Compendium on methods and tools to evaluate impacts of, and vulnerability and adaptation to, climate change

UNFCCC Secretariat

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1. Introduction

Parties to the United Nations Framework Convention on Climate Change (UNFCCC) are obligated by the Convention and various decisions of the Conference of the Parties (COP) to assess their national-level impacts of climate change and their efforts to adapt to these impacts as inputs for their national communications. Parties need to select from a daunting array of potentially applicable methods and tools for making these assessments, and from various sources of information concerning their use. New methods and tools are constantly being developed and the application of those that are already in use is steadily being refined. There is therefore a need for a centralized source of information that can be maintained and regularly updated.

In 1999, the UNFCCC Secretariat took a first step towards disseminating information on methods and tools when it produced a report entitled *Compendium of Decision Tools to Evaluate Strategies for Adaptation to Climate Change*. Since then, the adaptation assessment process has changed considerably and in some ways grown more sophisticated. The UNFCCC Secretariat has subsequently updated the original compendium and broadened its scope. An updated compendium entitled *Compendium of methods and tools to evaluate impacts of, and vulnerability and adaptation to, climate change* was launched in 2004.

The current revision of the compendium was undertaken as part of the Nairobi work programme on impacts, vulnerability and adaptation to climate change. Among its activities the work programme seeks to:

- Promote the development and dissemination of methodologies and tools for impact and vulnerability assessments, such as rapid assessments and bottom-up approaches, including as they apply to sustainable development

- Promote the development and dissemination of methods and tools for assessment and improvement of adaptation planning, measures and actions, and integration with sustainable development.

The revision draws on information provided by Parties and organizations on existing and emerging assessment methodologies and tools; and views on lessons learned from their application; opportunities, gaps, needs, constraints and barriers; possible ways to develop and better disseminate methods and tools; and training opportunities. The submissions and a synthesis report can be found on the UNFCCC website (http://unfccc.int/3922.php).

The challenge of continuously updating is not only to expand the structure of the compendium to include new tools that have come into use and to modify it to include tools applicable to the entire process of vulnerability and adaptation assessment (not simply decision making), but also to reorganize it so as to capture the range of thinking reflected in the different recent approaches to the assessment process.

The earlier work (sometimes referred to as the first generation) in climate change impacts and adaptation studies focused more on impacts than on adaptation. The motivation for the research was often driven by the need to understand how great the impacts of climate change might be to know how much urgency to give to the mitigation agenda or the stabilization of greenhouse gas concentrations in the atmosphere. This work was facilitated by a number of "guidance documents," among which the most prominent were:

- SCOPE Report on impact Assessments (Kates et al., 1985)
- Intergovernmental Panel on Climate Change (IPCC) Guidelines (Carter et al., 1994; see Chapter 2 of this document)
- U.S. Country Studies Program (Benioff et al., 1996; see Chapter 2 of this document)
- United Nations Environment Programme (UNEP) Handbook (Feenstra et. al., 1988).

The first generation studies were generally based on climate scenarios derived from general circulation models (GCMs). The chosen scenarios were commonly applied to models of ecosystems, to specific species within an ecosystem, or to a component of the biogeophysical environment such as sea level; coastal zones, including coral reefs; the hydrological cycle; mountains; deserts; or small islands. These "first order" impacts were sometimes carried forward to the modeling of "second order" impacts on economic sectors such as agriculture, forestry, water resource management, human health, and so forth. Only at the end of a long research process was adaptation considered, and only infrequently were socioeconomic scenarios developed alongside the climate scenarios.

More recently there has been an upsurge in interest and concern about adaptation linked to current climate variability and current vulnerability in addition to the concern with future climate and vulnerability. The context has also been broadened to include other environmental and social stressors, and changes in socioeconomic conditions and sustainable development.

This change in emphasis has led to the development of a second generation of studies that begin with current climate variability and current adaptation (or the lack of adaptation or maladaptation). This empirical approach provides a grounding in reality on which to base projections of future impacts, vulnerability, and adaptation. New methods, frameworks, and guidelines are being developed to facilitate second order studies, including:

- The United Nations Development Programme (UNDP) Adaptation Policy Framework (Burton et al., 2004; see Chapter 2 of this document)

- The National Adaptation Programmes of Action (NAPA) Guidelines (UNFCC, 2002; see Chapter 2 of this document)

- The Assessments of Impacts and Adaptations to Climate Change (AIACC) projects (see Chapter 2 of this document).

Much of the work under way includes a blend of first and second-generation approaches and tools, and the research approaches are evolving rapidly, as is to be expected in a relatively new area of research and study. The more recent emphasis on current climate variability, and current vulnerability and adaptation, has been associated with more sophisticated approaches to socioeconomic scenarios, to stakeholder participation, to adaptation policies and measures, and to the assessment and strengthening of adaptation capacity. These changes are reflected in the content and structure of this updated version of the compendium, making it more relevant to today's needs. This is not the end of the road, however. As understanding of climate change impacts expands and as social and economic circumstances change, there will be a continued need for new approaches and new research tools and methods. Users of this compendium are thus challenged to go past the role of passive users and to make their own contributions to the improvement of methods and tools.

1.1 Focus and Scope of the Compendium

This updated compendium is organized in a way that allows existing adaptation analysis and decision frameworks and tools to be catalogued in manner that is clear and easy to use and does not prescribe or recommend methods or tools. Whereas the original compendium for the most part organized discrete adaptation decision tools according to sectors of application, echoing the sectoral model based approach to vulnerability and adaptation assessment of the time, the organization of this revised compendium reflects the expanded scope and comprehensiveness of methods currently in use.

Thus, the revised compendium attempts to reflect the current state of knowledge by collecting and summarizing three broad categories of frameworks, methods, and tools. First, it reviews some of the complete frameworks (both what are previously referred to as first generation approaches and second generation approaches), those methods that prescribe an entire process for the assessment of vulnerability and adaptation and in some instances assemble toolkits to support this process. These frameworks offer a broad strategic approach.

Second, the compendium establishes a structure for cataloging tools that assist in addressing key cross-cutting themes or whose application spans multiple steps of the assessment process, as well as discrete tools that are applicable to multiple sectors. These are not comprehensive frameworks, nor are they tools applicable only to a specific sector and step of an assessment framework. Some constitute partial frameworks or particular research orientations that prescribe an approach to undertaking an assessment (e.g., stakeholder analysis) and can be applied at various stages of the assessment. Others are tools that are applicable to more than one sector or tend to address a particular stage of an assessment (e.g., GCM downscaling, socioeconomic scenario building, decision making).

Third, as the first version of the compendium did, this revised version organizes discrete tools specific to particular sectors. Much of the content of the original compendium has been conserved here. We have significantly updated the agriculture sector to reflect the development and use of new methods and tools.

The compendium is intended for use by either assessment managers or technical researchers; it does not require extensive technical knowledge of modeling or specific decision-making techniques. Some of the frameworks and tools described in the compendium may require particular expertise, and these requirements are explicitly described.

The compendium provides users with key information about available frameworks and tools, special features of each framework or tool, and information about how to obtain documentation, training, or publications supporting each tool. It has been designed to be used as a reference document to identify available frameworks and tools for assessing vulnerability and adaptation. This is not a manual describing how to implement each tool, but rather a survey of possible tools that can be applied to a broad spectrum of situations and a map to point users to additional sources of information.

Each framework or tool is described in a summary table that summarizes its key features. With these tables as a reference, users can decide which frameworks and tools they want to use and then can obtain further documentation for the listed contact to fully evaluate each option. Each tool has been summarized to identify its potential applications. Looking at the resources available and the individual needs of the project, the user can identify which tools may be most appropriate to analyze the adaptation options they are considering.

The compendium is not a "cookbook." It does not provide full documentation for frameworks, models, or other tools. Users will need to obtain this information from the providers. Furthermore, users should carefully consider the alternative frameworks and tools discussed in the compendium. The appropriateness and usefulness of each may vary depending on users' circumstances and information needs. Options for analysis should be carefully investigated and considered.

Tables include relevant topics from the following list:

- ***Description.*** Explains the type of framework or tool being presented (e.g., spreadsheet, process-based model) and what type of information this tool helps the user to evaluate (e.g., monetary costs, human health risks). This area also provides a basic summary of how the tool works, including the type of data required and the processes used to evaluate these data.

- ***Appropriate use.*** Describes where the framework or tool is (and is not) applicable. This gives the user an idea of the stage at which it is appropriate to use.

- ***Scope.*** Covers the fields in which the framework or tool is applicable, including geographic (i.e., whether it is specific to a particular region) and assessment characteristics (e.g., national or site-specific).

- ***Key output.*** Describes the final product of the framework or tool (e.g., a model, a cost-effectiveness evaluation, an organizing framework).

- ***Key input.*** Explains the information or data required to use the framework or tool.

- ***Key tools.*** For frameworks, describes discrete tools that would play an important role in implementing a complete framework.

- ***Ease of use.*** Describes the level of difficulty associated with implementing the framework or tool.

- ***Training required.*** Describes the level of expertise and any specific skills required to use the framework or tool effectively.

- ***Training available.*** Describes the training available to learn how to use the framework or tool effectively.

- ***Computer requirements.*** Describes the computer hardware and software necessary to use the framework or tool.

- ***Documentation.*** Provides the citations for sources describing in detail how to use the framework or tool. Generally this is a user's manual or similar document.

- ***Applications.*** Briefly describes actual cases and projects where the framework or tool has been applied.

- ***Contacts for framework/tools, documentation, technical assistance.*** Provides information on who to contact for further information, documentation, and technical assistance. Generally the agency or firm that developed the framework or tool, or, for several of the tools applicable to multiple sectors, someone who can provide a reference to an expert for a particular application.

- ***Cost***. Provides the monetary cost of obtaining documentation or software for the framework or tool. Where applicable, gives information on the approximate cost of implementing the framework or tool. Where the exact cost is unavailable, relative cost is used (e.g., high, medium, or low relative to other described).
- ***References.*** Lists the citations for documents, articles, etc., that have critically discussed use of the framework or tool.

Finally, this compendium is part of an ongoing process and should be considered a living document. As the frameworks and tools it describes are used and field tested, they will be steadily improved and their application refined. Furthermore, the compendium is in no way intended to provide a comprehensive listing of approaches, cross-cutting issues, or sectors or of the potential frameworks and tools that might be characterized as such. Rather, the hope is to set up a structure that will accommodate the addition of other tools and frameworks currently in use as well as new approaches that will be developed in the future.

Notes on using the compendium

Summary tables in the compendium provide an overview of the framework or tool in question. They are designed to assist the user in identifying methods and techniques to investigate further. The main function is to direct users how to obtain more information, not to instruct the user on how to apply any particular framework or tool.

Many of the frameworks and tools overlap with one another. They should not be thought of as representing discrete points on a continuum, embodying either-or choices. Users may find that more than one framework or tool might be suited to their goals. It may be that users might benefit from combining elements of different methods or techniques that are profiled here.

The compendium is intended to be a living document. It reflects the state of knowledge at the time it was compiled. Additionally, it provides a structure that should allow it to grow to incorporate new frameworks and tools.

1.2 Organization of the Compendium

Chapters 2, 3, and 4 of the compendium contain the summary tables that describe each framework or tool. Table 1.1 summarizes their organization and lists the frameworks and tools described in the compendium.

Table 1.1. Organization of frameworks and tools in the compendium

Chapter 2: 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)
- Assessments of Impacts and Adaptations to Climate Change in Multiple Regions and Sectors (AIACC)
- Guidelines for the Preparation of National Adaptation Programmes of Action (NAPA)
- United Kingdom Climate Impacts Programme (UKCIP) Climate Adaptation: Risk, Uncertainty and Decision Making

Chapter 3: Cross-Cutting Issues and Multisector Approaches

3.1 Development and Application of Scenarios

3.1.1 General tools

- IPCC-TGCIA Guidelines on the Use of Scenario Data for Climate Impact and Adaptation Assessment
- The Climate Impacts LINK Project
- NCEP Global Ocean Data Assimilation System (GODAS)
- RClimDex
- SimCLIM
- UKCIP02 Climate Change Scenarios
- Climate Information and Prediction Services (CLIPS) Project and Regional Climate Outlook Forums (RCOFs)

3.1.2 Climate downscaling techniques

- Statistical Downscaling
- Statistical DownScaling Model (SDSM)
- Dynamical Downscaling
- MAGICC/SCENGEN
- Weather Generators
- COSMIC2 (COuntry Specific Model for Intertemporal Climate Vers. 2)
- PRECIS (Providing REgional Climates for Impacts Studies)

Table 1.1. Organization of frameworks and tools in the compendium (cont.)

3.1.3	**Socioeconomic scenarios**
	Developing Socioeconomic Scenarios: For Use in Vulnerability and Adaptation Assessments
	Adoption of Existing Socioeconomic Scenarios
	Qualitative and Quantitative Scenarios Emphasizing Stakeholder Input
	UKCIP Socio-Economic Scenarios
3.2	**Decision Tools**
	Policy Exercise
	Benefit-Cost Analysis
	Cost-Effectiveness
	Multicriteria Analysis (MCA)
	Tool for Environmental Assessment and Management (TEAM)
	Adaptation Decision Matrix (ADM)
	Screening of Adaptation Options
	Climate-Related Risks Estimate as Indicators of Necessity for Adaptation Responses
	Costing the Impacts of Climate Change in the UK
	Identifying Adaptation Options
	UKCIP Adaptation Wizard
	Adaptation Actions
	Business Area Climate Impacts Assessment Tool (BACLIAT)
	Nottingham Declaration Action Pack (NDAP)
	Community-based Risk Screening Tool – Adaptation & Livelihoods (CRiSTAL)
3.3	**Stakeholder Approaches**
	Stakeholder Networks and Institutions
	Scoping
	Vulnerability Indices
	Agent Based Social Simulation
	Livelihood Sensitivity Exercise
	Multistakeholder Processes
	Global Sustainability Scenarios
	MPPACC (Model of Private Proactive Adaptation to Climate Change)
3.4	**Other Multisector Tools**
	Climatic Change and Variability (CCAV)
	Expert Judgment

Table 1.1. Organization of frameworks and tools in the compendium (cont.)

		Historical or Geographic Analogs: Forecasting by Analogy
		Uncertainty and Risk Analysis
		Estimating Adaptation Costs: M-CACES
		Impacts Database
		PAGE2002 (Policy Analysis for the Greenhouse Effect)
		Resource Approach to Assessment of Climate Change Impact on Human Activity
		Comprehensive Hazard and Risk Management (CHARM)
		Community-Based Disaster Risk Management Field Practitioners' Handbook
		Guidelines for Emergency Assessment
		Guidelines on Climate Watches
		Natural Disaster Mitigation in Drinking Water and Sewerage Systems: Guidelines for Vulnerability Analysis
		Handbook for Estimating the Socio-Economic and Environmental Effects of Disasters
		The Good Practice Guide: Community Awareness and Education in Emergency Management
Chapter 4: 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
		Model of Agricultural Adaptation to Climatic Variation (MAACV)
		Relative Risk Index (RRI)
		Government Support in Agriculture for Losses due to Climatic Variability
		AgroMetShell
		Agroclimatic Water Stress Mapping
		Local Climate Estimator (New_LocClim)
		FAOClim 2.0
		CLIMWAT 2.0
		CM Box

Table 1.1. Organization of frameworks and tools in the compendium (cont.)

	CLOUD (Climate Outlooks and Agent-based Simulation of Adaptation in Africa)
	CRAM (Canadian Regional Agriculture Model)
	Process Crop Models: Decision Support System for Agrotechnology Transfer (DSSAT) developed under the International Consortium for Agricultural Systems Applications (ICASA)
	Process Crop Models: General-Purpose Atmospheric Plant Soil Simulator (GAPS 3.1)
	Process Crop Models: Erosion Productivity Impact Calculator (EPIC)
	Irrigation Model: CROPWAT
	Irrigation Model: AquaCrop
	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)
4.2	**Water Sector Tools**
	WaterWare
	Water Evaluation and Planning System (WEAP)
	RiverWare
	Interactive River and Aquifer Simulation (IRAS)
	Aquarius
	RIBASIM
	MIKE BASIN
	Spatial Tools for River Basins and Environment and Analysis of Management Options (STREAM)
	CALVIN (CALifornia Value Integrated Network)
	OSWRM (Okanagan Sustainable Water Resources Model)
	European Flood Alert System (EFAS)
4.3	**Coastal Resources Tools**
	Inter-governmental Panel on Climate Change (IPCC) Common Methodology (CM)
	UNEP Handbook Methodology
	Bruun Rule
	SURVAS
	DIVA and DINAS-COAST

Table 1.1. Organization of frameworks and tools in the compendium (cont.)

	CoastClim of Simulator of Climate Change Risks and Adaptation Initiatives (SimClim)
	Community Vulnerability Assessment Tool (CVAT)
	Decision Support Models: COSMO (Coastal Zone Simulation Model)
	The South Pacific Island Methodology (SPIM)
	Shoreline Management Planning (SMP)
	RamCo and ISLAND MODEL
	ReefResilience Toolkit
	Smartline
4.4	**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)
4.5	**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)

1.3 Definitions

Methodology /ay /approach: A complete framework that prescribes an entire process for the assessment of vulnerability and adaptation and offers a broad strategic approach. An approach in some instances assembles certain methods and toolkits to support this process. Examples include: IPCC Technical guidelines (1994), NAPAs guidelines (2002), Adaptation Policy Framework (2004).

Method. A set or sequence of steps that should be followed in order to accomplish a specific task within a larger framework. Method can be implemented through using a number of tools. Examples include: Methods for development and use of scenario data in the vulnerability and adaptation assessment, e.g. those presented in the UNEP Handbook (1998) and IPCC-TGCIA Guidelines on the Use of Scenario Data for Climate Impact and Adaptation Assessment (1999).

Tool. A means or instrument by which a specific task is accomplished. Examples include: RCMs, impact models, decision tools (cost-benefit analysis, MCA, TEAM, ADM, etc), stakeholder tools (vulnerability indexes, Livelihood Sensitivity Exercise, etc.).

References

Benioff, R., S. Guill, and J. Lee (eds.). 1996. *Vulnerability and Adaptation Assessments: An International Guidebook.* Kluwer Academic Publishers, Dordrecht, The Netherlands.

Lim, B. and E. Spanger-Siegfried (eds.). 2004. *Adaptation Policy Framework (APF) for Climate Change: Developing Strategies, Policies and Measures*. United Nations Development Programme, New York. Available at http://ncsp.undp.org/report_detail.cfm?Projectid=151

Carter, T.R., M. L. Parry, H. Harasawa, and S. Nishioka (eds.). 1994. *IPCC Technical Guidelines for Assessing Climate Change Impacts and Adaptations*. Department of Geography, University College, London.

Feenstra, J., I. Burton, J. B. Smith, and R. Tol (eds.) 1998. *Handbook on Methods for Climate Change Impact Assessment and Adaptation Strategies*. Institute for Environmental Studies, Free University, Amsterdam.

Kates, R. W., J. Ausubel, and M. Berberian (eds.). 1985. *Climate Impact Assessment. Studies of the Interaction of Climate and Society. Scientific Committee on Problems of the Environment. SCOPE Report No. 27.* John Wiley and Sons, Chichester, United Kingdom.

UNITAR. 2003. *Developing Human and Institutional Capacity to Address Climate Change Issues in LDCs: Preparing for NAPAs*. United Nations Institute for Training and Research. Available at http://www.unitar.org/ccp/LDCreport.pdf.

2. Complete Frameworks and Supporting Toolkits

The complete frameworks and associated toolkits described in this chapter of the compendium, listed in Table 2.1, span a broad range of approaches. The IPCC Technical Guidelines, the UNEP Handbook, and the U.S. Country Studies Program represent examples of first generation approaches to the assessment of vulnerability and adaptation. They have an analytical thrust, and focus on an approach that emphasizes the identification and quantification of impacts. The APF is a second-generation assessment and places the assessment of vulnerability at the center of the process. The AIACC approach (technically a collection of projects rather than an explicit framework) incorporates elements of both first generation and second-generation assessments. The NAPA Guidelines provide some conceptual and procedural oversight for the process of producing a document that identifies national priorities for adaptation. The UKCIP report provides guidance to those engaged in decision-making and policy processes. It lays out an approach to integrating climate adaptation decisions and more generally climate influenced decisions into the broader context of institutional decision-making. The UKCIP framework is distinctive in that it casts the assessment process in risk and decision under uncertainty terms.

