European Agrometeorological Perspectives on the Conservation of Natural and Environmental Resources in Harmony with Agricultural Production Systems

Zoltán Dunkel
Hungarian Meteorological Service
Budapest, Hungary

Abstract

This paper summarizes some ideas about the basic tasks of agricultural meteorology in the present situation when agrometeorologists must face some new challenges. The scope of agricultural meteorology as many other applied disciplines has changed during the last decades. While the basic task of agricultural meteorology has stayed the same, the socio-economic expectations of society have changed in the last decades. It seems that the stress has somehow shifted from the increasing of yield towards sustainable development in agriculture. There is also an additional problem in that the focus of agrometeorological activities varies from region to region. This poses problems to international organizations. The basic aim of "agrometeorology" is to improve the applications of meteorology to agriculture and environment in reference to crop management, groundwater contamination by fertilisers and pesticides, erosion, etc. This paper provides an overview of various European agrometeorological activities in relation to the conservation of natural and environmental resources.

Introduction

In the framework of the World Meteorological Organization (WMO), there are several technical commissions that provide technical advice and direction to WMO members. The Commission for Agricultural Meteorology (CAgM) is one of these commissions and from time to time it organises working groups to evaluate the position of agricultural meteorology. Collecting the information to give a general answer is difficult because the problems are highly varied from regional association to regional association. The WMO as worldwide organisation would like to give useful information to every member. In this case, solving problems is a challenge because we can give mainly a philosophic approach, taking into consideration the complexity of the possible agrometeorological tasks we face with the scientific and user's community. The role of the CAgM is to provide guidance in the field of agricultural meteorology by studying and reviewing available science and technology; to propose international standards for methods and procedures; to provide a forum for the examination and resolution of relevant scientific and technical issues; to promote training and the transfer of knowledge and methodologies; and to promote international cooperation and maintain close cooperation in scientific and technical matters with other international organizations.

A new working structure was established during the XIIIth session of the CAgM held in Slovenia in October 2002. Under the Open Programme Area Group (OPAG) 1, an Expert Team on the Management of Natural and Environmental Resources for Sustainable Agricultural Development

(ETMNER) was established and was given seven basic tasks to answer the modern questions of agrometeorological activity from the point of view of environmental resources:

a) to assess and report on the appropriate agrometeorological criteria to conserve and manage natural and environmental resources for the benefit of agricultural, rangelands, forestry, and fisheries, and for other relevant rural activities;
b) to survey the status of and summarise the information on trends in land degradation at the national and regional levels;
c) to document case studies of successful measures to manage land use, protect land and mitigate land degradation;
d) to provide liaison with the Joint WMO/Intergovernmental Oceanographic Commission (IOC) Technical Commission for Oceanography and Marine Meteorology (JCOMM) on inter-commission activities on natural disaster reduction in coastal lowland areas;
e) to establish practical guidelines from an agrometeorological perspectives for the conservation of natural and environmental resources in harmony with agricultural production systems;
f) to establish operational guidelines for fire weather agrometeorology;
g) to prepare reports in accordance with timetables established by the OPAG and/or Management Group (MG).

The present paper tries to add some ideas to item “e.” In general, we state that the need for sustainable agriculture and the sustainable agriculture does not refer to a prescribed set of practices. A systems perspective is essential to understanding sustainability, encompassing the individual farm to the local ecosystem to the communities affected by the farming system. Weather and changing climate are major factors affecting agricultural production in both developed and developing countries. Natural disaster mitigation plans should be factored into strategies for managing natural and environmental resources for sustainable agricultural development. These strategies for managing natural and environmental resources for sustainable agriculture can be achieved only through effective partnerships of experts from all disciplines and with all affected sectors of society.

The agrometeorological perspectives for the conservation of natural and environmental resources in harmony with agricultural production systems were outlined. We can define agrometeorology as an applied and crosscutting science. The first products in the field of agricultural meteorology were estimating yields, and then expanded to date of ripening, planning of planting, irrigation forecast, fertilizer, and plant protection. To solve these problems, scientists observed phenomena and measured standard meteorological values and special elements including evapotranspiration, soil moisture, and canopy fluxes. Also calculated were different variables and parameters. A major focus of the field was measuring and modelling the water budget of the soil-plant-weather system. Yield estimation can be performed using statistical or dynamic/simulation methods, which have quickly increased their role in relation to issues of climate change and extreme events in European agriculture.

