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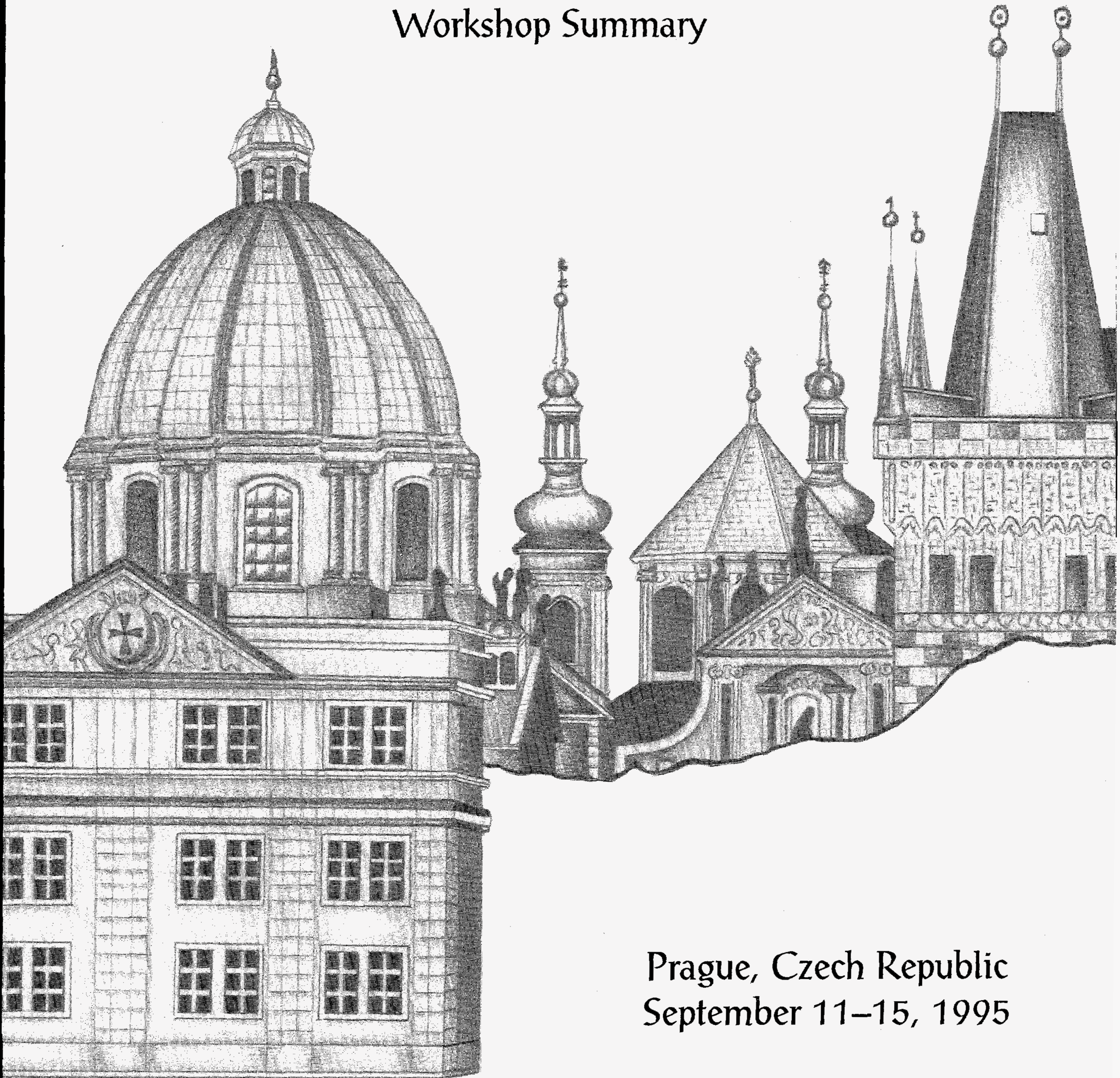
Climate Variability and Climate Change Vulnerability and Adaptation

Workshop Summary



Prague, Czech Republic
September 11–15, 1995

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Table of Contents

Introduction and Summary

Representatives from fifteen countries met in Prague, Czech Republic, on September 11–15, 1995, to share results from the analysis of vulnerability and adaptation to global climate change. The workshop was cosponsored by the Institute of Atmospheric Physics and Charles University in Prague and the U.S. Country Studies Program (U.S. CSP), with support from Environment Canada and the European Commission. The workshop focused on the issues of global climate change and its impacts on various sectors of a national economy. The keynote address was offered by U.S. Secretary of Energy Hazel R. O'Leary.

The U.N. Framework Convention on Climate Change (FCCC), which has been signed by more than 150 governments worldwide, calls on signatory parties to develop and communicate measures they are implementing to respond to global climate change. An analysis of a country's vulnerability to changes in the climate helps it identify suitable adaptation measures. These analyses are designed to determine the extent of the impacts of global climate change on sensitive sectors such as agricultural crops, forests, grasslands and livestock, water resources, and coastal areas. Once it is determined how vulnerable a country may be to climate change, it is possible to identify adaptation measures for ameliorating some or all of the effects.

The U.S. CSP has been providing technical advice and support to fifty-five countries in the conduct of their vulnerability and adaptation analyses. As part of this support, countries have been provided with technical training, computer simulation models, data from general circulation model (GCM) studies, and ongoing support from technical experts in selected fields. This workshop was one part of the technical support effort and was designed to bring together the country researchers to exchange their results and experiences. Researchers from Austria, Bulgaria, Canada, the Czech Republic, Estonia, Germany, Hungary, Kazakhstan, the Netherlands, Poland, Romania, the Russian Federation, the Slovak Republic, Spain, Ukraine, and the United States participated in the climate change vulnerability and adaptation sessions.

