Department of Economic and Social Affairs

Commission on Sustainable Development
Ninth Session
16 - 27 April 2001, New York

- PROTECTION OF THE ATMOSPHERE -

IMPACTS OF CLIMATE CHANGE AND VARIABILITY:

ASSESSMENT AND ADAPTATION

BACKGROUND PAPER NO. 6

Prepared by the
United Nations Environment Programme and
the World Meteorological Organization

DESA/DSD/2001/6

Protection of the Atmosphere

(Chapter 9 of Agenda 21)

Background report

Impacts of climate change and variability: assessment and adaptation *

Contents

* This report was prepared by UNEP and WMO as task managers for Chapter 9 of Agenda 21, in accordance with arrangements agreed to by the Inter-Agency Committee on Sustainable Development (IACSD).

I. Impacts of climate change and variability

A. Human Health

1. Activities to address the relationship of weather and climate to health are accomplished within two thrusts of the Climate Agenda: climate services for sustainable development; and, climate impact assessment and response strategies to reduce vulnerability. In the second Inter-Agency Committee on the Climate Agenda (IACCA) session, held in Geneva in 1998, the establishment of an Inter-Agency Network on Climate and Human Health was proposed, with a secretariat coordinated by WHO. Joint activities of the Interagency Network began in 1999, between WHO, WMO and UNEP.

2. The work focuses on three areas: capacity building, information exchange and research promotion:

(a) Capacity building activities include assisting Member States in: (i) undertaking national assessments of climate-induced human health impacts; (ii) in determining and meeting capacity-building and research needs in order to identify and address priority areas; (iii) and in identifying and implementing adaptation strategies and preventive and mitigating measures, designed to effectively reduce adverse health impacts.

(b) Information exchange includes: (i) provision of information to Member States, national and international training and research institutions, and to the public at large, on the state-of-the-art in the global research effort on climate and health interactions, their consequences for population health and for public health response; and, (ii) fulfilling "clearing house" functions to ensure free access to information including databases needed for research on climate variability and climate change on human health in developing countries.

(c) Research promotion entails: guidance of research programmes on the human health implications of climate and of global environmental change, including the impacts of climate variability, climate change and stratospheric ozone depletion.

3. Activities are undertaken within these three main areas as follows:

(a) Development of methods for health impact assessments related to climate and promote these through workshops, training, and the publication of guidelines.

(b) A report addressing Near-term Health Benefits of Greenhouse Gas Reductions (with a focus on methodology) has been prepared. It addresses the potential for "win-win" scenarios and in this particular case, the benefits of reduced health impacts of air pollution associated with reductions in fossil fuel combustion.

(c) The development of guidelines for the evaluation of adaptation strategies is an important additional task for national impact assessments. Adaptation options specifically for climate-sensitive diseases will need to be evaluated for cost-effectiveness. One specific activity began in Europe with a project on: "Climate change and adaptation strategies for human health".

(d) A report dealing with "Monitoring the health impacts of climate change on human health in Europe" has been prepared and is currently under review.

(e) Information is distributed through the Internet from agencies' Home Pages. WHO is regularly producing updates on climate and health issues.

(f) A regional workshop to address the health impact of climate on Small Island Developing States (SIDS) was held in the Samoa in 2000. The objectives of the workshop included awareness raising and information exchange related to vulnerability to the health impacts, strategies for climate and health impact assessment, and strategies to prevent and protect communities on the islands. A companion workshop for climatologists will be presented in New Zealand in December, and a follow-up workshop for SIDS is planned for the Caribbean in 2001.

(g) For 2001, a book dealing with climate and health is being considered for joint preparation by WHO, WMO and UNEP.

(h) WHO's Roll Back Malaria project is interested in climate variability and human health and specifically in the relation between climate and malaria epidemics. A Technical Resource Network for prevention and control of malaria epidemics was set up in 1998. Early warning indicators to aid in prevention and control of malaria epidemics need to be developed.

(i) UNEP developed the initial plans for the implementation of Warning Systems for Heat-waves. The resulting Heat/Health Warning Systems are now being implemented in selected cities (Rome, Shanghai) as showcase projects together with WMO and WHO, with contributions from a number of national agencies and industry organizations.

