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Item 3 of the provisional agenda
Scientific, technical and socio-economic aspects of impacts of, and vulnerability and adaptation to, climate change

Application of methods and tools for assessing impacts and vulnerability, and developing adaptation responses. Background paper

Note by the secretariat

Summary

This background paper was prepared to facilitate discussion at the in-session workshop on adaptation scheduled for Wednesday, 8 December 2004. It is a summary of application of methods and tools for assessing impacts and vulnerability and developing adaptation responses. Particular attention is given to regional climate models and the practices and models used by relevant expert communities. The paper also includes some discussion on issues that the Subsidiary Body for Scientific and Technological Advice may wish to consider in relation to methodologies for impact and vulnerability assessment.

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<u>Annexes</u>

I. Introduction

A. Mandate

1. The Subsidiary Body for Scientific and Technological Advice (SBSTA), at its twentieth session, agreed that at its twenty-first session it would consider the exchange of information and sharing of experiences on two topics: application of methods and tools, including regional models, for assessing impacts of, and vulnerability and adaptation to, climate change; and linkages between adaptation and sustainable development. It requested the secretariat to organize a workshop during its twenty-first session allowing for in-depth discussion on the topics.[1]

2. To facilitate the discussion at the workshop, the SBSTA requested the secretariat to prepare a background paper on the application of methods and tools, including regional models, for assessing impacts and vulnerability and developing adaptation responses, inter alia, drawing on the practices of the relevant expert communities, including those responsible for dealing with natural disasters.[2]

B. Scope of this background paper

3. This document covers methods and tools for assessing impacts of, and vulnerability to, climate change and the development of appropriate adaptation responses. Within this broad scope, particular attention is given to the potential role of regional climate models as well as the practices and models used by relevant expert communities.

4. The document focuses on analysis and synthesis of current applications of methods and tools, but is not a comprehensive review of existing methods and tools. The paper explores:

(a) The types of the approaches, methods and tools available for assessing impacts of, and vulnerability to, climate change, as well as for the development of appropriate adaptation responses

(b) Experiences in applying such methods and tools in developing and developed countries

(c) Limitations associated with the use of different methodologies

(d) The type of questions these methods and tools can address, as well as questions which these models are not set up to answer but for which they may be inadvertently used to supply proxy data to stakeholders, or policy makers.

5. The document draws on information in the sources listed in annex II.

C. Possible action by the Subsidiary Body for Scientific and Technological Advice

6. The SBSTA may wish to consider the information contained in this document, as well as any recommendations and conclusions from the in-session workshop, and identify appropriate next steps with regard to methodologies.

[1] FCCC/SBSTA/2004/6, paragraph 111.
[2] FCCC/SBSTA/2004/6, paragraph 112.

II. Approaches, methods and tools for assessing climate change vulnerability and adaptation

A. General overview

7. The Intergovernmental Panel on Climate Change (IPCC) Third Assessment Report (TAR) defines climate change impact, vulnerability and adaptation assessment as the practice of identifying and evaluating the detrimental and beneficial consequences of climate change on natural and human systems, and identifying and evaluating options for adapting to climate change. The TAR also provides definitions of key aspects of assessment: sensitivity, impacts, vulnerability and adaptation (box 1).[3]

8. There is a wide array of approaches, frameworks, methods and tools to assess impacts and vulnerability, and to prepare for adaptation, as well as many ways to categorize them. This paper will follow the outline proposed in the UNFCCC compendium on methods and tools to evaluate impacts of, and vulnerability and adaptation to, climate change – a web-based resource that provides key information on available frameworks, methods and tools, and their special features. It is designed to assist Parties and other potential users select the most appropriate methodology for their assessments of impacts and vulnerability, and development adaptation options. A summary description of the scope and structure of the compendium and examples of methods and tools under each of its categories are presented in annex I. Following the structure of the compendium, this section considers broad frameworks, and methods and tools (cross-cutting, multicultural methods and sector-specific).

1. Framework for assessment of impacts, vulnerability and adaptation

9. Framework in this document refers to a combination of (a) approach (such as top-down or bottom-up) that prescribes an entire process of assessment and which may include a certain (b) method or methods (sequence of actions designed to achieve a prescribed result), which in turn might employ various (c) tools (such as computer climate models). Examples of vulnerability assessment and adaptation frameworks include: the IPCC *Technical Guidelines for Assessing Climate Change Impacts and Adaptations* (the IPCC Guidelines), the United Nations Development Programme (UNDP) Adaptation Policy Framework (APF), and the national adaptation programmes of action (NAPA) guidelines developed in the UNFCCC process.

Box 1. Definitions, IPCC TAR 2001

Sensitivity is the degree to which a system is affected, either adversely or beneficially, by climate-related stimuli. The effect may be direct (e.g. a change in crop yield in response to a change in the mean, range or variability of temperature) or indirect (e.g. damages caused by an increase in the frequency of coastal flooding due to sea level rise).

Climate impacts are consequences of climate change on natural and human systems.

Vulnerability is the degree to which a system is susceptible to, or unable to cope with, adverse effects of climate change, including climate variability and extremes. Vulnerability is a function of the character, magnitude and rate of climate variation to which a system is exposed, and its sensitivity and adaptive capacity.

Adaptation to climate change refers to adjustment in natural or human systems in response to actual and expected stimuli or their effects, which moderates harm or exploits beneficial opportunities. Various types of adaptation can be distinguished, including anticipatory and reactive adaptation, private and public adaptation, and autonomous and planned adaptation.

10. The approach to be followed depends on the scale of the assessment and the questions that the assessment is to explore. Vulnerability and adaptation assessment can be conducted on different scales – from a global to local – and address fundamental questions, such as:

(a) What are the key long-term impacts of climate change?

