundation, 2008.
4. L. Toulios, G. Stancalie, P. Struzik, M. Danson, J. Mika, Z. Dunkel, E. Tsiros „Satellite Spectral, Climatic and Biophysical Data for Warning Purposes for European Agriculture”, Survey of Agrometeorological Practices and Applications in Europe Regarding Climate Change Impacts, COST, European Space Foundation, 2008.
5. P. Struzik, „Satellite Remote Sensing as a tool for monitoring of climate and environment”,http://www.cost734.eu/reports-and-presentations/3th-management-committee-meeting-in-poznan/COST_Poznan_Struzik.ppt/
6. P. Struzik, G. Stancalie, L. Toulios, „Use of Data from Remote Sensing as Input for Agrometeorology”, COST Action 718, Metorological Applications for Ariculture, COST Office 2006, Brussels

Case study on use of remote sensing data for operational irrigation scheduling (Italy, Austria)

Francesco Vuolo, Josef Eitzinger

Irrigation scheduling using remotely sensed crop coefficients

Satellite data are well suited to derive spatial distribution of ET, avoiding cost-intensive ground measurements with limited validity. Numerous techniques have been developed to estimate potential (ET_p) and actual evapotranspiration (ET_a). Currently, two different EO methodologies can be applied based on the FAO-56 concept by using visible and near infrared observations from satellite, which are available with the appropriate frequency and spatial resolutions to estimate the irrigation water demands. The above described products have been inserted into an operative processing chain in order to distribute the information sheet to users in “near-real time”, i.e. between 24 and 48 hours after the satellite overpass. Once CWR for every plot are calculated, the information is sent by using innovative (e.g., email, SMS, MMS, web interfaces, etc.) to the farmers/water managers. Examples of operational applications of these procedures are available (see for example the link: www.consulenzairrigua.it, in Italian) and a brochure from an Austrian project where this method will be implemented for annual crops (see Fig. 1, below).

Another example of an online irrigation scheduling system from DWD (Germany) is shown in Fig. 2.

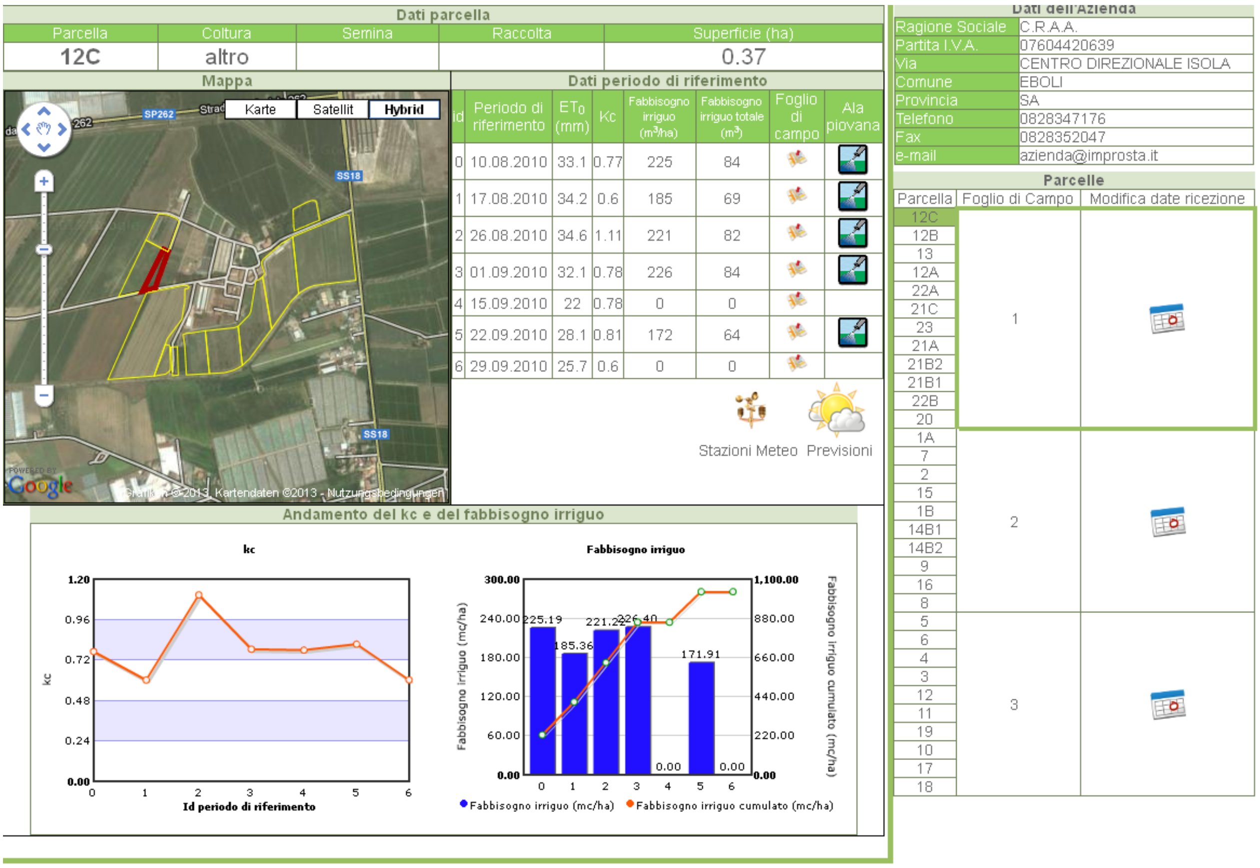


Fig.1: Operational, web based irrigation scheduling (field scale based) using FAO56 method and actual Kc values from remote sensing data. http://www.consulenzairrigua.it/

Fig. 2: Online irrigation scheduling system, offered by DWD, Germany

Task A5.3

5) new challenges or tasks for agrometeorological services and products related to ongoing climate change impacts; To identify and evaluate	A5.3 Develop recommendations triggering services/products for a better support to decision making on mitigation/adaptation options to climate change A5.4 Identify unsolved research tasks and problems in the field

Authors: Cathleen Frühauf, Ulrich Otte, Josef Eitzinger

Introduction

Global climate change will lead to shifts in climate behaviour and cause manifold impacts on ecosystems in the next decades. Through a change in climatic conditions and variability, for example, extreme weather events (especially heat waves, droughts, heavy precipitation) are likely to occur more frequently in different spatial and time scales in future. Since agriculture is one the man' activities more dependent on weather behaviour, the impact on risks of agricultural production is indeed one of the most important issues in climate change assessments. On the other hand potential adaptation measures can provide a big potential to reduce risk and potential losses. An important aspect is also that there are increasing regional differences in the crop production potential in Europe due to climate change and that positive or negative impacted agricultural systems can vary in a relatively small spatial scale, depending on the specific limiting environmental conditions such as climate or soil conditions (especially in complex terrain). Although dominating risks such as increasing drought and heat are similar in most regions, the vulnerabilites in the different regions are very much influenced by characteristics of the dominating agroecosystems and prevailing socio-economic conditions. This will be even be more significant for potential adaptation measures at the different levels, which have to reflect the regional conditions.

Example 1: Developing agrometeorological products considering climate change - Germany

This topic will be demonstrated on the activities of the German Weather services (DWD) as follows. The Braunschweig Agrometeorological Research Centre (ZAMF) of the Deutscher Wetterdienst (DWD) has many years of experience in application of the impact models included in the agrometeorological software package AMBER in conjunction with regional climate models. Within the departmental research initiative KLIWAS of the Federal Ministry of Transport, Building and Urban Development (BMVBS), an initiative is currently under way with the aim of supporting the DWD's climate and environment consultancy services and which compiles the simulation results from 21 regional climate models for Germany into an ensemble overview for comparison and evaluation. All models use the SRES emission scenario A1B. For the next IPCC report (2014) new so called RCP (Representative Concentration Pathways) scenarios are applied. The new scenarios were added, when the data are available.
The results from this study of the DWD's relating to the spectrum of observed and simulated climate change impacts in Germany have just recently been included in the Adaption Action Plan (Aktionsplan Anpassung, APA) of the German Strategy for Adaptation to Climate Change (Deutsche Anpassungsstrategie, DAS) to be used for providing political and climate advice for national and regional government authorities.

The Helmholtz-Gemeinschaft also had developed a climate atlas (www.regionaler-klimaatlas.de) and the Climate Service Centre shows climate signal maps (http://www.climate-service-center.de/031443/index_0031443.html.de), which give an information, how reliably the results of the regional climate models are. At both web pages only meteorological parameter (temperature, precipitation, summer days, days with heavy rain etc.) are displayed.

German Climate Atlas

The German Climate Atlas (www.deutscher-klimaatlas.de) presents an overview of the development of certain agriculturally important parameters over the expected developments until 2100 on the basis of about 21 ensemble forecasts from regional climate models.
The parameters are calculated with the agrometeorological software package AMBER.
Following parameters are currently available:

- start of the vegetation period
- beginning of blossom of rape
- number of days with changing frost
- soil moisture under winter wheat, sandy soil
- soil moisture under sugar beet, heavy soil
- maize ripeness
- yield of maize
- yield of grassland (first cut)

In the last month new parameters were prepared and are available at the beginning of September 2012.

- soil frost depth, uncovered median / middle / medium heavy soil
- maximum of soil surface temperature, uncovered median / middle / medium heavy soil (see Fig. 1)
- Huglin-index (heat index for cultivation of different grape varieties)
- Canadian forest fire index (see Fig. 2)
- bark-beetle development

This substantial choice at different agrometeorological parameters allow a special view at the climate change related changes for the farmers. The maps show regional differences. Seven different 30-years periods can be selected. The results are displayed as percentiles for each grid point as changes in comparison to the time period 1961-1990. The values of 70 percent of all models are between the 15. and 85. percentile. Only 15 percent have lower or higher values.