The objectives of the vulnerability and adaptation workshop were to:

- Provide an opportunity for countries to describe their study results
- Encourage countries to learn from the experience of the more complete assessments and adjust their studies accordingly
- Identify issues and analyses that require further investigation
- Summarize results and experiences for governmental and intergovernmental organizations

The U.S. CSP has recently launched a new activity to help countries prepare national climate change action plans. This support is intended to help countries use the results of their climate change country studies to develop national plans for implementing priority adaptation and mitigation measures and to use these plans as a basis for preparing national communications to meet FCCC commitments.

Workshop Summary

The workshop discussions were divided into sessions dealing with climate change scenarios and with sectoral impact analyses. The sectoral sessions included discussions of climate change impacts on crops, forests, water resources, coastal areas, and grasslands and soils. In all sessions, there was general agreement that the analyses being conducted were providing useful information that could be used by decisionmakers seeking to develop policies to deal with changing climate. However, it was also recognized that there was still uncertainty in these analyses of climate change vulnerability and adaptation. Steps taken by policymakers must recognize this level of uncertainty, and there must be a willingness to make midcourse corrections as more information and better analyses become available.

The participants agreed on the importance of developing reliable scenarios for climate change in central and eastern Europe that could be used as the basis for conducting sectoral impact analyses. While the current procedures for developing scenarios in the region (use of general circulation models, incremental scenarios, or analogue scenarios) were adequate for now, significant improvements in the predictions of the extent of climate change were necessary, particularly at a local or regional scale. There was some debate as to how much of any available research funding in the vulnerability and adaptation assessment area should go to the development of scenarios versus the development of sectoral impact analyses. Climate change research funding should go to developing better scenarios. This opinion was based on the recognition that the scenarios are the starting point for any analysis. If these are inadequate, all of the subsequent impact analyses will be inadequate as well.

In the analysis of the impacts of climate change on agronomic crops, the participants indicated that the analysis techniques were sufficiently advanced that information on the extent of the effects could be given to decisionmakers in central and eastern Europe on a country-by-country basis. It must be noted, however, that this confidence in the results was not universal. A comparison of crop models using the same data and scenarios showed that the models could give contradictory results. The participants were in agreement on the desirability of improving the sophistication and level of detail of techniques for analyzing impacts on crops. Studies reveal that crop models using production function techniques overestimate the impacts of climate change by not considering all the means farmers could use to adapt to the changes.

The water resource analysts concluded that there is a need to improve the ability of GCMs to generate reliable scenarios for water resource analysis in central and eastern Europe. The small size of many countries in the region creates demands for more spatially disaggregated data from the models. Using the currently available set of scenarios, the water resource analyses indicate that there will be some climate-change-induced impacts on water resources in the region but that none of the projected effects will be disastrous. Adaptation measures, although costly, should be able to ameliorate any negative effects. Even with this general conclusion, it is recognized that some areas (e.g., semiarid areas, mountain ecosystems) may experience serious problems from climate change. Of special concern in the region is the impact of extreme events (floods, droughts, storms), which can have significant negative impacts.

The participants in the forest impact session indicated that analyses have been carried out using a number of different models. While the results have been good to date, there is a need for better understanding of the ecophysiological response of trees to climate changes. Dramatic losses of forest species are predicted by some models under some climate change scenarios. However, forests are more adaptable than is indicated by most models. Given the long-term nature of forest growth and the uncertainties in predicting the ultimate consequences of climate change, the group also acknowledged the difficulty of conveying to policymakers the need to take steps now to ensure against forest loss.

The coastal resource analysts dealt with the need for improvements in the methodologies for coastal analyses. The participants identified saltwater intrusion, extreme events (e.g., flooding, storm damage), ecosystem impacts, and climate change effects other than sea level rise (for example, precipitation changes, river discharge changes) as factors that need to be considered as part of the standard process of evaluating land losses due to sea level rise as outlined in the IPCC Common Methodology. Application of integrated coastal zone management (ICZM) techniques is crucial to the analysis of the coastal resource impacts of climate change. The participants noted that the evolution of sea level rise scenarios seems to be such that the range of possible increases in sea level is being gradually lowered. Current projections of sea level rise are lower than earlier estimates. The group also noted the importance of sharing information with the general public on the possible impacts of sea level rise.

The session on grasslands and soils reviewed results of analyses completed in the region. The studies showed some losses in livestock productivity due to losses in forage land. However, some of these impacts may be relieved by changes in grazing patterns. Changes in the frequency or duration of extreme conditions (e.g., periods of high temperature) due to climate change can have a detrimental effect on livestock health and on the risk of fire. The most important needs identified by the group were the need for better scenarios on climate change and the need for a better understanding of the plant acclimatization process.

In the final workshop session, Secretary O'Leary addressed the workshop on "Climate Partnerships: Growth and Sustainability." The Secretary reviewed the potential impacts of global climate change on various economic sectors. She also identified possible response options, emphasizing the importance and effectiveness of the joint implementation projects designed to address global climate change. Secretary O'Leary cited examples of the cost savings that could be accrued by having developed and transition nations collaborate on projects to reduce global carbon dioxide (CO_2) emissions. The United States and the Czech Republic recently signed an agreement to convert the Decin power station from coal to natural gas, which would result in a 31-percent decrease in greenhouse gas emissions from the plant. The Secretary quoted from a study done by the Electric Power Research Institute in the United States that indicated that projects jointly implemented by developed and developing countries to reduce CO_2 emissions from power generation could achieve worldwide savings in excess of US$1.5 trillion through the year 2100.