[3] These are working definitions that are continually being refined and clarified by specialists and practitioners, and the same terms have sometimes different meaning in different communities.

(b) To what extent can the harmful effects of climate change be reduced through adaptation?

(c) What can a country or community do to adapt to climate change?

(d) How can adaptation policies best be developed and applied?

11. The choice of suitable approach, methods and tools depends on what question an assessment is focusing on, as well as a number of other issues, including the sector/system under consideration and time frame. Approaches typically fall into two major categories, namely: top-down (scenario-driven) and bottom-up (vulnerability-driven).

12. **Top-down/scenario-driven** approaches have been widely used to address the first two questions in paragraph 10. This type of approach is described in the IPCC Guidelines and elaborated in guidelines prepared for the United States Country Studies Program and the United Nations Environment Programme (UNEP) *Handbook on Methods for Climate Change Impact Assessment and Adaptation Strategies* (see annex II for references).

13. Taken together, these guidelines and the ways they have been applied have become known as the "standard approach" based on climate scenarios derived from general circulation models (GCMs), as well as on some consideration of socio-economic scenarios. The climate scenarios chosen were commonly applied to models of ecosystems, and to a variety of sectoral impact models designed to quantify the magnitude of the physical impacts on vulnerable sectors. Possible options to adapt to those future impacts were identified at the last stage of the assessment.

14. Studies using this approach (referred to in a number of sources as "first generation" of vulnerability and adaptation assessments) have an analytical thrust that emphasize the identification and quantification of impacts.

15. Key methods and tools used in this approach include various downscaling techniques for developing scenarios of future climate and socio-economic conditions, sectoral impact models, and sometimes tools for assessing and prioritizing adaptation options. The approach and tools are strong in biophysical aspects of impacts and certain types of dynamic interactions, but do not do well in representing human interactions and local abilities to adapt. For example, crop impact modelling can yield information on the magnitude of potential impacts but sheds little light on the distribution of these impacts among local communities.

16. **Bottom-up/vulnerability-driven** approaches are oriented towards localized vulnerability. This type of approach (also called the "multi-stressors" approach) is increasingly considered the most appropriate for addressing the last two questions in paragraph 10 above. It centres on assessing current vulnerability to both climate related factors (e.g. climate variability, drought, flooding and extreme weather events) and non-climate factors (e.g. lack of resources, inadequate institutions and poverty) and examining current practices in adaptation. It also includes evaluation of vulnerability to future climate related risks (and involves key stakeholders in the evaluation process) and eventually leads to formulation of adaptation policies that strengthen adaptive capacity. The approach also addresses longer-term vulnerability to climate change, hence contributing to sustainable development. New frameworks are being developed (and tested), including the UNDP APF, and the NAPA guidelines.

17. Studies using this approach (referred to in a number of sources as "second generation" assessments) are more attuned to the local institutional, economic and productivity contexts, and are better able to represent local options and constraints than are scenario-driven studies. They are useful for developing specific strategies and in the implementation of policy. They are often limited, however, by lack of data (in terms of type and level of detail).

18. Key methods and tools used include stakeholder tools, risk assessment techniques and decision-support tools, which are strong in integrating information and accounting for dynamic interactions between human and natural systems but weak in addressing scale and magnitude. For example, community-level studies can yield information on how communities have managed to adapt to multiple local stresses (drought, poverty, etc.) but shed little light on how such experiences can be "scaled-up" or integrated over time and space.

19. The two approaches are not necessarily competing or exclusive. Studies using a vulnerability-driven approach can be conducted in parallel with or integrated in scenario-driven studies, and are designed to meet the needs of adaptation policy development. Moreover, no approach or type of approach is entirely adequate, and most methods can be used in a variety of contexts. For instance, any discussion of the future will rely on scenarios at some stage. Also, stakeholders should be involved at some stage in all assessments, even those that are top-down.

2. Methods and tools

20. The methods and tools used for vulnerability and adaptation assessment encompass a broad range of applications – from cross-cutting or multicultural (e.g. climate models, scenario-building methods, stakeholder analysis, decision-making tools) to specific sectoral (e.g. crop or vegetation models, methods for coastal zone vulnerability assessment).

21. The following paragraphs together with annex I present specific tools and methods that have either been widely used or are likely to take a more prominent role in future vulnerability and adaptation assessments, based on emerging adaptation research results and a growing understanding of the links between vulnerability, impacts and adaptation. Discussion of regional climate modelling tools is considered in more detail in chapter III.

22. **Scenario methods and tools** are mainly used by climate change analysts and decision makers asked to consider vulnerability and adaptation options in the context of different possible future conditions. The IPCC–Task Group on Scenarios for Climate Impact Assessment (TGCIA) *Guidelines on the Use of Scenario Data for Climate Impact and Adaptation Assessment* (see annex II) address this application generally, discussing a wide range of issues relating to the application of both climate scenarios and socio-economic baseline scenarios.

23. There are several methods and tools (e.g. those presented in annex I) that can be used for downscaling climate data or developing socio-economic scenarios. The downscaling techniques can be used to produce small-scale climate data of the type often required by impact models and to develop future climate scenarios at the local and national scales. The approaches to socio-economic scenario construction are all part of larger frameworks but can be used separately. In practice, the process of developing scenarios depends on the nature of the planned assessment. None of the following is a "one-size-fits-all" method/tool for developing socio-economic scenarios, but rather should be viewed as informing a necessarily ad hoc process.