Table 2.1. Complete frameworks and supporting toolkits

IPCC Technical Guidelines for Assessing Climate Change Impacts and Adaptations
U.S. Country Studies Program (USCSP)
UNEP Handbook on Methods for Climate Change Impact Assessment and Adaptation Strategies
UNDP Adaptation Policy Framework (APF)
Assessments of Impacts and Adaptations to Climate Change in Multiple Regions and Sectors (AIACC)
Guidelines for the preparation of National Adaptation Programmes of Action (NAPA)
United Kingdom Climate Impacts Programme (UKCIP) Climate Adaptation: Risk, Uncertainty and Decision Making

IPCC Technical Guidelines for Assessing Climate Change Impacts and Adaptations

Description	A set of technical guidelines for the scientist that does not seek to prescribe a single preferred method but rather a range of methods, some of which may be more suitable than others to particular tasks, but which yield comparable results across regions and sectors. The guidelines aid users in assessing the impacts of potential climate change and in evaluating appropriate adaptations. The Guidelines outline a seven-step process: (1) definition of the problem, (2) selection of the methods, (3) testing of the methods, (4) selection of the scenarios, (5) assessment of biophysical and socioeconomic impacts, (6) assessment of autonomous adjustments, and (7) evaluation of adaptation strategies. A range of methods is identified at each step.
Appropriate Use	To enable comparable estimates of impacts and adaptations in different sectors or regions.
Scope	All regions and sectors.
Key Output	Most suitable strategies for minimizing the effects of climate change.
Key Input	Depends on existing data, methods that will be used, and the particular objectives of the assessment.
Key Tools	General circulation model scenarios, use of the scenario data in impacts assessment (see Section 3.1) economic models, biophysical models, cost-benefit analysis (see Section 3.2). Please see the UNEP manual for more information on methods used (see summary table in Section 3.1.3). Summary of the methods used under this approach can be found in the first (FCCC/SBI/1999/11), second (FCCC/SBI/2000/15), third (FCCC/SBI/2001/14 and Add.1), fourth (FCCC/SBI/2002/16), and fifth (FCCC/SBI/2003/13) compilations and syntheses of initial national communications from non-Annex I Parties at http://unfccc.int/2709.php
Ease of Use	Depends on specific application.
Training Required	Depends on user familiarity with prescribed tools. It is likely that some training is required to complete the seven steps, particularly in using advanced quantitative models and in linking model inputs and outputs.
Training Available	No formal training currently offered though IPCC, though training may be available for particular tools the guidelines prescribe, directly from their source. See also training module of the UNITAR Climate Change Programme at http://www.unitar.org/ccp/.
Computer Requirements	No explicit requirements for employing framework, though use of associated tools will require software and in some cases significant computing resources.
Documentation	Carter, T.R., M.L. Parry, H. Harasawa, and S. Nishioka. 1994. *IPCC Technical Guidelines for Assessing Climate Change Impacts and Adaptations*. London: Department of Geography, University College London. Also, Parry, M. and T. Carter. 1998. *Climate Impact and Adaptation Assessment: A Guide to the IPCC Approach*. London: Earthscan. Guidelines are available at http://www-cger.nies.go.jp/ or http://www-cger.nies.go.jp/cger-e/e_report/r_index-e.html, or can be obtained from Department of Geography, University College London, 26 Bedford Way, London, WC1H 0AP, United Kingdom.

IPCC Technical Guidelines for Assessing Climate Change Impacts and Adaptations (cont.)

Applications	U.S. Country Studies (see summary that follows), UNEP Country Studies (Contact Ravi Sharma, ravi.Sharma@unep.org), UNDP National Communications Support Programme (project documents at http://www.gefonline.org/), and the UNFCCC compilations of the INCs at http://unfccc.int/2709.php.
Contacts for Framework, Documentation, Technical Assistance	Tim Carter; e-mail: tim.carter@vyh.fi.
Cost	No cost for obtaining documentation of framework. Actual cost of conducting such an assessment can vary widely. A detailed study can cost more than several hundred thousand US dollars, although useful results can be obtained from small-scale studies costing US$50,000-100,000.
References	Benioff, R., S. Guill, and J. Lee (eds.). 1996. *Vulnerability and Adaptation Assessments: An International Guidebook.* Dordrecht, The Netherlands: Kluwer Academic Publishers. Erda, L., W.C. Bolhofer, S. Huq, S. Lenhart, S.K. Mukherjee, J.B. Smith, and J. Wisniewski (eds.) 1996. *Climate Change Vulnerability and Adaptation in Asia and the Pacific*. Dordrecht, The Netherlands: Kluwer Academic Publishers.

U.S. Country Studies Program (USCSP)

Description	The aim of the USCSP (no longer in existence) was to assist developing countries and countries with economies in transition in meeting their obligations under the UNFCCC. Countries participating in the USCSP focused on assessing the vulnerability of their climate sensitive sectors and resources and, to a lesser extent, opportunities for adaptation. The general approach prescribed by the program involved six steps: (1) define scope of assessment process, (2) select scenarios, (3) conduct biophysical and economic impact assessments, (4) integrate impact results, (5) analyze adaptation policies and programs, and (6) document and present results to decision makers. At the center of this process is the evaluation of biophysical effects.
Appropriate Use	Best employed when an analysis of biophysical impacts of climate change (e.g., change in rainfall or crop yields) is the central goal. Relatively simple methods can still be applied when date quality and availability are limited.
Scope	All regions, coastal resources, agriculture, grasslands/livestock, water resources, forestry, human health, fisheries, and wildlife.
Key Output	Climate change impacts and, to limited extent, adaptation options.
Key Input	Climate change and baseline socioeconomic scenarios.
Key Tools	Climate change scenarios (e.g., GCM scenarios), socioeconomic baselines (e.g., $IS92_{a\text{-}f}$), and biophysical impact models (e.g., CLIRUN, Holdridge Life Zone Classification model, CERES-Maize; see appropriate sectoral summary tools in Chapter 4).
Ease of Use	Depends on specific application.
Training Required	Training is required in the use of certain models.
Training Available	Contact Stratus Consulting, P.O. Box 4059, Boulder CO 80302. Tel: +1.303.381.8000; e-mail: jsmith@stratusconsulting.com.
Computer Requirements	Depends on particular models and sectors examined.
Documentation	Benioff, T., Guill, S., and Lee, J. (eds.). 1996. *Vulnerability and Adaptation Assessments: An International Guidebook*, Dordrecht, The Netherlands: Kluwer Academic Publishers.
Applications	49 countries participated, investigating impacts in one or more of eight sectors: coastal resources, agriculture, grasslands/livestock, water resources, forests, fisheries, wildlife, and health.
Contacts for Framework, Documentation, Technical Assistance	Joel Smith, Stratus Consulting Inc., P.O. Box 4059, Boulder, CO 80302, USA; Tel: +1.303.381.8000; e-mail: jsmith@stratusconsulting.com.
Cost	Depends on breadth of assessment.

U.S. Country Studies Program (USCSP) (cont.)

References	USCSP. 1999. *Climate Change: Mitigation, Vulnerability, and Adaptation in Developing Countries*, U.S. Country Studies Program, Washington, DC Smith, J.B., N. Bhatti, G. Menzhulin, R. Benioff, M. Campos, B. Jallow, and F. Rijsberman. 1996. *Adaptation to Climate Change: Assessments and Issues*, Springer-Verlag, New York; Benioff, R., S. Guill, and J. Lee (eds.). 1996. *Vulnerability and Adaptation Assessments: An International Guidebook.* Dordrecht, The Netherlands: Kluwer Academic Publishers; Smith, J.B., Huq, S., Lenhart, S., Mata, L.J., Nemesova, I., Toure, S. 1996. *Vulnerability and Adaptation to Climate Change. Interim Results from the U.S. Country Studies Program.* Kluwer Academic Publishers; Dixon, R.K. 1997. "Forward." *Climatic Change* 36:1-2; Smith, J.B. and J.K. Lazo. 2001. "A Summary of Climate Change Impact Assessments from the U.S. Country Studies Program." *Climatic Change* 50:1-29.

UNDP Adaptation Policy Framework (APF)

Description	The APF provides guidance on designing and implementing projects that reduce vulnerability to climate change, by both reducing potential negative impacts and enhancing any beneficial consequences of a changing climate. It seeks to integrate national policy making efforts with a "bottom-up" movement. The framework emphasizes five major principles: adaptation policy and measures are assessed in a developmental context; adaptation to short-term climate variability and extreme events are explicitly included as a step toward reducing vulnerability to long-term change; adaptation occurs at different levels in society, including the local level; the adaptation strategy and the process by which it is implemented are equally important; and building adaptive capacity to cope with current climate is one way of preparing society to better cope with future climate. The APF is a flexible approach in which the following five steps may be used in different combinations according to the amount of available information and the point of entry to the project: (1) defining project scope and design, (2) assessing vulnerability under current climate, (3) characterizing future climate related risks, (4) developing an adaptation strategy, and (5) continuing the adaptation process. The framework focuses on the involvement of stakeholders at all stages.
Appropriate Use	The APF is particularly applicable where the integration of adaptation measures into broader sector specific policies, economic development, poverty reduction objectives, or other policy domains is desirable.
Scope	All sectors, all regions, particularly developing countries.
Key Output	Increased adaptive capacity through prioritized adaptation strategies that can be incorporated into development plans.
Key Input	Depends on the particular application and available information. Stakeholder derived information is a key input at all stages.
Key Tools	Vulnerability mapping, dynamic simulation of sustainable livelihoods, multistakeholder analysis (see Section 3.3), cost-effectiveness, decision trees, multicriteria analysis (see Section 3.2), among others.
Ease of Use	Depends on specific application.
Training Required	Depends on nature of particular application.
Training Available	A User's Guidebook is available on the APF web page (see below). Training will be developed (see UNDP web page).
Computer Requirements	In most cases personal computer is sufficient. Depends on tools employed, however.
Documentation	A User's Guidebook for APF and the technical papers that elaborate the APF can be obtained online at http://ncsp.undp.org/report_detail.cfm?Projectid=151.
Applications	Kenya, Honduras, Central America (see APF web page, above).
Contacts for Framework, Documentation, Technical Assistance	Bo Lim, Chief Technical Advisor, Capacity Development and Adaptation Cluster, UNDP, New York; Fax: 1.212.906.6998; e-mail: bo.lim@undp.org. Technical assistance on individual steps can be obtained from lead authors of the appropriate technical papers.
Cost	Depends on particular application.

UNDP Adaptation Policy Framework (APF) (cont.)

References	Burton, I., S. Huq, B. Lim, O. Pilifosova and E.L. Schipper 2002. *From Impacts Assessment to Adaptation Priorities: the Shaping of Adaptation Policy.* Climate Policy, Amsterdam, Vol.2, 145-159. Lim, B and E. Spanger-Siegfried (eds.). 2004. *Adaptation Policy Frameworks for Climate Change: Developing Strategies, Policies and Measures*. New York: United Nations Development Programme. Also see individual technical papers available on website for references.

Assessments of Impacts and Adaptations to Climate Change in Multiple Regions and Sectors (AIACC)

Description	AIACC is a global initiative to advance scientific understanding of climate change vulnerabilities and adaptation options in developing countries. AIACC aims to fill gaps in the current understanding of vulnerability and opportunities for adaptation by funding, training, and mentoring developing country scientists to undertake multisector, multicountry research of priority to developing countries. AIACC takes an approach to assessment that is research driven and focused on building capacity. While it does not prescribe an explicit framework for undertaking vulnerability and adaptation assessments it does offer a toolkit for researchers that are useful in the design of projects, as well as the tenets of a general approach. The toolkit also gives also information and links on climate models, agriculture models, water resources, ecosystems models. The AIACC regional studies are diverse in their objectives, scientific methods, and the sectors and systems to be investigated, but they share a common second generation assessment approach that places understanding vulnerability at the center of the assessment, engages stakeholders in the assessment process, and gives priority to strengthening the information base for making decisions about adaptation to climate change.
Appropriate Use	The 24 AIACC studies (funded to date) are best used as a source of lessons concerning the process or elements of the process of assessing vulnerability and adaptation options in particular sectors and regions. The AIACC web page can also be consulted for a listing of tools and methods that might be of use in designing such an assessment.
Scope	All sectors, all regions.
Key Output	Adaptation options to reduce vulnerability and risk.
Key Input	Stakeholder generated information about exposure, vulnerabilities, changes, risks, and driving forces.
Key Tools	Stakeholder analysis, sustainable livelihoods and indicators (see Section 3.3b), decision support systems, multicriteria analysis (see Section 3.2), cost-benefit analysis, among others (see http://sedac.ciesin.columbia.edu/aiacc/toolkit.html).
Ease of Use	Depends on specific application.
Training Required	Depends on design of particular assessment and tools employed.
Training Available	A formal series of workshops (on scenarios and on V&A) has been held for the benefit of project participants with several meetings scheduled for the near future (http://www.aiaccproject.org/meetings/meetings.html). Proceedings of past meetings can provide a useful source of information about AIACC projects and approaches. Mentoring and networking also comprise important components of the process. Regional networks will have the capacity to support continuing investigations and can be an important source of technical support (http://sedac.ciesin.columbia.edu/aiacc/resources/network2.jsp and http://sedac.ciesin.columbia.edu/aiacc/synthesis.html). There are also a newsletter and "AIACC Working Papers" to present information on the different project. The AIACC Technical Committee provides guidance on project design, assessment methods, scenario development, and use and training to AIACC projects.
Computer Requirements	Depends on design of particular assessment and tools employed.
Documentation	http://www.aiaccproject.org/.

Assessments of Impacts and Adaptations to Climate Change in Multiple Regions and Sectors (AIACC) (cont.)

Applications	Applications across a wide range of regions, countries, sectors, systems, and groups. There is a web-based information network to share information from the AIACC regional assessments (http://sedac.ciesin.columbia.edu/aiacc/, and a synthesis of AIACC projects (http://sedac.ciesin.columbia.edu/aiacc/synthesis.html). See also http://www.aiaccproject.org/aiacc_studies/aiacc_studies.html.
Contacts for Framework, Documentation, Technical Assistance	The project is managed by the AIACC Science Director and Project Coordinator and overseen by the AIACC Implementing Committee. The AIACC Technical Committee, including a Scenarios Advisory Group, provides guidance on project design, assessment methods, scenario development and use, training, and selection of projects. Sara Beresford, AIACC Project Coordinator; Tel: 202.462.2213; e-mail: sberesford@agu.org , Neil Leary, Science Director of AIACC; e-mail: nleary@agu.org, or general inquiries to aiacc@agu.org.
Cost	Depends on design of particular assessment.
References	A listing of AIACC reports and publications can be accessed at: http://www.aiaccproject.org/publications_reports/Pub_Reports.html.

Guidelines for the Preparation of National Adaptation Programmes of Action (NAPA)

Description	NAPA is a programme for least developed countries (LDCs) to address their current and urgent adaptation needs. Countries are required to rank adaptation measures for funding by the LDC Fund and other sources based on such criteria as urgency and cost-effectiveness. The NAPA Guidelines are not in themselves a detailed framework for the assessment of vulnerability and adaptation. Instead, they provide some guidance for the process of compiling a document that specifies priority adaptation actions in the LDCs. The Guidelines outline some "guiding elements" that inform this process and sketch out a process; however, they fall short of providing a structured framework. The guiding elements imply that the NAPA process should emphasize: (1) a participatory approach involving stakeholders, (2) a multidisciplinary approach, (3) a complementary approach that builds on existing plans and programs, (4) sustainable development, (5) gender equity, (6) a country driven approach, (7) sound environmental management, (8) cost-effectiveness, (9) simplicity, and (10) flexibility based on country specific circumstances. In the NAPA process, much of the work of assessing vulnerability and adaptation is intended to be drawn from existing sources. The Guidelines do stress the importance of conducting a participatory assessment of vulnerability to current climate variability and extreme events as a starting point for assessing increased risk due to climate change.
Appropriate Use	Relatively rapid prioritization of adaptation options.
Scope	All regions and sectors.
Key Output	A document describing priorities for adaptation action, emphasizing especially how these priorities and associated plans for action fit in with a country's development needs, other plans, and multilateral environmental agreements.
Key Input	Results from existing and ongoing assessment of vulnerability and adaptation to both current climate variability and climate change.
Key Tools	Cost-effectiveness analysis, cost benefit analysis, multicriteria analysis, stakeholder methods (see Sections 3.5 and 3.6).
Ease of Use	Relatively straightforward, given reliance on existing studies. Ranking of adaptations may be challenging.
Training Required	Some instruction in the NAPA process is helpful.
Training Available	Regional workshops devoted to increasing understanding of the NAPA process are organized by UNITAR. Materials from these workshops are available at http://www.unitar.org/ccp/napaworkshops.htm, http://www.napa-pana.org
Computer Requirements	None.
Documentation	Annotated guidelines at http://unfccc.int/files/cooperation_and_support/ldc/application/pdf/annguide.pdf Special website for LDCs at http://unfccc.int/2666.php
Applications	Ongoing UNDP, UNEP and World Bank projects to develop NAPAs in the 48 LDC Parties to the UNFCCC. Submitted NAPAs are available at http://unfccc.int/2679.php

Guidelines for the Preparation of National Adaptation Programmes of Action (NAPA) (cont.)

Contacts for Framework, Documentation, Technical Assistance	General information: Paul Desanker, UNFCCC secretariat; Tel: +49.228.815.1362; e-mail: Pdesanker@unfccc.int . For technical guidance and advice on the preparation and on the implementation strategy of NAPAs, including the identification of possible sources of data and its subsequent application and interpretation, contact the LDC Expert Group (LEG) at http://unfccc.int/2666.php.
Cost	No cost for obtaining Guidelines.
References	United Nations Institute for Training and Research. 2003. *Developing Human and Institutional Capacity to Address Climate Change Issues in LDCs: Preparing for NAPAs*. Available at http://www.unitar.org/ccp/LDCreport.pdf.

United Kingdom Climate Impacts Programme (UKCIP) Climate Adaptation: Risk, Uncertainty and Decision Making

Description	The report proposes a step-wise approach to vulnerability and adaptation assessment in a risk uncertainty decision-making framework. The framework and guidance aim to help decision-makers and their advisors in identifying important risk factors and to describe the uncertainty associated with each. It aims to help them judge the significance of the climate change risk compared to the other risks they face, so they can work out what adaptation measures are most appropriate. There are questions for the decision maker to apply at each stage, and tools that can be used. The report identifies methods and techniques for risk assessment and forecasting, options appraisal and decision analysis. There are eight stages in the framework: (1) identify problem and objectives, (2) establish decision making criteria, (3) assess risk, (4) identify options, (5) appraise options, (6) make decision, (7) implement decision, and (8) monitor, evaluate, and review. It prescribes a circular process in which feedback and iteration are encouraged, and emphasizes a sequential implementation of adaptation measures.
Appropriate Use	The UKCIP framework is applicable to any decision that is likely to be influenced by climate or made in specific response to climate, barring those related to mitigation. Diverse applications are possible. The methodology is particularly relevant to decision makers (1) who are responsible for areas or sectors that are sensitive to climate change, (2) who are responsible for managing the consequences of present day variability in weather or climate, (3) whose decisions could be vulnerable to assumptions about the risks associated with future climate, (4) who are responsible for commissioning or overseeing technical assessments of climate change vulnerability, impacts and associated adaptation options, or (5) who need to address the robustness of a proposed decision to assumptions associated with the nature of the future climate.
Scope	All regions, all sectors. Written from the UK perspective but applicable internationally.
Key Output	Preferred adaptation options (especially no regret and low regret options) based on evaluation criteria and information regarding optimal timing and extent of implementation. Feedback based on monitoring, evaluation, and review from the implementation of these options is an important output, and becomes a key input in the iterative process.
Key Input	Decision-makers' objectives, benchmark levels of climate risk, multiple climate and non-climate scenarios and feedback from already implemented adaptations.
Ease of Use	Depends on specific application.
Training Required	Depends on user familiarity with prescribed tools. It is likely that some training is required to complete the eight steps.
Training Available	No formal training currently offered, but UKCIP Technical Report provides fairly detailed instruction.
Computer Requirements	No explicit requirements for employing framework, though use of some associated tools will require software (see Appendix 4 of UKCIP Technical Report).
Documentation	Willows, R.I. and R.K. Connell. (eds.). 2003. Climate Adaptation: Risk, Uncertainty and Decision-Making. UKCIP Technical Report. UKCIP, Oxford.