During the workshop, small groups of analysts dealt with specific issues in the vulnerability and adaptation analyses. The discussions of these working groups are reported in the following sections.

Session Summaries

Global Climate Change Scenarios

Session Chairs: Jaroslava Kalvová, Charles University, Czech Republic
Ivana Nemešová, Institute for Atmospheric Physics, Czech Republic

Rapporteur: Joel Smith, Hagler Bailly Inc., USA

Participants: Technical presentations were given by the following experts: Jaroslava Kalvová (Czech Republic), Milan Lapin (Slovak Republic), Jânos Mika (Hungary), Anna Olecka (Poland), Olga V. Pilifisova (Kazakhstan), Kirill Selyakov (Russian Federation), and Joel Smith (USA).

All analysts addressed methods for creating regional scenarios of global climate change, with five focusing on using output from general circulation models (GCMs), one addressing the use of GCMs and incremental scenarios, and one dealing with paleoclimate-based scenarios of future climate change.

The session reviewed three sources for creating scenarios: GCMs, incremental, and analogue. GCMs are three-dimensional mathematical models of the climate system that have been used to simulate changes in climate due to increased atmospheric concentrations of greenhouse gases. Incremental scenarios involve combinations of changes in temperature, precipitation, and sometimes other variables. Analogue scenarios are derived from the instrumental record of paleoclimates.

All of the eastern European countries are using GCMs as a basis for creating climate change scenarios. Because of low resolution, the GCMs do not adequately simulate current climate, particularly precipitation. First generation GCM output results in a disturbed regional pattern, gives inadequate data, or does not estimate changes in interannual or daily variance. A number of countries have adopted innovative approaches to overcome these problems:

- The Czech Republic smoothed the annual course of $1 \times CO_2$ and $2 \times CO_2$ temperatures from GCMs to avoid the problem of erratic scenarios.
- The Slovak Republic is using correlation of variables based on observed climate relationships to estimate changes in variables not available to them, such as relative humidity.
- Poland is using a weather generator to examine changes in interannual variance based on the United Kingdom Meteorological Office (UKMO) transient GCM run.

In addition, Czech Republic analysts derived a number of incremental scenarios based on seasonal shifts in temperature and precipitation seen in the GCM output. Some of the Russian scientists are using climate change scenarios based on paleoclimate data to assess potential impacts of climate change.

Sources of Global Climate Change Scenarios

Most of the group discussion focused on use of GCMs, incremental changes, or analogues for creating climate change scenarios. A consensus was not reached on which approach for creating climate change scenarios is inherently superior to the others.

GCM Scenarios. General circulation models may offer the best source of information on potential regional climate changes from increased atmospheric concentrations of greenhouse gases. General circulation models are desirable because they can estimate changes in climate specifically due to increased greenhouse gas concentrations and because they provide physically consistent results. Increased model resolution would most likely result in increased accuracy of the models, particularly as they account for major orographic features, such as mountains and large bodies of water, and as they account for important forcing factors besides greenhouse gases, such as atmospheric aerosols. Results from coupled atmosphere-ocean models with high resolutions, such as 50 km^2, could provide credible estimates of regional climate changes. Higher resolution GCMs did a relatively poor job of simulating climate change over central Europe compared with the older, lower resolution Goddard Institute for Space Studies (GISS) model. Models are continually being improved, and it is important for the climate change impact assessment community to have ready access to the latest GCM outputs.

Incremental Scenarios. Incremental scenarios are a useful source for creating climate change scenarios because they can help identify sensitivities of sectors to changes in individual meteorological variables and because they can represent a wide range of climate change scenarios. There was disagreement, however, on how broadly incremental scenarios should be used and what emphasis they should receive in impact assessment. Incremental scenarios are quite useful because they are transparent, but they may be problematic because they can easily be created by anyone and may not represent a scientific approach to creating scenarios of climate change. There was agreement that GCM output should be used to bound incremental scenarios. For example, if all GCMs show a region getting warmer, all incremental scenarios should have increases in temperature.

Analogue Scenarios. The utility of analogues, in particular, paleoclimate scenarios, as a basis for developing climate change scenarios is debatable. Paleoclimate data may complement GCM output because regional climate changes associated with a particular mean climate change from a paleoclimate can be used to estimate regional climate changes from the same amount of mean warming caused by increased greenhouse gas concentrations. Paleoclimate changes may not be appropriate for use in climate change impact assessments because the atmospheric forcing is different (e.g., changes in Earth's orbit caused changes of radiative forcing of 20 to 30 watts per m^2) and because there are insufficient analogues for the rapid warming that greenhouse gases are likely to produce.

Using GCMs to Create Global Climate Change Scenarios

How can GCM data best be used to create climate change scenarios? Topics included downscaling from GCMs to sub-gridscales, interannual and daily variability of GCM-based climate change scenarios, and outputs needed from the models.

Downscaling. Downscaling could be used to help develop improved local-scale estimates of climate change. The impact-assessment community could apply a few downscaling techniques suggested by climatologists. Similarly, climate modeling centers such as the National Center for Atmospheric Research could continue to develop mesoscale models that can be nested in GCMs.

Variability. A number of opportunities to address interannual and daily variability were identified. The traditional approach for creating climate change scenarios has been to use average monthly changes from the GCMs and create scenarios with no change in interannual and daily variability. Recent coupled ocean-atmosphere GCM runs that simulate very long time periods could be analyzed with regard to the changes they estimate in the standard deviations of climate statistics. The changes in standard deviation of, for example, interannual variability, could be used to develop scenarios of changes in interannual variability.