24. **Stakeholder analysis tools** typically include a range of techniques that can be used to gain or account for on-the-ground perspectives – e.g. of highly vulnerable populations. They can also be used in processes aimed at untangling the sometimes competing perspectives of stakeholder groups. Some of the tools available are: agent-based simulation techniques, vulnerability indicators/indices, sustainable livelihood assessments, Delphi techniques, expert judgement and stakeholder thematic networks. Much of the recent literature relating to incorporating adaptation into national planning contexts, as well as recent efforts in adaptation research, places emphasis on the use of such tools. They can be readily used in bottom-up processes to identify and assess the attractiveness of adaptation options. Some of these

could also be considered decision-support tools. All are effective when used in the context of a stakeholder dialogue.

25. **Decision-support tools** encompass general analytical tools that assist analysts in making choices between adaptation options. They include cost–benefit analysis, multicriteria analysis, project screening/prioritization, decision matrices, environmental assessments and cost-effectiveness analysis (see examples of such tools in annex I). Some of these tools rely on a single monetary metric and focus on a single decision criterion (e.g. cost–benefit analysis). Others enable the user to define and incorporate more than one decision criterion (e.g. multicriteria analysis, tools for environmental assessment and management, and the adaptation decision matrix). Other tools seek to inform the larger policy decision questions, taking into account the institutions involved and affected when pursuing given adaptation options. Some are increasingly used within the context of NAPAs and adaptation research processes. These types of tools are used in bottom-up processes to identify and assess the attractiveness of adaptation options.

26. **Sector-specific methods and tools, and tools for integrated assessment**, mostly impact models, have been used in top-down/scenario-driven studies to assess impacts from climate change. They include crop models, water system evaluation tools, coastal resource tools, human health assessment methods and terrestrial vegetation tools. Annex I provides examples of the most commonly used tools in these sectors. Some of the more recent tools have used integrated analysis and have expanded it to provide assessments of vulnerability in multiple sectors rather than just physical estimates of sector-specific impacts. An example of integrated impact modelling is the Advanced Terrestrial Ecosystem Analysis and Modelling (ATEAM) tool for integrated assessments of vulnerability of a number of sectors (see box 2).

27. Sectoral tools can provide a quantitative estimate of the possible harm to certain sectors and/or systems due to future climate change. However, they are limited by the uncertainty inherent in the models and parameters, and by the fact that they are not able to represent local conditions well. Moreover, these tools are almost entirely limited to impact evaluation and do not lend themselves to evaluation of adaptation options.

B. Application

1. Identification of key climate change impacts on a global scale

28. What is the probability of dangerous climate change and what would be the costs of adapting to such change? This question is fundamental to the ultimate objective of the Convention and focuses on the need to define long-term strategies and primary targets for adaptation. Responding to this question requires exploration of various topics and application of a number of approaches.

29. The TAR examined a range of possible impacts under different scenarios, including rising sea levels, warmer surface air temperatures (especially at higher latitudes), increased intensity of extreme events, more rapid spread of disease, reduced agricultural productivity, and species extinction and loss of biodiversity, as well as low-probability, high-impact events and the damage they may cause. More recent studies of this topic also considered distributional and legal/social justice implications.

30. The methodologies employed are based on analysis of global climate scenarios resulting from different levels of greenhouse gas (GHG) emissions. The tools used for assessment of the costs of adaptation were mentioned earlier (e.g. cost–benefit analysis). More recent research from the Organisation for Economic Co-operation and Development (OECD) (see annex II) proposed a "numeraire" approach aimed at capturing non-market costs relating to emission of GHGs, measured in tonnes of carbon. The research proposed "five numeraires" as follows: market system costs, human

lives lost, species lost, distributional effects in changes in income differentials between rich and poor, and quality of life changes, such as heritage sites lost or refugees created.

31. It is argued that this kind of analysis of non-market costs is essential for fair and accurate assessment of climate change damage. Under this framework, the interests of developing countries and the less privileged within those nations would be given a greater weight on the basis of the threats to non-market entities like biodiversity, human life, and cultural heritage sites.

2. Assessment of impacts at the sectoral, national and regional levels and developing adaptation responses

32. The top-down/scenario-driven approach was applied almost exclusively in vulnerability and adaptation assessments in the period 1995–2002 and was reported in more than 117 national communications of Parties not included in Annex I to the Convention (non-Annex I Parties) and 43 third national communications from the Parties included in Annex I to the Convention (Annex I Parties). In most cases, approaches were consistent with the “standard approach” and analytical framework provided in the IPCC Guidelines.

33. These assessments identified impacts of long-term climate change and suggested possible options for adaptation with regard to water resources, agriculture, fisheries, drought, human health, forestry, sea-level rise, coastal and marine ecosystems, and socio-economics and infrastructure. In a number of cases the studies attempted to determine the cost and/or measure the effectiveness and benefits of individual adaptation options by using an adaptation decision matrix or other tool. Some of those studies produced results useful in studying farm-level adaptation measures, such as adjustments in application of fertilizer, pesticides, irrigation and other inputs. The studies provided useful information for policy makers on the likely key impacts of climate change at different stabilization levels and in different regions. On a national and local scale, they have been increasingly used to raise awareness, identify key issues and assess information requirements and gaps to advise development planners and local policy makers. The United Kingdom Climate Impacts Programme (UKCIP), a stakeholder-driven campaign to raise awareness and solicit involvement in climate adaptation, is a good example.

34. Many studies in both developing and developed countries noted a number of important limitations in this type of analysis, relating to the methodologies and the availability of data. These included limitations in the use of GCMs for developing climate change scenarios due to the large spatial and temporal scale of the outputs; uncertainties associated with sectoral models; and lack of research in the context of policies for adaptation or the key actors or stakeholders involved.