From the point of view of the author, national co-operation is declining; therefore, international cooperation is increasingly important. Therefore, cooperation needs to focus on the following issues: to develop the use of remote sensing data and of numerical weather models; to improve the application of seasonal forecast and to evaluate the impact of extreme events on agriculture; to develop and validate agrometeorological models; to apply climate scenarios for evaluating the impact of climate variability/change; to improve the methods of agrometeorological information dissemination; and to establish a network for agricultural meteorology.

Agriculture needs agrometeorological models to predict and forecast crop yields and productions, to support decisions, and to minimise environmental costs of agriculture with short-term consequences and outputs or inputs with long-term consequences (Marachhi, et al., 2005). The models are basically formal expressions of physiological functions fed with climatic forcing and other environmental variables.

The Tasks of Agricultural Meteorology

Agricultural meteorology is an applied, cross-cutting science. As in the case of any applied science, the basic initiators of the activity are the social and economical needs (Sivakumar, 2004). It is no doubt that the crop yield depends on the weather. If we know the relationship, we can determine an exact weather-plant growth function. Knowing any exact function, with a model, we are able to describe the soil-plant-weather (climate) system and we can predict the yield. If we can forecast not only the yield but also any other step of plant development a better product will result. The conclusion is very simple ─ we have to study the system. The possible questions we have to answer within the frame of agrometeorology and the scope of agricultural meteorology are:

Yield estimation, forecast:	- quantity - quality - date of ripening - dynamics of ripening
Support of agrotechnics	- planning of the cultivation - irrigation forecast - fertilizer application - plant protection
Determination of planting zones.	

The list is far from the complete because it concentrates mainly on agriculture and does not deal with the other CAgM mandated issues such as horticulture, forestry, or fishery which all have special problems. To solve these problems and to find new agrometeorological perspectives for the conservation of natural and environmental resources in harmony with agricultural production systems, it seems that there is no need to discover a new direction of agrometeorology, but only to properly restructure the knowledge collected in the last decades. To solve agrometeorological problems, we need:

Observation	- phenology
Measurement	- standard meteorological elements - special: i.e., evapotranspiration - special canopy climate (microclimate)

- soil moisture
- phenometry

Calculation, computation	- plant-soil-weather models (development, growing, biomass - transfer model (fluxes)

The increasing climate variability and climate change are new challenges to the entire agricultural meteorology community (Salinger, et al., 2005). In some places of the world, the main problem in agriculture is not the increase of yield but to maintain an acceptable level of production. This is the reason why traditional agrometeorology has lost its position and it should shift its activity in the direction of environmental protection. In the case of the observations for remotely sensed data use, new methods for solutions have opened up, mainly in regard to phenological observation (Van Vliet and Clevers, 2003). Agrometeorology could also have an important role in effective chemical use and environmental protection (Motha, et al., 2006). Unfortunately in some parts of the world, the lack of food has not yet been solved and the increase in yield continues to be a fundamental question. In this case, the traditional agrometeorological application has not changed from its original goals, but the conservation of the nature must continue to play an important role in other areas of the world. From this point of view, it's necessary to distinguish between the developed and less developed parts of the world. In order to give some perspective about the present socio-economic expectation towards agricultural meteorology, we will now discuss the research supported by the European Union from the point of view of the conservation of natural and environmental resources in harmony with agricultural production system.

Agrometeorology Themes Supported by EU Framework Programmes

The Research and Technological Development Framework Programme (RTDFP) of the European Community, the EU framework programme, was a research funding instrument developed during the 1980s following a long period of negotiations and experiments, which were subsequent to the European Council decisions in 1974 that established such activities at the community level. The measures were intended to answer the existence of the so-called technology gap of which Europe was suffering compared to its main competitors, the United States and Japan.