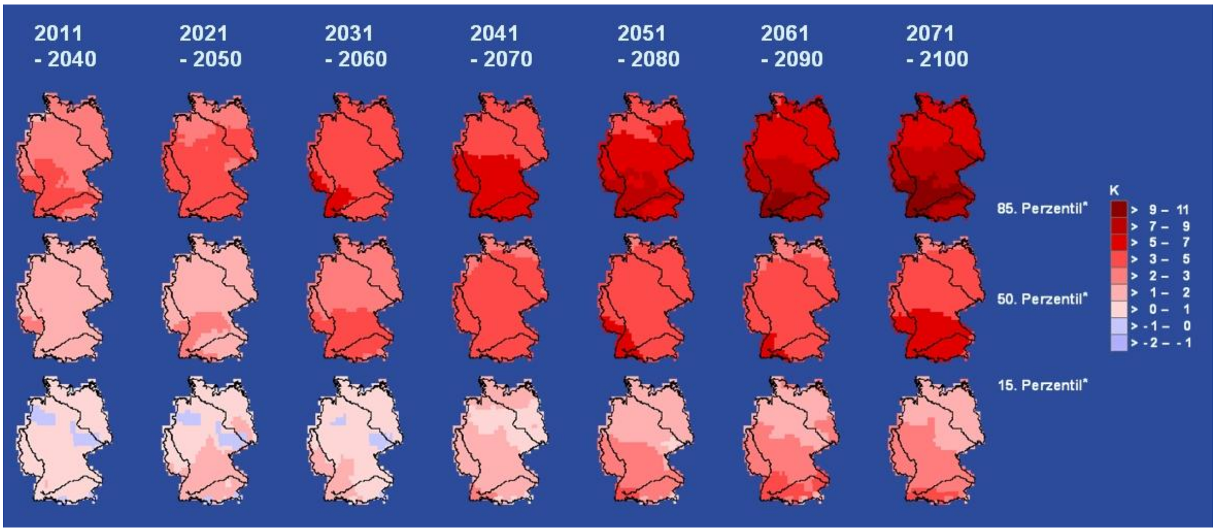


Fig. 1: change maximum of soil surface temperature, uncovered soil, August; results of 19 regional models

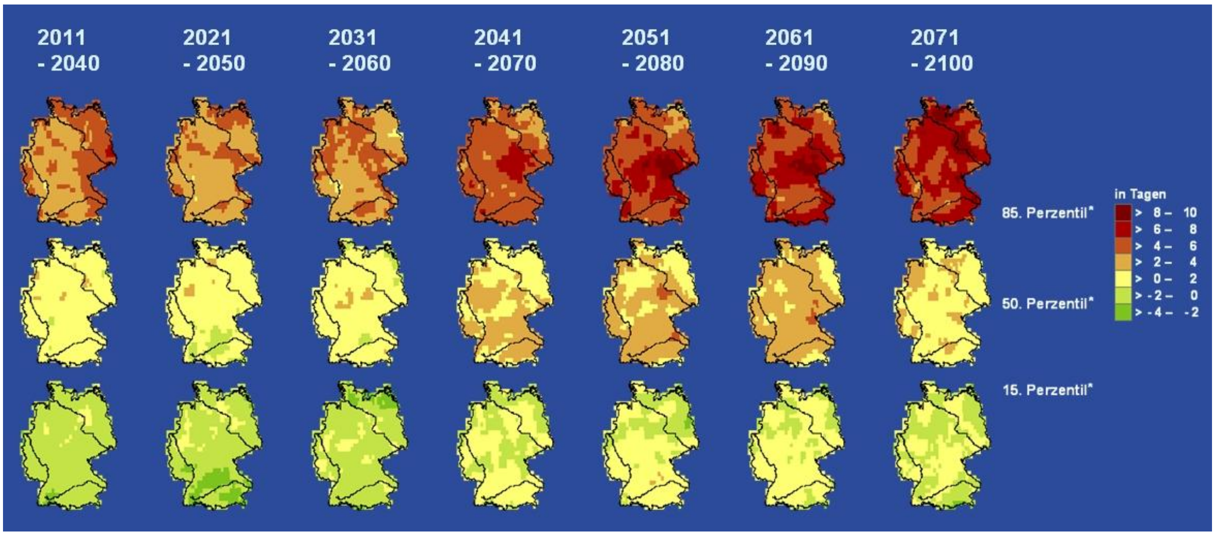


Fig. 2: change days with Canadian forest fire index ≥ 4, June; results of 16 regional models

A statistical analysis of the results of AMBER calculated with a multiplicity of regional climate models as input data and the presentation as maps is a good way to demonstrate the future variety. Additional parameters are planned.

Example 2 – Shift of agroecological zones due to climate change (Austria, Czech Republic)

In general, the results of many studies (i.e. Eitzinger et al, 2012; Trnka et al., 2011) predict significant agroclimatic changes over the entire European area during the 21st century, affecting agricultural crop production through various pathways. The effect of climate change on selected future agroclimatic conditions will change crop yield and variability (including the effect of higher ambient CO2 concentrations) and the most important yield limiting factors, such as water availability, nitrogen balance and the infestation risks posed by selected. The general shift of agroecological conditions can be expressed either by single climatic parameters (such as change in Temperatures, precipitation or evapotranspiration) or by a combination of parameters reflecting climatic needs of crop types, for example. Mostly such maps are still mostly available from scientific papers, books or climatic atlas, however, in some cases already on operational online platforms and maps (see case of Germany above). An example of the potential shift of agroecological (cropping) zones under a climate scenario in Central Europe is shown in Fig. 1, which indicates dramatic shifts to be expected in the next decades with strong relevance for agricultural production and long term decisions for agricultural management.

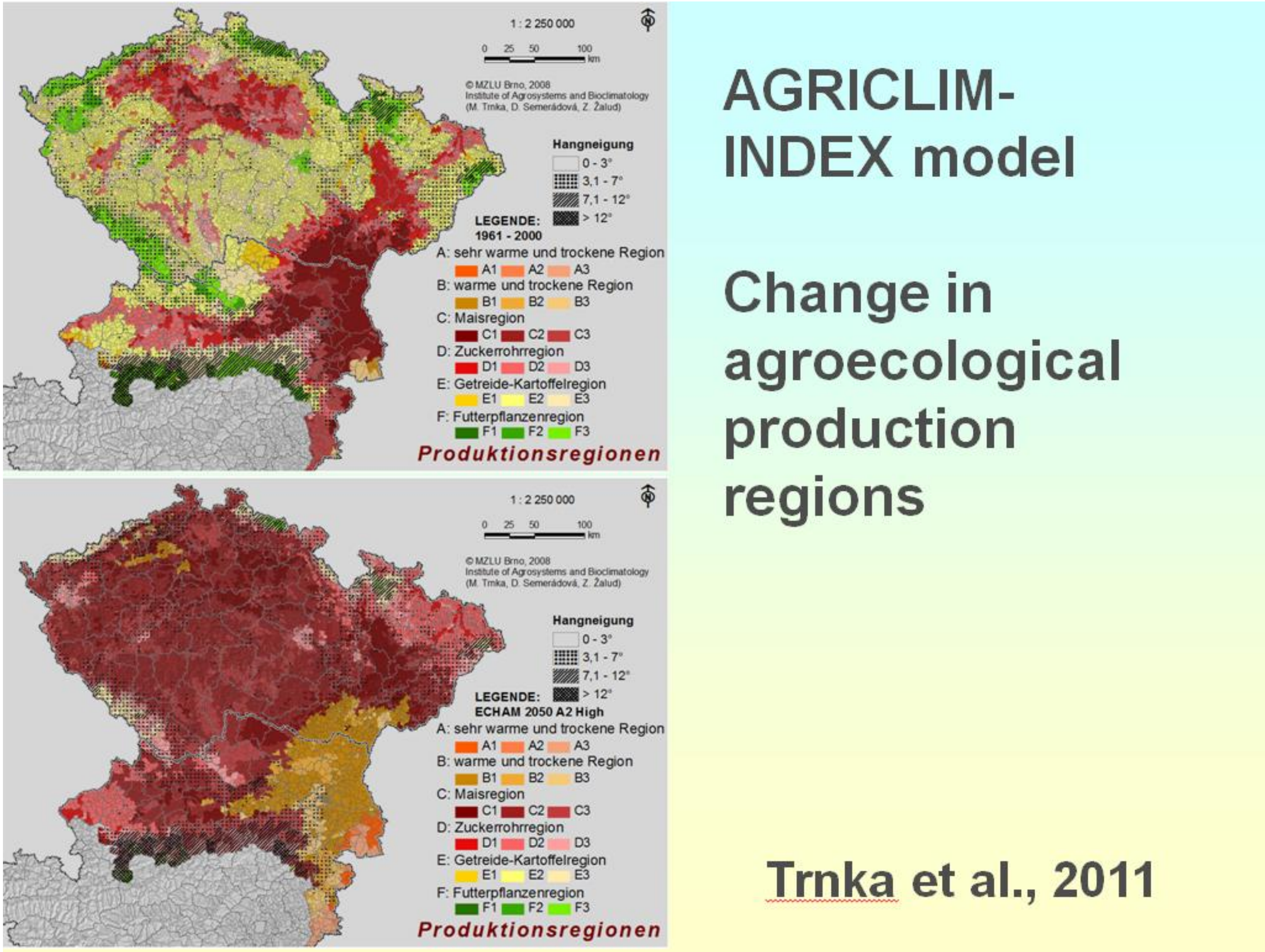


Fig. 1. Expected shift of production regions (agroecological zones) in Czech Republic and Austria under ECHAM 2050 SRES A2.