B. Climate impacts and adaptation studies

4. Through a Global Environment Facility (GEF) supported project on country studies on climate impacts and adaptation assessment, UNEP carried out studies in four countries: one in Africa – Cameroon; one of the SIDS – Antigua and Barbuda; one in Asia – Pakistan; and one of the economies in transition – Estonia.

1. Impacts assessments

5. The results of the UNEP country studies illustrate a diversity of climate impacts in developing countries and countries with economies in transition. Taken together, the studies underscore the importance of considering impacts and adaptation strategies within the context of present day realities and future trends. Confronting current socio-economic and environmental problems emerges as an important means of addressing climate impacts and facilitating adaptation to long-term climate change.

6. In the Sudano-Sahelian zone of Cameroon, high population pressure, inefficient management of soils, irrational exploitation of water resources, and inefficient management of protected areas were identified as current threats to the environment. Water scarcity is currently a serious issue in both Pakistan and Antigua and Barbuda. Scenarios of climate change superimposed on the current situation suggest that water scarcity may increase in the future,

sometimes in spite of precipitation increases due to increased rates of potential evapotranspiration. Addressing contemporary water management issues thus can serve as an important strategy for dealing with climate change.

7. In Estonia, globalization, changes in technology, and the rapid development of information technology have had a strong influence on the economy. The share of the traditional industrial and agricultural sectors in the national economy is diminishing, while newer sectors such as financial services, transportation, and information technology, are growing rapidly. The economic transition and restructuring of the Estonian economy have resulted in a dramatic decrease in energy consumption in the industrial and agricultural sectors. Within the context of these changes, the impacts of climate change were considered to be manageable.

8. The studies show that rather than promoting greater resiliency, many present day activities are increasing vulnerability to climate change, For example, in Antigua and Barbuda, population increases and tourist-based developments are contributing to major stresses on coastal resources. In Cameroon, the rapid growth of the city of Douala has led to urbanization of low-lying areas that are threatened by inundation and erosion. In Pakistan, population growth is decreasing per capita water availability, and has transformed the country from a water-affluent one to a water-scarce one. A growing demand for fuelwood has led to increased deforestation, accompanied by environmental problems that increase vulnerability to climate change, such as soil erosion and reservoir silting. The current situation is thus considered to be exacerbating the impacts of future climate change.

9. Vulnerability is linked to weaknesses in policies and planning or in some cases a lock of planning. In Antigua and Barbuda, the damage to infrastructure as a result of hurricanes can be traced to inappropriate standards and improper material used in roof construction. In Pakistan, agricultural production has been constrained by problems that are of a technical, institutional, and policy nature. For example, the warabandi system of providing the discharge of a watercourse to one farm for a seven-day rotation does not contribute to maximum efficiency in irrigating cropland. In Estonia, forests are under-utilised, in part due to the lack of a market, but also for institutional and legal reasons.

10. When the impacts of climate change are superimposed on contemporary environmental and social stresses, the options for sustainable growth are limited. The development of environmentally vulnerable areas such as coastal zones, was singled out as a threat to a sustainable future in Cameroon and Antigua and Barbuda. The country studies suggest that a focus on economic growth without consideration of the long-term implications for sustainability can result in increased vulnerability to climate change.

11. The cross-sectoral and interdisciplinary nature of climate impacts was clearly brought out. There was a considerable degree of overlap among the impacts and adaptation strategies considered by the various sectoral teams. The links between tourism and coastal resources in Antigua and Barbuda, for example, demonstrate that climate change policies must be integrative rather than sectoral, particularly when it comes to plans for economic development. In Cameroon, where the impacts of climate change on mangroves and infrastructure in the coastal zone were studied, linkages between the two sectors also became evident. Development

pressures account for the greatest threat to mangroves in the Cameroon Estuary, yet mangrove destruction in turn threatens the stability of infrastructure by increasing vulnerability to erosion. Superimposing climate change on these sectors magnifies the current pressures.