United Kingdom Climate Impacts Programme (UKCIP) Climate Adaptation: Risk, Uncertainty and Decision Making (cont.)

Applications	(1) Scoping study for the Isle of Man (http://www.gov.im/dlge/enviro/climatechange.xml. The study used the Risk, Uncertainty and decision-making framework to investigate projected impacts of climate change impacts across key sectors for the Island. (2) Climate proofing rural resource protection policies and strategies in Wales (http://publications.environment-agency.gov.uk/epages/eapublications.storefront - this is a link to the Environment Agency's publications catalogue).The study used the framework to investigate how robust rural resource protection policies and strategies are in the face of a changing climate. (3) Defra (Global Atmospheres Division) Climate change impacts and adaptation: Cross-regional research programme. Topic C: Water (http://www.futuredrought.org.uk/Defra_Home.htm). Study with the aim of aim of developing practical guidance on how to manage water resources in a changing climate.
Contacts for Tools, Documentation, Technical Assistance	enquiries@ukcip.org.uk
Cost	Technical report is available free of charge from the UKCIP website (http://www.ukcip.org.uk).
References	As above (applications) and: Branch project (http://www.branchproject.org/documents/FinalReport/Annex1.pdf), ESPACE decision testing tool (http://www.espace-project.org/part1/publications/pdf23.pdf), City of London Adaptation strategy (http://213.86.34.248/NR/rdonlyres/7347D392-3CF3-4344-8B2D-9AF9315E8801/0/SUS_climateadapt.pdf).

3. Cross-Cutting Issues and Multisector Approaches

The tools described in this part of the compendium encompass a broad range of applications. Some groups of tools address important cross-cutting themes such as use of climate or socioeconomic scenario data. Others such as decision analysis provide more detail on tools that might be most applicable to a particular step of the vulnerability and adaptation assessment process. Others still, such as stakeholder analysis, encompass not only a set of tools but also, in some instances, a partial framework that prescribes a process or an approach to undertaking several steps of a complete assessment.

3.1 Development and Application of Scenarios

The documents and techniques described in this section of the compendium (see Table 3.1) address the development and use of scenario data in the vulnerability and adaptation assessment process. The IPCC guidelines address this application generally, discussing a wide range of issues related to the application of both climate scenarios and socioeconomic scenarios. Several tools are descried that provide access to data and guidance to support the development and application of scenarios. The techniques that follow are more specific methods that can be used for downscaling climate data or developing socioeconomic scenarios.

The downscaling techniques described here can be used to produce small-scale climate data of the type often required by impact models and to develop future climate scenarios at local and national scales. Downscaling techniques represent only one particular way of generating climate change scenarios. Some of the techniques detailed here require considerable expertise and experience (e.g., dynamical downscaling), while others are relatively straightforward and easy to use (e.g., MAGICC/SCENGEN, SDSM, and weather generators).

The approaches to socioeconomic scenario construction, also listed in Table 3.1, are mostly part of larger frameworks, with the exception of the UKCIP scenarios. While users might consider employing an approach that is derived from a framework similar to that which they are implementing, the approaches described can be used independently of their parent frameworks. In practice, the process of developing scenarios will depend on the nature of the planned assessment. None of the following approaches provides a “one size fits all” method for developing socioeconomic futures, but should instead be viewed as informing a necessarily ad hoc process.

Table 3.1 Development and application of scenarios

3.1.1 General tools
IPCC-TGCIA Guidelines on the Use of Scenario Data for Climate Impact and Adaptation Assessment
The Climate Impacts LINK Project
NCEP Global Ocean Data Assimilation System (GODAS)
RClimDex
SimCLIM
UKCIP02 Climate Change Scenarios
Climate Information and Prediction Services (CLIPS) Project and Regional Climate Outlook Forums (RCOFs)
3.1.2 Climate downscaling techniques
Statistical Downscaling
Statistical DownScaling Model (SDSM)
Dynamical Downscaling
MAGICC/SCENGEN
Weather Generators
COSMIC2 (COuntry Specific Model for Intertemporal Climate Vers. 2)
PRECIS (Providing REgional Climates for Impacts Studies)
3.1.3. Socioeconomic scenarios
Developing Socioeconomic Scenarios: For Use in Vulnerability and Adaptation Assessments
Adoption of Existing Socioeconomic Scenarios
Qualitative and Quantitative Scenarios Emphasizing Stakeholder Input
UKCIP Socio-Economic Scenarios

3.1.1 General tools

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

Description	The Intergovernmental Panel on Climate Change (IPCC) Data Distribution Centre (DDC) www.ipcc-data.org provides access to data sets, climate and other scenarios, and other materials (e.g., technical guidelines on use of scenarios). The DDC operates under the oversight of the Task Group on Data and Scenario Support for Impact and Climate Assessment (TGICA), which was established by the IPCC to facilitate wide availability of climate change-related data and scenarios to enable research and sharing of information across the three IPCC working groups. There are four technical guideline documents: (1) General Guidelines on the use of Scenario Data for Climate Impact and Adaptation Assessment (2007); (2) Guidelines for Use of Climate Scenarios Developed from Regional Climate Model Experiments; (3) Guidelines for Use of Climate Scenarios Developed from Statistical Downscaling Methods; (4) Future climate in world regions: an intercomparison of model-based projections for the new IPCC emissions scenarios (Regional Scatter Diagrams). There is also a visualisation tool, providing maps of observed and projected climate variables and a help desk.
Appropriate Use	Scenario data should be applied as part of a greater methodological framework for climate change vulnerability and adaptation assessment (see Chapter 2).
Scope	All regions and sectors. IPCC approved data and technical guidelines on its use
Key Output	The data available from the DDC should be used in conjunction with the technical guidelines. Primarily designed to serve the impacts, adaptation and vulnerability research community. Also of potential interest to policy makers, planners and the general public. The DDC provides technical guidelines and three types of data: observed global climate data sets, nonclimatic (other environmental, socio-economic and emissions) baseline and scenario information, and results from global climate model experiments.
Key Input	Queries and user feedback.
Key Tools	Data visualisation, data archive, technical guidelines on use of data.
Ease of Use	Depends on techniques employed.
Training Required	Depends on guidelines employed.
Training Available	No formal training offered.
Computer Requirements	Browser for data access. Additional software may be required to process some of the data. Details are provided on the DDC site www.ipcc-data.org.
Documentation	Available at http://www.ipcc-data.org/guidelines/TGICA_guidance_sdciaa_v2_final.pdf
Applications	Not applicable.

IPCC-TGCIA Guidelines on the Use of Scenario Data for Climate Impact and Adaptation Assessment (cont.)

Contacts for Framework, Documentation, Technical Assistance	Guidelines: Tim Carter, Finish Environment Institute; Tel: +358.9.40300.315; e-mail: tim.carter@vyh.fi. Data: IPCC Document Distribution Center, e-mail: ipcc.ddc@uea.ac.uk; website: http://ipcc-ddc.cru.uea.ac.uk. or Dr. Michael Lautenschlager, IPCC DDC Manager; Tel: +49.404.1173.297; e-mail: lautenschlager@dkrz.de.
Cost	Guidelines and data are provided free of charge.
References	IPCC-TGICA, 2007: *General Guidelines on the Use of Scenario Data for Climate Impact and Adaptation Assessment*. Version 2. Prepared by T.R. Carter on behalf of the Intergovernmental Panel on Climate Change, Task Group on Data and Scenario Support for Impact and Climate Assessment, 66 pp.

The Climate Impacts LINK Project

Description	The Climate Impacts LINK dataset at the BADC (http://badc.nerc.ac.uk/data/link/) contains output data from a large number of numerical climate models and experiments from the Hadley Centre (at the UK Met office). The data are mainly from the global HadCM3 and regional HadRM3 models, and these data are available for use by the climate impact research community. The BADC website contains additional documentation on the format of the data, output variables and structure of the archive. The data themselves are available via ftp and http. The Climate Impacts LINK Project is funded by the UK Department of the Environment, Food and Rural Affairs (DEFRA).
Appropriate Use	While the data are available to researchers, it is recommended that expert advice on the most appropriate model output to use be sought. For LINK data, this advice should come from the UK Met Office scientists who produced the data.
Scope	The model outputs have global and regional coverage, and are available as daily and monthly mean fields. Typically, the data contain various output atmospheric fields, though in some cases ocean variables are also available.
Key Output	The ouput model data are widely used for a number of climate change studies.
Key Input	Some understanding of the background to the model experiments, so that the most appropriate data can be used for a particular study.
Ease of Use	As above.
Training Required	As above.
Training Available	None.
Computer Requirements	None.
Documentation	See the BADC LINK webpage (http://badc.nerc.ac.uk/data/link/) for more information and web links.
Applications	Numerous climate change studies.
Contacts for Tools, Documentation, Technical Assistance	BADC helpdesk: badc@rl.ac.uk The British Atmospheric Data Centre, Space Science and Technology Department R25 - Room 2.122, CCLRC Rutherford Appleton Laboratory, Chilton, nr Didcot, Oxfordshire, OX11 0QX, England, UK; Tel: +44.1235.44. 64.32; Fax: +44.1235.44.63.14. UK Met Office: http://www.metoffice.gov.uk/
Cost	No charge is made for academic use of these data. Commercial users should contact the UK Met Office for more information.
References	None.

NCEP Global Ocean Data Assimilation System (GODAS)

Description	The Global Ocean Data Assimilation System (GODAS) is developed at the National Centers for Environmental Prediction (NCEP) using the Geophysical Fluid Dynamics Laboratory's Modular Ocean Model version 3 (MOM.v3) and a three-dimensional variational data assimilation scheme. A retrospective global ocean reanalysis for 1979-2004 has been generated, and is used to initialize the oceanic component of the NCEP Climate Forecast System (CFS). The historical data set and real time update of the ocean analysis provide a valuable data set for use in research and operational communities.
Appropriate Use	GODAS can be used to study the mean climate, as well as the sub-seasonal, seasonal and interannual variability of the ocean.
Scope	GODAS provides ocean temperature, salinity and velocity for the domain 75^{O}S to 65^{O}N.
Key Output	The GODAS web site contains data links, data validations and global oceanic monitoring products (http://www.cpc.ncep.noaa.gov/products/GODAS/).
Key Input	None.
Ease of Use	Users can extract the data using a Fortran program or download the plots from the GODAS web site.
Training Required	None.
Training Available	None.
Computer Requirements	Web browser and a desktop with Unix system.
Documentation	Documentation is provided on the GODAS web site.
Applications	Global oceanic monitoring products shown on the GODAS web site.
Contacts for Tools, Documentation, Technical Assistance	Dr. Yan Xue, Climate Prediction Center, NCEP; e-mail: Yan.Xue@noaa.gov.
Cost	None.
References	Behringer, D.W. and Y. Xue. 2004. Evaluation of the global ocean data assimilation system at NCEP: The Pacific Ocean. Eighth Symposium on Integrated Observing and Assimilation Systems for Atmosphere, Oceans, and Land Surface, AMS 84th Annual Meeting, Washington State Convention and Trade Center, Seattle, Washington. Behringer, D.W. 2007. The Global Ocean Data Assimilation System (GODAS) at NCEP. 11th Symposium on Integrated Observing and Assimilation Systems for the Atmosphere, Oceans, and Land Surface, AMS 87th Annual Meeting, San Antonia, TX.

RClimDex

Description	RClimDex is software that computes a total of 27 climate extreme indices recommended by the WMO CCl/CLIVAR/JCOMM joint Expert Team on Climate Change Detection and Indices (ETCCDI). These indices have been used to evaluate past changes in climate extremes. RClimDex runs in R, free software that provides an environment for statistical analysis.
Appropriate Use	RClimDex is used to generate indices for climate extremes from daily station data.
Scope	RClimDex was designed to analyze daily station data for all parts of the world. By applying the same tool in different parts of the world and generating the same types of indices, analyses conducted in different parts of the world can be compared, and merged together to seamlessly form a spatial map across the world.
Key Output	The final output is a set of indices for climate extremes.
Key Input	This tool requires daily values of station precipitation amount, and maximum and minimum temperatures.
Ease of Use	The software has a friendly graphical user interface. Programming skill is not required. Anyone who is able to use a computer should be able to run the software.
Training Required	Training is generally not required to run the software. However, the interpretation and future analysis of the indices requires some knowledge of climatic analysis.
Training Available	Training has been provided through ETCCDI organized workshops.
Computer Requirements	The software runs in MS-Windows, Linux and Unix. The statistical environment R needs to be installed before running the RClimDex. There is no special hardware requirement; a typical office PC, or any workstation should be sufficient.
Documentation	A user manual, in both English and Spanish, is available at http://cccma.seos.uvic.ca/etccdi.
Applications	This software has been used in ETCCDI workshops (see references below).
Contacts for Tools, Documentation, Technical Assistance	RClimDex was developed by Xuebin Zhang and Yang Feng of Environment Canada on behalf of the ETCCDI. For details and technical assistance contact Dr. Xuebin Zhang, Climate Research Division, Environment Canada, 4905 Dufferin Street, Toronto, Ontario, Canada, M3H 5T4; Tel: +1.416.739.4713; Fax: +1. 416.739.5700; e-mail: Xuebin.Zhang@ec.gc.ca.
Cost	RClimDex and the R environment are free. RClimDex is available at http://cccma.seos.uvic.ca/etccdi, and R is available at http://www.r-project.org.

RClimDex (cont.)

References	Aguilar, E., T.C. Peterson, P. Ramírez Obando, R. Frutos, J.A. Retana, M. Solera, I. González Santos , R.M. Araujo, A. Rosa Santos, V.E. Valle, M. Brunet India, L. Aguilar, L. Álvarez, M. Bautista, C. Castañón , L. Herrera, R. Ruano, J.J. Siani, F. Obed, G.I. Hernández Oviedo, J.E. Salgado, J.L. Vásquez, M. Baca, M. Gutiérrez, C. Centella, J. Espinosa, D. Martínez, B. Olmedo, C.E. Ojeda Espinoza, M. Haylock, R. Núnez, H. Benavides and R. Mayorga. 2005. Changes in precipitation and temperature extremes in Central America and Northern South America, 1961-2003. *Journal of Geophysical Research – Atmospheres* 110: D233107, doi:10.1029/2005JD006119. Alexander, L.V., X. Zhang, T.C. Peterson, J. Caesar, B. Gleason, A.M.G. Klein Tank, M. Haylock, D. Collins, B. Trewin, F. Rahimzadeh, A. Tagipour, K. Rupa Kumar, J. Revadekar, G. Griffiths, L. Vincent, D.B Stephenson, J. Burn, E. Aguilar, M. Brunet, M. Taylor, M. New, P. Zhai, M. Rusticucci and J.L. Vazquez-Aguirre. 2006. Global observed changes in daily climate extremes of temperature and precipitation. *Journal of Geophysical Research – Atmospheres* 111: DO5109, Klein Tank, A.M.G., T.C. Peterson, D.A. Quadir, S. Dorji, Z. Xukai, T. Hongyu, K. Santhosh, U.R. Joshi, A.K. Jaswal, R.K Kolli, A. Sikder, N.R. Deshpande, J. Revadekar, K. Yeleuova, S. Vandasheva, M. Faleyeva, P. Gomboluudev, K.P. Budhathoki, A. Hussain, M. Afzaal, L. Chandrapala, H. Anvar, P.D. Jones, M.G. New and T. Spektorman. 2005. Changes in daily temperature and precipitation extremes in Central and South Asia, *Journal of Geophysical Research – Atmosphere* 111: doi:10.1029/2005JD006316. New, M., B. Hewitson, D.B. Stephenson, A. Tsiga, A. Kruer, A. Manhique, B. Gomez, C.A.S. Coelho, D.N. Masisi, E. Kululanga, E. Mbambalala, F. Adesina, H. Saleh, J. Kanyanga, J. Adosi, L. Bulane, L. Fortunata, M.L. Mdoka and R. Lajoie. 2006: Evidence of trends in daily climate extremes over southern and west Africa, *Journal of Geophysical Research-Atmospheres* 111: D14102, doi:10.1029/2005JD006289. Peterson, T.C., X. Zhang, M. Brunet India and J.L.V. Aguirre.2007. Changes in North American extremes derived from daily weather data. *Journal of Geographical Research-Atmospheres*, submitted. Vincent, L.A., T.C. Peterson, V.R. Barros, M.B. Marino, M. Rusticucci, G. Carrasco, E. Ramirez, L.M. Alves, T. Ambrizzi, M.A. Berlato, A.M. Grimm, J.A. Marengo, L. Molion, D.F. Moncunill, E.Rebello, Y.M.T. Anunciação, J. Quintana, J.L. Santos, J. Baez, G. Coronel, J. Garcia, I. Trebejo, B. Bidegain, M.R. Haylock and D. Karoly. 2005. Observed trends in indices of daily temperature extremes in South America 1960-2000. *Journal of Climate* 18:5011-5023. Zhang, X., E. Aguilar, S. Sensoy, H. Melknyan, U. Taghiyeva, N. Ahmed, N. Kutaladze, F. Rahimzadeh, A. Taghipour, T.H. Hantosh, P. Albert, M. Semawi, M.K. Ali, M. Halal, A. Al-Shabibi, A. Al-Oulan, A. Zatari, I. Al Dean Khalil, R. Sagir, M. Demircan, M. Eken, M. Adiguzel, L, Alexander, T.C. Peterson and T. Wallis. 2005a. Trends in Middle East climate extremes indices during 1930-2003. *Journal of Geophysical Research – Atmospheres* 110:D22104, doi:10.1029/2005JD006181. Zhang, X. G. Hegerl, F.W. Zwiers and J. Kenyon. 2005b. Avoiding inhomogeneity in percentile-based indices of temperature extremes, *Journal of Climate* 18:1641– 1651.

SimCLIM

Description	SimCLIM is a flexible software package that links data and models in order to simulate the impacts of climatic variations and change, including extreme climatic events, on sectors such as agriculture, health, coasts or water resources. SimCLIM is a user-friendly "open-framework" system that can be customized and maintained by users. It contains tools for importing and analyzing both spatial (monthly, seasonal) and time-series (hourly, daily or monthly) data. For generating scenarios of future climate and sea-level changes, SimCLIM uses a "pattern scaling" method that involves the use of spatial data from complex atmosphere-ocean general circulation models (or AOGCMs) together with projections of global-mean climate changes. Standard tools presently include: degree-day model; domestic water tank model; extreme event analyzer; coastal erosion model; and data browser. Specific versions of SimCLIM are also available that interface with DHI hydrologic models and with ICASA crop models (DSSAT).
Appropriate Use	SimCLIM can be used to: describe baseline climates; examine current climate variability and extremes; generate climate and sea-level change scenarios; assess present and future climatic risks; assess present and future adaptation measures; conduct sensitivity analyses; examine sectoral impacts; examine uncertainties; facilitate integrated impact assessments.
Scope	SimCLIM contains a custom-built GIS and can thus be applied spatially to any geographic area and spatial resolution, from global to local. It also contains site-specific tools for examining time-series climate data and driving site-specific impact models.
Key Output	Spatial and site-specific scenarios of climate and sea-level changes (including changes in the risks of extreme events) and their sector impacts. Formats include spatial images, time-series projections, and graphical and tabular output.
Key Input	AOGCM and observed climate data are provided with SimCLIM for global and regional scenario generation, as well as some daily and monthly station data. Depending on user requirements, additional data for national and local situations can be included in the package. Other spatial and time-series data can be imported into the system by the user.
Ease of Use	Very user-friendly software. User and technical manuals are provided.
Training Required	For the basic functions, little training is required for users familiar with climate science. Training is advisable for users with limited background in climate change or for those who wish to gain experience with the full functionality of the system.
Training Available	Training sessions are held regularly depending on the demand. A training version of the model, called *TrainCLIM*, is also available and has been used extensively for purposes of training in climate change vulnerability and adaptation assessment.
Computer Requirements	Personal computer.
Documentation	The users and technical manuals can be obtained from CLIMsystems Ltd by request: info@climsystems.com
Applications	Used extensively in New Zealand (where it is called CLIMPACTS), Australia and North America, as well as in various Pacific Island Countries. A recent example was an application for studies conducted for the Asian Development Bank, 2005: http://www.adb.org/Documents/Reports/Climate-Proofing/
Contacts for Tools, Documentation, Technical Assistance	CLIMsystems Ltd, P.O. Box 638, Waikato Mail Centre, Hamilton 3240, New Zealand; e-mail: info@climsystems.com; website: www.climsystems.com.
Cost	Individual and site licenses available, at low-to-medium cost depending on user category.