35. In recent years, with increased interest in adaptation as a legitimate policy response, more studies have used the bottom-up/vulnerability-driven approach and/or associated tools. In most cases this approach has been used to expand the focus of scenario-based studies to address vulnerability, using tools such as vulnerability mapping, vulnerability indicators/indices, risk assessment techniques, and a variety of decision-support and stakeholder tools to explore local vulnerability and adaptation options.

36. These studies are presented in a number of national communications from developing and developed countries. The approach is also being tested and applied under a number of recent bilateral and multilateral projects. Examples include the Latin America pilot project on adaptation that aims to explore a range of approaches useful in implementing the UNDP APF; several case studies being conducted under the global Assessment of Impacts and Adaptation to Climate Change project funded by the Global Environment Facility (GEF); the Climate Change Adaptation Programme for the Pacific; and other efforts, including bilateral research projects under way in Parties included in Annex II to the Convention.

37. Box 2 contains three examples of application of different approaches, methods and tools.

Box 2. Examples of application of different approaches, methods and tools for vulnerability and adaptation assessment

Scenario-based assessment: coastal vulnerability modelling in the Philippines. As part of its first national communication, the Philippines followed a scenario-driven, global/expert approach to conduct a coastal resource vulnerability and adaptation assessment, following the IPCC method. It used future climate scenarios based on downscaling of various general circulation models. Essential to this process was the acquisition of an inventory of baseline information that consisted of limited site surveys and interviews to note the type of coast (e.g. rocky, sandy), system responses (such as erosion, saltwater intrusion), coastal disaster history, vegetation and socio-economic information. Adaptation measures and strategies were identified based on vulnerability assessments and were developed through a review of existing policies within each sector.

Integrated impact assessment: Advanced Terrestrial Ecosystem Analysis and Modelling (ATEAM). This Europe-based project involved more than 50 scientists from 10 countries to assess vulnerability to global climate change. It covered agriculture, forestry, carbon storage, energy, water, biodiversity and mountains. An important part of ATEAM was the development of a framework that allowed for the integration of output from ecosystem and hydrological models with socio-economic data. Socio-economic data were used to assess adaptive capacity on a sub-national scale, in a way that allowed for it to be projected into the future using the Special Report on Emission Scenarios (SRES)-based scenarios up to 2080. Consultations with sectoral stakeholders complemented the study. The information on potential impacts and adaptive capacity was then combined in a series of vulnerability maps, which are to be published as a digital atlas.

Vulnerability-based assessment: Strategies for increasing human resilience and adaptive capacity in Sudan. This project is one of the 24 regional projects being undertaken within the programme Assessments of Impacts and Adaptations to Climate Change (AIACC) developed in collaboration with the IPCC and funded by the GEF with collateral funding from a number of countries and agencies (see <http://www.aiaccproject.org/>). The project followed the sustainable livelihoods framework to assess the adaptive capacity of local communities to future climate change. The assessment involved community-led development of “resilience indicators” relating to specific aspects of livelihoods that are important for coping with drought. The study comprised several case studies that included a simple analysis of relevant policies and institutional frameworks. Their findings revealed the specific ways in which communities build and express coping capacity, as well as the promising actions that not only support adaptation but also reduce poverty, increase human security, and improve natural resource stocks and ecosystem integrity. Beyond its unique results, the study (due in 2005) argues that the sustainable livelihoods framework can be used as a tool for assessing and evaluating vulnerability and adaptation to climate change.

38. The Philippines coastal impact modelling represents a good example of the type of impact studies conducted in the initial round of developing-country national communications: sound analytically, rigorous in its compilation and review of pertinent data, and calling on the expertise of a group of specialists. The adaptation measures and strategies chosen for consideration were identified based on vulnerability assessments made in the various sectors and derived from various sectoral consultations. These measures were not prioritized and their relative value not assessed.

39. The ATEAM project also used a scenario-driven approach to assess the effects of climate change on ecosystems and the provision of ecosystem services up to 2080. However, in addition to climate scenarios, the project consulted extensively with sectoral stakeholders throughout the project period. It is this emphasis that renders it a unique example that combines a vulnerability-driven focus with scenario-driven elements. The third example, in Sudan, uses a sustainable livelihoods framework to examine the coping capacity of communities to climate variability, and to better understand their adaptive capacity to future climate change.

III. Regional climate models

40. Regional climate models (RCMs) are emerging tools that could provide more detailed predictions of future climatic conditions and, thus, support the understanding of climate change impacts at higher resolution levels. RCMs could also be useful in exploring local climate dynamics and, by extension, relevant adaptation options.

A. State of the art

41. GCMs, which are computer models that incorporate the basic physics and dynamics of the climate system and account for interactions between its various components, namely the atmosphere, biosphere, oceans, land and ice, have been the primary tools used for generating projections of climate change due to anthropogenic effects. The most advanced GCMs are capable of simulating the climate on a global scale and are known as (coupled) atmosphere–ocean general circulation models (AOGCMs). They provide a detailed, three-dimensional simulation of the circulations of the atmosphere and oceans.

42. The resolution of a typical AOGCM is limited by the computer resources required, and is typically in the range of 100 to 500 km. This is a key limitation to the use of AOGCMs for projections of climate change at the regional level, because significant differences in climate at this level can occur due to the presence of inland bodies of water, complex topography and coastlines, and other factors. In addition, AOGCMs are unable to describe extreme atmospheric events, such as hurricanes and tropical storms. Despite these limitations, the climate modelling community appears to recommend unanimously that methods be pursued to add detail to GCM simulations.