The establishment and development of the RTDFP coincided with the completion of the unified European market for which the final step was the Treaty of Maastricht in 1992. The first research actions under the RTDFP were initiated in 1983 and the Single European Act in 1986 was the first community legal document to set the legal grounds for community action in research. The second RTDFP was adopted following this in 1987 (as a comprehensive structure, it was in fact the first), nevertheless with individual research fields adopted separately by the European Council. Following the Treaty of Maastricht, the adoption procedure has been significantly simplified, and the multiannual programme structure covering the majority of research and technological development areas has been implemented.

Over the years the RTDFP developed into the third largest funding instrument of the European Community, nevertheless, this was small in comparison to the agricultural and structural funding. When considering the totality of spending on research in the EU, the RTDFP budget was also in the range 6 percent. These figures clearly show that the impact of community level programmes cannot be very strong. However, the RTDFP has established a practice of research and technological development policy, highlighted several structural deficiencies in technological development in the member states, and at the EU level forged a European community of researchers. The emphasis of the RTDFP was always on technological development.

The criteria which form the foundations of research funding at European level are named as "Riesenhüber criteria" after the German Ministry of Science and Technology who presided the European Council in 1983. These are conceived in the spirit of "subsidiarity," meaning that action at the community level should only be implemented when it is clearly advantageous. As such, the criteria applied to supporting research at the EU level are:

- This research should be of such a scale, that no member state can afford to support it;
- It should create additional benefit from having been jointly performed (later developed into the principle of the European Added Value);
- Benefits from the complementarity of research done at national level;
- Contributes to the cohesion of the common market and to the drafting of unitary regulatory acts;
- Contributes to the economic and social cohesion of the European Union.

The research topics linked with agrometeorological issues have been included in research into the natural environment, environmental quality, and global change with the aim to understand the basic mechanisms of the climate and natural systems and their impact on natural resources (Györffi, 2003). The main parts of the structure were the basic processes of the current and past climate system, climate variability, and simulation of climate and prediction of climate change. These were handled separately from the impact of climate changes and other environmental factors on natural resources with the objective of assessing the major impacts on natural resources and the capacity for sustainable adaptation under changing human pressure, as well as from climate variability and change. While not directly an agrometeorological theme, we also have to mention European water resources. The international research activity in Europe towards conservation of natural and environmental resources in harmony with agricultural production system began as early as 1994.

The research tasks of the first RTDFP were in agriculture, forests, and the natural environment with the objective of studying and assessing the probable effects of climate change and other environmental changes on crops, forests, and other land ecosystems, and its consequences for land resources in Europe. It provided a basis for assessing the socio-economic impact of these consequences and for developing strategies for future management. It also prescribed and invited analysis and description of the long-term impact of climate change and other human factors on the natural environment and on the sustainability and productivity of agriculture and silviculture in Europe. The second element of the project proposals were development, validation, and application of regional mechanistic models; which described the effects of changes to the climate and to parameters linked to the climate such as CO2 concentration on agriculture, silviculture, and natural ecosystems, taking into account other human factors. Thirdly, it mentioned development of forecasting models to assess the reaction of biodiversity to long-term environmental change; assessment of consequences of climate change in biodiversity; development of a scientific base for in situ conservation strategies; and establishment of criteria for optimizing the landscape structure with a view to preventing extinction and maintaining appropriate diversity.

Specific emphasis was on the study of the particular effects of climate change on the northern forests and on marginal ecosystems such as wetlands, tundra, and taiga in the arctic and subarctic zones, and on Mediterranean forests. The more vulnerable territories to climate change impact received concentrated interest at the beginning of the research. The integrated studies of the effects of the climate and of human factors on mountain ecosystems and establishment of links to assess socio-economic impact were handled under a different topic. The changing composition of the atmosphere, mainly ozone depletion, was separately discussed under the development of models assessing the potential impact of increased UV-B radiation on the environment (both natural and urban) and on health. The UV-B question of course is not a typical agricultural problem since it affects mainly human beings. The most important theme was the assessment of the way in which land use, through such activities as forestry, agricultural practices, urbanization, the collection and processing of waste, water drainage, concentration of specific industrial activities in coastal zones, tourism, and civil engineering projects, can influence eutrophication and the contamination of aquatic systems. Last but not least, there were issues of the modifications and rehabilitation of forest ecosystems after forest fires.