SimCLIM (cont.)

References	Warrick, R.A. and G. Cox. 2007. New developments of SimCLIM software tools for risk-based assessments of climate change impacts and adaptation in the water resource sector. In M. Heinonen (ed.), Proceedings of the Third International Conference on Climate and Water. Helsinki, Finland, 3-6 September 2007. SYKE, Helsinki, p. 518-524. Warrick, R.A. In press. From CLIMPACTS to SimCLIM: the Development of an Integrated Model for Assessing Impacts and Adaptation to Climate Change and Variability. In C.G. Knight and J. Jaeger (eds.), *Integrated Regional Assessment: Challenges and Case Studies*. Cambridge University Press, UK. Warrick, R.A., W. Ye, P. Kouwenhoven, J.E. Hay and C. Cheatham. 2005. New Developments of the SimCLIM Model for Simulating Adaptation to Risks Arising from Climate Variability and Change. In Zerger, A. and Argent, R.M. (eds.) MODSIM 2005. International Congress on Modelling and Simulation. Modelling and Simulation Society of Australia and New Zealand, December 2005, pp. 170-176. Warrick, R.A. 2006. Climate Change Impacts and Adaptation in the Pacific: Recent Breakthroughs in Concept and Practice. In Chapman, R., Boston, J. and Schwass, M. (eds.) *Confronting Climate Change: Critical Issues for New Zealand*. Wellington: Victoria University Press. Warrick, R.A. 2007. SimCLIM: Recent Developments of an Integrated Model for Multi-scale, Risk-based Assessments of Climate Change Impacts and Adaptation. Proceedings of the 2007 ANZSEE Conference on Re-inventing Sustainability: A Climate for Change, held 3-6 July 2007, Noosaville, Queensland, Australia, http://www.anzsee.org/2007conference/conference_papers.asp.

UKCIP02 Climate Change Scenarios

Description	The UKCIP02 climate change scenarios provide four alternative descriptions of how the climate of the UK might evolve over the course of this century.
Appropriate Use	The UKCIP02 scenarios have become a standard reference for impacts and adaptation work in the UK. Ways in which they have been used can be broadly divided into research, communication and decision- and policy-making.
Scope	The climate change scenarios cover only the UK (though underlying model output is also available for the Republic of Ireland), meaning their scope is limited to UK-based climate impacts and adaptation.
Key Output	The information contained in UKCIP02 is provided to users in three main ways: (i) Headline messages - provide a national overview of the main changes described by UKCIP02. They also include historic trends, to allow recent observations to be compared with future projections. (ii) Published material - explains the science behind UKCIP02, examines historic climate trends in the UK and gives more information about the projected future changes. It includes a range of prepared maps & graphs to help visualise the changes described. (iii) Numerical information - provides the basis for the changes described by UKCIP02, allowing further processing and analysis (e.g. as input to other modelling software). Much has been converted to GIS-format files in order to facilitate its use. A series of datasets of historic climate of the UK provide information on the observed climate.
Key Input	None required for headline messages and published material. Numerical information requires users to complete a registration form. Use of UKCIP02 is most effective if users dedicate some time to understand how the scenarios were produced, what they offer and the uncertainties involved. Their use is enhanced through use of the other UKCIP tools.
Ease of Use	No information available.
Training Required	No information available.
Training Available	None provided.
Computer Requirements	No information available.
Documentation	UKCIP02 briefing report and science report; Scenarios Gateway web-pages (www.ukcip.org.uk/scenarios/ukcip02).
Applications	Set of case studies is being developed. Ways in which they have been used can be broadly divided into research, communication and decision- and policy-making.
Contacts for Tools, Documentation, Technical Assistance	Richard Westaway
Cost	No charge.
References	Hulme et al. 2002. Climate Change Scenarios for the United Kingdom: The UKCIP02 Briefing Report. 15pp. Hulme et al. 2002. Climate Change Scenarios for the United Kingdom: The UKCIP02 Scientific Report. 120pp.

Climate Information and Prediction Services (CLIPS) Project and Regional Climate Outlook Forums (RCOFs)

Description	Climate Information and Prediction Services (CLIPS) is a project of the World Meteorological Organization (WMO) designed to assist in the provision of climate information and predictions for improved economic and social decision making, and thereby support sustainable development. CLIPS builds on the rapidly developing atmospheric and oceanographic research (e.g. atmospheric predictability beyond weather prediction, ocean predictability, regional circulation indices such as ENSO and NAO, ocean-atmosphere interactions, etc.) as well as the wealth of climate data, experience and expertise within the National Meteorological Hydrological Services (NMHSs) and related entities and provides a framework to deliver operational user-targeted climate services. The CLIPS project is an effective framework within which regional climate variability and change information and the associated adaptation issues can be integrated. Development of training curricula, training workshops and regional showcase projects are key components of CLIPS. The Regional Climate Outlook Forums (RCOFs), promoted by WMO along with other international agencies, constitute an important vehicle in developing countries for providing advanced information on the future climate information for the next season and beyond, and for developing a consensus product from amongst the multiple individual predictions (based on ensembles of different dynamical climate model outputs, statistical relationships between surface ocean and continental anomalies, validated by some human expertise) . RCOFs stimulate the development of climate capacity in the NMHSs and facilitate end-user liaison to generate decisions and activities that mitigate the adverse impacts of climate variability and change and help communities to build appropriate adaptation strategies. There is a great potential for the regional climate activities that currently take place under RCOFs and through CLIPS training to expand, through the actions of the WMO regional associations and the NMHSs, the use of currently available downscaling tools to more countries and to include information on climate change scenarios assembled by the World Climate Research Programme (WCRP), such as climate projections created for the IPCC Fourth Assessment Report (AR4). This would enable NMHSs to contribute to their national communications to the UNFCCC and to develop or enhance their dialogue with users of climate information on climate risks and vulnerability (especially their governments), and would also support improved regional coordination on climate matters, standardization of tools and increased evaluation (feedback) on model outputs. While there is a range of climate modeling and downscaling tools is available today, there is as yet no global framework to train and apply these tools to meet the user needs. CLIPS/RCOFs provide this framework and bring value to the model applications and their data and facilitate their access to the users.
Appropriate Use	It is important that appropriate partnerships with the application sectors are put in place to understand the user needs. It is most appropriate to develop RCOFs for groups of nations having common climate information needs. Effective networking of the representatives of climate information providers and user sectors from the participating countries is also essential for successful operation of RCOFs. It is important for producers of climate predictions at seasonal to inter-annual scales to demonstrate the potential benefit that users can draw for their application by using the forecasts. This can easily be done using hindcasts.

Climate Information and Prediction Services (CLIPS) Project and Regional Climate Outlook Forums (RCOFs) (cont.)

Scope	CLIPS framework is applicable at the local, national, regional and global level. RCOFs operate at sub-continental scale.
Key Output	Training workshops, CLIPS curriculum, tailored climate products, regional climate outlooks, guidance on best practices in CLIPS operations, verification and user liaison, consensus-based climate products (e.g., WMO El Niño/La Niña Updates and seasonal climate outlooks issued by the RCOFs), downscaled climate prediction products for national/regional levels, etc.
Key Input	National/regional/global climate data, climate prediction products from WMO Global Producing Centres (GPCs) for long range forecasts and WMO Regional Climate Centres (RCCs)/RCC Networks, data on climate-sensitive sectors for impact assessment.
Ease of Use	Requires expertise in climate processes, analysis and modeling, and knowledge of climate-related risk management aspects.
Training Required	Training required in downscaling of climate prediction/projections to appropriate regional/national scales, verification, and development of user liaison. Training is also required for the generation of tailored climate products.
Training Available	WMO supports limited CLIPS training through its global series of workshops. Training is also an integral component of the RCOF process. In addition, there are other international agencies providing training on CLIPS- and RCOF-related topics.
Computer Requirements	High-performance computing facilities are required to run regional climate models. However, for statistical downscaling and development of regional/national climate products, a personal computer with the latest technology with relatively high processing, memory and storage capacities will be adequate. A high-speed internet connectivity will be most essential to access global/regional climate products.
Documentation	CLIPS Brochures and related guidance documents and meeting reports.
Applications	CLIPS has been promoted worldwide, and a number of CLIPS Focal Points exist in many countries. RCOFs are active in Africa, South America, Central America, Asia and Pacific Islands. For more information, please visit http://www.wmo.int/pages/prog/wcp/wcasp/clips/outlooks/climate_forecasts.html.
Contacts for Tools, Documentation, Technical Assistance	Chief, World Climate Applications & CLIPS Division, World Climate Programme Department, World Meteorological Organization,7bis, Avenue de la Paix, Case Postale No. 2300, 1211, Geneva 2, Switzerland; Tel: +41.22.730.8377; Fax: +41.22.730.8042; e-mail: wcac@wmo.int.
Cost	WMO facilitates free access to some specialized climate prediction software as well as climate prediction/projection products, through its Members and partnering agencies. Resources will be required to organize training sessions and RCOF operations.

Climate Information and Prediction Services (CLIPS) Project and Regional Climate Outlook Forums (RCOFs) (cont.)

References	CLIPS brochures and RCOF links available at WMO World Climate Applications and Services Programme and CLIPS web pages: http://www.wmo.int/pages/prog/wcp/wcasp/wcasp_home_en.html Coping with the Climate: A Way Forward, A multi-stakeholder review of RCOFs. 2000. http://iri.columbia.edu/outreach/publication/irireport/PretoriaSumRpt2.pdf. Palmer, T.N., A. Alessandri, U. Andersen, P. Cantelaube, M. Davey, P. Délécluse, M. Déqué, E. Díez, F.J. Doblas-Reyes, H. Feddersen, R. Graham, S. Gualdi, J.-F. Guérémy, R. Hagedorn, M. Hoshen, N. Keenlyside, M. Latif, A. Lazar, E. Maisonnave, V. Marletto, A. P. Morse, B. Orfila, P. Rogel, J.-M. Terres and M. C. Thomson. 2004. Development of a European multi-model ensemble system for seasonal to inter-annual prediction (DEMETER). Bulletin of the American Meteorological Society 85: 853-872. http://ams.allenpress.com/amsonline/?request=get-abstract&doi=10.1175/BAMS-85-6-853 Patt, A.G. and J. Winkler. 2007. Applying Climate Information in Africa: An Assessment of Current Knowledge. Written in support of NOAA, Boston University and the International Institute for Applied Systems Analysis (IIASA). http://www.iiasa.ac.at/Publications/Documents/XO-07-006.pdf .

3.1.2 Climate downscaling techniques and regional models

Statistical Downscaling

Description	Downscaling is a method for obtaining high-resolution climate or climate change information from relatively coarse-resolution global climate models (GCMs). Typically, GCMs have a resolution of 150-300 km by 150-300 km. Many impacts models require information at scales of 50 km or less, so some method is needed to estimate the smaller-scale information. Statistical downscaling first derives statistical relationships between observed small-scale (often station level) variables and larger (GCM) scale variables, using either analogue methods (circulation typing), regression analysis, or neural network methods. Future values of the large-scale variables obtained from GCM projections of future climate are then used to drive the statistical relationships and so estimate the smaller-scale details of future climate (see also weather generators).
Appropriate Use	Statistical downscaling may be used whenever impacts models require small-scale data, provide suitable observed data are available to derive the statistical relationships.
Scope	All locations.
Key Output	Small scale information on future climate or climate change (maps, data, etc).
Key Input	Appropriate observed data to calibrate and validate the statistical model(s). GCM data for future climate to drive the model(s).
Ease of Use	Difficult to apply from first principles since it requires access to large data sets and considerable expertise to derive the statistical relationships. User-friendly software to facilitate use is available (see SDSM — Statistical DownScaling Model, on next table).
Training Required	Considerable knowledge and experience is required to work from first principles. Use of packages like SDSM, however, requires relatively little training.
Training Available	A training course for SDSM was held in late 2002, but there are currently no plans for future courses.
Computer Requirements	Personal computer.
Documentation	Numerous publications in the scientific literature. The SDSM package provides a list of the most useful such publications arranged by category.
Applications	Widely applied in many regions and over a range of climate impact sectors. For a specific example, see Wilby et al. (1999) in References below.
Contacts for Framework, Documentation, Technical Assistance	SDSM may be obtained by registering at https://co-public.lboro.ac.uk/cocwd/SDSM/.
Cost	SDSM is free.

Statistical Downscaling (cont.)

References	Wilby, R.L. and T.M.L. Wigley. 1997. Downscaling general circulation model output: A review of methods and limitations. *Progress in Physical Geography* 21:530-548. Wilby, R.L. and T.M.L. Wigley. 2000. Downscaling general circulation model output: A reappraisal of methods and limitations. In *Climate Prediction and Agriculture,* M.V.K. Sivakumar (ed.). Proceedings of the START/WMO International Workshop, 27-29 September 1999, Geneva. International START Secretariat, Washington, DC, pp. 39-68. Wilby, R.L., L.E. Hay, and G.H. Leavesley. 1999. A comparison of downscaled and raw GCM output: Implications for climate change scenarios in the San Juan river basin, Colorado. *Journal of Hydrology* 225:67-91. Wilby, R.L., T.M.L. Wigley, D. Conway, P.D. Jones, B.C. Hewitson, J. Main, and D.S. Wilks. 1998. Statistical downscaling of general circulation model output: A comparison of methods. *Water Resources Research* 34:2995-3008.

Statistical DownScaling Model (SDSM)

Description	SDSM is a user-friendly software package designed to implement statistical downscaling methods to produce high-resolution monthly climate information from coarse-resolution climate model (GCM) simulations. The software also uses weather generator methods to produce multiple realizations (ensembles) of synthetic daily weather sequences.
Appropriate Use	SDSM can be used whenever impact assessments require small-scale climate scenarios, provided quality observational data and daily GCM outputs for large-scale climate variables are available.
Scope	All locations.
Key Output	Site-specific daily scenarios for maximum and minimum temperatures, precipitation, humidity. SDSM also produces a range of statistical parameters such as variances, frequencies of extremes, spell lengths.
Key Input	Quality observed daily data for both local-scale and large-scale climate variables to calibrate and validate the statistical model(s). Daily GCM outputs for large-scale variables for future climate to drive the model(s). The current version (4.2) contains observed data libraries for use in model calibration, and GCM data for making future projections.
Ease of Use	The user-friendly software is largely self explanatory. It comes with comprehensive instructions for use.
Training Required	Requires little training for those familiar with climate science but it requires expert knowledge and reiterated efforts to establish realistic and accurate statistical relationships.
Training Available	There are currently no plans for any training courses.
Computer Requirements	SDSM 4.2 has been tested on the following minimum specifications: PC Windows 98/NT/2000/XP (it may also work on Windows 95 but has not been tested on this OS); Memory - 5 MB RAM, 48 MB ROM; Processor - 133 MHz; Coding language - Visual Basic 6.0. Note: for older machines SDSM may work but may crash or take longer to perform certain analyses when large data sets are processed.
Documentation	Numerous publications in the scientific literature. User's manual at https://co-public.lboro.ac.uk/cocwd/SDSM/SDSMManual.pdf.
Applications	Widely applied in many regions and over a range of climate impact sectors. See References (below) for examples of applications.
Contacts for Framework, Documentation, Technical Assistance	New users can register and download the software package at https://co-public.lboro.ac.uk/cocwd/SDSM/.
Cost	SDSM is free.
References	Please see https://co-public.lboro.ac.uk/cocwd/SDSM/refs.html for a full list of SDSM references.

Dynamical Downscaling

Description	Downscaling is a method for obtaining high-resolution climate or climate change information from relatively coarse-resolution global climate models (GCMs). Typically, GCMs have a resolution of 150-300 km by 150-300 km. Many impacts models require information at scales of 50 km or less, so some method is needed to estimate the smaller-scale information. Dynamical downscaling uses a limited-area, high-resolution model (a regional climate model, or RCM) driven by boundary conditions from a GCM to derive smaller-scale information. RCMs generally have a domain area of 106 to 107 km^2 and a resolution of 20 to 60 km.
Appropriate Use	Dynamical downscaling can be used whenever impacts models require small-scale data.
Scope	All locations.
Key Output	Small-scale information on future climate or climate change.
Key Input	Typically six-hourly, gridpoint GCM data for future climate to drive the RCM.
Ease of Use	Requires considerable expertise in climate modeling — for specialists only.
Training Required	Considerable knowledge and experience required.
Training Available	No specific training courses available.
Computer Requirements	Same computer requirements as a GCM — i.e., high-level supercomputer or massive parallel computer.
Documentation	Numerous publications in the scientific literature.
Applications	Widely applied in many regions and over a range of climate impact sectors. For a specific example, see Hay and Clark (2003) in References below.
Contacts for Framework, Documentation, Technical Assistance	None.
Cost	High. Impractical except for academic or government institutions.
References	Ding, D.J. Griggs, M. Noguer, P.J. van der Linden, X. Dai, K. Maskell, and C.A. Johnson (eds.). Cambridge University Press, Cambridge, UK, pp. 583-638. Hay, L.E. and M.P. Clark. 2003. Use of statistically and dynamically downscaled atmospheric model output for hydrologic simulations in three mountainous basins in the western United States. *Journal of Hydrology* 282:56-75. Leung, L.R., L.O. Mearns, F. Giorgi, and R.L. Wilby. 2003. Workshop on regional climate research: Needs and opportunities. *Bull. Amer. Met. Soc.* 84:89-95. Giorgi, F., B. Hewitson, J. Christensen, M. Hulme, H. Von Storch, P. Whetton, R. Jones, L. Mearns, and C. Fu. 2001. Regional climate information — Evaluation and projections. In *Climate Change 2001. The Scientific Basis, Contribution of Working Group I to the Third Assessment Report of the Intergovernmental Panel on Climate Change,* J.T. Houghton, Y.