43. Adding finer detail to GCMs is an initial approach to modelling regional climate; in fact, available regional climate models are approximations of GCMs focused on the regional level. The fundamental assumption upon which RCMs are based is that, given large-scale atmospheric conditions, a limited-scale model with a good characterization of physical details (e.g. topography, land–water distribution, land-use patterns) and a less strongly parameterized description of climatic processes (e.g. convection) can generate realistic and dependable information consistent with large-scale models.

44. Different “regionalization” techniques have therefore been developed over the past decade or so to improve the regional information provided by AOGCMs, and to provide climate information at a fine scale. A number of techniques have been proposed for this “regionalization”. They fall in the categories outlined below:

(a) **High resolution experimentation.** This involves selecting short periods of time (“time-slices”) and modelling them at a higher resolution, which allows simulations to be conducted with a spatial resolution on the order of 50 km. This technique assumes that large-scale circulation patterns in both the coarse and the high resolution do not differ significantly. High-resolution experiments use the same algorithms, processes, and formulations used to reproduce current climate conditions at coarser spatial scales and, thus, some climatic processes may be misrepresented at finer resolutions. Finally, although feedback effects are included from finer to coarser scales, they only apply to the local region under consideration, whereas it is known that feedbacks from different regions are interactive and should be accounted for;

(b) **Nesting techniques.** RCMs are mathematical representations of the atmosphere limited to specific regions of interest. RCMs need meteorological data from the boundaries of the domain under which they operate. Nesting techniques consist of using the output of a GCM (referred to as the “driving model”) to provide “boundary conditions”. Limitations to this technique derive from the fact that regional model simulations are affected by the systematic errors in the driving model. This technique requires high computational resources and data storage;

(c) **Statistical downscaling**. Empirical and statistical methods are used to downscale coarse resolution GCM outputs to finer resolution outputs that correspond to local and regional conditions. This can be done by, first, developing a mathematical model that relates large-scale climate information to regional and local variables; and, second, feeding the outputs from a GCM simulation into this mathematical model to estimate regional implications. An example of such a tool is the scenario generator (SCENGEN).[4] This technique is limited because it is based on empirical models and not on models that describe the physical processes affecting the climate. In addition, it works under the assumption that the statistical relationships described for the present will remain valid in the future.

45. Modelling regional climate change is subject to several levels of uncertainty of differing nature, as follows:

(a) The uncertainty associated with the emission and corresponding concentration of forcing agents such as GHGs and aerosols

(b) The uncertainty resulting from the simulation of the transient climate response by AOGCMs for a given emission scenario. This uncertainty is associated with an imperfect knowledge and/or representation of physical processes, simplifications and assumptions in the models, and has both global and regional aspects

(c) The uncertainty relating to the regionalization of the AOGCM simulations, because different regionalization models provide different representation of local climates even under the same AOGCM forcing

46. It is also important to recognize that regional climate observations can be characterized by a high level of uncertainty, especially in remote regions and in regions of complex topography.

47. In order to improve the reliability of regional modelling, several technical activities have been undertaken, including:

(a) Better parameterization to ensure that the physics of higher resolution RCMs conform to local conditions

(b) Ensuring that RCMs can produce results consistent with observed climate. This depends on the accuracy of the GCM and on the quality of the regional model’s representation of local features. Case studies are being conducted around the world to explore the question of how well RCMs are able to reproduce the driving data and observed climate, but more coordinated effort may be needed for better validations through improved models and climate observations

48. In summary, existing studies of regional modelling confirm that the task of simulating regional climate change and evaluating the uncertainties associated with the simulations is an extremely difficult one. In particular, modelling evidence shows that both topography and the land surface conditions strongly affect the surface climate change signal at scales smaller than the (grid resolution interval) of AOGCMs. This implies that the information obtained from AOGCMs needs to be used cautiously in studies of the impacts of climate change, particularly in regions that are characterized by pronounced variability in forcing on fine scales. A coherent picture of regional climate change, achieved through available regionalization techniques, will require more coordinated effort to evaluate the different methodologies, and will require improved observational data on a regional scale.

B. Application

49. The application of RCMs in vulnerability and adaptation assessment, and indeed of global climate models in general, remains a lively point of debate. Within national communications, almost all

[4] See <http://www.cru.uea.ac.uk/~mikeh/software/>.

impact studies that followed a scenario-driven approach used regionalization techniques to obtain regional and local climate scenarios. The following is a list of the most widely used RCMs:

(a) PRECIS (Providing Regional Climates for Impact Studies) is a regional climate modelling system that can be applied to any area of the globe to generate detailed climate change predictions. Current applications include regional climate simulations in China, India and South Africa

(b) HADRM3H is a regional model that has about a 50-km resolution and is forced at its lateral boundaries by a high resolution (~150 km) atmosphere-only GCM. It has been used in the United Kingdom and southern Africa to examine local climate change scenarios for the future

(c) Canadian Regional Climate Model (CRCM), based on the MC2 (Mesoscale Compressible Community) GCM is currently being used to conduct simulations in two regions of North America

(d) ALADIN, based on a numerical weather prediction model, is being used by the Regional Centre Limited Area Modelling in Central Europe (LACE). The RCM has a horizontal resolution of about 20 km and is being used at a temporal scale of at least one year

(e) RegCM3 has been applied mostly in studies of regional climate and seasonal predictability around the world

(f) MM5 uses a 36-km domain that covers the continental United States and a 12-km resolution over the southeast United States.

50. Experiences in the application of RCMs are limited and lessons are slowly unfolding. Nevertheless, various experiences indicate that RCMs have a tendency to match up well in some regions and less well in others. For example, tests conducted using the CRCM for the winter season yielded high relative errors for the forecasting of precipitation rates in dry areas in North America; this was not the case when the model was applied to European conditions.