Information from the GCMs on daily variability exist to support the development of daily variability scenarios. For example, Poland is using a weather generator to estimate changes in daily variability, based on daily data output from the UKMO transient model. The utility of weather generators may be limited if information on the change in circulation patterns is missing. Some climatologists question whether this technique would simulate longer term extreme events such as droughts. Daily data from GCMs is so poor that it is premature to use GCM output to devise scenarios of changes in daily variability.

Outputs from GCMs. In the future, more information should be provided by GCM modelers to the climate change impact community. Specifically, modelers should provide information on changes in circulation patterns, humidity, winds, interannual variance (e.g., annual or monthly data), and daily variance (daily data).

Usefulness of Scenarios to Policymakers

In spite of the uncertainties regarding regional climate change and the limitations of each approach for creating scenarios, the potential danger from global climate change is real and policymakers need assessments of potential climate change impacts. Providing policymakers with a narrow range of climate change scenarios may make it easier for policymakers to focus on a relatively consistent set of results. Extreme scenarios may receive attention from policymakers, but this approach could be dangerous because it would not inform policymakers about the range of uncertainty about regional climate changes and impacts. Policymakers should act on this uncertainty to make adjustments as necessary and then make midcourse corrections as estimates of regional climate change improve.

Crop Impacts

Session Chair: Gennady Menzhulin, State Hydrological Institute, Russian Federation

Rapporteur: Ellen K. Hartig, Goddard Institute for Space Studies, USA

Participants: Papers were presented by Vesselin Alexandrov (Bulgaria), Josef Eitzinger (Austria), Ellen K. Hartig (USA), Gennady Menzhulin (Russian Federation), Svetlana V. Mizina (Kazakhstan), Olga Nasanova (Russian Federation), and Oleg Sirotenko (Russian Federation).

The problems of vulnerability and adaptation were discussed. Most participants have used GCM scenarios and crop simulation models. Other scenarios (e.g., paleoclimate and incremental scenarios) as well as crop models developed on other principles were evaluated. In general, the agriculture challenges in central European countries were quite similar and related to water limitations. In contrast, the problems of adaptability for Russian agriculture were related to soils rather than water resources.

Scenarios

Well-developed and validated empirical models for year-to-year crop yield changes are available. In future investigations, additional scenario information is desirable. Future scenario preparation tasks should be expanded and not only focus on calculations of the statistical means, but also include other statistical parameters for climate. The resolution of GCM-generated scenarios needs to be improved. Specifically, special techniques that would allow interpolation between grid points for GCMs need to be developed, and new models should be prepared that include information on air humidity, which would be of benefit to some models used for conducting crop productivity assessments.

Vulnerability Assessments

The participants agreed that, as a result of experience gained in working with data and interpreting results, the vulnerability assessment of the country or region being examined could be improved. Vulnerability depends on economics, environmental conditions, and plant species used in crop production. Vulnerability would be better understood through comparing results from central Europe with other regions. Vulnerability issues will have to be repeatedly reassessed in the future as new models, scenarios, and data become available.

Adaptation Analysis

The participants identified two types of adaptation measures. The first involves plant adaptation and includes choice of species, planting locations, and varieties/breeds. The second type is agrotechnical adaptation and includes soil protection (erosion reduction), irrigation, and introduction of optimization techniques (e.g., planting winter wheat (*Triticum*) instead of spring wheat).

Results and Conclusions

There are different estimates for the degree of climate change in the central European countries. Several of the more vulnerable areas found that agrotechnologies may not be available to them. For example, in Kazakhstan it is unlikely that irrigation would be available, in part due to lack of financial and water resources. There is concern about long-term impacts of climate change.

In contrast, in the eastern part of the former Soviet Union (the European territory including Ukraine, European Russia, Belarus, and the Baltic republics) there is an expected increase in water resources. This may ameliorate some of the climate change problems there. It was even calculated using one of the crop models that, with fertilizers and other inputs, Russian agricultural production could increase by as much as 67 percent. Nevertheless, these same countries recognize that they have a problem with soil degradation.

Sea level rise could lead to increased problems with saltwater intrusions into agricultural areas (e.g., in the Netherlands, Poland, and Germany, as well as in countries in other regions, such as Iraq and Egypt). Exchange of information with other sectors involved in adaptation analysis, including information about coastal resources, water resources, forests, grasslands, and wetlands, is desirable.

Next Steps and Research Needs

Future research needs include models and methodologies to account for environmental factors that have an influence on crop productivity, including carbon content, ozone and other greenhouse gas pollutants, and ultraviolet radiation increase. The confidence intervals of values of climate elements and crop parameters is limited. Detailed soil information, including water holding capacity and soil types, is needed. Land-use changes due to climate change shifts need to be considered. An inventory of present land use and land cover would be useful. Estimation of variability of crop yields due to extreme events (including flooding or drought conditions) would aid policymakers. Finally, there is a need to recognize the economic ramifications of climate change on agricultural practices.

Water Resource Impacts

Session Chairs: Václav Dvořák, Water Research Institute, Czech Republic
Milan Lapin, Slovak Hydrometeorological Institute, Slovak Republic

***Rapporteur*:** Kenneth Strzepek, Strzepek and Associates, USA

***Participants*:** The water resources session was attended by Josef Buchtele (Czech Republic), Jaroslava Kalvová (Czech Republic), Ladislav Kašpárek (Czech Republic), Kim Man Kyu (Germany), Jan Kubat (Czech Republic), Bohuslava Kulasova (Czech Republic), Olga Majerčáková (Slovak Republic), Bela Novaky (Hungary), Beatrice Popescu (Romania), Cristian Rusu (Romania), Nadezhda Shumova (Russian Federation), Ivan I. Skotselyas (Kazakhstan), and Paul Tuinea (Romania).