In regards to the conservation of natural and environmental resources in harmony with agricultural production systems, one of the most important themes was land resources and the threat of desertification and soil erosion in Europe. The objectives aimed to provide an integrated approach to understanding, in the context of climate change, the process of desertification and soil erosion in Europe, in the interest of reversing this process. This took into account the complexity of the system of varying interdependent factors leading to the deterioration of land resources in areas susceptible to desertification and soil erosion. Simultaneously, the most important issue was the development of the scientific foundations for rational management of land resources in certain parts of Europe, which are threatened or affected by desertification and soil erosion. With regards to climate change and the reports of WMO/United Nations Environment Programme (UNEP) Intergovernmental Panel on Climate Change (IPCC), and the predicted climate for Europe, the issue of desertification appeared to be the main challenge to European agriculture.

The most important research tasks in the context of desertification were:

- Integrated research to assess qualitatively and quantitatively the relative roles of the various processes involved in desertification and soil erosion: climatic, hydrological, biological and soil-related;
- Modelling of the complex dynamics of the various processes concerned, on different spatial and temporal scales, in systems which are desertified or susceptible to

desertification or soil erosion, including their repercussions on the climate, so as to predict the future course of the phenomenon;

- Setting-up of suitable sets of data with which to detect any change and validate models; identification of indications of potential desertification and soil erosion;
- Development and improvement of countermeasures and strategies to control and reduce the deterioration of land resources in areas susceptible to desertification and soil erosion, including assessment of essential technological intervention.

There were 15 projects accepted under the "Agriculture, forests and the natural environment" during the life-span of the first Research and Biotechnological Development Framework Programme (RTDFP), out of which three were more related to the natural environment (Ghazi, et al., 1997).

The projects could be grouped under the conservation of natural and environmental resources in harmony with the agricultural production system:

- Climate change experiment with the objective of studying the response of entire catchments to increased CO2 and temperature;
- Predicted Impacts of Rising Carbon Dioxide and Temperature on Forests in Europe at stand scale;
- Long-term carbon dioxide and water vapour fluxes of European forests and interactions with the climate system;
- Forest response to environmental stress at timberlines;
- Spatial modelling at the regional scale of the response and adaptation of soils and land use systems to climate change;
- Climate change, climatic variability and agriculture in Europe: an integrated assessment;
- Improving wheat model accuracy and suitability for regional impact assessment to develop a new model for assessing the impact of environmental change on European wheat production to predict the impact of climate change at the regional-scale, which places particular emphasis on the ability to predict increasing CO2 concentration across diverse sites;
- Changing climate and potential impacts on potato yield and quality;
- Managing European grasslands as a sustainable resource in a changing climate to investigate the long-term responses of a representative selection of European semi-natural grassland ecosystems to elevated CO2 and climate change across a European transect which exploits the natural gradients in environmental variables;
- Carbon and water fluxes of Mediterranean forests and impacts of land use/cover changes;
- Long-term regional effects of climate change on European forests: Impact assessment and consequences for carbon budgets;
- Model evaluation of experimental variability to improve the predictability of crop yields under climate change.

In the framework of "Land resources and the threat of desertification and soil erosion in Europe," 22 projects were supported, namely:

- An integrated approach to assess and monitor desertification processes in the Mediterranean basin. Using an integration of ecological models and information from operational earth observation and meteorological satellites to assess and monitor regional scale indicators of sensitivity to desertification;
- Characterisation of the aridity processes on Mediterranean Europe. Protection and management guidelines;
- Policy-relevant models of the natural and anthropogenic dynamics of degradation and desertification and their spatio-temporal manifestations of southern Europe;
- An integrated methodology for projecting the impact of climate change and human activity on soil erosion and ecosystem degradation in the Mediterranean: a climatic gradient and dynamic systems approach;
- Concerted Action on desertification and its relevance to contemporary environmental problems in the Mediterranean;
- An integrated approach for sustainable management of irrigated lands susceptible to degradation/desertification which would develop and validate management-oriented models accounting for bypass flow that may increase hazard of salinization of subsoil and groundwater, significantly decreasing efficiency of salt-leaching and crop yield;
- Modelling Mediterranean Ecosystem Dynamics which would undertake computer based simulation modelling of plant community dynamics;
- Restoration of degraded ecosystems in Mediterranean regions;
- Synthesis of change detection parameters into a land-surface change indicator for long-term desertification studies;
- Consequences for the mitigation of desertification of EU policies affecting forestry activity: a combined socio-economic and physical environmental approach (Focuses on the hydrological and soil degradation consequences of various EU Policies and Funds including the 1992 Common Agricultural Policy (CAP) reforms relating to aforestation of agricultural land which impact on forestry activity);
- Modelling within storm dynamics on soil erosion;
- A spatial modelling tool for integrated environmental decision-making in the northern Mediterranean region;
- Relating research and policy in formulating and implementing environmental policies for combating land degradation and desertification in the Mediterranean basin;
- Modelling the effect of land degradation on climate;
- Mediterranean desertification and land use that would consolidate fundamental areas of research, field investigations and modelling that are necessary for quantifying and understanding desertification processes at selected sites across southern Europe;
- Mediterranean desertification and land use that would apply and integrate the existing knowledge, obtained in the different Mediterranean Desertification and Land Use (MEDALUS) projects in targeted areas along the northern Mediterranean that are already desertified or threatened by desertification at regional scale;
- Mediterranean desertification and land use that would develop a set of regional indicators which provide a planning tool for application to desertification at regional, national and European scales;

- Mediterranean desertification and land use that would improve the understanding of the impact of desertification on headwater channels and rivers, where desertification is understood to include the effects of both human activities and climatic changes;
- Modelling vegetation dynamics and degradation in Mediterranean ecosystems;
- Remote sensing of Mediterranean desertification and environmental changes;
- Wind erosion on European light soils;
- Wind erosion and loss of soil nutrients in semi-arid Spain.

The Agrometeorological-Related Proposals of the 5th RTDFP

The 5th RTDFP featured a new approach in structuring European research funding in trying to achieve a better integration of research fields (Ghazi, et al., 1997). The programme was based on the major elements of the 4th Framework Programme, however, the links among different parts were supposed to be more organic. Research topics linked with agrometeorology have been considered again from their environmental aspect, and classified as such into the Energy, Environment and Sustainable Development part of the programme. The programme on “energy, environment and sustainable development” centred around six key actions: sustainable management and quality of water; global change, climate and biodiversity; sustainable marine ecosystems; the city of tomorrow and cultural heritage; cleaner energy systems, including renewable; economic and efficient energy for a competitive Europe; as well as generic activities, and Research and Technological Development (RTD) infrastructure and facilities. The strategic goal of this part of the programme was to promote environmental science and technology so as to improve our quality of life and boost growth, competitiveness and employment, while meeting the need for sustainable management of resources and protection of the environment in line with the goals and objectives of the fifth action programme on the environment. The results were supposed to provide the basis for policies formulated at community level relating to the environment or deriving from international environmental commitments in particular, the implementation of the Kyoto Protocol requiring urgent support for RTD on a number of issues.

Issues of interest from agro-meteorological point of view were tackled in “Key Action 2: Global Change, Climate and Biodiversity.” The aim of this key action was to develop the scientific, technological and socio-economic basis and tools necessary for the study and understanding of changes in the environment. Aiming for an integrated approach, the priorities were:

- To understand, detect, assess and predict global change processes with the aim to focus on mainly on European and subregional causes and impacts of specific global change problems, such as climate change, ozone depletion, biodiversity loss, loss of fertile land and habitats, disruptions to ocean circulation;
- To foster better understanding of terrestrial (including freshwater) and marine ecosystems and their interactions with emphasis on interactions with land surfaces and land use, soil, water, atmosphere and ocean; role of biodiversity and climate change; interactions between ecosystems, biogeochemical cycles, large-scale land degradation and desertification;
- Scenarios and strategies for responding to global issues with the aim to provide a sound scientific basis for the development of tangible management strategies and actions to address the adverse consequences outlined in the key action;

- European component of the global observing systems with the aim to identify and fill key gaps in existing observation system capacity in order to ensure that the necessary data are available to address the prediction, impact assessment and response options to global change.