51. The appropriate role of RCMs in vulnerability and adaptation assessment ultimately depends on the questions that the models are able to address. In particular, a number of applications have shown that even the most sophisticated models still have severe limitations when it comes to generation of the type of information required in development planning. For development planning, models should provide future estimates of different climate characteristics, including their variability and extremes and not only values of mean temperature or precipitation, and at finer resolutions, which is associated with even higher uncertainty. With more time and resources, better models of future climate will no doubt be produced. It is unclear, however, how much improvement will be achieved and how soon. It is argued that the design of adaptation measures is unlikely to be influenced much by climate scenarios, at least in the short term.

52. Even given these limitations, however, it should be noted that GCM scenarios can be applied to usefully identify a range of uncertainties for the purpose of strategic policy-making. On a longer time frame, there is a need to understand stakeholders’ demand for information relating to policy development and planning. Supplying this information requires development of risk assessment and risk management tools (such as probabilistic scenarios, not just RCMs), stakeholder identification of risk domains, and a wide array of tools to analyse decisions. Such multidisciplinary research and development is still lacking.

IV. Some considerations of the applicability of methods and tools used in other relevant communities, in particular the disaster risk management community

53. Although adaptation to climate change is a relatively new area of work, humankind has a long history of adapting to a wide range of climatic conditions and, thus, there is considerable amount of empiric information relevant to vulnerability and adaptation methods and ways to assess them. Existing methods and tools used in the fields of agriculture, forestry, ecology and others, have been of great importance in assessing the impacts of climate change and adaptation strategies. In fact, many methods and tools developed in other disciplines have been “borrowed”, adjusted and used in vulnerability and adaptation assessments. Examples include techniques for environmental impact assessment, and agriculture and forestry models (where climatic variables have been incorporated into hydrological modelling), and valuation techniques. Methods and tools borrowed from social and political science include stakeholder participation tools and vulnerability assessments; examples are given in annex I.

54. Authorities around the world and the disaster risk management (DRM) community share a common concern with the climate change community on the need to assess and reduce the risk associated with climate hazards (such as hurricanes and floods) and lessen adverse impacts. In recent years there has been increased recognition by the climate change community of the usefulness of the knowledge and methodologies accumulated in the DRM community. The climate change community is especially interested in so-called “second generation” studies referred to in chapter II of this paper.

55. Methodologies used in the DRM community can be grouped in the two categories: methodologies for risk assessment; and methodologies for assessment of past disaster damage and related needs.

56. The DRM community defines **risk assessment** the analysis of potential hazards and the evaluation of existing conditions of vulnerability that could pose a potential threat to people, property, livelihoods and the environment. It entails the quantitative and qualitative understanding of risk, its physical, social, economic and environmental factors, and its consequences. Risk assessment encompasses the systematic use of available information to determine the likelihood of certain events and the severity of their possible consequences. It is generally agreed that the process includes:[5]

(a) Identifying the nature, location, intensity and probability of a threat

(b) Determining the existence and degree of vulnerabilities and exposure to those threats

(c) Identifying the capacities and resources available to address or manage threats

(d) Determining acceptable levels of risk.

57. The tools used by the DRM community vary from simple qualitative ones to quantitative ones. Some examples are summarized in box 3; other examples can be found in the guidelines developed by different international and national institutions and organizations.[6]

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[5] See United Nations International Strategy for Disaster Reduction, 2004: <http://www.unisdr.org/eng/about_isdr/bd-lwr-2004-eng.htm>.

[6] For example, a number of guidelines/tools have been developed by institutions as varied as the United Nations Disaster Management Training Programme; the Asian Disaster Preparedness Center; the International Federation of Red Cross and Red Crescent Societies; the Office of Critical Infrastructures and Emergency Preparedness, Government of Canada; Emergency Management Australia; Action Aid; Care; World Resource Institute; the Pan American Health Organization; and the National Oceanic and Atmospheric Administration, United States Department of Commerce. See <http://www.unisdr.org/eng/task%20force/tf-working-groups3-eng.htm>.

Box 3. Examples of methods and tools used in the disaster risk management community

Qualitative vulnerability and risk surveys: Examples include the Food and Agriculture Organization of the United Nations (FAO) and World Food Programme (WFP) assessment missions; and the Save the Children Fund–United Kingdom, Household Food Economy Approach

Database development and analysis using spreadsheets: Examples include the University of Pittsburgh Graduate School of Public and International Affairs, Interactive Intelligent Spatial Information System

Geographical Information Systems (GIS) and satellite technologies and mapping: Examples include the WFP–Vulnerability Analysis and Mapping Unit.

Vulnerability and Capacity Analysis (VCA): For example, as used by the Federation of Red Cross and Red Crescent Societies.

The insurance industry has developed advanced methodologies to assess risk to disasters. These are based on historical disaster databases to identify the dynamic aspects involved in vulnerability, providing the criteria to assign relative weights to different dimensions of vulnerability in risk assessment exercises.

58. In the DRM community, risk is assessed within the context of long-term preparedness and planning, and the approaches and tools required tend to rely on quantitative estimations. Such tools include computer modelling, databases and GIS and satellite technologies. In practice, these tools may be used to develop, for example, hydrologic stream flow models, risk maps, or a brief quantitative report of high risk groups. These approaches and tools are critical in providing information before analysts use on-site rapid appraisal techniques, and when an initial estimate of the number of people affected is needed during an emergency. They are also important given their capacity for prediction, insofar as they can assist decision makers in preparing and budgeting for future disasters by identifying potentially vulnerable areas and people.