Water Management in Europe in the Face of Climate Change

Water resource management is the interaction of technology, economics, and institutions to balance water supply with water demand. Most western European countries have completed the major capital-intensive developments of their water resource infrastructures. Water managers in western Europe are faced with a stable population and increased pressure for the incorporation of environmental protection objectives into the operation of the existing water resource system. The issue is efficient water management. With environmental concerns severely limiting any new development, water managers in the developed countries ask, "Can the management of a current system be modified to adapt to climate change?" By its very nature, water resource management is an adaptive process, on various time scales, and this experience provides a wealth of knowledge.

The issue of water resource development is central to climate change assessments. Water managers in central and eastern Europe are facing economies in transition and severe environmental problems. With development and increased demands by a stable population for improved water supply and sanitation, massive capital expenditures are needed to develop the required infrastructure. With planning and construction times of 20 to 30 years or more for major water development projects, the question asked by many water resource managers in the transition countries is, "How might climate change affect the design of a new water resource infrastructure?"

Uncertainties exist at the local and regional level about climate change impacts on unmanaged hydrologic resources. This uncertainty will then be propagated into uncertainty about future water supplies from the managed water resource system. Additionally, the same local and regional uncertainties will add uncertainty to already uncertain future water demands, which are driven by socioeconomic processes.

Global Climate Change Scenarios

Climate change scenarios are viewed in two perspectives: *operational*—issues related to the use of current generation GCMs in the next 5 to 10 years; and *scientific*—issues related to the next generation of GCMs to better meet the needs of hydrologic impact analysis.

Hydrologic systems are strongly affected by changes in precipitation, much more than temperature. Many precipitation features are locally determined by topographical features that are very important in runoff formulation. The next generation GCMs need to do a much better job of modeling these local precipitation patterns in the current climate. This will require very high resolution spatial scales and a better model of the hydrologic cycle within the GCM to provide for the local feedback of precipitation and evapotranspiration.

Given the relatively small sizes of European countries and the large spatial scale of current GCMs, precipitation is poorly modeled in $1\times CO_2$ runs as compared to current climate, and there is little confidence in the precipitation results for $2\times CO_2$ or transient GCM runs. To overcome this problem in the short run, use of a statistical approach of matching local precipitation patterns to observed atmospheric pressure patterns is recommended. General circulation models would provide pressure patterns, while precipitation would be generated preserving the observable meteorology processes. Another alternative is to use a small spatial scale (mesoscale) weather model within the boundary conditions of a GCM to get a finer spatial resolution. At a minimum, it is suggested that, in addition to the normal GCM outputs of temperature and precipitation, other variables be reported for use by impact modelers, such as humidity, wind speed, solar radiation, and cloudiness.

Vulnerability Analysis

For the assessment of climate change impacts on water supply, monthly water balance models are recommended because of their limited data needs and their close agreement with temporally and spatially disaggregated models for average water supply.

To date, this highly important area of impact analysis has been ignored and it may turn out to be one of the biggest impacts of climate change on the hydrologic cycle. The extreme events in hydrology are floods and droughts. Droughts by definition are long-term, monthly scale, dry periods, usually accompanied by increased temperature. Because this phenomenon is at the monthly scale, it can be captured by the GCMs and by current water balance models.

Seasonal floods like the Indian subcontinental monsoon, the Nile River flood, or snowmelt floods can be captured by the GCM/water balance approach. Flash floods, or daily and weekly scale floods, cannot be modeled with a monthly time step. This flood process is driven by weather, not by climate, so weather models are needed to model precipitation. Hydrological models with a maximum time scale of one day also need to be used. Current-generation weather forecasting models are capable of this type of forecast, but are computationally burdensome when considered in climate change assessments. An operational timeframe alternative is to use stochastic weather generators to produce daily weather driven by statistical weather parameters and GCM monthly precipitation and other climate parameters.

Although temperature data appear to be adequate, especially within the European continent, precipitation data are another matter. Monthly precipitation data appear to be available from 1960. However, over much of Europe there are data from the late 19th century, even daily values. These data are archived and sometimes inaccessible to impact modelers. It is recommended that a strong effort be made to put these data into electronic form so they can be used by hydrologic modelers to assess extreme event frequencies and better calibrate models. Data reduction and correction are needed in order to free the impact modeler to focus on impacts and not climatological issues.

Three economic sectors deal with land-atmospheric water fluxes. These are forests, agriculture, and water resources. In many cases, for the same regions, different models of potential evapotranspiration (PET) are used. It is recommended that PET methods across impact sectors be standardized for geographical regions within countries and within Europe to ensure consistent results.

Land use and land cover greatly affect the generation of runoff. However, the driving forces of land-use and land-cover changes, whether economic or climate-induced, are beyond the scope of the water resource impact modelers to assess. For example, changing dryland farmland into irrigated farmland will change the seasonal flow in rivers and particularly affect base flow. The assumption that irrigation water is available may be wrong as well. There needs to be an integrated effort of water, forest, and agricultural impact models working together to more accurately model the potential impacts of climate change on runoff.