Out of 267 projects funded, only 22 were linked with agrometeorological issues:

- Assessing climate change effects on land use and ecosystems: from regional analysis to the European scale;
- Biodiversity and economics for conservation;
- Scenarios for reconciling biodiversity conservation with declining agricultural use in the mountains of Europe;
- Biodiversity in herbaceous semi-natural ecosystems under stress by global change components;
- Age-related dynamics of carbon exchange in European forests. Integrating net ecosystem productivity in space and time;
- An investigation on carbon and energy exchanges of terrestrial ecosystems in Europe;
- Effects of land-use changes on sources, sinks and fluxes of carbon in European mountain areas;
- Securing gene conservation, adaptive breeding potential and utilisation of a chestnut tree (Castanea-sativa Mill.) model in a dynamic environment;
- Conservation of soil organism diversity under global change;
- European phenological network - a network for increasing efficiency, added value and use of phenological monitoring, research, and data in Europe;
- Exploitation of aphid monitoring systems in Europe to improve observation and prediction of global change impacts on terrestrial ecosystems;
- Forest carbon - nitrogen trajectories;
- Sources and sinks of green-house gases from managed European grasslands and mitigation scenarios.
- European Forum on Integrated Environmental Assessment;
- Modelling the impact of climate extremes;
- Greenhouse gas mitigation for organic and conventional dairy production;
- Multifunctional landscapes: towards an analytical framework for sustainability assessment of agriculture and forestry in Europe;
- Development of operational monitoring system for European glacial areas - synthesis of earth observation data of the present, past and future;
- Phenological observations and satellite data Normalized Difference Vegetation Index (NDVI): trends in the vegetation cycle in Europe;
- Predictability and variability of monsoons, and the agricultural and hydrological impacts of climate change;
- Regional assessment and modelling of the carbon balance within Europe.

The Results of the Research

The results obtained within the work performed in the projects show that atmospheric concentrations of greenhouse gases are increasing leading to an expected warming while regional aerosol loading increases are expected to have net cooling effect (Ghazi, et al., 1997). These changes are mainly due to fossil fuel combustion and other industrial processes, agriculture and land-use/land-cover changes whose combined effect is expected to alter the climate on European and global scale affecting the temperature, soil moisture, precipitation, sea level and ecosystems. In terms of hydrological regimes and water resources in Europe the implementation of climate change scenarios belonging to different time horizons allows a better estimation of the vulnerability of river-based dependent activities such as inland navigation, drinking water supply, irrigation and tourism with implications for tourism and agricultural production. On-going research projects provide a strong, rigorous methodological basis for estimating how forests will be affected by rising atmospheric concentration of carbon dioxide and change in other climatic parameters, and how forests will influence regional carbon, water and energy fluxes. There is also a growing realisation at several levels of the need to recognise formally and to provide actions against the deeply embedded but growing problem of desertification in European countries, especially those of the Mediterranean. The extensive research also carried out within the framework programmes addressed the questions of what actions are needed, where and by what means, to mitigate the impact of desertification in Europe and what technical issues have to be resolved from scientific, political, social and economic perspectives.

Since the 1950s there have been major changes in land use, which are supplemented by prospects of climate with evidence that this will hinder rather than help the progress towards sustaining water supplies and agricultural productivity. Drier winter conditions are the largest potential problem, but much depends on the changes in rainfall patterns for which there is as yet no reliable predictive methodology. There is also evidence of decreasing rainfall in the Mediterranean basin a trend for which is not possible to establish whether it is due to global warming or simply to natural decadal time-scale variability. A complex blend of geographical, social, economic and scientific information combined with carefully developed policy and the instruments to implement that policy are required by mitigation strategies.