MAGICC/SCENGEN

Description	MAGICC/SCENGEN is a user-friendly software package that takes emissions scenarios for greenhouse gases, reactive gases, and sulfur dioxide as input and gives global-mean temperature, sea level rise, and regional climate as output. MAGICC is a coupled gas-cycle/climate model. It has been used in all IPCC reports to produce projections of future global-mean temperature and sea level change, and the present version reproduces the results given in the IPCC Third Assessment Report (TAR). MAGICC can be used to extend results given in the IPCC TAR to other emissions scenarios. SCENGEN is a regionalization algorithm that uses a scaling method to produce climate and climate change information on a 5° latitude by 5° longitude grid. The regional results are based on results from 17 coupled atmosphere-ocean general circulation models (AOGCMs), which can be used individually or in any user-defined combination.
Appropriate Use	Can be used whenever future atmospheric composition, climate or sea level information is needed.
Scope	All locations.
Key Output	MAGICC gives projections of global-mean temperature and sea level change. SCENGEN gives the following regional outputs on a 5° latitude by 5° longitude grid: changes in or absolute values of temperature and precipitation, changes in or absolute values of temperature and precipitation variability, signal-to-noise ratios based on intermodel differences or temporal variability, and probabilities of temperature and precipitation change above a specified threshold. The software also quantifies uncertainties in these outputs.
Key Input	Emissions scenarios for all gases considered in the SRES (Special Report on Emissions Scenarios) scenarios: CO_2, CH_4, N_2O, CO, NOx, VOCs, SO_2, and the primary halocarbons considered by the Kyoto Protocol (including SF6). The user also has control over various climate model and gas-cycle model parameters.
Ease of Use	The user-friendly software is largely self explanatory. It comes with a user manual and a technical manual.
Training Required	Requires little training for those familiar with basic climate science.
Training Available	A training course for an earlier version was held in 2000, but there are currently no plans for future courses.
Computer Requirements	• Windows 95/98/NT/2000/XP • 64 MB RAM • 100 MB free disk space
Documentation	Numerous publications in the scientific literature.
Applications	Widely applied in many regions and over a range of climate impact sectors. See References below.
Contacts for Framework, Documentation, Technical Assistance	The primary developer, Tom Wigley, can be contacted at wigley@ucar.edu. See also: http://www.cru.uea.ac.uk/~mikeh/software.
Cost	MAGICC/SCENGEN is free.

MAGICC/SCENGEN (cont.)

References	Santer, B.D., T.M.L. Wigley, M.E. Schlesinger, and J.F.B. Mitchell. 1990. Developing Climate Scenarios from Equilibrium GCM Results. Max-Planck-Institut für Meteorologie Report No. 47, Hamburg, Germany. Wigley, T.M.L. and S.C.B. Raper. 1992. Implications for climate and sea level of revised IPCC emissions scenarios. *Nature* 357:293-300. Wigley, T.M.L. and S.C.B. Raper. 2001. Interpretation of high projections for global-mean warming. *Science* 293:451-454. Wigley, T.M.L. and S.C.B. Raper. 2002. Reasons for larger warming projections in the IPCC Third Assessment Report. *Journal of Climate* 15:2945-2952. Other information is given in the atmospheric chemistry, climate projections, and sea level chapters of the IPCC TAR Working Group 1 report, Houghton, J.T., Y. Ding, D.J. Griggs, M. Noguer, P.J. van der Linden, D. Xiaosu, and K. Maskell (eds.). 2001. *Climate Change 2001: The Scientific Basis*. Cambridge University Press, New York. Wigley,T.M.L., Raper,S.C.B., Hulme,M. and Smith,S. 2000. The MAGICC/SCENGEN Climate Scenario Generator: Version 2.4, Technical Manual, Climatic Research Unit, UEA, Norwich, UK, 48pp. Wigley, T.M.L. 1993. Balancing the carbon budget. Implications for projections of future carbon dioxide concentration changes. *Tellus* 45B:409-425. Raper, S.C.B., T.M.L. Wigley, and R.A. Warrick. 1996. Global sea level rise: past and future. In *Sea-Level Rise and Coastal Subsidence: Causes, Consequences and Strategies,* J. Milliman and B.U. Haq (eds.). Kluwer Academic Publishers, Dordrecht, The Netherlands, pp. 11-45.

Weather Generators

Description	Weather generators are not, strictly speaking, downscaling techniques, but are often used in conjunction with the techniques outlined in this section. A weather generator is a statistical model used to generate realistic daily sequences of weather variables — precipitation, maximum and minimum temperature, humidity, etc. Such data are often referred to as synthetic data. Usually precipitation sequences are generated first, and other data sequences are derived using statistical relationships between these data and precipitation, with different relationships used for wet and dry days. Precipitation is divided into an occurrence process (i.e., whether the day is wet or dry) modeled as a Markov chain, and an amount process (the amount of precipitation on a wet day) sampled randomly from an appropriate distribution, such as a Gamma distribution. By using different random seeds, a large number of sequences can be generated, all of which have the same statistical properties as the original data used to calibrate the statistical model — akin to realizations from a set of parallel universes. This is a crucial factor in assessing uncertainties associated with the chaotic nature of daily weather variability. The SDSM software has a weather generator component.
Appropriate Use	Weather generators are used whenever impacts models require small-scale data on a daily time scale, provided suitable observed data are available to derive the statistical relationships.
Scope	All locations.
Key Output	Station-level information on future precipitation, maximum and minimum temperatures, humidity, etc.
Key Input	Appropriate observed data to calibrate and validate the statistical model(s). GCM data for future climate to drive the model(s).
Ease of Use	There are a number of weather generator software packages requiring different levels of expertise for their use (see References below). The user-friendly software in SDSM's weather generator component is largely self explanatory and comes with comprehensive instructions for use.
Training Required	Requires little training for those familiar with basic climate science.
Training Available	There are currently no plans for future courses.
Computer Requirements	Personal computer. Specific requirements will depend on the selected weather generator.
Documentation	Numerous publications in the scientific literature. The earliest papers date from the 1960s.
Applications	Widely applied in many regions and over a range of climate impact sectors. See References below.
Contacts for Framework, Documentation, Technical Assistance	New users of SDSM can register at http://www.sdsm.org.uk/.
Cost	Depends on the weather generator. SDSM, for example, is free.

Weather Generators (cont.)

References	Nicks, A.D., L.J. Lane, and G.A. Gander. 1985. Weather generator. In *USDA-Water Erosion Prediction Project: Hillslope Profile and Watershed Model Documentation*, D.C. Flanagan and M.A. Nearing (eds.). USDA-ARS National Soil Erosion Research Lab. Report No. 10, West Lafayette, IN. Richardson, C.W. 1981. Stochastic Simulation of daily precipitation, temperature and solar radiation. *Water Resources Research* 17:182-190. Wilby, R.L., Hay, L.E. and G.H. Leavesley. 1999. A comparison of downscaled and raw GCM output: implications for climate change scenarios in the San Juan river basin, Colorado. *Journal of Hydrology* 225:67-91. Wilks, D.S. and R.L. Wilby. 1999. The weather generation game: A review of stochastic weather models. *Progress in Physical Geography* 23:329-357. (See also SDSM.)

COSMIC2 (COuntry Specific Model for Intertemporal Climate Vers. 2)

Description	The COSMIC2 model provides climate-change impact modellers and policy analysts a flexible system that can produce a full range of dynamic country-specific climate-change scenarios. The need for this type of modeling capability was discussed at the IPCC Asia-Pacific Workshop on Integrated Assessment Models held in Tokyo in 1997. That Workshop aimed at improving communication between experts in a variety of disciplines and policy analysts/policy makers. One goal was to expand the use of integrated-assessment modelling for addressing the potential impacts of climate change in a way that better reflected the experiences of researchers from developing countries. These researchers (and others at universities around the world) may not have access to state-of-the-art transient general circulation model (GCM) simulations. The expense of running these supercomputer models limits their availability and ease of use. The COSMIC2 model helps remove this limitation. COSMIC2 can provide easy access to credible climate-change scenarios that are consistent with the state-of-the-art, fully coupled, transient ocean-atmosphere GCM simulations.
Appropriate Use	Can be used for estimating country level climate change. The climate change scenarios can be used in impact, vulnerability, and adaptation assessments.
Scope	Provides country level (158 countries) climate change and sea level rise estimates from 2000 up to 2200 for 28 emission scenarios. These include the initial IPCC stabilization scenarios, SRES, and post-SRES CO2 stabilization scenarios.
Key Output.	Monthly mean temperature and precipitation along with annual global mean temperature change, sea level rise, and equivalent CO2 concentration.
Key Input	The user chooses one of 14 GCM's, the country, one of 28 emission scenarios and various climate model parameters (climate sensitivity, sulphate scenario, and sulphate forcing) along with the terminal year.
Ease of Use	The installation and use assume average competence with personal computers. There is a built-in help facility.
Training Required	Requires some familiarity with climate change literature. IPCC publications would provide all necessary background information.
Training Available	Training courses for an earlier version (COSMIC) were held in various countries under the US Department of Energy Country Studies Program. There are currently no plans for additional courses.
Computer Requirements	Personal computer with Windows XP/2000/9X operating system.
Documentation	Numerous publications in the scientific literature.
Applications	COSMIC is in use by 130 research groups in 50 countries.
Contacts for Framework, Documentation, Technical Assistance	COSMIC2 was developed by: Michael E. Schlesinger, Department of Atmospheric Sciences, University of Illinois at Urbana-Champaign; e-mail: schlesin@atmos.uiuc.edu. Larry J. Williams, Global Climate Change Research, Electric Power Research Institute; e-mail: ljwillia@epri.com.
Cost	The software is free. Send request to Larry J. Williams (ljwillia@epri.com)

COSMIC2 (COuntry Specific Model for Intertemporal Climate Vers. 2) (cont.)

References	Schlesinger, M.E. and S. Malyshev, 'Changes in near-surface temperatures and sea level for the Post-SRES CO2-stabiliztion scenarios', *Integrated assessment*, 2: 95-110. Schlesinger, M.E., S. Malyshev, E.V. Rozanov, F. Yang, N.G. Andronova, B. de Vries, A. Grübler, K. Jiang, T. Masui, T. Morita, J. Penner, W. Pepper, A. Sankovski and Y. Zhang, '2000: Geographical distributions of temperature change for scenarios of greenhouse gas and sulfur dioxide emissions.', *Tech. Forecast. Soc. Change*, 65, 167-193. Williams, Larry J., Shaw, Daigee, Mendelsohn, Robert: 1998,'Evaluating GCM Output with Impact Models', *Climatic Change*, 39: 111-133. Yohe, Gary and Schlesinger, Michael E.: 1998,'Sea-Level Change: The Expected Economic Cost of Protection or Abandonment in the United States', *Climatic Change*, 38: 337-472.

PRECIS (Providing REgional Climates for Impacts Studies)

Description	PRECIS is essentially a regional climate modeling system. It is based on the third generation of the Hadley Centre's regional climate model (HadRM3), together with user-friendly data processing and a visualization interface. Its flexible design allows for applications in any region of the world. Like any other regional climate model, PRECIS is driven by boundary conditions simulated by general circulation models (GCMs). To facilitate the application, boundary conditions simulated by the Hadley Centre GCM experiments forced by four SRES marker scenarios are supplied with the software.
Appropriate Use	PRECIS can be used to generate finer-resolution, physically consistent regional climate projections when GCM outputs are not sufficient to provide regional details as required by V&A assessment.
Scope	Any region in the world (with a minimum area of 5,000km by 5,000 km) given that sufficient observed data are available to validate model outputs.
Key Output	(Typically) hourly climate variables at approximately 50 km horizontal resolution.
Key Input	Modeling domain, details of the driving GCM experiment, length of integration, specification of output files.
Ease of Use	Requires considerable expertise in climate modeling.
Training Required	Considerable knowledge and experience required.
Training Available	Attendance at training workshops (funded from a variety of UK Government sources over the years) are a pre-condition of provision of PRECIS. To date workshops have been held in South Africa, Cuba, Bhutan, Brazil, India, Turkey, Argentina, Ghana, and five in the United Kingdom. Hadley Centre staff are subsequently available (via email etc.) for consultation. Further workshops are planned..
Computer Requirements	A PC running the Linux operating system is required. It should have a minimum specification of a 1GHz processor, 500 Mb of memory, 60 Gb of disk space, and a tape drive to allow offline storage. A PC with a 1.4 GHz Athlon processor takes approximately 4~6 months to carry out a 30-year simulation.
Documentation	Information on PRECIS is available at http://precis.metoffice.com/ and covers aspects such as availability, support and requirements.
Applications	The model has been provided for use in several regions, including south Asia, central America, southern Africa and China. PRECIS modelling underlies sectoral impacts modelling work within Defra-funded research projects in India and China.
Contacts for Framework, Documentation, Technical Assistance	The Regional Modelling Group at the Hadley Centre, Met Office, Hadley Centre, FitzRoy Road, Exeter, Devon, EX1 3PB, United Kingdom, Tel: +441344.854938; Fax: +44.1344.854898; e-mail: précis@metoffice.com.

PRECIS (Providing REgional Climates for Impacts Studies)

Cost	The PRECIS DVD will be supplied to institutions free of charge (subject to the terms of the PRECIS license agreement) by the Hadley Centre only in conjunction with a PRECIS workshop . In keeping with the objectives behind the development of PRECIS, priority will be given to training users in developing countries, providing funding can be found to deliver the courses. The software, together with a suite of supporting materials and boundary condition data, are provided free of charge to developing countries and countries with economy in transition. Users from institutions in developed countries will be assessed a charge of 5000 Euros plus 17.5% VAT. This charge contributes to the costs of development and providing training.
References	Please see http://precis.metoffice.com/other_links.html for links to projects, reports and publications.

3.1.3 Socioeconomic scenarios

Developing Socioeconomic Scenarios: For Use in Vulnerability and Adaptation Assessments

Description	This UNDP manual provides approaches to developing scenarios of the future, both without climate change and with climate change and adaptation. The first part of the guidance is consistent with the IPCC's *Special Report on Emissions Scenarios*: development of qualitative "storylines" of the future and selection of proxy values to represent important elements of socioeconomic conditions, all supplemented by research and quantitative data, as appropriate. The second part of the guidance demonstrates an approach to sectoral scenarios by using quantitative indicators to calculate food security. Moreover, the guidance recommends a stakeholder involvement process.
Appropriate Use	The guidance can be used in analyses of vulnerability and adaptation to climate change at local, sectoral, regional, and national scales. Thus, the scenarios can contribute to developing countries' National Communications, National Adaptation Programmes of Action (NAPAs), and grant proposals to, e.g., the Global Environment Facility (GEF).
Scope	Local, sectoral, regional, and national.
Key Output	A qualitative or qualitative and quantitative description of the social and economic characteristics of a sector or geographical location as they exist currently and may evolve in the future. The descriptions are focused on key variables, called proxy values, which summarize or otherwise simplify relevant information.
Key Input	Qualitative and/or quantitative information on the sector or region of interest.
Ease of Use	Depends on complexity of data gathering and analytic techniques chosen — from rigorous stakeholder input and other qualitative methods to complex, model-based techniques.
Training Required	No training required, unless unfamiliar models are chosen for use.
Training Available	No formal training currently offered.
Computer Requirements	None, unless project teams choose computer-based methods.
Documentation	Developing Socioeconomic Scenarios: For Use in Vulnerability and Adaptation Assessments. May 2001. Available at http://ncsp.undp.org/report_detail.cfm?Projectid=151.
Applications	Has been piloted in several countries; will be used in conjunction with the UNDP's Adaptation Policy Framework to develop adaptation strategies, policies, and measures (see APF summary table in Chapter 2).
Contacts for Framework, Documentation, Technical Assistance	Bo Lim, Chief Technical Advisor, National Communications Support Programme, UNDP-GEF, Room 1607, 304 East 45th St, NY, NY 10017, USA; Tel: 1.212.906.5730; Fax: 1.212.906.6568; e-mail: bo.lim@undp.org.
Cost	No cost.
References	See Documentation above and APF summary table in Chapter 2 (http://ncsp.undp.org/report_detail.cfm?Projectid=151).

Adoption of Existing Socioeconomic Scenarios

Description	The UNEP Handbook describes an approach to developing sectoral assessments of impacts and adaptation. In general, analysts are encouraged to use existing scenarios of both socioeconomic conditions and climate change, to integrate them, and to develop adaptation strategies. The definition of socioeconomic includes demographic and economic data, technology, legislation, culture, decision-making processes – “everything that shapes a society.” Table 2.1 in the handbook lists relevant variables for each of the sectors covered (water resources, coastal zones, agriculture, human health, energy, forestry, livestock and grasslands, wildlife and biodiversity, and fisheries). Sources for data-based scenarios are given, and using multiple scenarios is recommended. Specific guidance is sparse.
Appropriate Use	The Handbook can be used for analyses of sectoral impacts and adaptation to climate change.
Scope	Local, sectoral, regional, and national. However, sources for existing socioeconomic scenarios are global and regional only, except for the World Bank, which includes countries.
Key Output	Scenarios that are either “borrowed” from the literature or “inspired” by historical trends and geographical analogues.
Key Input	Qualitative and/or quantitative information on the sector of interest.
Ease of Use	Relatively easy, especially if literature sources are used instead of primary data gathering and scenario development.
Training Required	No training required.
Training Available	No formal training currently offered.
Computer Requirements	None, although data may be downloaded from sources such as the World Bank and manipulated by spreadsheet or other computer-based programs.
Documentation	Feenstra, J.F., I. Burton, J.B. Smith, and R.S.J. Tol (eds.). 1998. *Handbook on Methods for Climate Change Impact Assessment and Adaptation Strategies*. Version 2.0. Available at http://www.falw.vu.nl/images_upload/151E6515-C473-459C-85C59441A0F3FB49.pdf
Applications	The first phase of the Netherlands Climate Change Study Assistance Programme (NCCSAP) lists 17 countries where socioeconomic scenarios are being or will be developed. The projects' synopses explicitly mention development of climate scenarios and socioeconomic scenarios to be used in the impact and adaptation studies. Information is on http://www.ivm.falw.vu.nl/Research_projects/index.cfm/home_subsection.cfm/subsectionid/CBFAAE8F-05BA-4EA0-A7C17193212663D0. The book 'Climate Change in Developing Countries' mentioned on this site may be of interest as well.
Contacts for Framework, Documentation, Technical Assistance	Dr. Michiel van Drunen, Institute for Environmental Studies, Vrije Universiteit, Amsterdam; e-mail: michiel.van.drunen@ivm.falw.vu.nl
Cost	No cost.
References	See Documentation above.

Qualitative and Quantitative Scenarios Emphasizing Stakeholder Input

Description	The second and third steps of the Adaptation Policy Framework (APF) (see Chapter 2 for a description of the entire framework), assessing current vulnerability and characterizing future climate risks, involve developing socioeconomic scenarios (called "conditions and prospects"). Technical Paper 6 is devoted to guidance on this topic. Users are advised to include indicators (qualitative or quantitative or a mix of both) in five categories: demography, economics, natural resource use, governance/policy, and culture. The baseline should include current adaptations to current climate. Users are then given guidance on constructing storylines of the future and exploring at least two significantly different but possible futures.
Appropriate Use	The guidance on socioeconomic scenarios is designed as part of a larger process of developing adaptation strategies, policies, and measures. Other analyses that interact with socioeconomic scenarios are climate risks and vulnerability analyses. Crosscutting guidance is given on involving stakeholders and increasing adaptive capacity.
Scope	Local, sectoral, regional, and national. The APF will be most useful at the local and sectoral levels.
Key Output	Scenarios that include demographic, economic, governance/policy, and cultural indicators and data.
Key Input	Qualitative and/or quantitative information from various sources, including expert and stakeholder input.
Ease of Use	The whole APF process requires a substantial commitment of time and resources; the scenario portion can be developed using existing data and stakeholder input or more sophisticated methods such as tailored computer-based models.
Training Required	No training required.
Training Available	Formal training is being planned but is not currently offered.
Computer Requirements	None.
Documentation	See http://ncsp.undp.org/report_detail.cfm?Projectid=151 for the User's Guidebook and the Nine Technical Papers.
Applications	GEF projects in Latin America are being designed using the APF, but it has not yet been employed in the projects.
Contacts for Framework, Documentation, Technical Assistance	Bo Lim, Chief Technical Advisor, National Communications Support Programme, UNDP-GEF, Room 1607, 304 East 45th St, NY, NY 10017, USA; Tel: 1.212.906.5730; Fax: 1.212.906.6568; e-mail: bo.lim@undp.org.
Cost	No cost.
References	See Documentation above.