References

Eitzinger, J., Trnka, M., Semerádová, D., Thaler, S., Svobodová, E., Hlavinka, P., Šiška, B., Takáč, J., Malatinská, L., Nováková, M., Dubrovský, M., Žalud, Z. (2012). Regional climate change impacts on agricultural crop production in Central and Eastern Europe – hotspots, regional differences and common trends. *Journal of Agricultural Sciences*, in print.

Trnka, M., Eitzinger, J., Semeradova, D., Hlavinka, P., Balek, J., Dubrovsky, M., Kubu, G., Stepanek, P., Thaler, S., Mozny, M. & Zalud, Z. (2011). Expected changes in agroclimatic conditions in Central Europe. *Climatic Change* **108**, 261-289.

Example 3 – Small scale climate information - Terroir of a vineyard region in Austria

On the small scale, several adaptation measures can be developed based on high-resolution information, such as was demonstrated for hedgerow effects. One of these adaptation measures involves planning the distances between hedgerows or mixed crop farming to maximise wind-breaking effects and minimise unproductive evapotranspiration for the relevant crop (increasing crop water productivity). Other options include precision farming techniques such as adapting irrigation, soil cultivation and fertilisation to the spatial variations of the soil conditions. Further, the timing of field work could be changed to minimise soil water losses at vulnerable locations or sites (e.g., timing of mulching, crop rotation, crop selection). For medium scales, which include orography and land-use effects in addition to small-scale effects, adaptation measures can be identified for land-use planning or crop selection. Mapping the local climatic conditions can help to optimise cultivar selection and location (e.g. in vineyards) or identify risky sites with extreme climate impacts (e.g., cold-air lakes, sites with high wind speed, dry and wet locations) or increased risks for diseases related to air humidity.

This example maps demonstrate the value of high resolution climatic fields (terroir characteristics), in specific monthly and annual microclimatic conditions within the vineyards, provided for long term stakeholder decisions on vineyard management, i.e. under climate change conditions for the next decades. Climatic maps include parameters such as air and soil temperatures (mean, maximum, minimum, daily amplidude), air humidity, wind field, HUGLIN index, frost risk (Fig.1 – 3).

Regions with blue lines are wine growing areas within the region. Additionally high resolution maps of soil conditions and geological conditions are provided by maps. Descriptions include regional seasonal weather patterns and their relations (severity and frequency) of weather extremes.

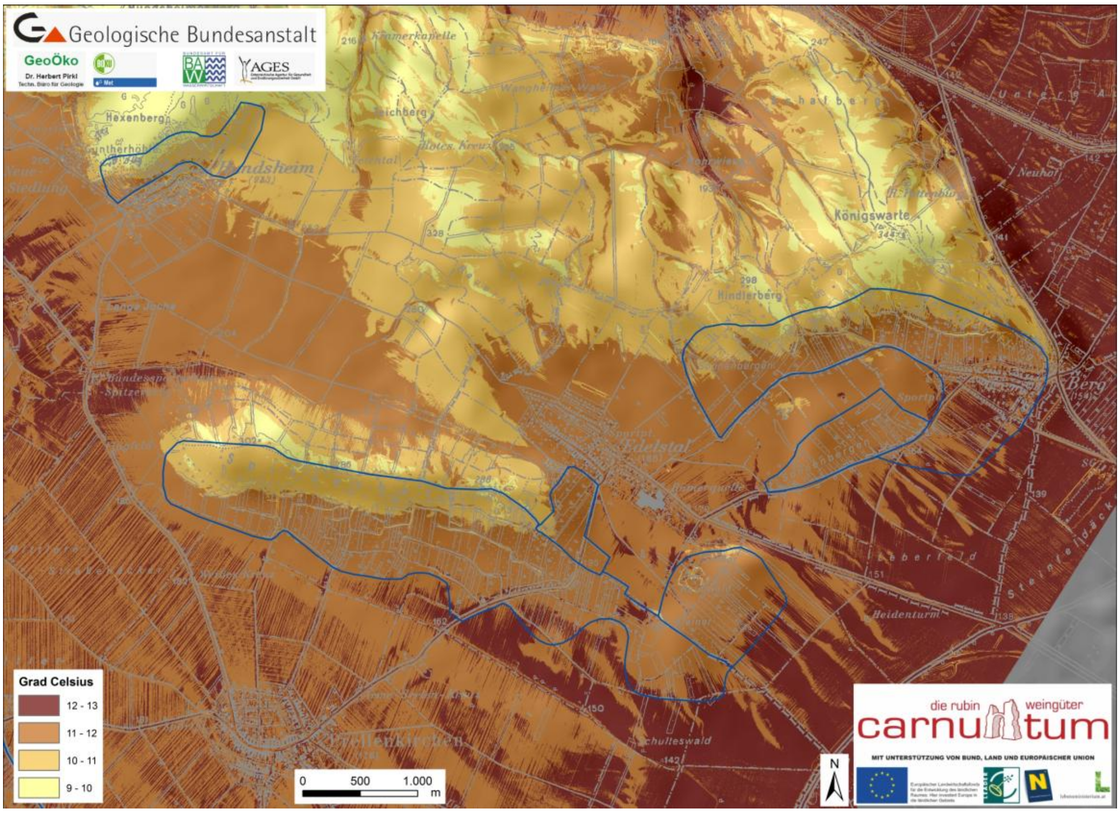


Fig.1: Mean (1980-2009) daily temperature amplitude in June; 50cm above soil surface.

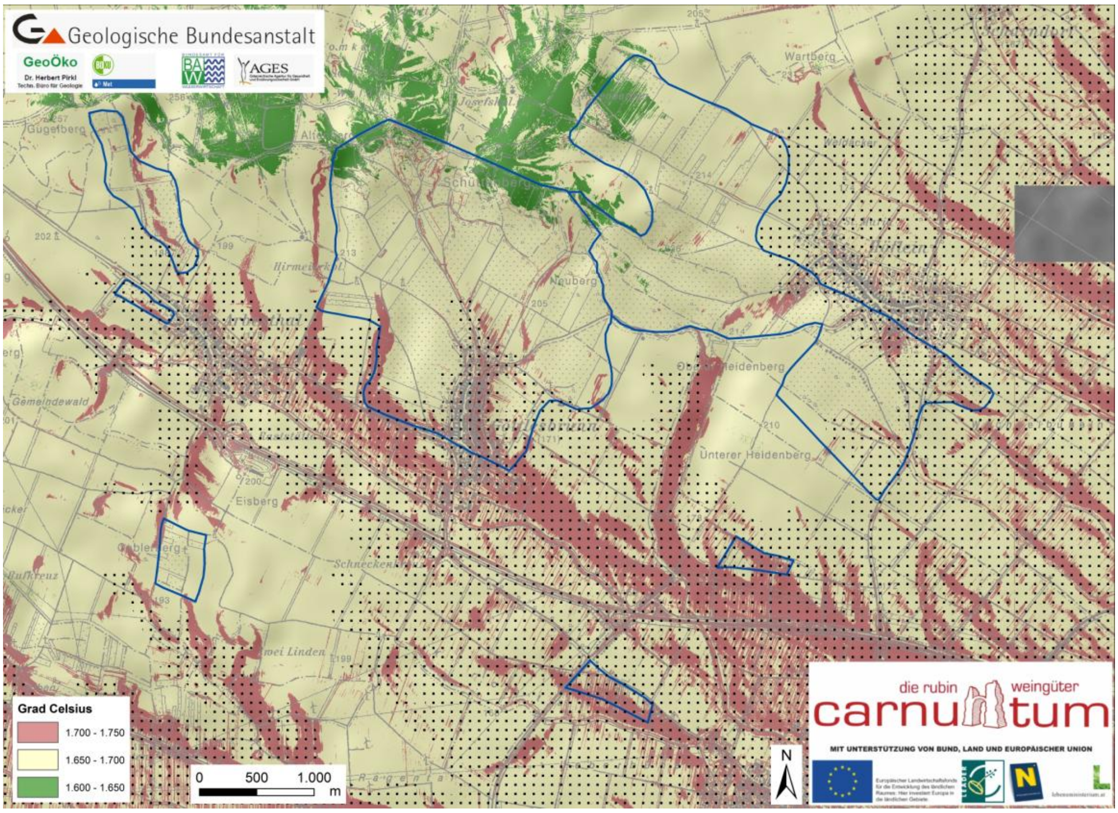


Fig.2: Mean (1980-2009) HUGLIN index 50cm above soil surface and late frost risk areas (dotted area).