12. The studies suggest that change in climate variability and extreme events are in some cases of greater concern than a change in average temperature or precipitation. One single extreme event, such as a strong hurricane, can cause more coastal erosion and landwards retreat of beaches than a decade of sea level rise. An increase in the frequency and intensity of hurricanes could thus have a much greater impact on the coastal zone than a gradual change in climate. The mangroves of Antigua and Barbuda and Cameroon will not be affected by temperature change as much as by a positive or negative change in the intensity of precipitation, which could alter the ratio of seawater to freshwater and thus damage the ecosystem. In Pakistan, a combination of increased river flows and increased pressures on flood plains means that flood hazards may be one of the most serious problems associated with climate change.

13. Not all impacts discussed in the studies were considered negative. In Estonia, the impacts of climate change on agriculture and forestry were considered beneficial. In particular, agriculture could become more competitive in the future, and it is likely that most crops of southern origin, such as maize, summer wheat and buckwheat, will become more productive. Furthermore, the capital city of Tallinn will be out of the freezing zone of the Baltic Sea in the second half of the 21st century.

2. Adaptation strategies

14. The studies placed a heavy emphasis on the analysis of adaptation strategies for climate change. Until recently, adaptation has not been given much attention, as attention had focused primarily on mitigation. According to the UNEP Handbook (1996,p. 2-1), "adaptation refers to all those responses and adjustments to climate change that may be used to reduce vulnerability, and strengthen resilience". It also relates to actions that exploit new opportunities resulting from climate change.

15. The studies emphasized the need to address climate change through policy and planning. This includes long-term physical planning in the case of Antigua and Barbuda, such as the establishment of appropriate setbacks along coastal areas. It also means the control of urban settlements in coastal areas of Cameroon. In Pakistan, addressing climate vulnerability through policies and planning was considered a key adaptation strategy. This involves, for example, improving and expanding Pakistan's infrastructure base, which has deteriorated as a result of budgetary constraints. The Estonian study emphasized the fact that climate change impacts are likely to be overshadowed by political and economic changes. The range of uncertainties associated with future socio-economic scenarios thus adds to the uncertainties in adapting to climate change.

16. In some cases, cross-sectoral contradictions became evident with respect to adaptation strategies. For example, to address water scarcity in Antigua and Barbuda, it was recommended that the government consider an incentive system to encourage the public to construct larger water storage tanks to collect rainwater. However, the health sector identified cisterns or above-

groundwater storage tanks as breeding habitat for mosquito that transmits dengue, and recommended that piped water be used in new housing developments to reduce dependence on stored water and reduce the health risks associated with climate change. Integrated country studies enable the identification of such contradictory strategies.

17. The studies examined some of the actions or adjustments that are already being used to address climate variability. For example, investments in drip irrigation technology to address water scarcity in Antigua and Barbuda could represent an effective adaptation strategy to long-term climate change. Responses to climate variability were seen as one way of adapting to future climate change.

18. Several of the country studies expressed some degree of confidence regarding the potential for adaptation, especially if climate change is considered a gradual phenomenon. In Estonia, it was emphasised that the projected positive trends of climate change, both for temperature and precipitation, will occur on the background of the natural change experienced over past centuries. Comparing scenarios of climate change with the observational record, it was found that the changes are within the limits of historical air temperature fluctuations.

19. The recognition that the climate has changed or varied in the historical past guided the adaptation strategies for future climate change. Resiliency emerged as an important factor in adapting to long-term climate change.

20. This was especially emphasized in Pakistan study where it was concluded that increases in average temperatures would not result in catastrophic changes for Pakistan's farmers, or for countries like Estonia. However, if climate change is characterized by changes in the frequency and intensity of extreme events, then such complacency may be misplaced. Exposure to extreme events may increase or intensify under climatic change. In addition, there may be significant changes in the timing and duration of seasons. Changes in the onset and timing of rainfall were considered to be critical for agriculture. The magnitude of any change in climate is also important.

21. Addressing current problems is often seen as one way to increase overall resilience to climate change. An assessment of climate adaptation strategies reveals that economic reforms, policy changes, improved management and increased monitoring are important means of addressing long-term climate change. In fact, most of the adaptation measures identified in the studies could be considered necessary or beneficial, even in the absence of climate change. These measures are often referred to as "win-win" strategies. Nevertheless, most of the adaptation measures identified in the studies require strategic actions, and few will occur autonomously.