Results and Conclusions

With the current state of knowledge, several conclusions can be drawn for climate change impacts on European hydrologic resources. First, the hydrologic systems are sensitive to climate change, especially in terms of precipitation changes. Second, with the results of current GCM scenarios it would seem that there will be some, but not disastrous, impacts on the water resources of Europe and that adaptation, at a cost, can be achieved. And third, semiarid and border regions, as well as some fragile mountain ecosystems, are very vulnerable to climate change, both wetting and drying.

While many specific water-conserving engineering solutions were proposed, there was universal agreement that the most powerful adaptive process was the development of economic and institutional instruments for water demand management. The most powerful was water pricing.

The next steps for the impacts of water resource climate change in central and eastern Europe are to examine the water resource systems and their adaptability, examine international river basin issues, examine water quality issues, study, in depth, extreme events, and develop regional methodologies for weather generation.

Forest Impacts

Session Chair: Steven M. Winnett, Environmental Protection Agency, USA

***Rapporteur*:** Neeloo Bhatti, Argonne National Laboratory, USA

***Participants*:** Formal presentations were delivered by Ognjan Grozev (Bulgaria), Vladimir Henzlik (Czech Republic), A. Leliakin (Russian Federation), Michal Marek (Czech Republic), Jozef Mindaš (Slovak Republic), and Steven M. Winnett (USA).

These presentations addressed various aspects of the vulnerability of forest ecosystems to potential climate changes and the adaptation responses that could be implemented to deal with this phenomenon.

Vulnerability Assessment Methods

A variety of methods to assess the impacts of climate change on forest ecosystems have been used. The most frequently used techniques appear to be the "gap" model and the Holdridge lifezone model. Although use of these models provides information on the possible shifts in vegetation zones as a result of climate changes predicted by various GCMs, the researchers mentioned various difficulties and limitations in using these models. The Ukrainian forestry profession uses assessment indices to classify forests, as well as to characterize plant responses to biological, geological, and climatological factors different than those required by the gap models. In addition, gap models are designed to simulate natural stands; and in many of the eastern European countries, a large portion or majority of forests are managed or established as plantations.

A carbon (C) balance model called the CCBF has been used by the Russian Federation to estimate CO_2 fluxes from the Russian forests. This model was used to estimate C flux under current conditions and to assess how predicted climate changes would affect C transfer and CO_2 flux in forest systems. An analysis of the ecophysiological response of forests to elevated CO_2 levels was presented by the Czech Republic. This involved the use of open-top chambers to determine the cellular-level response of tree species to various concentrations of CO_2. Both short-term and long-term responses were studied. Another study by the Czechs involved the grouping of all forests in the country into nine vegetation zones and seven ecological groups. Management models were then used to determine the shift in vegetation zones from the present to 2010 and 2030 for two sites—one in the relatively high precipitation southeast region, the other in the dry central region.

Adaptation Analysis

Specific adaptation responses could be undertaken to reduce the vulnerability of forest ecosystems to climate change. In general, the most common response was to shift to forest species that would be better adapted to higher temperatures and perhaps to drier conditions. In most cases (in both the United States and in central and eastern Europe), this involved a switch from coniferous species to deciduous ones. In particular, in the Slovak Republic and in the Czech Republic, this involved a shift away from Norway spruce *(Picea)* (the most common species in much of the forests of these two countries) toward beech *(Fagus)*. Beech tends to be the optimal species for much of this area under current conditions, although economically it is not as important as spruce.

Degraded lands and the need for shelterbelts in the lowlands of Bulgaria could be an opportunity to adapt to climate change. Afforestation of these areas would offer significant benefits, such as enhancing agricultural production by preventing soil erosion and creating a more favorable microclimate, increasing biodiversity, enhancing wildlife habitat, and providing wood products. In addition, through the planting of tree species better adapted to climate changes (warmer, drier), these areas could serve as reservoirs for forest species under altered climate conditions. Appropriate species in this case would include oak *(Quercus)* and other deciduous species and would exclude coniferous species.

Economic Analysis

Economic analyses were reported for the United States that used gap model growth and yield data showing that, in all but the Southern United States, the growth of hardwoods improved. In all regions but the Rocky Mountains, the growth of softwoods (conifers) declined. The economic consequences of these results were that, overall, the economy suffered welfare losses, although forest landowners were made better off by the higher prices commanded for scarcer wood. In the Slovak Republic, the shift from the current forests dominated by Norway spruce in many parts of the country to beech and other deciduous species would cost approximately 175 to 275 million Sk annually. The afforestation of wastelands and expansion of shelterbelts in Bulgaria have been estimated to cost $35 million.

Results and Conclusions

In the United States, modeling studies reveal that pine *(Pinus)* growth declines the farther south and west trees grow as the climate becomes hotter and drier; other modeling work demonstrates that the ranges of various typical eastern species—beech, hemlock *(Tsuga)*, birch *(Betula)*, and maple *(Acer)*—shrink precipitously to the south and expand somewhat to the north.

Using the CCBF model to estimate C flux from Russian forests, it has been determined that, under current conditions, these forests serve as sinks for CO_2. Forests sequester approximately 160Tg C annually. By 2010, this sink is estimated to increase to 200 to 240 Mt C/year. One problem with this assessment is that products harvested from these forests are not considered in these calculations. Also, precipitation is assumed not to be limiting under future climate conditions.