The frequency of occurrence of agriculturally significant extreme events is strongly altered by relatively small changes in climate. Among the extreme factors analysed were crop-specific high-temperature thresholds, length of frost-free periods, understanding and the effects of CO_2 and temperature on crop yield. Simulations of crop responses to current and possible future environmental conditions have improved. Current differences in crop productivity between northern and southern Europe are likely to increase under climate change. The inter-annual variability of yields is particularly sensitive to changes in climatic variability. Climate change and land use changes will therefore be an important aspect to consider in the future, in particular, in relation with land management and spatial planning. In parallel, the progress in forecasting inter-annual and seasonal variations of European climate will, among other benefits, help to maintain agricultural productivity.

Conclusions

In the summarising the research activity of the European Union, we can state that the agrometeorological activity, including research, development, and application has not disappeared, only its national, mainly national meteorological service level presence has moved into wider and sometimes hidden platform. They have achieved results in the effective conservation and management of natural and environmental resources. They have been impacted by climate variability, climate change, increasing energy costs, environmental regulations, changing demographics, and access to appropriate technologies. There is no change that developing better modelling and forecasting tools to provide users with greater flexibility in decision making is significant both for the scientific issues involved as well as for the practical relevance of the results. The impact of weather and climate on conservation and management of natural and environmental resources is increasingly viewed in the context of risk management. Land degradation, water resource management, drought, and fire are the main topics that agrometeorologists need to focus on in the future. The increasing tendency of weather extremes and natural disasters as consequence of climate change, combined with explosive population growth, seriously challenge the future quality of life for all, therefore effective coping strategies for natural disasters are essential.

The major agrometeorological themes in managing natural resources for sustainable agricultural development include: preparedness (best practices), monitoring (data), assessment (vulnerabilities), mitigation, and adaptation. Good stewardship of the land is essential for sustainable agriculture. There is a growing recognition that land degradation is a major worldwide issue and there is a need for more complete evaluation of the expansion of degraded land around the world.

It is still essential that provision of adequate and appropriate weather and climate information from the meteorological observation networks to users on a near real-time basis is especially needed for developing risk management strategies to cope with climate variability and climate change. The idea that many national meteorological services should produce income mainly from the data or service information is not valid in many countries. As consequence of the commercial activity, there is some conflict between the agrometeorological research and data suppliers. Of course to integrate station, gridded, and remotely sensed data in order to improve model accuracy and provide more useful products is primary expectation from both sides. We have to stress that the use of remotely sensed data has rapidly grown among the data resources. The commercial conflict partly could be solved using a free accessible satellite data. Placing high priority on free and open access among disciplines for data, results, findings and management would succeed to increase cost effectiveness but currently that seems to remain the dream of scientists. To disseminate rapidly time sensitive information regarding meteorological phenomena and its application for land resource management would be a very effective way for the conservation of natural and environmental resources in harmony with agricultural production systems.

In this context, greater emphasis should put on the quantification of natural and environmental resources by developing and providing access to hydrological, meteorological and geographical databases and environmental impacts. A long-term perspective of resource use for sustainable agricultural development should be promoted rather than short term measures since there is a finite capacity of natural resources and the environment, especially under changing demographics.

The agrometeorological activity can provide assistance to current strategies for conservation and management of natural resources and incorporate preparedness and mitigation plans to effectively cope with the increasing frequency of extreme events and natural disasters and their impacts on agriculture. It should be ensured that risk and vulnerability assessments are carried out at an appropriate scale and incorporate socio-economic factors along with the agrometeorological analysis. Analyses of economic values of the information products and services should be provided by the agro-meteorology community.

We should promote the use of an integrated risk management framework that takes into account preparedness, monitoring, assessment, mitigation, and adaptation and encourage the development of robust models that provide probability based results. We have to re-emphasize the current agriculture zoning and practices in response to climate variability and change. Among others it is an ancient agrometeorological theme that should be re-evaluated. It is essential to support the decision makers with information tailored to their needs through rapid dissemination such as internet-based, early warning, and decision support systems that also include geographic information. Maybe it is not the basic job of agrometeorologists but they should maintain some kind of feedback mechanisms constantly evaluated and updated.

Finally we have to mention the importance of education and training mainly in the less developed area of the world and in which the WMO can give great help to its members. We have to increase the outreach and education regarding the impacts of climate variability and weather extremes on land conservation while recognizing the need for that land to support an ever-increasing population.

Author E-mail contact: dunkel.z@met.hu

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