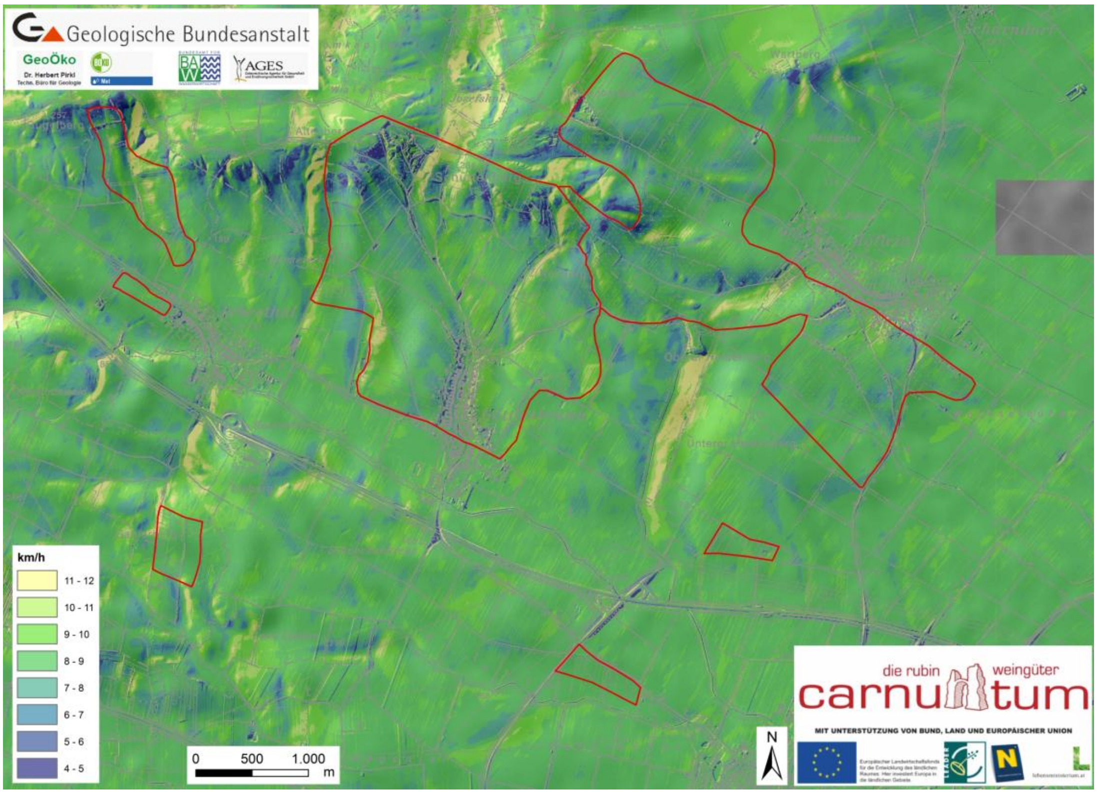


Fig.3: Mean (1980-2009) wind field, 2m above soil surface.

Recommendations and unsolved problems in the RA VI region

• Related products should be tailored for different stakeholder groups such as farmers (primary production) and commercials and institutions (i.e. food chain, transport etc.) considering specific conditions in the different countries. Spatial and temporal scales of information should be optimized (reliability of the information with the scale and nature of the decision).

• Current applications for agroclimatic conditions operate mostly still on a large scale/low spatial resolution with limited accuracity for decision making at the local level. As local climates and climatic parameters can vary in a wide range depending on small scale topography, high resolution terroir maps need to be developed, which are relevant for the farmers field scale.

• Several stress indices are used to predicting impact of climate change on crops (i.e.agrometeorological drought indices). Often these are describing general impacts or changes, but not crop specific. Crop specific stress indices, considering sensitivities and various thresholds, even cultivar specific ones (e.g. water stress tolerance), would be of great interest and application potential for farm level applications, such as irrigation scheduling. Of course, this needs as well a high resolution and accurate map on soil physical properties, which should be developed at regions where not available.

• The meaning and limitations of indices should be well defined, easily to understand and be calibrated for homogeneous climatic regions before operational use. Results under climate scenarios should be described by probability statistics and ensemble results. The related uncertainties and statistics should be explained in a simple way and be regular part of any results, maps and graphs presented for stakeholders, to avoid any misunderstandings for long term decision making.

• Agrometeorological indices or empirical methods operationally applied under climate change conditions should be recalibrated regularly (i.e. 10 years) in order to avoid emerging biases. This counts especially where a limited set of influencing parameters is used for calculation of complex processes such as evapotranspiration.

• The topic of climate change and impacts on agriculture should be introduced well in education and agricultural schools. This would significantly improve a proper use of related operational services and products in the future.

Task A6

6) Use of climate and meteorological resources in the RA VI high-quality agricultural production chain; to review and access	A6.1 Identification of current strength and weakness in the agrometeorological support to the whole agro-food chain (input supply industry, farmers, agro-food industry and distribution systems). A6.2 Identification of new tools potentially useful for the actors of the agro-food chain and suggestions for their implementations. A6.3 Prepare a regional report of best agrometeorological practices to be adopted for a XXI Century European farming design

Authors: Luigi Mariani, Federica Rossi

Introduction

The main objective of this task is to clarify the essential role of meteo-climatic variables as resources and limitations for agricultural activity in an advanced agricultural context, strongly integrated in a complex agro-food system. Our reflections, drawn taking into account the contents of the new Gamp (WMO n. 134), are referred to the introductory writing and the list of the Terms of Reference of the TT-AGM.

Background

The new European agro-food system

The European approach to food production (Fisher et al., 2005) evolves towards an advanced agro-food system providing for the integration of four main subsystems: agricultural subsystem (crop cultivation and husbandry), input-supply-industry (machinery, seeds, agro-chemicals, energy, animal nutrition, etc.), agro-food-industry (primary and secondary food processes) and distribution (wholesale/retail). An interesting element of the agricultural subsystem is represented by the spread of externalized services (external contractors – "contoterzisti", in Italian language) which manage the land surfaces of an increasing number of farmers and can adopt in short times new machinery and agro-techniques, representing a powerful element of innovation.

This new paradigm of the European agro-food system (Aramyan et al., 2006) includes as corollaries (i) the full traceability of products along the agro-food chains, (ii) the evaluation of both consumers and farmers as primary entities in the agro-food chains, (iii) the full satisfaction of the expectance of consumers in a "farm to fork" perspective and (iv) the overall sustainability of agricultural activity, based an balanced use of resources, low environmental impact, multi-functionality, full meet of needs of food industry/consumers and rational evaluation of economic limitations.

A relevant role in this new scenario is played by atmospheric variables (solar radiation, temperature, humidity, precipitation, wind, etc.) because they are primary drivers for the agro-ecosystem. These variables, acting both as resources and limitations determine quantity and quality agricultural production of vegetal and animal origin. This justifies a relevant potential interest of all the actors of the agro-food system for the space and time evolution of atmospheric variables and for the quantitative evaluation of their effects on agricultural production.

A new role for agrometeorological services

The above-described context opens a wide set of opportunities for meteorological and hydrological services able to produce high quality agrometeorological information by means of enhanced systems of measurement and modeling and to broadcast it to final users in a timely way. Agriculture, livestock, forestry and fisheries activities may all take advantage by adopting such opportunities. Moreover it must be considered that an approach to agriculture in the light of atmospheric variables could represent a model for non-European countries in order to improve the rational use of resources in a food security perspective.
Lower input costs, high yield potential, efficient use of available machinery and labor, and availability of financial incentives are some of the key elements for farmers for choices referred to crops and crop rotations.

ACTIVITIES AND RESULTS

1. Studies and implementation on Geo-traceability

In the context of the analysis described in our report of June 2011 we are approaching the concept of geo-traceability (Oger et al., 2010) in order to combine geographical information with conventional traceability data in the context of the high quality agro-food chains.
The inclusion of geographical information relating to the environment of production involves not only geo-morphological and pedological characteristics but also a specific attention to climate aspects (climatic normals) and meteorological aspects of the cropping period (solar radiation, air temperature and relative humidity, rainfall, wind speed). This information is obviously founded on the geolocation of production fields and suitable GIS technologies can be adopted.

In the European area the need of geotraceability is driven by two main factors:
- the growing demand for differentiated quality products.
- the food safety problems (e.g.: micotoxins or bacterial contamination),

1-a Geo-traceability –example for grapevine and cereals

A specific example of this approach has been analyzed for the agro-industry of wine (Mariani and Failla, 2004). In the specific case of vine the current approach of cellars is aimed to produce wines with characteristics stable along the years. This is often reached hiding the peculiar contribution to wine quality of meteorological driving variables of each specific year.

In our case, taking into account meteorological data coming from operational agrometeorological networks, it is possible to obtain a specific description of:
- the characteristics of the wine production of single years, giving an aid to characterize the so called “wine style”
- the space variability of wine quality in a given terroir.

With reference to the wine production of single years it is interesting to distinguish:
- cool-rainy years that give rise to wines fresh flavored and low alcoholic (oceanic wines)
- dry-sunny years that give rise to body wines with flavours of ripened fruits (Mediterranean wines).

In this case the final consumer can be aided to reach a new perception of wine in the light of the contribution of the determinant characteristics of the year of production.

With reference to the space variability of wine quality, the geo-traceability increases the awareness of consumers about the plasticity of grapevine, a peculiar crop that gives rise to original and high quality products in a wide range of climatic conditions, ranging from Central Europe to the south of the Mediterranean.

In the field of cereal production, the above-defined geo-traceability could be also interesting in order to evaluate the risk of mycotoxins (e.g. DON toxins from Fusarium fungi).

2. Integration and contributions to WMO activities

At the INTER-COMMISION COORDINATION GROUP ON THE WMO INTEGRATED GLOBAL OBSERVING SYSTEM- WIGOS, held in Geneva, Switzerland, 26-30 September 2011, our TT was invited to contribute on behalf of the CAgM to further WIGOS Implementation Plan.

Documents on benefits to Members, Regional Associations, Technical Commissions and Partners and technical guidance on the implementation activities by Members and the Regional Associations are in fact strategic to develop comprehensive further common strategies. The implementation of WIGOS as a self-sustaining evolving observing system within four years (2012-2015) are also important to be considered from the services delivery perspective, how to satisfy the multifaceted requirements of end-users for the benefit of society, sustainable development, production activities, and environmental protection: Agrometeorology in hence one of the primary potential data-user and data-provider and strongly contributes to add value to the existing WMO observing systems; building on, and leveraging existing mechanisms. Our task to Use climate and meteorological resources in the RA VI high-quality agricultural production chain is willing to have tuned information about effective data/products that meet real needs of users., and may provide an active contribution with its own expertise and resources in implementing WIGOS, and to be at the same time a WIGOS primary user.

Review on agrometeorological data contribution to land suitability protocols for crop production

(controbution from: Gabriele Cola, Massimo Compagnoni, Luigi Mariani, Simone Parisi, Federica Rossi, Nicola di Virgilio)

The knowledge of the overall complexity of a given territory is a precondition to maximize benefits coming from the presence, in it, of agricultural productions.
Finding the most proper place where major conditions are favourable to a given crop, or are able to positively influence crop quality and quantity, leads to the land suitability concept. A land suitability map evidences areas where the pool of environmental characteristics is able to better satisfy crop requirements and merges the specific characters/features (physical, chemical and biological) for an optimal and sustainable management of the production chain.