The ecophysiological analysis indicates that the short-term (hours to days) response of these tree species to increased levels of CO_2 is to increase biomass production. However, the longer term (years to decades) response of these species to elevated concentrations of CO_2 is a decline in the rate of biomass production, compared with baseline conditions. This implies that the overall result of increased concentrations of CO_2 would be to reduce growth rates. This is contrary to current theories of the impacts of elevated CO_2 levels on growth of tree species. The forest management models used in the Czech Republic to assess climate change impacts indicate that at a wet site in the southwestern part of the country, there will be a shift to oak species (from spruce) in 2010, but that under continued climate change, this site would revert back to the current species in 2030. At a dry site in the central part of the country, there would be a permanent shift from spruce to oak during this time period. This model takes into account temperature and precipitation, but not solar radiation. This radiation effect could influence these shifting patterns as spruce is very sensitive to both the quality and quantity of solar radiation.

Discussion

A number of researchers indicated that forest policies in their countries do not consider the issue of climate change. This has resulted in the presence of forest ecosystems that are not well adapted to the potential stresses that would result from climate change. Forest management practices also do not address the issue of climate change.

It is difficult to get policymakers to address issues that have so much uncertainty associated with them and for which the time horizon is measured in multiple decades rather than years. Thus, economic arguments for managing forests in ways that address concerns related to climate change should be developed. The benefits of long-lived, healthy forests (watershed, flood retention, water filtration, soil retention, air quality, fisheries, wildlife habitat, and recreation), which are not traditionally measured in monetary terms, should be quantified.

Research Needs

An ecophysiological understanding of the response of forest trees to various changes resulting from climate change is needed. In particular, a greater understanding of the effect of CO_2 at the cellular level is needed. One participant suggested that ecophysiological research needed to focus on plant response to extreme conditions, not just to the mean. Ecophysiological research was the most popular choice as a research priority. The scenario analysis and modeling of future climates also needs to be improved. In general, gap models need to be made more applicable to the target regions and species, and climate models need to be improved.

Coordination and unification of monitoring activities for this region should be undertaken. There is also a need to identify, collect, and classify species that represent the future of successful forestry, as well as to develop methods to introduce or move them into appropriate niches, or select for them in appropriate situations. Forest compositions that will cover the range of current and potential future conditions should be investigated.

Coastal Resource Impacts

Session Chair: Are Kont, Institute of Ecology, Estonia

Rapporteur: Ryszard Zeidler, Polish Academy of Sciences, Poland

Participants: Yuri Anokhin (Russian Federation), Are Kont (Estonia), Lubov Lebed (Kazakhstan), and Ryszard Zeidler (Poland) presented papers.

Global Climate Change Scenarios

General circulation models have been employed directly for enclosed seas, such as the modeling of the water resources of the Caspian Sea for the Volga catchment area. The application of GCMs may be indirect, whereby weather predictors/models constitute an input to sea level rise (SLR) scenarios. In such cases, the GCM-generated data are taken as deterministic inputs for Monte Carlo simulation of all possible SLR outputs.

Storminess and its change are included in climate change scenarios for coastal zones, although they do not stem directly from GCMs. Other non-SLR factors of climate change are not commonly included in the derivation of climate change scenarios. Some changes in wind circulation patterns, and their impact on coastal circulation, sediment transport, and coast evolution, have been taken into account for the Polish coastal zone. Efforts are made to incorporate precipitation, which affects the coastal zone in several ways (including groundwater conditions, vegetation, dune and cliff stabilization, and land-use patterns). Hence, GCMs are employed in developing climate change scenarios, either directly or indirectly.

Methods and Data for Conducting Vulnerability Assessments

The IPCC methodology and other tools derived for vulnerability and adaptation analysis in various countries have been used. Some gaps and weaker points of the IPCC methodology have been identified and may be bridged in the future. Sorely needed methodological improvements include regional development, climate change, and consensus-building factors.

Other possible methodological improvements include guidelines for producing flooding scenarios (e.g., the present methodology is not specific on how to compute the areas lost or at risk due to dike breaching or other causes, and the corresponding probabilities; the combination of riverine and storm-induced flooding is not addressed); guidelines on assessment of seawater intrusion, together with clarification of complex computations of potential losses and impacts due to salinity effects in the wake of seepage, irrigation, drainage, and so forth; suggestions on quantitative descriptions of the impact of groundwater and salinity changes on the coastal vegetation and agricultural productivity, in different time scales; socioeconomic guidelines and algorithms for both assessment of the current prices (and non-market values) and the 30-year scenario of socioeconomic developments in the study area.

Data acquisition problems may be encountered in the countries in transition, where some data are unavailable (e.g., reliable long-term socioeconomic factors or databases for areas that previously were military grounds) and other data are expensive to assemble, thus creating financial constraints. Geographic information systems (GIS) should become a common tool for coastal applications, coastal zone management (CZM) in particular; and every effort should be made to share experiences and exchange information in this rapidly developing field.

Economic Analysis

There are two basic aspects of economic analyses for vulnerability and adaptation assessments: current prices of various land-use categories and shore protection systems and derivation of the 30-year development scenario and the respective prices in 30 years. Worldwide information and experiences should be shared. The market situation in the developing countries is unstable, equilibrium prices are not established, and sources of information are insufficient. Thus, guidance with regard to derivation of sound adaptation schemes and their economic substantiation will be fruitful. Non-market values for ecological areas, nature reserves, and so forth should be given particular attention.

Adaptation Analysis

Adaptation strategy analysis has not been carried out in some countries because of resource constraints. If applied in the next step, adaptation measures should be taken with caution and upon consultation with coastal engineers. Headland control proposed for some countries implies generation of pocket beaches, which are not always acceptable if there is no land to abandon. Other measures must be optimized as to design and cost, and their effects on the adjacent coasts must also be taken into account.