UKCIP Socio-Economic Scenarios

Description	The UKCIP socio-economic scenarios (SES) describe how society may change in the future in accordance with policy decisions made in the future. The SES should be used together with climate change emission scenarios to produce an integrated assessment of potential impacts under climate change.
Appropriate Use	The SES can be used in climate change impacts and vulnerability and assessments, and to consider the capacity different types of future worlds will have to cope with climate change.
Scope	They should be used for UK-based studies only.
Key Output	A description of future worlds in which climate changes might occur.
Key Input	Various social and economic indices.
Ease of Use	Users generally find these difficult to apply as they are not quantitative, and those used to assessing physical climate impacts may not feel comfortable dealing with socio-economic issues. Where the SES have been used, they have been found to have a major impact on study findings.
Training Required	Understanding of SES and their application is helpful.
Training Available	No formal training supplied, but UKCIP can advise on application.
Computer Requirements	None.
Documentation	Technical report on SES. Reference below.
Applications	The SES have been used in a number of UKCIP scoping studies. Some of them are included in the report (reference below). Also see the UKCIP website (www.ukicp.org.uk) for further information on applications.
Contacts for Tools, Documentation, Technical Assistance	Megan Gawith, Scientific Officer, UKCIP; e-mail: megan.gawith@ukcip.org.uk.
Cost	None.
References	UK Climate Impacts Programme. 2001. Socio-economic scenarios for climate change impact assessment: a guide to their use in the UK Climate Impacts Programme. UKCIP, Oxford.

3.2 Decision Tools

The tools described in this section assist analysts in making choices between adaptation options (Table 3.2). Some of these tools rely on a single monetary metric and focus on a single decision criterion (e.g., benefit-cost analysis, cost-effectiveness). Others enable the user to define and incorporate more than one such decision criterion (e.g., MCA and the three examples of which, TEAM, Adaptation Decision Matrix, and screening of adaptation options, are included in this section). Other tools are more generally aimed at supporting decision and policy makers who are faced with identifying and appraising the selection and implementation of adaptation measures, taking into account the institutions involved and affected when pursuing given adaptation options.

Table 3.2. Decision tools
Policy Exercise
Benefit-Cost Analysis
Cost-Effectiveness
Multicriteria Analysis (MCA)
Tool for Environmental Assessment and Management (TEAM)
Adaptation Decision Matrix (ADM)
Screening of Adaptation Options
Climate-Related Risks Estimate as Indicators of Necessity for Adaptation Responses
Costing the Impacts of Climate Change in the UK
Identifying Adaptation Options
UKCIP Adaptation Wizard
Adaptation Actions
Business Area Climate Impacts Assessment Tool (BACLIAT)
Nottingham Declaration Action Pack (NDAP)
Community-based Risk Screening Tool – Adaptation & Livelihoods (CRiSTAL)

Policy Exercise

Description	A flexible structured method designed to synthesize and assess knowledge from several relevant fields of science for policy purposes directed toward complex, practical management problems. Policy exercise techniques provide an interface between scientists, academics, and policy makers. At the heart of the process are scenario writing ("future histories," emphasizing nonconventional, surprise rich, but still plausible futures) and scenario analyses via the interactive formulation and testing of alternative policies that respond to challenges in the scenario. These scenario based activities typically take place in an organizational setting reflecting the institutional feature of the issues that are addressed.
Appropriate Use	Policy exercise can be used to generate adaptation options or evaluate already identified adaptation options, especially in the early phases of regional adaptation studies when there is a strong need to structure the problem or in later phases to determine if sectoral policy responses might support or undermine each other.
Scope	All regions, all sectors.
Key Output	Scenarios that inform the adaptation decision process and increase understanding of the organizational and institutional setting in which the process is carried out.
Key Input	Views and ideas of representatives from key institutions.
Ease of Use	Depends on participation of experienced facilitators.
Training Required	Little or no training would be required for participants. Facilitators and support staff require specialized training.
Training Available	No formal training offered. Sources of assistance in organizing a policy exercise can be obtained from contact listed below.
Computer Requirements	Use of personal computers may be necessary to support the variety of models that the exercise might employ.
Documentation	Toth, F.L. 1998. Policy exercises: Objectives and design elements. *Simulation and Games* 19:235-255. Toth, F.L. 1998. Policy exercises: Procedures and implementation. *Simulation and Games* 19:256-276.
Applications	Southeast Asia (see References below). The exercises involved senior national-level policy makers and senior analysts exploring policy responses under different climate change and impact scenarios.
Contacts for Framework, Documentation, Technical Assistance	Ferenc Toth, International Atomic Energy Agency, Wagramer Str. 5 P.O. Box 100, A-1400, Vienna, Austria; Tel: +43.1.2600.22787; e-mail: F.L.Toth@iaea.org.
Cost	No cost to obtain documentation and supplementary information. Cost of implementing will depend upon the scope of inquiry.

Policy Exercise (cont.)

References	Brewer, G.D. and M. Shubik. 1979. *The War of Game: A Critique of Military Problem Solving*. Harvard University Press, Cambridge, MA. Toth, F.L. and E. Hizsnyik. 2005. Managing the inconceivable: participatory assessments of impacts and responses to extreme climate change. International Institute for Applied Systems Analysis. Working Paper FNU74. Toth, F.L. 1992a. Global change and the cross-cultural transfer of policy games. In *Global Interdependence*. D. Crookall and K. Arai (eds.). Springer, Tokyo, pp. 208-215. Toth, F.L. 1992b. Policy implications. In *The* Potential Socioeconomic Effects of Climate Change in South-East Asia, M.L. Parr, M. Blantran de Rozari, A.L. Chong, and S. Panich (eds.). United Nations Environment Programme, Nairobi, Kenya, pp. 109-121. Toth, F.L. 1992c. Policy responses to climate change in Southeast Asia. In *The Regions and Global Warming: Impacts and Response Strategies,* J. Schmandt and J. Clarkson (eds.) Oxford University Press, New York, pp. 304-322. Toth, F.L. 2003. State of the art and future challenges for integrated environmental assessment. *Integrated Assessment* 4(4):250-264.

Benefit-Cost Analysis

Description	This approach uses a conceptual framework for analyzing an adaptation measure by identifying, quantifying, and monetizing the costs and benefits associated with the measure. Spreadsheet software is often used to facilitate analysis; however, the specific approaches used are highly dependent on the measure under consideration. This tool can be used to determine whether the benefits of the adaptation measure outweigh the costs, whether net benefits are maximized, and how the measure compares to other options.
Appropriate Use	A benefit-cost analysis is useful when the adaptation being considered is likely to involve significant expenditures of capital and labor. Benefit-cost analyses of adaptation responses often involve a high degree of uncertainty when quantifying nonmarket goods and services as well as when anticipating the direction and magnitude of climate change.
Scope	All locations; all sectors; national or site-specific.
Key Output	A monetary comparison of the costs and benefits of a proposed adaptation measure.
Key Input	Quantitative values for all significant costs and benefits associated with the proposed response.
Ease of Use	A major undertaking, involving extensive research and economic analysis.
Training Required	Knowledge in economics as well as training in estimating the monetary values of costs and benefits. Knowledge of physical sciences related to benefits.
Training Available	Contact Stratus Consulting for more information (see Contacts below).
Computer Requirements	Lotus 1-2-3 or Excel spreadsheet software helpful.
Documentation	The World Bank. Environmental Assessment Sourcebook: Vol. 1. Policies, Procedures, and Cross-Sectoral Issues. Published October 1996 by World Bank ISBN: 0-8213-1843-8 SKU: 11843 Vol. 2. Sectoral Guidelines. Published September 1995 by World Bank ISBN: 0-8213-1844-6 SKU: 11844 Vol. 3. Guidelines for Environmental Assessment of Energy and Industry Projects. Published December 1994 by World Bank ISBN: 0-8213-1845-4 SKU: 11845 Available at http://publications.worldbank.org/ecommerce/catalog/product-detail?product_id=194213&
Applications	Used to evaluate sea level rise adaptation options in Maine, USA.
Contacts for Tools, Documentation, Technical Assistance	Bob Raucher, Stratus Consulting, P.O. Box 4059, Boulder, CO 80306 USA; Tel: +1.303.381.8000; Fax: +1.303.381.8200; e-mail: braucher@stratusconsulting.com; website: http://www.stratusconsulting.com/.
Cost	Price of Vol. 1: $ 22.00. Price of Vol. 2: $ 30.00. Price of Vol. 3: $ 22.00. Analysis entails a high cost in terms of time for an economic analyst. Method can be modified if financial constraints prohibit a full-scale analysis.
References	Smith, J.B., S.E. Ragland, R.S. Raucher, and I. Burton. 1997. Assessing Adaptation to Climate Change: Benefit-Cost Analysis. Report to the Global Environment Facility, prepared by Hagler Bailly Services, Inc., Boulder, CO, USA. Tol, R.J.S. 2000. Equitable Cost-Benefit Analysis of Climate Change. In *Efficiency and Equity of Climate Change Policy,* Carlo Carraro (ed.). Dordrecht, The Netherlands: Kluwer Academic Publishers. 368pp.

Cost-Effectiveness

Description	Cost-effectiveness analysis takes a predetermined objective and seeks ways to accomplish it as inexpensively as possible. Unlike cost-benefit analysis, the level of the benefit is treated as an external given, and the objective of the analysis is to minimize the costs associated with the achievement of this specified objective.
Appropriate Use	Cost-effectiveness on the adaptation side might be used when, under different climate change scenarios, a required minimum level of a public good or service (e.g., flood protection) is specified and the option to deliver this good at the lowest cost is sought. Also particularly applicable to those cases where the analyst may be unwilling or unable to monetize the most important policy impact. Cost-effectiveness is generally more applicable for individual project decisions that are applying decision rules or procedures which have already been determined in policy, strategic, or program decisions.
Scope	All regions. Can be difficult to apply to those sectors where the market does not apply a satisfactory measure of value for costs.
Key Output	Ranking of alternatives relative according to cost-effectiveness.
Key Input	Cost data for a specified level of policy outcome.
Ease of Use	Can be a significant undertaking. Valuing nonmarket goods can require knowledge of specialized techniques.
Training Required	Knowledge of economics as well as training in estimating the monetary values of costs, especially nonmarket values.
Training Available	Contact Stratus Consulting for more information (see Contacts below).
Computer Requirements	Personal computer.
Documentation	Boardman, A.E., D.H. Greenberg, A.R. Vining and D.L. Weimer. 1996. *Cost-Benefit Analysis: Concepts and Practice.* Prentice Hall, Upper Saddle River, NJ, USA.
Applications	Analysis of pathways to stabilization. See also UKCIP and APF frameworks in Chapter 2.
Contacts for Framework, Documentation, Technical Assistance	Bob Raucher, Stratus Consulting, P.O. Box 4059, Boulder CO 80306; Tel: +1.303.381.8000; e-mail: braucher@stratusconsulting.com; website: http://www.stratusconsulting.com/
Cost	Method can entail a high cost in terms of time for an economic analyst.
References	Goulder, L.H. and S.H. Schneider. 1999. Induced technological change and the attractiveness of CO_2 emissions abatement policies. *Resource and Energy Economics* 21:211-253. Ha-Duong, M., M. Grubb, and J.C. Hourcade. 1997. Influence of socioeconomic inertia and uncertainty on optimal CO_2 emission abatement. *Nature* 390:270-273. Wigley, T.M.L., J. Edmonds, and R. Richels. 1996. Economic and environmental choices in the stabilization of atmospheric CO_2 concentrations. *Nature* 379(6582):240-243.

Multicriteria Analysis (MCA)

Description	MCA describes any structured approach used to determine overall preferences among alternative options, where the options accomplish several objectives. In MCA, desirable objectives are specified and corresponding attributes or indicators are identified. The actual measurement of indicators need not be in monetary terms, but are often based on the quantitative analysis (through scoring, ranking and weighting) of a wide range of qualitative impact categories and criteria. Different environmental and social indicators may be developed side by side with economic costs and benefits. Explicit recognition is given to the fact that a variety of both monetary and nonmonetary objectives may influence policy decisions. MCA provides techniques for comparing and ranking different outcomes, even though a variety of indictors are used. MCA includes a range of related techniques, some of which follow this entry.
Appropriate Use	Multicriteria analysis or multiobjective decision making is a type of decision analysis tool that is particularly applicable to cases where a single-criterion approach (such as cost-benefit analysis) falls short, especially where significant environmental and social impacts cannot be assigned monetary values. MCA allows decision makers to include a full range of social, environmental, technical, economic, and financial criteria.
Scope	All regions, all sectors.
Key Output	A single most preferred option, ranked options, short list of options for further appraisal, or characterization of acceptable or unacceptable possibilities.
Key Input	Criteria of evaluation as well as relevant metrics for those criteria.
Ease of Use	Depends on the particular MCA tool employed. All rely on the exercise of some expert judgment.
Training Required	Choice and application of appropriate MCA technique require some expertise, but can be acquired fairly easily.
Training Available	The United Kingdom Department for Transport Local Government and the Regions (see Documentation) provides nontechnical descriptions of MCA techniques, potential areas of application, and criteria for choosing between different techniques, and sets out the stages involved in carrying out MCA.
Computer Requirements	Personal computer.
Documentation	DEFRA. 2003. Use of multi-criteria analysis in air quality policy: A Report. DTLR. 2001. Multi Criteria Analysis: A Manual. ETR. 1999. Review of Technical Guidance on Environmental Appraisal: A Report by Economics for the Environment Consultancy (http://www.defra.gov.uk/environment/economics/rtgea/8.htm).
Applications	World Commission on Dams. Integrated Decision Making Framework. (http://www.dams.org/report/contents.htm). World Conservation Union Office for West Africa. Sustainable Development Planning Process (http://www.iucn.org/themes/wetlands/). Tyndall Center for Climate Change Research. Framework for Carbon Mitigation Projects (http://www.tyndall.ac.uk/publications/working_papers/wp29.pdf).

Multicriteria Analysis (MCA) (cont.)

Contacts for Framework, Documentation, Technical Assistance	For general information and contact information for sources of assistance for particular tools: Stratus Consulting, P.O. Box 4059, Boulder CO 80306; Tel: +1.303.381.8000; Fax: 303.381.8200; e-mail: jsmith@stratusconsulting.com.
Cost	Depends on particular MCA tool applied, but in general is inexpensive.
References	Bell, M.L., B.F. Hobbs and H. Ellis. 2003. The use of multi-criteria decision-making methods in the integrated assessment of climate change: implications for IA practitioners. Socio-Economic Planning Sciences 37(4):289-316. Hamalainen, R.P. and R. Karjalainen. 1992. Decision support for risk analysis in energy policy. *European Journal of Operational Research* 56:172-183. Jones, M., C. Hope, and R. Hughes. 1990. A multi-attribute value model for the study of UK energy policy. *Journal of the Operational Research Society* 41:919-929 Pearman, A.D., P.J. Mackie, A.D. May, and D. Simon. 1989. The use of multi-criteria techniques to rank highway investment proposals. In *Improving Decision Making in Organisations,* A.G. Lockett and G. Islei (eds.). Springer Verlag, Berlin, pp. 158-165.

Tool for Environmental Assessment and Management (TEAM)

Description	This software package creates graphs and tables that allow experts to compare the relative strengths of adaptation strategies using both quantitative and qualitative criteria. TEAM assists the user in evaluating issues such as equity, flexibility, and policy coordination. The user lists the strategies across the top of the table and the evaluation criteria down the side, and then enters a score indicating the relative performance of each strategy under the various criteria. This table can then be used to construct a variety of graphs of the data. It will not necessarily identify the optimal strategy (unless one strategy outperforms all others in all criteria), but is instead designed to allow the user to more clearly see the strategies' relative strengths and weaknesses.
Appropriate Use	TEAM is useful when it is important to consider a wide range of criteria and to explicitly identify unquantifiable and uncertain aspects associated with potential adaptations. It should be used in conjunction with other decision-making tools (e.g., cost-benefit analysis, discussion and workshops with key decision-makers).
Scope	All locations; covers coastal zones, water resources, agriculture, as well as a general assessment component; national or site-specific.
Key Output	Relative effectiveness of alternative adaptation measures across a range of criteria.
Key Input	A ranking of how well policy objectives are met using alternative strategies.
Ease of Use	Relatively easy to apply; more rigorous results require more analysis; only basic computer skills are needed.
Training Required	A user with an understanding of key policy objectives could achieve proficiency in 1 to 2 days.
Training Available	Contact Susan Herrod-Julius for more information (see Contacts below).
Computer Requirements	IBM-compatible 386 with a 3.5" drive and a mouse; Microsoft Windows 3.1 and Excel 5.0c spreadsheet software.
Documentation	The user's manual can be obtained from Ms Susan Herrod Julius (see the email given below). See also the web site http://www.epa.gov/eims/global/team1.pdf.
Applications	Used in China, Costa Rica, Venezuela, Trinidad, Italy, Egypt, and Malawi.
Contacts for Tools, Documentation, Technical Assistance	Susan Herrod-Julius, 8601D, U.S. EPA Headquarters. Ariel Rios Building, 1200 Pennsylvania Avenue, N.W., Washington, DC 20460; Tel: 202.564.3394; e-mail: herrod-julius.susan@epa.gov.
Cost	Free to obtain documentation.
References	Smith, A., H. Chu, and C. Helman. 1996. Tool for Environmental Assessment and Management: Quick Reference Pamphlet. Decision Focus Incorporated, Washington, DC. Smith, A., H. Chu, and C. Helman. 1996. Documentation of Tool for Environmental Assessment and Management. Decision Focus Incorporated, Washington, DC. Burton, I., J. Smith, and S. Lenhart. 1998. Adaptation to climate change: Theory and assessment. In *Handbook on Methods for Climate Change Impact Assessment and Adaptation Strategies,* J. Feenstra, I. Burton, J. Smith, and R. Tol (eds.). UNEP and Vrije Universiteit Amsterdam, Amsterdam, The Netherlands. Herrod Julius, S. and Scheraga, J.D. The TEAM Model for Evaluating Alternative Adaptation Strategies.

Adaptation Decision Matrix (ADM)

Description	The ADM uses multicriteria assessment techniques to evaluate the relative effectiveness and costs of adaptation options. Users are asked to specify criteria that will be used to evaluate options and weight the criteria. Scenarios of current climate and climate change can also be used. Users are asked to give a score (e.g., 0 to 5) on how well each criterion is met under a particular scenario for each option. The scoring can be based on detailed analysis or expert judgment. Scores can be multiplied by weights and summed up to estimate which options best meet the criteria. The scores can be compared to relative costs to assess cost-effectiveness.
Appropriate Use	This approach is useful when many important benefits of meeting policy objectives cannot be easily monetized or expressed in a common metric. However, detailed research and analysis are needed to provide a basis for the evaluation; otherwise the scoring may be mainly subjective.
Scope	All locations; all sectors; national or site-specific.
Key Output	Relative cost-effectiveness of alternative adaptation measures.
Key Input	A ranking of how well policy objectives are met using alternative strategies; estimated costs of adaptation measures.
Ease of Use	Relatively easy to apply; more rigorous results require more analysis; only basic computer skills are needed.
Training Required	A user with an understanding of key policy objectives could achieve proficiency in 1 to 2 days; however, additional training may be required to develop skill in estimating costs of adaptation measures.
Training Available	Contact Stratus Consulting for more information (see Contacts below).
Computer Requirements	IBM-compatible 286; Lotus 1-2-3 or Excel spreadsheet software helpful.
Documentation	Benioff, R. and J. Warren (eds.). 1996. *Steps in Preparing Climate Change Action Plans: A Handbook.* Washington, DC: U.S. Country Studies Program. USCSP. 1999. *Climate Change: Mitigation, Vulnerability, and Adaptation in Developing Countries*, U.S. Country Studies Program, Washington, DC
Applications	Used by participants in the U.S. Country Studies and UNEP assistance programs (e.g., Kazakhstan, Cameroon, Uruguay, Bolivia, Antigua, Estonia, Pakistan and Barbuda).
Contacts for Tools, Documentation, Technical Assistance	Joel Smith, Stratus Consulting, P.O. Box 4059, Boulder, CO 80306 USA; Tel: +1.303.381.8000; Fax: +1.303.381.8200; e-mail: jsmith@stratusconsulting.com; website: http://www.stratusconsulting.com/.
Cost	No cost for documentation or diskette with template of the decision matrix.
References	Mizina, S.V., J.B. Smith, E. Gossen, K.F. Spiecker, and S.L. Witkowski. 1999. An evaluation of adaptation options for climate change impacts on agriculture in Kazakhstan. *Mitigation and Adaptation Strategies for Global Climate Change* 4:25-41.