The land suitability approach addressed here regards different types of agricultural systems. One of them is a high-value traditional agricultural species (grapevine) , for which “quality” brand (as recognized by EC) gives status to a food product produced entirely within a defined geographical area and linked to its geographical origin (e.g. PDOs).
Another example is reported for annual food crops, and a third is for energy crops.
Urgent decision-support tools set-up are in fact needed for no-food crops, which most proper allocation in a traditionally food crop oriented geography as the European one has to be looked for in the light of new emerging energy policies and bio-based products economy. In this case most proper land allocation should be assessed considering the competition for land with traditional agricultural food crops, together with environmental sustainability criteria.

The following review considers updated state-of-art, FAO papers on land suitability, GAMP (WMO n. 134) and Author's case studies

Quantitative approach to land suitability - physical, chemical, biological, environmental background.

Agricultural production is founded on the interception of solar radiation by plants canopy, triggering the process of photosynthesis, which uses CO_2 and water to produce the fundamental bricks for biosynthesis processes.
The production of organic matter from photosynthesis is prone to the limitations imposed by temperature: thermal relations for a given plant can be described by a response curve defined by the following four parameters: the Minimum Cardinal (MinC), the Lower and Upper Optimal (LowO and UppO) and the Maximum Cardinal (MaxC).
These cardinals define two null-ranges (belowMinC and above MaxC), a range of increasing activity (between MinC and LowO), a range of optimal activity (between LowO and UppO) and a range of decreasing activity (between UppO and MaxC).
This approach has been successfully (even if roughly) applied to the growth process on the whole (e.g.: grapevine is active in a range between 7 and 35 °C, with an optimum in the 22 - 28 °C range) but still has to be deepened when it has to be related to the single biochemical processes involved in plant metabolism.

Another relevant limitation for plant activities is given by the availability and amount of water resources. Useful water for plants results from the dynamic balance between the inputs from precipitation and groundwater and the output due to evapo-transpirational losses (function of temperature, relative humidity, wind and net radiation). Even in this case, a response function parameterized with specific water levels and ranges can be defined (maximum water capacity, field capacity, easily useful water capacity and wilting point).

Further restrictions on plant production are represented by limitations of nutrients (due to the partial local availability of primary and secondary macro or micronutrients) and to those related to pests and biotic/abiotic diseases (fungi, insects, weeds, strong winds, hail, etc.). The degree of these last limitations is strongly influenced by atmospheric variables, and each of them can be approached with specific response curves.
The biomass produced after all the above-described regulations is allocated to the different plant organs (leaves, stems, roots and fruits). Also, the partitioning among the organs is a function of the atmospheric variables (temperature and others), since it is dependent on the phenological stage.
In addition to the above relationships plant-meteorological drivers, also chemical and physical properties of soil (e.g. soil texture, soil depth, etc.) have to be considered, given their extremely relevant role in the determination of quantity and quality of plant production. They affect for instance, the limitations due to shortage of water and nutrients or the diseases caused by pests and biotic/abiotic factors.
The approach to land suitability analysis is founded here on the quantitative evaluation of resources and limitations, and on assessing their role in acting as constraints for reaching sustainable yields for current or novel crop production chains.

The spatial approach to land suitability for a given crop production

Such a quantitative evaluation is crucial to characterize a given territory for circumscribing homogeneous areas, intended as land portions where environmental factors are constant in space within the borders. The identification of these areas thus represents the spatial extension where crop will be constant for those traits (e.g. yields and quality) linked with environmental factors (e.g. temperatures, rainfall, etc.), and where optimized crop management as a function of the specific objectives of the agro-food chains are also defined.

The division of a territory into homogeneous areas is based on the study of two complementary aspects:

a. the definition of potentially homogeneous areas, i.e. areas that maintain their specificity for a long time (on the order of decades) based on the analysis of different information (time series of weather data, soil data etc.).
This definition can drive the strategic decisions of farmers and of other players of the agro-food chain (e.g.: choice of species and varieties for tree crops, mechanization levels, water management etc.).

b. the evaluation of the specific effects of the single year ("vintage effect?") which results from the interaction of atmospheric variables (solar radiation, temperature, relative humidity, wind, precipitation) with physical, chemical and biological features of the potentially homogeneous areas, establishing the original patterns of resources.
This evaluation is useful to guide:
- tactical decisions (date of sowing or harvesting, fertilization, irrigation, ...)
- the definition of the spatial patterns of quantity and quality of harvested crop production, useful to manage the agro-food chain in the compartments of storage, transformation, wholesale and retail.

Information layers (Check list)

A Digital Elevation Model of the studied territory: maps of slope, aspect, altitude
Land use maps
Meteorological datasets: air temperature, relative humidity, wind speed and direction, solar radiation, precipitation, soil temperature (the ideal time series length is 30-50 years time series)
Geological layers
Soil layers
Crop layers
Agronomical layers (eg: irrigation management, training systems, plant densities etc).

Algorithms for data treatment

The analysis of the suitability of the selected territory for a given crop consists of the five following steps respectively based on suitable time series of meteorological data (ideally 30 years time series), geological maps, pedological maps or *ad hoc* observations (soil profiles and soil drillings):

a) Quantitative description of the properties of the selected crop/variety (physiological, morphological and phenological features) useful to parameterize the empirical/mechanistic modelling approaches hereafter cited. Information are temperature requirements, annual rainfall requirements, limits in altitude, killing temperature, light intensity, optimal soil characteristics related to pH, depth, texture, fertility, drainage, salinity, etc.. The above information can be found in crop catalogues (e.g. the FAO databases ECOCROP the crop environmental requirements database and the crop environmental response database, or in the portal ECOPORT: Ecological knowledge management system: http://ecoport.org/), and within the published scientific literature and state-of-art.

b) Analysis of geological and pedological features of the territory with production of:
geological map (homogeneous territorial units considering of the age, lithology and origin of the parent material)
Landscapes map (homogeneous territorial units considering of the slope, exposition, altitude, soil use and parent material)
Soils map (homogeneous territorial units where it is possible to expect a particular association of soils characterized each one by specific physical and chemical properties, like the sequence of the horizons, the texture and structure of each horizon, the macroporosity and the available oxygen, the permeability and the vertical drainage, the limitation or impediment to the penetration of roots,

cation exchange capacity (CEC), base saturation, electrical conductivity (EC) and content in mineral element and nutrient)

c) General climatic characterization, founded on applications of:
Static climatology (statistical analysis of temperature, precipitation, relative humidity, wind, etc.)
Dynamic climatology (analysis of weather types - foehn/stau, anticyclones, disturbances…- affecting a given territory and analysis of the effects on surface weather elements) (see example under Task 5.3)

d) Analysis of agro-climatic resources:
▪ Soil water resources (basic data are evapotranspiration and precipitation). A daily water balance can be applied in order to evaluate the time evolution of resources
▪ Solar radiation: Potential Photosynthetically Active Radiation – PPAR (potential = in absence of cloud coverage). This index is obtained applying astronomical equations for sun to a Digital Elevation Model.
▪ Thermal resources (e.g.: Growing Degree Days or Normal Heat Hours approach)

e) Analysis of agro-climatic limitations:
▪ Thermal limitations: definition based on the analysis of frequency and persistence of temperatures below critical thresholds
▪ Soil water limitation: cumulated values of deficit
▪ Quantitative evaluation of risk of hail is founded on data from networks of grelimeters.

f) Phenological / physiological analysis: multi-year biological observations carried out on representative field in order to study of the relations with climatic features:
▪ phenological observations
▪ quantity and quality of crop productions by means of suitable crop production models (e.g.: total biomass production and protein content of wheat, sugar content of sugarcane, …)

All above-listed data will be processed as information layers in a GIS with pixels of about 100 x 100 m.

Tools
The capacity to examine the environment, understand all factors that characterize it, is a precognition to carry out a land suitability study, and main tools are represented by Geographic Information Systems, capable to capture, extract, store, manipulate, analyze, manage, display the data.

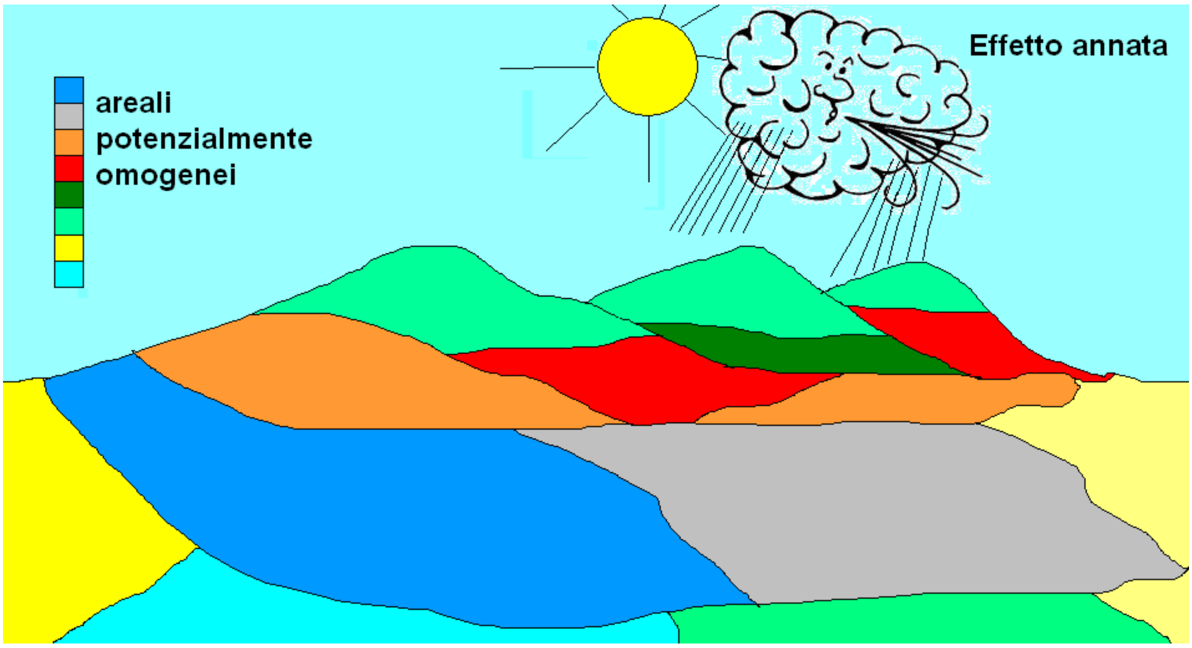


Figure 1 – The single year effect acts on the potentially homogeneous areas resulting in quantity and quality of production.