59. Adaptive options, for example different levels of preparedness for drought response, can be weighed based on their ability to reduce vulnerability vis-à-vis the consequences of specific hazards. Often, adaptation is a cascade of interventions relating to timing (upstream before the hazard, or downstream in response to a disaster) and level of effort. Thus, responses to a drought might be modelled as options ranging from diversification of household crop production (upstream, local) to supporting off-farm employment (both upstream and downstream, often regional) and procedures for food relief (downstream, nationally organized).

60. **Damage and needs assessments** are set within an emergency relief framework approaches and tools are rapid, qualitative and rely on public consultations and stakeholder approaches at the national, regional and community levels. Such qualitative tools include rapid appraisals of people at risk of, for example, flood emersion or hunger. Good examples of this type of assessment are the ones conducted annually by FAO/WFP in Africa.

61. In the past, the **application of methodologies used by the DRM community** for assessment of vulnerability and adaptation to climate change has been limited. However, as mentioned in paragraph 54 above, in recent years there has been increased use of this knowledge by the climate change community, especially in bottom-up vulnerability-driven (“second generation”) studies referred to in chapter II of this paper.

62. For example, in the DRM community, specific methods and tools are selected on the basis of their ability to answer certain questions and on their potential to contribute to the understanding of the

socio-economic, geographic and geophysical aspects of vulnerability. Such questions were posed by the Stockholm Environment Institute[7] as follows:

(a) Who is vulnerable?

(b) To what are they vulnerable?

(c) What are the specific reasons for their vulnerability?

(d) Where are the vulnerable located?

(e) How have they come to be vulnerable (or under what circumstances will they become vulnerable)?

63. A similar set of questions needs to be considered in the vulnerability-driven approach to climate change vulnerability and adaptation assessment.

64. On the other hand, in top-down/scenario-driven climate change assessments referred to in chapter II, increased attention has been given to DRM risk assessment techniques in an attempt to counter uncertainties inherent in climate modelling and in the response of natural and social systems to climate change. The already mentioned UKCIP risk management framework is an example of such an application.

65. To assess the appropriateness of specific disaster assessment methods and tools in the context of vulnerability and adaptation to climate change, both their ability to reflect the social and physical sides of vulnerability, and the data/information required for their use, need to be considered. For example, the Save the Children Fund (United Kingdom) Household Food Economy Approach and zoning method have been adapted by various institutions for profiling vulnerable people, to understand how communities with shared livelihoods are affected by natural and man-made disasters. Some specific tools applied in vulnerability and adaptation assessment, such as GIS and mapping systems that employ remote sensing data, have proved to be useful for the identification of geographical vulnerability.

V. Conclusions and issues for further consideration

66. The overview of frameworks, approaches and associated methods and tools for vulnerability adaptation and assessment presented in this document suggests some conclusions and raises several issues that the SBSTA may wish to consider in relation to the following topics.

67. **Approaches, methods and tools.** The approaches, methods and tools for assessment of impacts, vulnerability and adaptation are in this paper classified into two broad categories: top-down/scenario-driven approaches and bottom-up/vulnerability-driven approaches, both with associated tool kits and methods.

68. The scenario-driven (top-down) approach is useful in evaluating possible long-term climate change impacts and in support of international processes, stakeholder awareness and decision-making in response to changing climatic risks. The approach can also be the basis for developing long-term targets for adaptation (in the time frame of decades or centuries). The approach has severe limitations, however, when it comes to developing practical adaptation responses and policies at a national or community level.

69. The vulnerability-driven (bottom-up) approach is more suited to the development of adaptation responses and policies within time frames shorter than those used in traditional scenario-driven methods (i.e. years and decades). A vulnerability-driven approach applied in parallel with a scenario-driven

[7] See <www.vulnerabilitynet.org>.

approach can guide actions for pre-emptive/anticipatory adaptation and for strengthening adaptive capacity to current climate risks, while addressing longer-term vulnerability. Such a combination of approaches also fits well within the context of sustainable development and thus is in harmony with donor considerations.

70. The choice of the approach, methods and tools is made at the national level and depends on national priorities, time frames, the questions to be addressed and available resources. It is important to ensure that all Parties have adequate access to information about available methods, including associated uncertainties and limitations. Several ongoing efforts under the UNFCCC support dissemination of methodologies and information about their use and applicability.[8]

71. A number of tools and methods are used in other research/policy communities, particularly in the DRM community, that might be useful for assessing climate change risks and developing adaptation. It may be important to learn more about methods and experiences.

72. The SBSTA may wish to consider what additional activities might be warranted to ensure that Parties have adequate access to information about available methodologies and tools, their application and new developments. For example, the following specific options may be considered in this regard:

(a) Request the secretariat, possibly in cooperation with IPCC, to regularly up-date and review the UNFCCC compendium on methods and tools to evaluate impacts of, and vulnerability to, climate change; and to extend it to include methods reviewed in the fourth assessment report of the IPCC

(b) Encourage Parties in their national communications to report information on methods according to the format presented in the UNFCCC compendium

(c) Request the secretariat to organize an expert meeting with representatives of relevant organizations to identify appropriate methods and tools used in other communities, including the disaster risk management community, and the ways and means of providing this information to Parties

73. **Scenario-based studies and regional climate models.** Scenario-based studies will be necessary for informing policy-making at the national, regional and international levels. These studies are also useful for furthering the understanding about the balance between the level of adaptation versus mitigation in the context of Article 2 of the Convention, and for identifying long-term targets for adaptation.

74. It is important that work to improve the modelling tools continues, but with a fuller understanding of underlying limitations for providing timely policy advice. Analysis has shown that even the most sophisticated models still have severe limitations when it comes to generating the type of information required for designing adaptation policies.