Screening of Adaptation Options

Description	This matrix-based decision-making tool sets up a series of criteria that allow the user to narrow the list of appropriate adaptation measures. The user sets up a table with evaluation criteria across the top: Will the measure target a high-priority area? Will it address targets of opportunity? Is it likely to be effective? Will it generate other benefits (e.g., economic, environmental)? Is it inexpensive? Is it feasible? The user can insert or substitute other criteria if they are more appropriate. The user then evaluates each measure against these criteria, entering a simple "yes" or "no" in the cells. This tool is frequently combined with expert judgment.
Appropriate Use	This is a useful tool at the beginning of the decision-making process, allowing the user to create a manageable although possibly subjective list of options, which can then be analyzed more rigorously.
Scope	All locations; all sectors; national or site-specific.
Key Output	A simple matrix, clearly showing the strengths and weaknesses of a wide range of options.
Key Input	Basic summary information about options under consideration.
Ease of Use	Depends on specific application.
Training Required	Requires background knowledge of both the options and the climate change issue being addressed.
Training Available	Contact Stratus Consulting for more information (see below).
Computer Requirements	IBM-compatible 286; Lotus 1-2-3 or Excel spreadsheet software helpful.
Documentation	Benioff, R. and J. Warren (eds.). 1996. Steps in Preparing Climate Change Action Plans: A Handbook. U.S. Country Studies Program, Washington, DC. USCSP. 1999. Climate Change: Mitigation, Vulnerability, and Adaptation in Developing Countries, U.S. Country Studies Program, Washington, DC
Applications	Used by several participants in the U.S. Country Studies and UNEP assistance programs (e.g., Kazakhstan, Cameroon, Uruguay, Bolivia, Antigua, Barbuda, Estonia, and Pakistan).
Contacts for Tools, Documentation, Technical Assistance	Joel Smith, Stratus Consulting, P.O. Box 4059, Boulder, CO 80306; Tel: +1.303.381.8000; Fax: +1.303.381.8200; e-mail: jsmith@stratusconsulting.com; website: http://www.stratusconsulting.com/.
Cost	No cost to obtain documentation or diskette with template of the decision matrix.
References	Mizina, S.V., J.B. Smith, E. Gossen, K.F. Spiecker, and S.L. Witkowski. 1999. An evaluation of adaptation options for climate change impacts on agriculture in Kazakhstan. *Mitigation and Adaptation Strategies for Global Climate Change* 4:25-41.

Climate-Related Risks Estimate as Indicators of Necessity for Adaptation Responses

Description	Adaptation measures could be taken when climate-related risks to economic objects, environment or people's lives arise. The methodology of climate risk assessment outlines a three step process: (1) to estimate probability of dangerous weather event or climate anomaly on the given territory; (2) to evaluate social damage as correlation between people's number in the endangered region and damage probability; "fuzzy set" method could be used for complex risk estimation; (3) to calculate damage expressed in relative or monetary units taking into account GDP.
Appropriate Use	This tool is useful when it is necessary to make decision about adaptation measures.
Scope	All regions and sectors.
Key Output	A quantitative estimate of climate-related risks for specific objects and processes in various economic and social spheres.
Key Input	Meteorological data about recurrence and intensity of the dangerous weather events and climate anomalies, cost data including GDP, population in the specific region.
Ease of Use	Depends on specific application.
Training Required	"Fuzzy set" method requires training in use of statistical software. Knowledge of economics and estimating the monetary values of costs and benefits is needed.
Training Available	No formal training currently offered. Sources of assistance / consulting can be obtained from contact listed below.
Computer Requirements	Personal computer.
Documentation	Numerous publications in the scientific literature.
Applications	Whirlwind probability assessment for the third power-generating unit of Leningrad nuclear power station.
Contacts for Tools, Documentation, Technical Assistance	Nina Kobysheva, Voejkov Main Geophysical Observatory, 194021 Karbyshev Str. 7, St. Petersburg, Russian Federation; Tel: +7.812.297.4390; Fax: +7.812.297.8661; e-mail: director@main.mgo.rssi.ru or kobyshnv@main.mgo.rssi.ru.
Cost	Depends on particular application.
References	Akentyeva, E.M. 2006. Climate-related risks for power generation, transportation and consumption in Russian Federation. In Proceedings - Living with Climate Variability and Change: Understanding the Uncertainties and Managing the Risks, Espoo, Finland. Kobysheva, N.V. and M. V. Klueva. 2000. Estimation of risk of forest fires. *Risk Excellence Notes* 2(6). Kobysheva, N.V. 2007. Adaptation measures in oil and gas industry. International Conference "Adaptation strategies in fuel – energy sector" Nignij Novgorod, Russian Federation. Kobysheva, N.V. 2007. The problems of weather and climate related safety and sustainable development in technical sphere. Fifth International Conference "Actual Problems of Industrial Safety: from Projecting to Insurance, St. Petersburg, Russian Federation.

Costing the Impacts of Climate Change in the UK

Description	This costing guidance describes a method for calculating the cost of climate impacts and explains how to compare these to the costs of adaptation measures.
Appropriate Use	The proposed method is flexible enough to be applied across a wide range of scales from broad aggregated impacts on a sub-national region to well-defined disaggregated impacts on a particular receptor. The guidance is provided through two reports (Overview Report and Implementation Report), a series of case studies and a web-based spreadsheet tool (limited in terms of sectors and impacts scope). The Overview Report, including a specific set of case studies, is designed to provide guidance to the non-economists who need to commission and interpret costing studies, whereas the more detailed Implementation Report is aimed at providing guidance for economists who need to undertake these studies.
Scope	The guidance has been specifically developed for use within the UK, but could be further developed to work elsewhere. This would necessitate the development of costing matrices for the direct and knock-on effects of the identified impacts. The web-based spreadsheet tool has also been specifically developed for use with in the UK. The principles and concepts of the methodology are transferable and can provide a framework for broader application. Sectors specifically supported through the provision of impact matrices include coastal zones, water resources, agriculture, and buildings and infrastructure. Impacts on non-market goods or services are difficult to value, and so the guidance includes individual guidance for valuing the impacts on habitat and biodiversity, human health, recreation and amenity, cultural objects, leisure and working time, and non-use benefits.
Key Output	Specifically identified physical impacts are converted into monetary values and then, after calculating the resource costs of adaptation options, information is available to support the weighing up of the costs and benefits of the adaptation options towards choosing the preferred option. This assessment of adaptation options is seen to take place within a risk assessment framework that accounts for the risks and uncertainty (e.g., UKCIP risk framework).
Key Input	Inputs include identifying and measuring (quantifying) climate impacts in physical units (e.g., through a climate impact assessment); impact valuations matrices that allow for the identification of costs/unit of direct impacts of climate change and knock-on (higher-order) effects. This includes both market price data that should be readily available. Also required are the values associated with impacts on non-market goods or services which result from conducting primary valuation studies. Also required are the costs of adaptation options such as those required to support a cost-benefit analysis.
Ease of Use	The guidance, including the web-based spreadsheet version and case studies does provide the non-economist with the ability to obtain a preliminary understanding of the potential costs. It is intended, however, for an economist to undertake a more comprehensive assessment of the costs for a particular concern.
Training Required	Training is required, including using this guidance in conjunction with a risk assessment procedure (e.g., UKCIP risk framework). For a more detailed analysis it is essential that an experienced economist be involved.
Training Available	Training is not available at this time. The guidance and availability of case studies and the web-based spreadsheet version of the tool do provide a limited learning environment.
Computer Requirements	The costing reports, case studies and web-based spreadsheet version are all available from the UKCIP website and are accessible using any web browser software. The web-based spreadsheet costing tool requires Microsoft Excel.
Documentation	The costing reports, case studies and web-based spreadsheet version are all available from the UKCIP website (www.ukcip.org.uk/resources).

Costing the Impacts of Climate Change in the UK (cont.)

Applications	Case studies included with the report include: agriculture: the cost of not meeting irrigation needs; transport disruption: the cost of time lost due to short-term disruptions; water resources: the cost of increasingly stringent effluent standards; and flooding: the cost of flood alleviation.
Contacts for Tools, Documentation, Technical Assistance	Roger Street, Technical Director, UK Climate Impacts Programme; e-mail: roger.street@ukcip.org.uk or through enquiries at: enquiries@ukcip.org.uk; or Alistair Hunt, Metroeconomica Limited.
Cost	There is no charge for access to this guidance. It is expected that users of this guidance (and all UKCIP tools) would provide feedback to UKCIP regarding the overall results, as well as comments and suggestions towards improving the guidance. Enhancing the scope of the guidance or developing it for use outside of the UK will necessitate developing the various matrices and costs information, including through primary valuation studies which could be relatively costly depending on the scope and ease of availability of the costing information.
References	Included with the guidance are case studies that demonstrate the use of the costing guidance. Metroeconomica carried out a study of the costs and benefits of climate change associated with different sectors. This is one of the first studies to apply costing methods to sectors on a microscale. Details of this and other cross-regional studies are available on the Defra website at www.defra.gov.uk/environment/climatechange/uk/adapt/research.htm. Final reports are available through the Defra research pages at www2.defra.gov.uk/research/project_data/default.asp (search by "cross regional").

Identifying Adaptation Options

Description	Guidance on the identification and selection of adaptation options that can be used to respond to climate risks.
Appropriate Use	The guidance note is aimed at supporting decision and policy makers who are faced with identifying and appraising the selection and implementation of adaptation measures that address identified climate risks. It is intended to be used as a companion piece to other UKCIP tools such as the Adaptation Wizard; Risk, Uncertainty and Decision-Making Framework; Business Areas Climate Impacts Assessment Tool (BACLIAT), Adaptation Actions database, and the guidance on costing the impacts of climate change.
Scope	The guidance note explores adaptation options relating them to their intended purpose - Building Adaptive Capacity or Delivering Adaptation Actions. It also considers the options in the context of strategic intentions - living with and bearing losses or risks, preventing effects or reducing exposure to risks, sharing responsibility for any losses or risks, or exploiting opportunities. Each of these is further explored through generic examples with real-world specific examples provided.
Key Output	The intention is that after reading this guidance note, decision and policy makers will have the information that will allow them to identify an appropriate set of adaptation options using the other UKCIP tools and guidance.
Key Input	None required.
Ease of Use	The note is targeted for users and has both generic and real-world examples of adaptation options.
Training Required	None.
Training Available	None.
Computer Requirements	The guidance note is available from the UKCIP website and is accessible using any web browser software.
Documentation	This guidance note is available at www.ukcip.org.uk/resources/tools/adaptationoptions.asp.
Applications	None.
Contacts for Tools, Documentation, Technical Assistance	Roger Street, Technical Director, UK Climate Impacts Programme; e-mail: roger.street@ukcip.org.uk or through enquiries at: enquiries@ukcip.org.uk.
Cost	There is no charge for access to this guidance. It is expected that users of this guidance (and all UKCIP tools) will provide feedback to UKCIP regarding the overall results, as well as comments and suggestions towards improving the guidance.
References	None.

UKCIP Adaptation Wizard

Description	The Wizard is a tool to help users adapt to climate change. It is a generic, high-level tool that can be used to raise awareness of the adaptation process, and help those who are preparing to adapt. It is more a decision-support than decision-making tool.
Appropriate Use	The Wizard can help users to: • Teach themselves, their colleagues and wider professional network about climate change impacts and adaptation. • Access the information, tools and resources UKCIP provides to help them deal with climate change. • Assess their vulnerability to current climate and future climate change. • Make a decision, or develop a project, programme, policy or strategy, that is resilient to climate change. • Develop a climate change adaptation strategy The Wizard will not produce a tailor-made climate adaptation strategy at the click of a button. Instead, it will help users generate the information they need to prepare their own adaptation strategy.
Scope	The audience for the Wizard is decision-makers in organizations. It has been developed as a generic tool that can be tailored for the particular application of the user.
Key Output	An adaptation strategy document that includes: a record of the users' vulnerability to current climatic variability; a prioritized list of climate risks; a list of possible adaptation measures to address those risks; adaptation options appraisal; and an implementation strategy.
Key Input	• Time to complete the process • Participation of relevant individuals from within and outside of the organization concerned • An understanding of how decisions are made within the users' organization and how to bring about change • In-house experience and evidence of the consequences of past weather events on the organization or activity • Climate change scenario information • Socio-economic scenario information • Tools or techniques for costing climate impacts and for costing and evaluating adaptation options
Ease of Use	The Wizard is accessible and easy to use.
Training Required	No specific training is required. However, awareness of climate change scenarios and risk assessment methods would be helpful. Specialist skills may be required to complete specific tasks, such as costing climate impacts and adaptation options, and conducting a quantitative risk assessment. These activities can be commissioned separately if necessary and the results incorporated into the process.
Training Available	UKCIP can offer support and advice on application of the Wizard. The level of support available will depend on uptake of the tool.
Computer Requirements	The wizard is web-based and can run using any web browser software. Adobe Acrobat is needed to display some of the tables and most of the reports referred to in the Wizard as sources of information. Microsoft Word would be useful to compile the resulting adaptation strategy document, but any another word processing package would suffice. Should the UKCIP costings tool be used to cost impacts and adaptation options, Microsoft Excel would be required.

UKCIP Adaptation Wizard (cont.)

Documentation	All documentation is contained within the Wizard's website.
Applications	The prototype version of the Wizard was used to inform the development of a new school in Worcestershire, United Kingdom. This case study is available from the Wizard's website. Further case studies are being developed.
Contacts for Tools, Documentation, Technical Assistance	Megan Gawith, Scientific Officer, UK Climate Impacts Programme; e-mail: megan.gawith@ukcip.org.uk.
Cost	There is no charge for using the Wizard. The process of completing the Wizard will, however, incur some costs, the scale of which will be determined by the nature of the application. Costs would arise from, amongst other things: staff time to complete the process, possible associated travel and meeting costs, commissioning further research to fill information gaps where necessary, implementing adaptations.
References	The Wizard is based on the report: Willows, R.I. and R.K. Connell. (eds.). 2003. Climate Adaptation: Risk, Uncertainty and Decision-Making. UKCIP Technical Report. UKCIP, Oxford.

Adaptation Actions

Description	An online searchable database that has been developed and is maintained by UKCIP staff. Adaptation Actions contains examples of activities people in the UK have undertaken to exploit the opportunities that climate change might provide or to adapt to the risks of our changing climate. The database only includes examples of activities that have actually been implemented and does not include adaptation activities that are "a good idea". Users can search the database to see what others have done to adapt and get ideas on how to adapt to reduce their climate risks or exploit opportunities.
Appropriate Use	To stimulate thinking on the types of actions that could be taken to adapt to climate change. Note that this is not a definitive list, and the adaptation actions included in the database have not been validated or endorsed by UKCIP.
Scope	Includes mostly UK but some international actions.
Key Output	Information on examples of different types of adaptation actions.
Key Input	A user-specified sector or searchable field.
Ease of Use	Extremely easy to use.
Training Required	None.
Training Available	None.
Computer Requirements	Access to the internet.
Documentation	All documentation is provided within the database.
Applications	A prompt to identifying adaptation options.
Contacts for Tools, Documentation, Technical Assistance	Jacquie Yeates, Scientific Officer, UKCIP; e-mail: jacquelyn.yeates@ukcip.org.uk.
Cost	None.
References	None.

Business Area Climate Impacts Assessment Tool (BACLIAT)

Description	The UKCIP Business Areas Climate Impacts Assessment Tool (BACLIAT) is a starting point for exploring the implications of climate change on a particular organization or sector. It comprises a simple checklist for assessing the potential impacts of climate change under the following generic headings: logistics, finance, markets, process, people, premises and management implications.
Appropriate Use	BACLIAT can be used by an individual but is of most value when used as the basis of a brainstorming exercise with a group of relevant managers or representatives from the organization or sector in question. It can also be used in more general awareness-raising workshops to illustrate the breadth of impacts that climate change could have.
Scope	BACLIAT can be used at the level of a single organization or an entire industrial sector. It encourages the consideration of both threats and opportunities. Although it was designed for use by a business or sector, it can be used for other non-commercial organizations.
Key Output	A long list of potential impacts of climate change on an organization or sector.
Key Input	• A reasonable knowledge of all aspects of the organization or sector. • The headline messages from UKCIP climate change scenarios. • A short amount of time.
Ease of Use	BACLIAT is accessible and easy to use.
Training Required	None.
Training Available	UKCIP can facilitate BACLIAT workshops where appropriate and where resources permit.
Computer Requirements	None.
Documentation	A Changing Climate for Business is available free of charge from UKCIP either electronically or as a paper publication.
Applications	BACLIAT has been used by several UK trade associations and professional bodies as well as individual companies including Serco's Colnbrook Immigration Centre at Heathrow, Scottish Electrical Contracting, and several small and medium-sized enterprises.
Contacts for Tools, Documentation, Technical Assistance	Kay Johnstone, Project Officer (Business), UK Climate Impacts Programme; e-mail: kay.johnstone@ukcip.org.uk.
Cost	There is no charge for using BACLIAT. The only cost is the time taken to go through the process, which normally takes between one and three hours.
References	Metcalf, G. and K. Jenkinson. 2005. A Changing Climate for Business, UKCIP.

Nottingham Declaration Action Pack (NDAP)

Description	Website providing support to local authorities drawing up Action Plans to tackle climate change. It is structured into five project management stages with council roles divided into: corporate functions; service provider and community leader, and covers both adaptation and mitigation.
Appropriate Use	It is primarily intended to provide guidance to English local authorities drawing up Climate Change Action Plans in accordance with the commitments of signatories to the Nottingham Declaration but could also be of use to any public sector organizations wishing to respond to the challenges of climate change. The adaptation threads of the tool are based on the UKCIP risk framework methodology modified to suit the requirements of UK local authorities.
Scope	The tool is designed for use by all types of English local authorities: district, unitary and county, but could potentially be of use at regional or sub-regional scales.
Key Output	A practical Climate Change Action Plan -- NDAP provides a framework for the production of a comprehensive action plan for a local authority area covering both climate change mitigation and adaptation. However, it is structured to allow selective use to cover only specific areas of local authority operations.
Key Input	NDAP encourages local authorities to identify their local climate risks and vulnerabilities through the use of UKCIP scenarios and the drawing up of a Local Climate Impacts Profile (LCLIP) based on recent local exposure to weather events.
Ease of Use	NDAP provides basic guidance for local authority officers to draw up a Climate Change Action Plan. It is intended to be easy to use and to require little, or no, specialist technical knowledge.
Training Required	NDAP is intended to be sufficiently easy to use that it does not require any specific training (see below).
Training Available	Regional training events were organized following the launch of NDAP version 1 in July 2006. These were focused on some of the basic principles of climate risk impact assessment and adaptation. Currently there is no training available, but this is kept under review.
Computer Requirements	Any system with web access.
Documentation	No documentation beyond the website itself.
Applications	NDAP is currently being used by a number of English local authorities to produce Climate Change Action Plans.
Contacts for Tools, Documentation, Technical Assistance	Laurie Newton, Local Authority Project Manager, UKCIP; e-mail: laurie.newton@ukcip.org.uk.
Cost	Free.
References	See www.nottinghamdeclaration.org.uk.