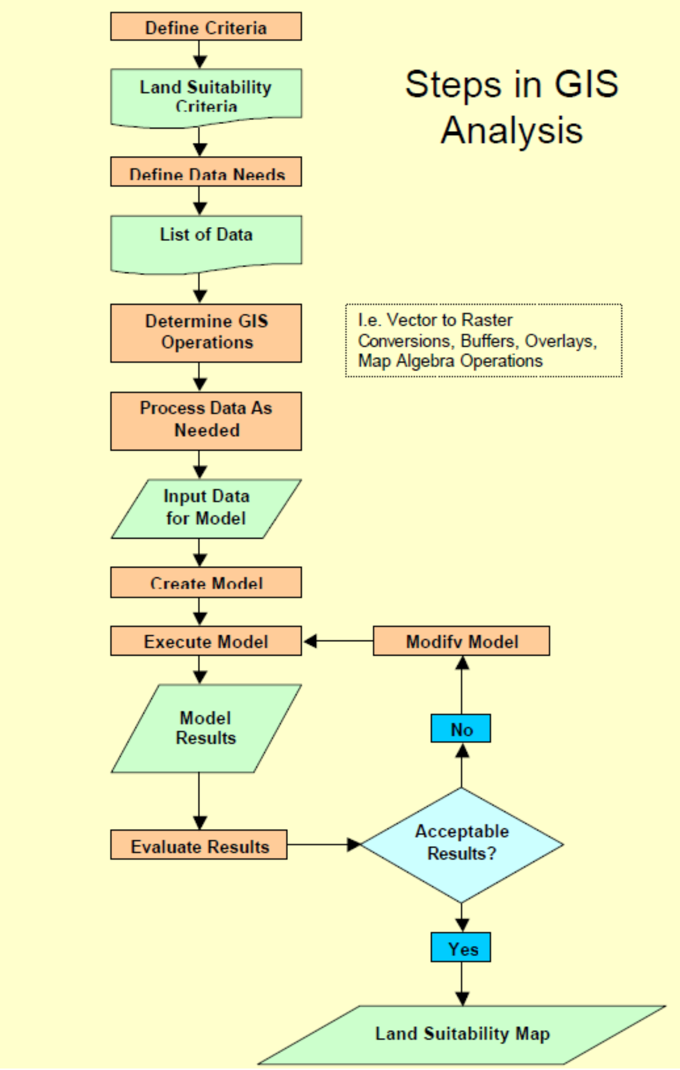


Figure 2. Steps necessary for performing a land suitability analysis (from Land Suitability Analysis User Guide. For ArcView 3.x and ArcGIS 9.x. NC Division of Coastal Management, NC Center for Geographic Information And Analysis.

Conclusions

The above described protocols describe the potential usefulness of agrometeorological and soil data in improving EC land suitability assessment for some major crops.

They are intended to evaluate and integrate as much as possible factors able to characterize a territory under different point of views in order to obtain land suitability maps with high level of reliability.

To completely overview land suitability components, it has to be remarked that, in addition to agrometeorological and soil analysis, several important additional factors should be considered when dealing with socio-economical aspects of land suitability.

These last factors are less directly linked with potentials of crop yield and quality, but in several cases they may determine the suitability of crop production chains also under optimal pedo-climatic conditions. They are represented, for example, by the farm structure and specific characteristics, e.g. the average extension, by the typical mechanization equipment of a region, or by the presence of a high value crop-chain that may be a constraint for the introduction of a new crop, even if environmentally suitable.

The suitability evaluation should also take in consideration the environmental impact of a crop production chain in relation to site-specific land vulnerability. Growing a crop it also means to use fertilizers, chemicals, fossil fuels, machineries, etc. that implies resourses needs and emissions bringing to environmental impacts. One crop can be, in fact, more impacting respect to another in relation to the intensification of his production chain. Furthermore, the same crop may result in a higher or lower impact with respect to the selected agronomic technique (zero tillage, low fertilizer input, organic farming, etc.). Moreover, the local environment can be more or less sensible to a specific impact, e.g. high sand content soils are more vulnerable to eutrophication respect to clay soils, because of the ability of these last to retain nutrients and, then, protect groundwater. The impact of a same production chain can be different based on the vulnerability level of the location.)

Recommendations Task A 6

• **Geo-traceability** of agricultural products increases the awareness of consumers and has potential for developing specific product standards (including environmental standards) which can be related not only to specific locations but also to weather conditions of specific years. This can be applied through the whole food chain from the farmer (primary production) to the consumer and is of relevance for food security including quality and quantity aspects. For agrometeorological services and products geo-traceability this offers not only to provide site specific climatic information for relevant products and but on the other hand opportunities to develop warning systems for the whole transport and storage chain of a product (i.e. energy demand for cooling, risks related to climate extremes etc.). Cooperation of agrometeorological services with research institutions and the food industry would foster the development of relevant services and products.

• **Land Suitability maps**, where local climate conditions play a crucial role can help to increase efficiency and sustainability of local agricultural production. In this context a high spatial resolution, reflecting the variability of soil conditions and local climates is crucial. In many regions, such high resolution data base with site representative data is still not available. Thus an important task for the next decades is to develop high resolution data bases of soil conditions, agronomic conditions and local climates.

Appendix Task A 6

Reported case studies

AGROMETEOROLOGICAL ANALYSIS FOR ZONING VITICULTURAL APTITUDE AT DIFFERENT SCALES

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ABSTRACT

The adaptability of wine-grapes (*Vitis vinifera* L.) to a wide range of climate and soil types is the result of the species genetic plasticity associated with the multiplicity of management practices and training systems developed by the viticulturists in the different environment as a consequence of a long historical evolution .

In the light of this, agroclimatic analysis is an important instrument for comparing, evaluating and zoning viticultural aptitude at different scales, form macro to microscale. An example will be discussed referred to the Europe mountain areas which take part of the CERVIM (European Research Centre for Mountain Viticulture). Some other examples referred to Varese province (Italy) and Kosovo are also discussed. These analyses are principally founded on the study of territorial distribution of temperature and thermal resources (Growing Degree Days – GDD), precipitation and Potential Photosynthetically Active Radiation (PPAR).

An important improvement of the previous approach is represented by the introduction of multi-year observations carried out on representative vineyards and related to phenology, maturity curves (sugar, acidity and phenols), yield, vigor and grape quality evaluation including vinification and wine assays. This approach will be discussed with some examples referred to areas of Oltrepò Pavese and Valtellina.

INTRODUCTION

It is impossible to refer about viticultural aptitude without take into account the strong plasticity of this culture. Plasticity means adaptability to a wide range of conditions.

The following principal types of plasticity can be considered:
- plasticity of the genetic base (referred to grape variety and rootstock);
- plasticity of the training systems (frequently result of a long historical evolution);
- plasticity of management practices (e.g.: pruning, canopy and soil management, irrigation).
- plasticity of enological models (technology of wine production).

Result of plasticity is the distribution of wine-grapes worldwide (fig. 1) and in specific viticultural area. For example, in Italy vine is present in very different environments (from the Alps to the centre of the Mediterranean).

Other consequences of plasticity is that criteria used to define aptitude can be quite different in different areas. A good viticultural aptitude can be proper of very different zones (e.g.: Champagne and Aegean area).

Another important consequence of plasticity is that viticulture can effectively react to variability of weather conditions, climate or consumer needs).

Changes in the seasonal weather course may be counteracted by changes in the cultural management (irrigation, leaf removal, etc.) and/or in winemaking processes. Also the style of wine may modified according to the seasonal weather course, even if this fact has to be emphasized by a proper marketing policy. Wines from a particular year may have a different characters: e.g. in a cool year, wines fresh flavoured ("Oceanic" wines) will be obtained; while in a warm year, body wines with flavours of ripened fruits ("Mediterranean" wines) will be obtained. The marketing policy should establish a link between wine and year.

In the medium-long period, the whole set of variables of the viticultural and enological model (variety, rootstock, planting design, etc.) can be modified.
Why *Vitis vinifera* is so plastic? A possible reason can be retrieved in the history of the domestication of the plant and the successive migration of this culture.
Domestication of cereals in fertile crescent was about 10500 years BP; afterwards the spreading toward west can be proved.

Wine-grapes domestication was probably in Anatolian and circum Mesopotamian area, 6000 years BP, and successive migration of viticulture (fig. 2) followed a model similar to agriculture spreading (Mariani, 2004), but important differences have to be noticed:
- a delay of 3000 years;
- a northwards limitation due to climatic factors;
- a successive exposure to climatic fluctuations (from 5000 BP to today);
- a recursive process of domestication (secondary, tertiary, quaternary and quinternary centers where proposed due to hybridization of foreign domestic vines with local wild vines - *Vitis vinifera silvestris* Beck. - already present in Europe).