22. Much of the discussion regarding greenhouse gas mitigation in a South-North perspective focuses on the transfer of technology and the need to help developing countries adapt to climate change (e.g. UNFCCC Articles 4.8 and 4.9). Nevertheless, adaptation measures based on technological or engineering solutions were seldom identified as priorities over management improvements based on the precautionary principle.

23. In summary all of the UNEP country studies stressed the primacy of contemporary socio-economic challenges and environmental policies. The studies suggest that climate impacts in developing countries may differ significantly from impacts in countries with economies in transition. The reasons for this include different ecological conditions, different levels of industrialization, and different degrees of dependency on the natural resource base.

24. Nevertheless, it is also evident that climate impacts vary significantly among developing countries. Each country faces a particular set of contemporary challenges that must be addressed when considering the impacts of climate change. These challenges also form the basis for evaluating potential adaptation strategies.

25. All of the studies stress the need to address current problems in order to face a future with climate change. In some cases this means increasing institutional capacity to administer and regulate environmental issues, and in other cases it means a greater commitment of resources to support existing measures. Some contradictions emerged in the studies that need to be addressed at the policy and operational levels. These contradictions include an emphasis on economic growth at any cost within sectors that are likely to be affected by climate change.

26. The studies show that vulnerability to climate change cannot be addressed outside of the social and economic realities prevalent in each country, and without recognizing the changes that are occurring in response to national and global economic and political processes. Economic changes, along with political, social and demographic changes and increasing pressure on environmental resources, mean that some regions or sectors may become more vulnerable to climate change in the future, while others may become more resilient. The dynamic aspects of climate vulnerability that emerged in the UNEP country studies can be used to develop and direct strategies for addressing climate impacts and adaptations.

II. Vulnerability and adaptation assessment

27. Along with mitigation of greenhouse gas (GHG) emissions, adaptation to climate change will be required, due to the long life span of GHGs in the atmosphere. A precautionary approach that plans effective adaptation strategies is now justified. This requires new tools of vulnerability assessment that provide guidance on coping capacity and adaptation. Both vulnerability and adaptation are important priority areas in the UN Framework Convention on Climate Change (UNFCCC).

28. Vulnerability and adaptability are concepts that have been well developed in several decades of work in natural hazards, food aid, and development. However, there is considerable debate, as to the best way to conceptualise the evolution of vulnerability on the time scales of climate change.

29. The application of vulnerability concepts to climate change issues has gathered momentum in the past decade. Most of the applications have been “bottom up”, that is describing the structures and processes that result in deprivation or criticality at the local level, and superimposing climate change risk. For the purposes of international comparisons, a “top

down" approach is generally followed, one that seeks to capture the hierarchy of development from the national to local level using available indicators. Such an approach would combine development with the prospects of climate change.

30. Planning effective adaptation must begin with a clear understanding of vulnerable populations and regions based on an assessment of the capacity of these groups to cope with climate variability and change. Certain strategies require institutional infrastructures (e.g., agriculture extension services, and insurance markets); others require public expenditures (e.g., flood control, disaster relief, subsidized disaster insurance); others (e.g., informal income support) benefit from the presence of tightly knit communities.

31. A quantitative assessment of vulnerability needs to define indicators of sensitivity and adaptability. This search for quantitative indicators distinguishes this effort from current climate impacts studies.

32. Vulnerability and adaptation are central to international policy on climate change, in both the UNFCCC and the Kyoto Protocol. Phase II adaptation actions are being considered. The impact of climate change is unlikely to be evenly (or equitably) distributed around the world. Economic valuation of impacts should include equity. A simple approach would be to weigh impacts according to per capita income (a dollar of impacts in Bangladesh is worth much more than a dollar lost in the US). However, economic estimates do not capture the true measure of vulnerability or the full range of "dangerous" interference in the climate system. Consideration of non-market social, cultural, and institutional factors, better described in a vulnerability assessment than in economic estimates, are required.

33. It is useful to distinguish between adaptive measures or options (specific technologies available in the short run) and adaptive capacity (the longer-term ability to develop new options and deliver them to vulnerable populations). Similarly, sensitivity is related to resistance (the ability to resist change) and resilience (the ability to return to previous conditions after a perturbation).

A. Examples for climate change impact assessment

34. A few studies have begun to apply vulnerability indices to climate change. Here, we highlight a mixture of examples including both bottom-up (for Bangladesh and the water resources) and top-down approaches (international comparisons for sea level rise, global security, environmental susceptibility, and an integrated framework).