Results and Conclusions

Some studies are more descriptive than quantitative, and they lack the adaptation component. Even if assessments are completed, there still can be more room for sophisticated tools supporting the decisionmakers in their selection of optimum strategies and solutions. Such tools can be made available to coastal researchers dealing with vulnerability and adaptation studies. Software for cost-benefit analysis, multicriteria analysis, and other decision-support packages would be very useful. The adaptation strategy evaluator (ASE) program produced so far seems to suffer from structural faults, and its second version might be more helpful.

Identification of Next Steps

Adaptation strategies will be developed by the countries that have completed vulnerability assessments (e.g., Estonia or the Russian Federation). Detailed analyses of various adaptation strategies are carried out by some (e.g., Poland). More climate change factors and impacts can be added in future vulnerability and adaptation assessments.

Regional cooperation between regions and countries sharing the same coastal environment should be enhanced. In the case of the Baltic Sea, Latvia and Lithuania should be encouraged to participate in regional efforts. In the case of the Caspian Sea, the many countries having access to it should join in integrated efforts to preserve their sea and coast and to make optimum use of it in a concerted way.

Integration and feedback with other vulnerability and adaptation assessment groups (e.g., agriculture, forests, and water resources) should be encouraged. National vulnerability and adaptation-oriented programs should be regionally coordinated. Socioeconomic considerations are important in regional and transnational cooperation.

Research Needs

Region-specific or example flooding scenarios, along with the methodology behind them, are needed. The combination of riverine and sea-induced flooding is a relatively unexplored area of paramount importance. Saltwater intrusion patterns and impacts should be explored. Ecosystem studies should aim at balanced inclusion of environmental effects in vulnerability and adaptation analyses. Shore erosion due to extreme storm events in less-explored shore types should be investigated, as should other non-SLR climate change effects, such as wind, precipitation, temperature, river discharge, and their impacts on the coastal resources. Field campaigns should aim to verify and validate the various models and assumptions employed in the analysis and forecast of coastal phenomena. Integrated coastal zone management (ICZM) is crucial for the sustainable development and cross-sectoral, balanced use of the delicate coastal environments.

Soils and Grassland Impacts

Session Chair: Juan Puigdefábregas, Estación Experimental de Zonas Arídas, Spain

***Rapporteur*:** Viliam Novák, Institute of Hydrology, Slovak Republic

***Participants*:** Participants in the session included Yuri Ankohin (Russian Federation), Vasile Cuculeanu (Romania), Are Kont (Estonia), Pavizhan Kozbakhmetov (Kazakhstan), Milan Lapin (Slovak Republic), Lubov Lebed (Kazakhstan), Viliam Novák (Slovak Republic), Juan Puigdefábregas (Spain), Vlasta Śtekauerová (Slovak Republic), and Paul Tuinea (Romania).

Global Climate Change Scenarios

Five GCM scenarios—the General Fluid Dynamics Laboratory (GFDL), Goddard Institute of Space Studies (GISS), Oregon State University (OSU), United Kingdom Meteorological Office (UKMO), and Canadian Climate Centre (CCCM) models—are widely used. Outputs of the GCMs are rarely compared to existing data. In the Slovak Republic, GCM predictions of increasing air temperature correspond with existing trends; but for precipitation, the results of GCMs are not consistent with actual trends. Changes in ambient temperature and precipitation are higher than extrapolated values.

Vulnerability Assessment Methods

Simple water balance models have been used for assessment of water balance and crop production in the Slovak Republic (annual and monthly terms). Empirical models have been used for assessment of future grassland production in Kazakhstan and sheep breeding under expected climate changes in Kazakhstan. Interpretation of empirical data has been used as a way to qualitatively assess regional trends of landscape formation, soils, rivers, and land use in Spain.

Adaptation Analysis

As a result of predicted global change, ambient temperature will increase and precipitation will decrease in Kazakhstan. From this, it follows that grassland production will increase during spring and will decrease during summer, which could result in a decrease of forage production of as much as 20%. Adaptation strategies should rely on management of breeding systems and on structural attributes of grasslands (rotation of pasture sites). Climate change could influence the structure of sheep breeding in Kazakhstan. Adaptation of sheep ranching appears possible.

Results and Conclusions

Potential climate changes in Kazakhstan could cause an essential decrease in grassland productivity and quality. This impact could be mitigated by shifting the onset of vegetation periods to early spring and by rotation of pastures. A decrease in sheep productivity is expected in the far south of Kazakhstan due to the increase in air temperature (a threat to the health of sheep), as well as the sharp decrease of grassland productivity.

In the Mediterranean area, climate change is expected to interact with land-use patterns, resulting in a shift from marginal agriculture to shrub lands and forests, increasing susceptibility to fire, and modification of the water balance due to increased evapotranspiration. Soil water content during the vegetation period in the Slovakian lowlands could even be increased during the summer period. Therefore, plant production could increase by up to 10%.

Conclusions and Research Needs

It is necessary to create scientifically based adaptation procedures for grassland systems. Adaptation procedures developed to date result from empirical procedures only. In the opinion of many participants, global changes should not be restricted to changes in CO_2 concentrations. It is believed that natural changes or changes related to land use are very important and should be taken into account.

It would be useful to promote cooperation between economic sectors. Attention should be paid to high-quality, continuous monitoring of environmental and economic parameters in grasslands, as well as other sectors, all around the world.

Emphasis should be placed on the development of reliable scenarios of global climate changes. Current scenarios are not completely reliable for morphologically complex areas. Plant physiological characteristics under increasing CO_2 concentrations (that is, adaptation or acclimation of plants) are needed to calibrate models.

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