This latter fact could explain:
1. the increase of genetic variability (which means better plasticity with aptitude to a wider range of environments);
2. the distinctiveness of each specific varietal assortment that represent the basis of vocation of the European viticultural territories.

THE VITICULTURAL APTITUDE
According to these introductory considerations, the central question can be approached: how qualify/quantify the viticultural aptitude of a territory?
The aptitude of a given territory is the result of many elements:
- agroclimatic features;
- soil characters;
- plant phenological and physiological aspects;
- characters of intermediate/final products
- varieties, training systems, management practices, enological models;
- economical aspects;
- social aspects (growers and consumers);
- history of vine in the selected territory.

The consequence is that the definition of aptitude is a complex and multiform question, that need an integrated approach (with many different types of knowledge) with a final goal: to define the best viticultural/enological model. In this communication only agro-climatic analysis will be focused.

AGROCLIMATIC ANALYSIS
Agroclimatic analysis applied to the study of viticultural aptitude (Mariani, 2002) presents four fundamental steps.
1) General characterization of climate, founded on methods of:
- static climatology (statistical analyses of T, RH, Wind, etc.)
- dynamic climatology (analysis of weather types - föhn/stau, anticyclones, disturbances - affecting a given territory and analysis of the effects on surface weather elements).

2) Analysis of agroclimatic resources:
- solar radiation: a relatively easy to obtain index (Olaya, 2004) is represented by the Potential Photosynthetically Active Radiation – PPAR (potential = in absence of cloud coverage). This index is obtained applying astronomical equations for sun to a Digital Elevation Model.
- Thermal resources (e.g.: Growing Degree Days above the minimum cardinal temperature are the base for indexes like Winkler’s index or Huglin’s index);
- water resources (basic fields are evapotranspiration and precipitation). A monthly water balance can be used if daily date are not available) (Allen et al., 1998).

3) Analysis of agroclimatic limitations (temperatures below/above critical thresholds, water limitations, hail):

- Thermal limitations: definition based on the analysis of frequency and persistence of temperatures below critical thresholds for vine (-15/-18°C for well hardened vines; -1°C after bud break).
- Quantitative evaluation of risk of hail is founded on data from networks of grelimeters. Time series of this kind are available for some Italian areas (Trentino, Friuli V.G., Emilia Romagna).

4) Phenological/physiological analysis: multi-year biological observations carried out on representative vineyards are fundamental for the study of the relations with climatic features:

- phenological observations;
- maturity curves (sugar, acidity, phenols);
- maturity degree (technological and phenolic maturity);
- time of ripening;
- yield;
- vigour;
- grape and wine assays.

All collected data are processed as information layers in a GIS with pixel of about 100 x 100 m.

SOME EXAMPLES AT DIFFERENT SCALES

Example 1 is referred to vine areas of CERVIM (European Research Centre for Mountain Viticulture), an association that collects mountainous and/or steeply sloped viticultural areas of some European countries like Austria, Suisse, Italy, Portugal, Spain, France, Germany (Mariani e Failla, 2005).
Europe is located at mid latitudes and presents a strong variability in circulation. This means:
- a strong time variability in meteorological variables at surface;
- as a final result a climate substantially stable (stability from variability).
On a dynamic basis (classification criteria = influence of westerlies and Azores anticyclone and effects of mountain ranges) three European macroclimates where defined (fig. 3):
O=Oceanic climate
A=Mediterranean climate
AO=transitional climate
M=mountain climate.
A set of indexes was adopted to qualify the aptitude of each zone (yearly precipitation – mm - and rainfall days, length of vegetative season - days with temperature above10°C, growing degree days above 10°C, Huglin's index, evapotraspiration - mm, water balance expressed as number of days with empty soil water reserve, global solar radiation - MJ year^{-1}).
In particular thermal indexes where referred to the extreme elevation levels of each "vine belt" (e.g. for Valtellina different indexes where obtained for an elevation of 250 m and of 700 m a.s.l.) and a range of values was produced.
For each zone all data where resumed in a card.

Example 2 is referred to Kosovo, a region of the former Yugoslavia. The central government of Yugoslavia (a planned economy) carried out in '70 years a viticultural expansion in Kosovo in 4 zones. After Balkan wars, vineyards and wineries were neglected and UNDP (United Nations Development Program) asked for an evaluation of agro-ecological resources for a possible recovery.
Agroclimatic analysis (fig. 4) was referred to thermal resources (Winkler's and Huglin's indexes), PPAR, ETM, water balance with definition of the first day with empty water storage, and yearly days with empty water storage, thermal limitation (cold and hot spells).
Analysis show the good level of thermal resources and a significant thermal limitation due to winter temperatures that can be overcome applying correct management practices.
About water resources, soils with a good maximum water storage show a moderate water deficit only in the late season (August - September), a phenomenon can enhance the quality of production.

Operational conclusion is that viticulture is technically sustainable. The final product of this work was a check of suitability of present varieties and thematic maps useful for the choice of new varieties.

Example 3 is referred to Varese province, an hilly area of Lombardy, a region located in North Italy near lake Maggiore, in an area with mild climate but high rainfall. Main goal of our work was to support the request for the registration of a new wine IGT (Typical Geographic Indication).
Analysis of PPAR distribution (MJ m^{-2} $year^{-1}$), air temperature (mean monthly values, growing season limits), Winkler's degree days, evapotransipiration, precipitation (fig. 5) and water balance.
Conclusion was that thermal and radiation resources are not limiting factors and the principal limiting factor is represented by soil water excess during the vegetative period. In other words the main vocational factor resulted to be a low soil available water capacity - AWC. On this base the area was subdivided in 4 zones (fig. 6):
Zone 1 (cyan): the whole area is suitable. Soil with very high AWC should be avoided.
Zone 2 (green): the main part of the area is suitable; viticulture is possible only in soils with AWC<100 mm in the first 100 cm of depth.
Zone 3 (yellow): the main part of the area is non suitable; viticulture is possible only in soils with AWC<50 mm in the first 100 cm of depth.
Zone 4 (red): non suitable.

Example 4 is referred to Oltrepò Pavese, an area of Lombardy, with viticulture distributed on hilly slopes. Main goal of the work was the delimitation of premium quality zones (DOCG).
Every year, for three years (1998-2000), phenology, maturity curves, yield, vigor and grape analysis data were collected in about 150 representative vineyards for the three principal varieties of this area (Barbera, Croatina and Pinot noir).
Agroclimatic analysis was referred to precipitation, thermal and radiation resources. A water balance was also carried out.
The conclusion is that water deficit is an important limiting factor for ripening; this means that the presence of deep soils with high AWC is the main vocational factor.
On the base of these conclusion were prepared legends for land suitability (an example is represented in table 1) and detailed maps for different varieties. Sensorial profiles obtained by panel test comparing selected and unselected areas showed a significant difference (fig. 7).

Example 5 is referred to Valtellina, a great Alpine valley, east to west oriented. Vineyards are mainly located on the south-facing slope from 300 to 700 m a.s.l. (Failla et al., 2004). Viticultural model is based on vineyards on small terraces on steep slopes. The main goal of this work was the validation of a previous delimitation of DOCG area.
Every year, for three years (1998-2000), phenology, maturity curves, yield, vigor and grape analysis data were collected in 54 representative vineyards (fig. 8). The work was referred to *Nebbiolo*, a late ripening red variety.
Doc zone presents Winkler's index from 1100 to 1900 GDD, potential photosynthetically active radiation from 2700 to 3200 MJ $m^{-2}year^{-1}$ and yearly mean precipitation: 900-1200 mm.
Conclusions of this work are that:

- altitude and PPAR are main determinants for timing of bud break, flowering and veraison (highest precocity is recorded at low altitude and high PPAR)
- altitude is the main determinant of technological maturity (highest maturity is recorded at low altitude)
- Crop load, PPAR and altitude are main determinants of phenolic maturity (highest phenolic maturity recorded in low cropping vines at low altitude and low PPAR availability).

Conclusions
The general conclusion of this mini review is that for agro-climatic zoning for viticulture the key factors are resources and limitations in climate and soil; the effects of these factors on phenological and physiological features must be studied and quantitatively evaluated.
Another conclusion is that a general rule does not exist and key factors are quite different in different areas.

This means that different factors need a detailed study and an approach founded on the interaction of specialists in viticulture with agrometeorologists, soil scientists, economists and so on.
Another important question, that is not treated in this paper, is the importance of the acceptance of conclusions of zoning by farmers.

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Table 1 – Suitability legend (optimal characteristics are represented in bold).