35. A study coordinated by the Bangladesh Centre for Advanced Studies (BCAS) evaluated vulnerability at the sub-national scale (Huq et al. 1999). Scenarios of climate change were developed, including sea level rise of 30cm and 1m, increased temperatures of +1 and +3 °C, and precipitation changes of ± 10%. Complementing the scenarios of climatic risk, two states of future development were compared: "low", a continuation of trends in poverty and underdevelopment, and "high", increased infrastructure and reduced vulnerability. A variety of methods were pursued to compile a synthesis of vulnerability at the regional level. Impact

models were used where validated. Expert opinion was drawn upon to rank impacts where models and data were scarce. Methods of multi-criteria analysis and integration across sectors and scales were used to aggregate indicators to a regional view. The final conclusion was that the economic cost of climate change impacts would be comparable to 30 years of development expenditure.

36. The BCAS approach illustrates how a variety of methods can be used to provide insight into local vulnerability. The vulnerability model uses formal methods and quantified indicators, but seeks to do so in ways that capture underlying vulnerability and reflects expert knowledge as much as what data are available.

37. Water resource issues have been tackled through various approaches to vulnerability assessment at the river basin scale. Hurd et al. (1999, and in press) present a comprehensive assessment for the US. Indicators were selected according to their appropriateness and relevance, transparency and feasibility. The indicators are grouped into two sub-indices: water supply, distribution and use (level of development, natural variability, dryness ratio, groundwater depletion, industrial water use, flexibility, institutional flexibility) and instream use, water quality and ecosystem support (flood risk, navigation, ecosystem thermal sensitivity dissolved oxygen, low flow sensitivity, species at risk). They note that caution is needed since the regional, aggregate characterisations are highly sensitive to the methods for combining the chosen indices. They do not explicitly account for future development of vulnerability or the effects of climate change.

38. The Alliance of Small Island States (AOSIS) have developed an Environmental Vulnerability Index (EVI), recognising that small island developing countries face special circumstances related to their remoteness, small size, dispersion, economic conditions and limited natural resources. While most of the small island states are not poor--they are not in the lowest levels of the Human Development Index for example--they are closely tied to their environment and face the certainty of sea level rise with few resources for protection. The EVI has been developed as part of a substantial project with significant regional and expert participation.

39. The EVI is based on three dimensions of vulnerability: risks to the environment (natural and anthropogenic), innate ability of the environment to cope with the risks (resilience) and ecosystem integrity (the condition of the environment as a result of past impacts). The three dimensions correspond to three sub-indices: Risk Exposure, Intrinsic Resilience and Environmental Degradation. A total of 57 indicators are used, with the EVI as a weighted average of scores ranging from 0 to 7 on each indicator.

40. Two attempts to integrate an index of vulnerability into global change assessment models are worth noting. Both are preliminary efforts, representing initial attempts to devise a robust and insightful methodology.

41. One effort is the human security model being developed by the integrated assessment group at Kassel University. This model seeks to relate first-order measures of climate impacts, for example a national index of agricultural productivity, to historical crises, such as episodes of

famine. The model can then be used to explore scenarios of the future and how underlying assumptions of vulnerability would condition—either exacerbate or ameliorate—the impacts of climate change.

42. The second effort seeks to develop indices of vulnerability and link them to a global change model. The purpose is to analyse the role of social and economic conditions and institutions in reducing or amplifying the physical impacts of climate variability and change on societies. For example, why did hurricane Mitch devastate some Central American countries but produced comparatively little damage in others? The implications for climate impact assessment is that we need to understand the ways in which climatic triggering events interact with a variety of socio-economic and environmental factors, including economic and social conditions, individual or sub-group characteristics, spatial factors, temporal factors and environmental factors.

43. Vulnerability is defined as the propensity of a society, economic sector, or ecosystem to experience damage or disruption as a result of a climate or other hazard. It seeks to identify the socio-economic and environmental conditions that adversely affect the ability of different groups to adapt to climate variability and change. The conceptual framework to assess vulnerability focuses on valued attributes of societies/economies, including food security, water availability, safety of settlements, human population health, and ecosystem viability.