75. The climate scenarios and models need to be refined based on better data and more coordinated application, especially in developing countries. Data of high quality and resolution need to be obtained through systematic observation for validation and parameterization of models. At the same time, stakeholders need information to underpin decisions which must be made despite uncertainty.

[8] For example, the work of the secretariat on the compendium, the workshop on the status of modelling activities in response to decision 5/CP.7, and the development of hands-on training material on vulnerability and adaptation assessment for non-Annex I Parties in accordance with decision 5/CP.8.

76. The SBSTA may wish to consider what can be done:

(a) To encourage further development and refinement of regional models based on better observation data, and

(b) To identify information needs at different levels to help develop policy actions on adaptation.

77. As a first step, it may wish to consider how current activities to improve global earth observation and systematic climate monitoring can be enhanced and made useful in the context of the development of adaptation responses.

Annex I

Summary of information in the UNFCCC compendium on methods and tools to evaluate impacts of, and vulnerability and adaptation to, climate change

The UNFCCC compendium on methods and tools to evaluate impacts of, and vulnerability and adaptation to, climate change is a webbased resource that provides users with key information about available frameworks, approaches, methods and tools, their application, special features of each, and information about how to obtain documentation, training, or publications supporting each tool.

It is organized in a way that allows existing adaptation analysis and decision frameworks and tools to be catalogued clearly. It is easy to use and does not prescribe or recommend methods or tools.

Below is a summary of the organization of the UNFCCC compendium, which can be accessed at <http://unfccc.int/program/mis/meth/index.html>.

Organization and examples of frameworks, methods and tools in the compendium

I. Complete frameworks and supporting toolkits

- IPCC Technical Guidelines for Assessing Climate Change Impacts and Adaptations
- U.S. Country Studies Program (USCSP)
- UNDP Adaptation Policy Framework (APF)
- Guidelines for the Preparation of National Adaptation Programmes of Action (NAPA)
- United Kingdom Climate Impacts Programme (UKCIP) Climate Adaptation: Risk, Uncertainty and Decision Making

II Cross-cutting issues and multisector methods and tools

2.1 Application of Scenario Data in Impact and Adaptation Assessment

- IPCC–TGCIA Guidelines on the Use of Scenario Data for Climate Impact and Adaptation Assessment

2.1.2 Climate downscaling techniques

- Statistical downscaling
- Statistical downscaling model (SDSM)
- Dynamical downscaling
- MAGICC/SCENGEN
- Weather generators

2.1.3 Socio-economic scenarios

2.2 Decision tools

- Policy exercise
- Benefit–cost analysis
- Cost-effectiveness analysis
- Multicriteria analysis (MCA)
- Tool for Environmental Assessment and Management (TEAM)
- Adaptation decision matrix (ADM)
- Screening of adaptation options

2.3 Stakeholder approaches

- Stakeholder networks and institutions
- Vulnerability indices
- Agent-based social simulation
- Livelihood sensitivity exercise
- Multistakeholder processes
- Scoping
- Global sustainability scenarios

2.4 Other multisector tools

III Sector-Specific Tools

4.1 Agriculture Sector Tools

- APSIM (agricultural production systems simulator)
- WOFOST
- ACRU (Agricultural Catchments Research Unit)
- Process Soil and Crop Models: CENTURY
- ORYZA 2000
- Information and Decision Support System for Climate Change Studies in South East South America (IDSS-SESA Climate Change)
- Decision support systems linking agro-climatic indices with GCM-originated climate change scenarios
- Process crop models: International Consortium for Application of Systems Approaches to Agriculture (ICASA) – International Benchmark Sites Network for Agrotechnology Transfer (IBSNAT) Family of Models
- Process crop models: General-Purpose Atmospheric Plant Soil Simulator (GAPS 3.1)
- Process crop models: Erosion Productivity Impact Calculator (EPIC)
- Irrigation model: CROPWAT
- Process crop models: Alfalfa 1.4
- Process crop models: AFRC-Wheat
- Process crop models: RICEMOD
- Process crop models: GOSSYM/COMAX
- Process crop models: GLYCIM
- Economic models: Econometric (Ricardian-based) Models
- Economic models: Input-output modeling (with IMPLAN)

3.2 Water sector tools

- WaterWare
- Water Evaluation and Planning System (WEAP)
- RiverWare
- Interactive River and Aquifer Simulation (IRAS)
- Aquarius
- RIBASIM
- MIKE BASIN

3.3 Coastal resources tools

- Decision support models: COSMO (Coastal Zone Simulation Model)
- The South Pacific Island Methodology (SPIM)
- RamCo and ISLAND MODEL
- Dynamic Interactive Vulnerability Planning (DIVA)
- Shoreline Management Planning (SMP)

3.4 Human health sector tools

- MIASMA (Modeling Framework for the Health Impact Assessment of Man-Induced Atmospheric Changes)
- Environmental Burden of Disease Assessment
- CIMSiM and DENSiM (Dengue Simulation Model)
- UNFCCC Guidelines: Methods of Assessing Human Health Vulnerability and Public Health Adaptation to Climate Change
- LymSiM
- Mapping Malaria Risk in Africa (MARA) Low-end Information Tool (LITe)

3.5 Terrestrial vegetation sector tools

- LPJ (Lund-Postdam-Jena Model)
- IBIS (Integrated Biosphere Simulator)
- Medrush Vegetation Model
- Century
- MC1
- IMAGE (Integrated Model to Assess the Greenhouse Effect)
- AEZ (Agro-ecological Zones) Methodology
- CASA (Carnegie-Ames-Stanford Approach) Model
- TEM (Terrestrial Ecosystem Model)

Annex II

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