Cultivar	SOIL TEXTURE	ALTITUDE	SOIL DEPTH	SLOPE DIRECTION	PPAR MJ year-1 m-2
Croatina	**Loamy** **Clayey** **Loam-silt-clayey**	**Medium** Low	**Deep**	**South** East West	**> 2250**
Barbera	**Loamy** **Clayey**	**Low**	***Deep***	**South** East West	**> 2250**
Pinot n.	**Clayey** Loany	**High** **Medium**		**East** **West**	**> 2000**

Figure 1 – Wine grape distribution in the world (Mullins et al., 1992)

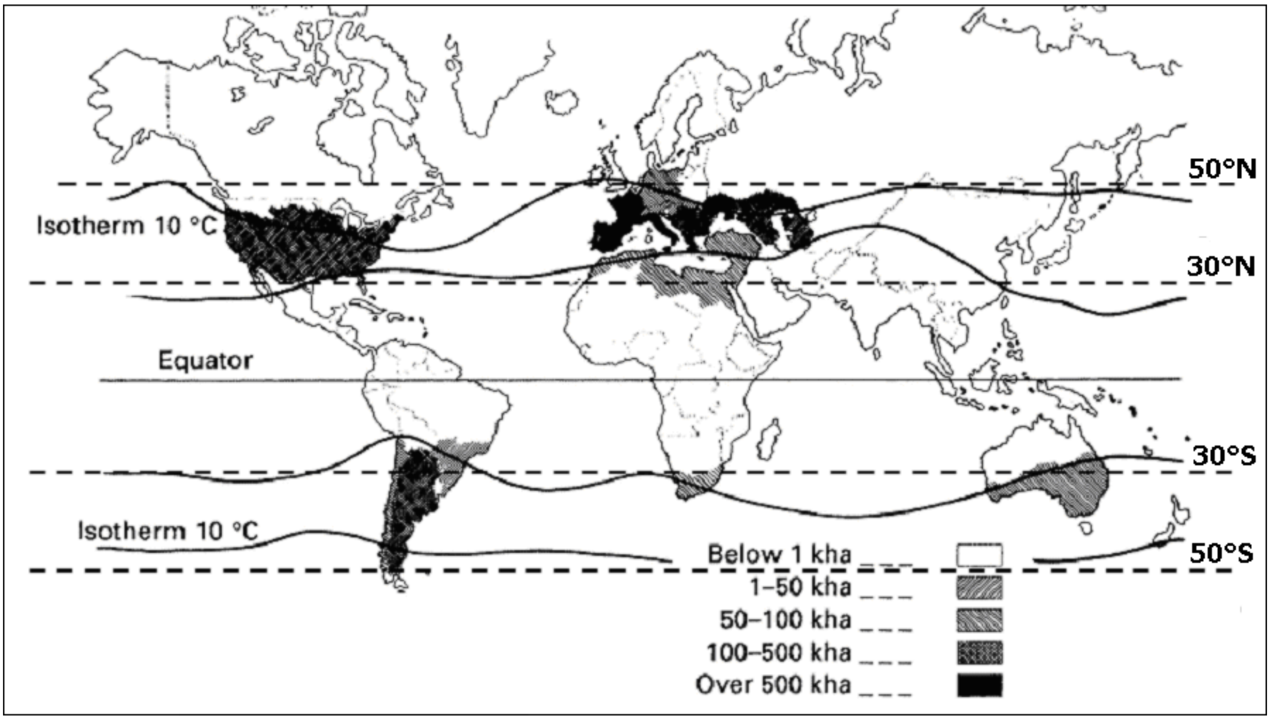

Figure 3 – European macroclimates defined for Cervim areas (from Mariani e Failla, 2005).

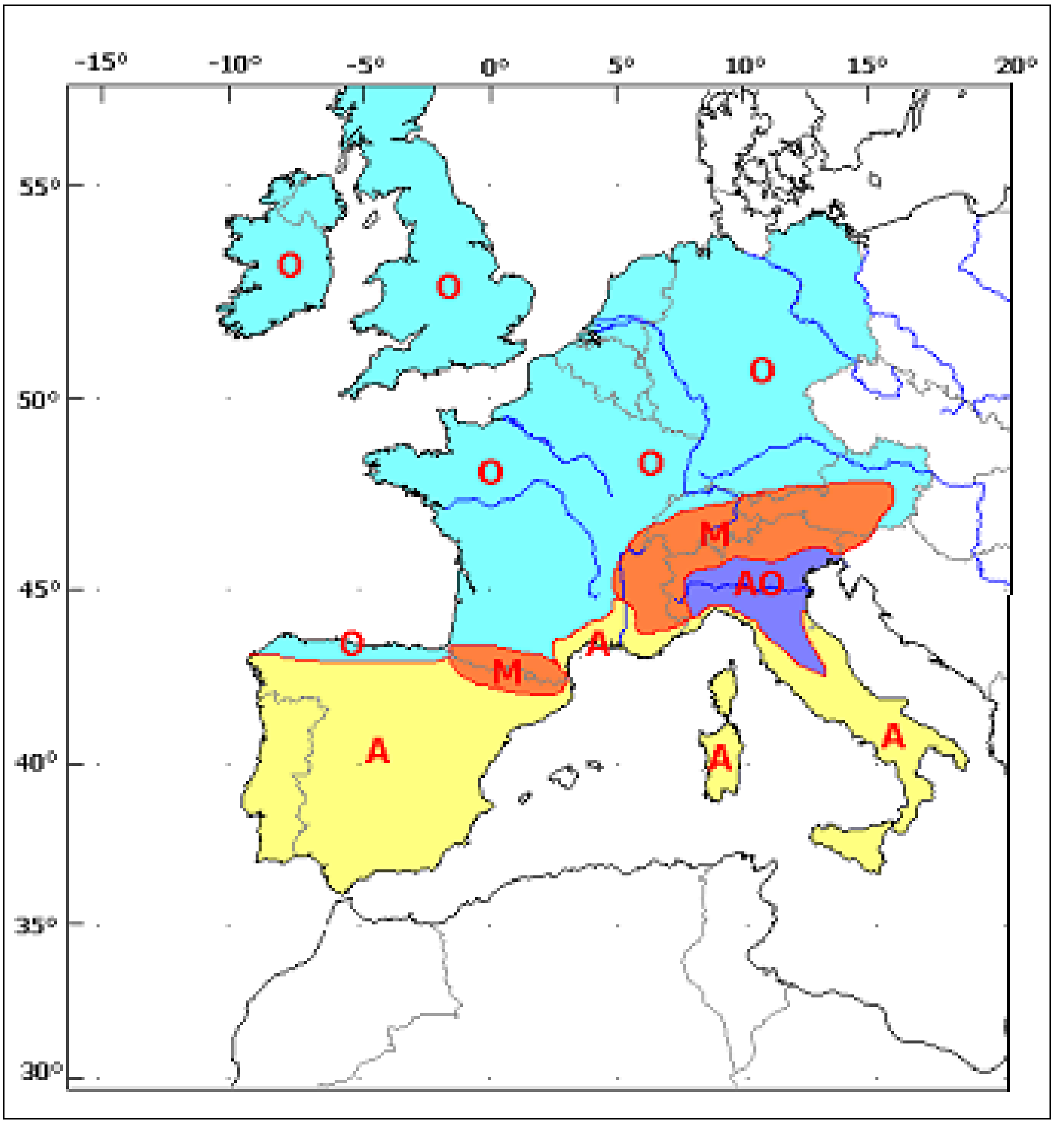

Figure 4 – Viticulture suitability map for Varese province
(for the description of the zones see in the text).

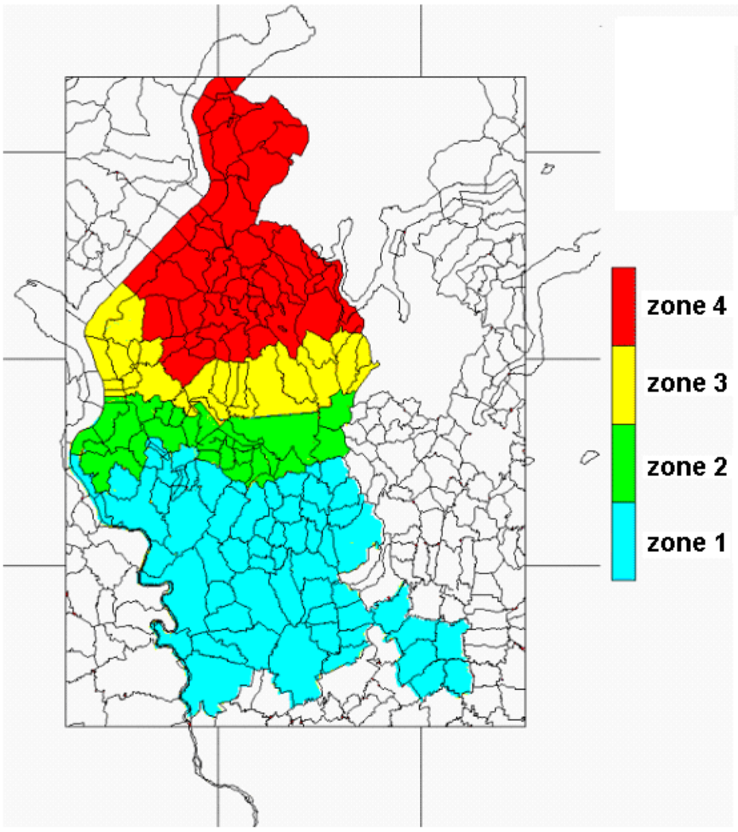

Figure 5 – Oltrepò Pavese, Croatina variety. Sensorial profile for selected and unselected areas.

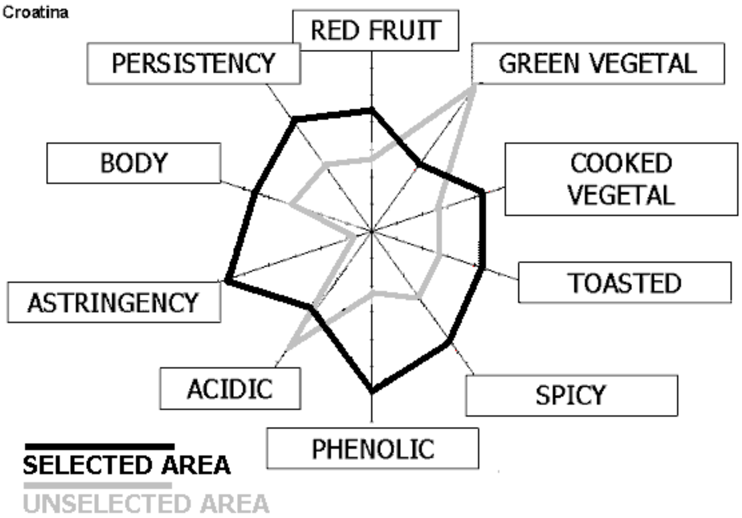

Figure 6 – Phenological relations for Valtellina (Precocity vs PPAR and altitude).