44. What are the lessons learned in the several decades of creating comparative indices? The above experience highlights important methodological issues in developing composite indices. In the following section, issues specific to climate change are reviewed.

B. Issues in climate change applications

45. The long-term nature of climate change impacts means that the evolution of vulnerability in the future is important, perhaps more so than present vulnerability. The capacity to adapt may be more important than present vulnerability. This implies that indicators should focus on adaptive capacity and its likely progression in the next decade or so. For example, growth rates in per capita income (e.g., a forecast of 2% per year) may be as relevant as the actual per capita income. However, most of the literature on adaptability focuses at the sector or strategic level, rather than addressing the question of how generic adaptability might be measured. One advantage of linking vulnerability to global change models, as in the Moss, Alcamo and PIK examples, is that it embeds these trends in vulnerability in a consistent way.

46. Since the intention is to use the index to reduce vulnerability, indicators may need to reflect capacity to apply international (and national) resources to enhance adaptive capacity. Sound governance at the local level may be more critical than the size of the state bureaucracy in central ministries.

47. Equity is a central concern in climate policy and must be reflected in the index. The index should highlight who is more susceptible and who is less so; and this will help sort out some of the equity implications. It may be desirable to reflect different views of equity in the index itself. Differential weighting of the component indicators may be important. For example,

vulnerability to loss of life, perhaps related to coastal storms, may be weighted higher than aggregate economic damages. In such cases, the index should be constructed so that weighting is transparent and can be changed according to the values of different groups.

48. Aggregate indices at the national level are unlikely to reflect the distribution of vulnerable populations at more local scales. For example, some regions in Brazil are as poor as the poorest of nations, although Brazil ranks fairly highly in the international league of average per capita income. The same can be said for many countries. Using distributions of indicators and thresholds for concern (such as the food poverty) is one way to capture sub-national issues. However, data remain a constraint.

49. Aggregate indices are also unlikely to reflect the vulnerability of specific populations. It would certainly be desirable to identify socio-economic groups, perhaps based on livelihood, and construct indices relevant to their vulnerability and adaptive capacity. However, data are certainly lacking for such an exercise.

50. The sub-national dimension of vulnerability must be emphasised. An international index should not rank countries per se. That is, countries are not vulnerable to climate change; regions and populations within countries are. The international comparison should point to the likelihood of vulnerable situations within each country being adversely affected by climate change.

51. Even at the national level, data are inadequate. The changing political map (e.g., devolution of the Former Soviet Union) means that time series of indicators are lacking, and indeed much relevant information is not provided for all countries. Even where numbers are published, the quality of the information is suspect in many cases. Few countries have robust sample surveys upon which to base estimates.

52. Because of the long-time frame of climate change, many social and economic indicators are likely to be related to each other. Thus, for example, higher levels of female education in the future may well result in higher rates of participation in the formal economy, fewer children and a drop in infant mortality rates. In a snapshot of the present, these variables can be assumed to be largely independent indicators of status. Even in constructing indices of present vulnerability, however, independence of the chosen indicators may be a problem. This is one argument for formal statistical transformations such as a factor analysis.

53. The nature of climate change impacts presents several critical issues in developing composite indices:

- Impacts are not uniform between nations, as noted.
- Impacts are also not uniform among populations within nations.
- Confidence in climate change impacts varies widely. Impacts driven by temperature and carbon dioxide concentrations (aspects of agriculture) are more likely to be robust than those that depend on the balance between mean changes in the hydrological cycle and changes in extreme events (such as water resources in the absence of a large storage capacity).

- Many of the impacts, even the direction of the change—whether beneficial or not—depend on the scenario of climate change. A new scenario could reveal a different set of impacts. Thus, scenarios should span a plausible range (and include unexpected non-linear "surprises").
- In many sectors, the impacts are also contingent upon assumptions about the future world without climate change. Most recent climate change scenarios are transient, seeking to capture the evolution of the climate system over time. Impact studies may also assume a moving baseline—the future social, economic and political conditions without climate change. Separating the climate change impacts from the implied adaptation strategies, whether autonomous or purposeful, is with problems.
- Scale issues are critical. Especially at the regional scale climate change projections are highly uncertain. Very localised impacts may not be as serious as changes to large regions.