Community-based Risk Screening Tool – Adaptation & Livelihoods (CRiSTAL)

Description	IUCN, IISD, SEI-US and Intercooperation have developed and tested a project planning and management tool called CRiSTAL (Community-based Risk Screening Tool – Adaptation & Livelihoods). The tool seeks to help project planners and managers to integrate risk reduction and climate change adaptation into community-level projects. CRiSTAL was developed in response to the outcomes of Phase 1 of the Livelihoods and Climate Change project, which examined how ecosystem management and restoration (EM&R) or sustainable livelihoods (SL) projects reduced community vulnerability to climate stress.
Appropriate Use	CRiSTAL can be used by local communities, project planners and project managers.
Scope	CRiSTAL is intended to promote the integration of risk reduction and climate change adaptation into community-level projects. By focusing on community-level projects, CRiSTAL promotes the development of adaptation strategies based on local conditions, strengths and needs.
Key Output	List of project activities that protect/enhance access to and availability of resources that are strongly affected by climate hazards or important to coping.
Key Input	Relevant (regional, national, eco-zone) information on climate change (if available/accessible), as well as information on local climate hazards, impacts, coping strategies, as well as livelihood resources, and project information.
Ease of Use	User-friendly.
Training Required	Training shouldn't be required to use CRiSTAL, as there is a User's Manual available.
Training Available	Training is currently being provided. A training session was held in Mozambique earlier this year for project planners and managers based in Eastern and Southern Africa, and preparations are currently underway for a West Africa version of the training. More is planned for 2008.
Computer Requirements	The self-extracting CRiSTAL file can be downloaded from http://www.sei-us.org/Cristal/Cristal_Setup.exe. If you run this file, the program (and all related files) should be installed on your C: drive in a folder you create named, "CRISTAL". In order to run the program, you simply open the "Session-Setup.xls" file in the CRISTAL folder. You should also make sure your security settings in Excel are set on medium in order to enable the macros to run. This can be done by accessing the Tools menu, then clicking on Options > Security > Macro Security.
Documentation	CRiSTAL tool, field reports and presentations available at: http://www.iisd.org/security/es/resilience/climate_phase2.asp .
Applications	In an effort to render this tool as useful as possible, IUCN, IISD, SEI-US and Intercooperation conducted a series of field tests on planned or ongoing natural resource management projects in Mali, Bangladesh, Tanzania, Nicaragua and Sri Lanka. Project team members travelled to the field sites to work with local project managers and community stakeholders in gathering relevant information, applying the tool and developing recommendations on how to adjust project activities so they take into account local adaptive capacity. Results from the field tests provided constructive feedback on the design and application of CRiSTAL, while the testing process itself has raised awareness of climate change issues in vulnerable communities. The tool provided an entry point for discussing local observations of climate variability and the impacts of climate change in a participatory manner, encouraging communities to look for opportunities to enhance their adaptive capacities. For project planners and managers, CRiSTAL provided a useful framework for understanding the links among climate, livelihoods and project activities.

Community-based Risk Screening Tool – Adaptation & Livelihoods (CRiSTAL) (cont.)

Contacts for Tools, Documentation, Technical Assistance	Anne Hammill, Livelihoods and Climate Change Project Manager, International Institute for Sustainable Development (IISD); e-mail:ahammill@iisd.org.
Cost	Free.
References	None.

3.3 Stakeholder Approaches

Stakeholder approaches in general emphasize the importance of ensuring that the decisions to be analyzed, how they are analyzed, and the actions taken as a result of this analysis are driven by those who are affected by climate change and those who would be involved in the implementation of adaptations. The stakeholder approaches described in this compendium, listed in Table 3.3, represent a way of analyzing the institutional and organizational context of the adaptation strategy planning process more than they do specific tools to be applied to an assessment. Application of the stakeholder network and institution approach might well employ a variety of tools, some of which are listed below. The vulnerability indices approach aims to provide the user with a metric for vulnerability and adaptive capacity, but again, its application would most likely rely on other tools. Agent based social simulation is a modeling approach to stakeholder networks and institutions and might in practice take different forms, depending on the user's aims. Livelihood sensitivity exercise is a means of integrating existing knowledge of climate vulnerability with livelihood analysis. Multistakeholder processes are tools emphasizing dialogue on consensus building, and might well be employed as part of the aforementioned approaches. Scoping, which can be used as the first step of a vulnerability and adaptation assessment, allows users to identify tools and approaches that might be applicable to their particular focus. Global sustainability scenarios can provide insight into future vulnerability and adaptive capacity and their associated quantitative indices might typically serve as an input for other approaches described in this section. The Model of Private Proactive Adaptation to Climate Change (MPPACC) is an analytical tool, which helps to understand the psychological determinants of individual adaptation behaviour. Many of these approaches are relatively new, at least in their application to the climate change problem, and consequently their methods are still being refined.

Table 3.3 Stakeholder approaches
Stakeholder Networks and Institutions
Scoping
Vulnerability Indices
Agent Based Social Simulation
Livelihood Sensitivity Exercise
Multistakeholder Processes
Global Sustainability Scenarios
MPPACC (Model of Private Proactive Adaptation to Climate Change)

Stakeholder Networks and Institutions

Description	The stakeholder networks and institutions approach focuses on understanding those who make the decisions and how they relate to one another. Building adaptive capacity over long time scales depends on understanding these relationships. Institutions can be viewed as the collective rules, norms, and shared strategies that define stakeholder behavior. This approach posits that understanding present capacity is key to predicting how it is likely to evolve in response to future risks. These relationships can be complex, and unraveling them can require the use of a number of tools (see below). Each stakeholder has different objectives, resources, and responsibilities, all of which must be investigated. Some stakeholders may have little voice in the process or may be assigned responsibilities in only part of the issue. New stakeholders may emerge and relationships may alter, particularly in a crisis.
Appropriate Use	Useful in determining the present adaptive capacity and how that capacity might be developed in the future. In general stakeholder approaches are oriented toward research teams that support policy making. They help set the framework for evaluating specific measures, and thus from an early part of the decision process, as well as helping to monitor capability over a longer term.
Scope	Global, but most appropriate at national or local level.
Key Output	Characterization of stakeholders and institutions in terms of levels of participation, positions, and boundaries in policy making. Insight into institutional capacity to adapt.
Key Input	A mixture of quantitative and qualitative data depending on actual tools employed in the approach.
Ease of Use	Varies, but application of some tools requires specialist training in policy analysis. Some can be readily adopted by practitioners.
Training Required	Some training is useful, but expertise in policy analysis is more important than specific analytical techniques.
Training Available	Many training courses on stakeholder engagement exist.
Computer Requirements	Varies.
Documentation	Working papers on institutions, institutional analysis, stakeholders, and case studies are available online.
Applications	See http://www.sei.se/oxford / for examples of applications.
Contacts for Framework, Documentation, Technical Assistance	Dr. Thomas Downing, Stockholm Environment Institute, Oxford Office, 10B Littlegate Street, Oxford, OX1 1QT, United Kingdom; Tel: +44.1865.202070; e-mail: tom.downing@sei.se.
Cost	No cost.

Stakeholder Networks and Institutions (cont.)

References	See http://www.sei.se/oxford/ for links to references. Ziervogel, G. and T. E. Downing. 2004. Stakeholder networks: Improving seasonal forecasts. *Climatic Chang*e 65(1-2):73-101.

Scoping

Description	A major step in designing an assessment of climate impacts, vulnerability, and adaptation is to scope the elements of the study. A spreadsheet has been developed to aid project teams in the scoping phase. The spreadsheet has a list of potential methods — over 70 general techniques that are appropriate in various stages of an assessment. A simple form allows users to choose answers to eight scoping questions. The answers are then used to screen the choice of potentially useful tools. A section of the spreadsheet has common flowcharts of projects (e.g., NAPA and APF) and a set of building blocks that users can link to make their own project diagram.
Appropriate Use	This tool can underpin a project design team or be used to backstop a participatory exercise where teams are required to prepare a poster of their project and explain the overall logic and steps to other teams.
Scope	Global.
Key Output	Project design and inventory of tools.
Key Input	Review and synthesis existing information on vulnerability and adaptation, existing development policies and priorities, adaptation needs and constraints, and a list of potential methods.
Ease of Use	Very simple, all data are in the spreadsheet if users wish to change any assumption.
Training Required	None necessary.
Training available	SEI has used this tool to backstop participatory design exercises.
Computer Requirements	PC Windows with Excel (macro functions work with more recent versions).
Documentation	Contained in the spreadsheet; see also the APF scoping technical paper (TP1). (http://ncsp.undp.org/report_detail.cfm?Projectid=151)
Applications	Flexible use in project design.
Contacts for Framework, Documentation, Technical Assistance	Dr. Thomas Downing, Stockholm Environment Institute, Oxford Office, 10B Littlegate Street, Oxford, OX1 1QT, United Kingdom; Tel: +44.1865.202070; e-mail: tom.downing@sei.se.
Cost	Free, available on the www.vulnerabilitynet.org web site.
References	Downing, T.E. 2003. Scoping Tool for Climate Change Assessment: An Excel Spreadsheet and Toolkit. Stockholm Environment Institute, Oxford, UK.

Vulnerability Indices

Description	Formal vulnerability indices can be helpful as part of an adaptation strategy. Vulnerability is defined by the IPCC as the combination of sensitivity to climatic variations, the probability of adverse climate change, and adaptive capacity. For each of these components of vulnerability, formal indices can be constructed and combined. Methods of aggregating across sectors and scales have been developed in other contexts (e.g., the Human Development Index) and are beginning to be applied to climate change. However, substantial methodological challenges remain — in particular estimating the risk of adverse climate change impacts and interpreting relative vulnerability across diverse situations.
Appropriate Use	They can help identify and target vulnerable regions, sectors or populations, raise awareness, and can contribute to a monitoring strategy. In general stakeholder approaches are oriented toward research teams that support policy making. They help set the framework for evaluating specific measures, and thus from an early part of the decision process, as well as helping to monitor capability over a longer term.
Scope	Global, but most appropriate at national or local level.
Key Output	Matrices of vulnerability indexes, vulnerability maps.
Key Input	A mixture of quantitative and qualitative data depending on actual tools employed in the approach. Examples of vulnerability indices are commonly available, including the Southeast Asia Environmental Framework (contact Vikrom Mathur at the SEI: www.sei.se) and food security scenarios for South Africa and India (contact Tom Downing at the SEI).
Ease of Use	Varies, but application of some tools requires specialist training in policy analysis. Some can be readily adopted by practitioners.
Training Required	Some training is useful, but expertise in policy analysis is more important than specific analytical techniques.
Training Available	A number of groups offer training in vulnerability assessment particularly related to disasters. The Vulnerability Network led by the SEI maintains a web site with discussion forums, a document hotel, and bibliographies: see www.vulnerabilitynet.org.
Computer Requirements	Varies.
Documentation	UNEP has sponsored a project to review formal vulnerability indices and a background paper has been prepared. A summary of the key issues is available as a PowerPoint presentation on the ECI website (see publications at http://www.eci.ox.ac.uk/). See also the Technical Paper 3 of the Adaptation Policy Framework at http://ncsp.undp.org/report_detail.cfm?Projectid=151.
Applications	Vulnerability indices have been used by the Bangladesh Centre for Advanced Studies in Dhaka, South Pacific Applied Geoscience Commission, Association of Small Island States, and Battelle Pacific Northwest Laboratory. The Potsdam Institute for Climate Impact Research has developed an analogous approach on environmental syndromes.
Contacts for Framework, Documentation, Technical Assistance	Dr. Thomas Downing, Stockholm Environment Institute, Oxford Office, 10B Littlegate Street, Oxford, OX1 1QT, United Kingdom; Tel: +.44.1865.202070, e-mail: tom.downing@sei.se. Dr. Antoinette Brenkert, Pacific Northwest National Laboratory, Joint Global Change Research Institute at the University of Maryland, 8400 Baltimore Avenue, Suite 201, College Park, MD 20740-2496, USA; Tel: +1.301.314.6759; Fax: +1.301.314.6760; e-mail: Antoinette.Brenkert@pnl.gov.

Vulnerability Indices (cont.)

Cost	No cost.
References	Downing, T. et al. 2001. *Vulnerability indices. Climate Change Impacts and Adaptation*. UNEP, Policy Series 3: 91 pp. (available at http://www.sei.e-collaboration.co.uk/OPMS/view.php?site=seiproject&bn=seiproject_hotel&key=1097073874)

Agent Based Social Simulation

Description	A computer assisted technique for knowledge elicitation assists in building rules of how people respond to a variety of stimuli and scenarios of environmental and social conditions. Agent based social simulation is a relatively formal approach to stakeholder and institutional analysis. It is a computer programming method that uses software agents to represent the positions, boundaries, and actions of stakeholders. This approach is one of the few means to realistically simulate the behavior of stakeholder networks in the context of the rules, norms, and shared strategies from social and economic institutions. This approach can be applied at various stages of an assessment. One example is that agent based social simulation can incorporate socioeconomic scenarios that are constructed as sets of rules regarding, for example, environmental values, regulation, and economic goals. An advantage of this approach is that the realization of socioeconomic scenarios is the outcome of stakeholder behavior rather than being exogenously imposed in a way that bears little relation to actual decision making processes.
Appropriate Use	Applicable to various stages of the design of a strategy to respond to climate change and its subsequent implementation in specific measures.
Scope	Global, but most appropriate at national or local level.
Key Output	Insight into how the decision making and implementation processes. For example, realistic socioeconomic pathways constructed as the outcome of multiple decisions.
Key Input	A mixture of qualitative and quantitative data.
Ease of Use	Varies, though constructing an agent based social simulation model would require significant expertise.
Training Required	Some training is useful, but expertise in policy analysis is more important than specific analytical techniques when it comes to using and interpreting results of agent based social simulation.
Training Available	Very little experience has been gained regarding these approaches to date, and hence no formal training or certification is available. However, occasional workshops are offered. See documentation section below.
Computer Requirements	Personal computer.
Documentation	Center for Policy Modeling at Manchester Metropolitan University is one of the world leaders in agent based social simulation. The CPM developed a user friendly software package (SDML) to facilitate model development. http://cfpm.org/.
Applications	Agent based social simulation is only beginning to be applied to climate change. Oxford University's Environmental Change Unit is collaborating with the CPM on various applications to integrated assessment of climate policy. Also, the Carnegie Mellon global change program has elements of agent behavior in the Integrated Climate Assessment Model. A European Union project on integrated water resource management (Freshwater Integrated Resource Management Agents, coordinated by the University of Surrey) will develop agent based approaches further.
Contacts for Framework, Documentation, Technical Assistance	Dr. Thomas Downing, Stockholm Environment Institute, Oxford Office, 10B Littlegate Street, Oxford, OX1 1QT, United Kingdom; Tel: +44.1865.202070; e-mail: tom.downing@sei.se.

Agent Based Social Simulation (cont.)

Cost	No cost.
References	West, J.J. and H. Dowlatabadi. 1999. On assessing the economic impacts of sea-level rise on developed coasts. In *Climate Change and Risk*, T.E. Downing, A.A. Olsthoorn, and R.S.J. Tol (eds.). Routledge, New York, pp. 205-220. Ziervogel, G., M. Bithell, R. Washington and T. Downing. 2005. Agent-based social simulation: a method for assessing the impact of seasonal climate forecast applications among smallholder farmers. *Agricultural Systems* 83(1):1-26.

Livelihood Sensitivity Exercise

Description	Livelihood sensitivity mapping exercise is a means of integrating existing knowledge of climate vulnerability with livelihood analysis. It commonly involves stakeholder participation. Initially the exercise can be conducted in the context of rapid workshop breakout group, but eventually can be formalized via the inclusion of expert analysis, impact models, or historical analogues: The exercise involves developing a matrix with three blocks of rows — beginning with ecosystem services (e.g., soil moisture), then livelihood activities (such as crop production) and finally a synthesis based on livelihoods themselves. Climatic stresses (e.g., drought) are listed as columns. Users then fill in the cells — rating the sensitivity of ecosystem services, activities and livelihoods to a range of hazards and stresses. Exposure across the hazards and impacts across the services/activities/livelihoods can be calculated as aggregated indices.
Appropriate Use	Livelihood sensitivity exercise is a useful tool for helping identify vulnerable livelihoods and consequently targeting adaptations that aim to increase the resiliency of particular livelihood strategies to climate change. Livelihood sensitivity exercise is best applied to a single sector or region at any one time. The approach has been used in regional training workshops for the NAPA teams.
Scope	All sectors. Most applicable at a local or regional level.
Key Output	Ranking of vulnerable livelihoods as well as an overall livelihood sensitivity index.
Key Input	Qualitative assessments of sensitivity of livelihoods to climatic threats.
Ease of Use	Easy.
Training Required	A familiarity with livelihoods, expert knowledge elicitation, and vulnerability indicators is helpful.
Training Available	The NAPA workshops have produced a range of presentations and a sample spreadsheet that are available at http://www.unitar.org/ccp/ and www.vulnerabilitynet.org. The spreadsheet includes notes on delineation of livelihoods and an illustrative example based on agriculture in southern Africa.
Computer Requirements	Minimal to none.
Documentation	Available at www.vulnerabilitynet.org.
Applications	See www.livelihood.org.
Contacts for Framework, Documentation, Technical Assistance	Dr. Thomas Downing, Stockholm Environment Institute, Oxford Office, 10B Littlegate Street, Oxford, OX1 1QT, United Kingdom; Tel: +44.1865.202070; e-mail: tom.downing@sei.se.
Cost	Free.
References	See www.livelihood.org. Downing, T.E. 2003. *Livelihood Sensitivity to Climatic Hazards. Annex to Technical Paper 3 of the Adaptation Planning Framework*. SEI, Oxford, UK. (http://ncsp.undp.org/report_detail.cfm?Projectid=151)

Multistakeholder Processes

Description	The aim of multistakeholder processes are to promote better decision making by ensuring that the views of the main actors concerned about a particular decision are heard and integrated at all stages through dialogue and consensus building. The process takes the view that everyone involved in the process has a valid view and relevant knowledge and experience to bring to the decision making. The approach aims to create trust between the actors and solutions that provide mutual benefits (win-win). The approach is people-centered and everyone involved takes responsibility for the outcome. Because of the inclusive and participatory approaches used, stakeholders have a greater sense of ownership for decisions made. They are thus more likely to comply with them.
Appropriate Use	For decisions that require cooperation between many different stakeholders, where a decision made by one group alone might not be complied with by the other groups. They are suitable for situations where dialogue between the different actors is possible and there is willingness to listen to and learn from others to reconcile different interests and reach consensus solutions. There is no one set approach. The exact nature of a given process will depend on the issues to be covered, the specific objectives, the expertise available, the participants, and the time and other resources available.
Scope	Global, national, and local. Can be used with a wide range of structures and levels of engagement.
Key Output	Transparent and inclusive decision making, strengthened stakeholder networks.
Key Input	Expertise in facilitation, willingness of participants to learn, time to allow trust building, quantitative and qualitative information (depending on tools used), participation of key actors.
Ease of Use	The approaches as well as the techniques used are based on common sense. Good planning is a vital part of ensuring a successful outcome and time must be allowed for the design stage of the process.
Training Required	There are a number of good texts available, but additional appropriate training would be beneficial (depending on time, resources, type of process). Need also to design the process to fit the specific needs and circumstances.
Training Available	This is still a new and evolving field. Much experience of using participatory processes at the local level is available but less at national and global levels. Some guidance on approaches is available (see Applications below for examples).
Computer Requirements	Depends on the process.
Documentation	For information about running stakeholder engagement processes: Multistakeholder processes for governance and sustainability, Minu Hemmati, (2002), Earthscan, London. http://www.earthscan.co.uk/.
Applications	Multistakeholder processes have been used in the Aarhus Convention Process, the Bejing+5 Global Forum Online discussions, United Nations sustainable development multistakeholder dialogue, the Environment Council/Shell — Brent Spar Project (see Hemmati above for more information on these) and the Adaptation Policy Framework (APF) (http://ncsp.undp.org/report_detail.cfm?Projectid=151).

Multistakeholder Processes (cont.)

Contacts for Framework, Documentation, Technical Assistance	Dr. Kate Lonsdale, Stockholm Environment Institute, Oxford, OX1 1QT; e-mail: kate.lonsdale@sei.se. Dr. Bo Lim, Chief Technical Advisor, National Communications Support Programme, UNDP-GEF, Room 1607, 304 East 45th St, NY 10017, USA; e-mail: bo.lim@undp.org.
Cost	Depends on the scale of the process.
References	Chambers, R. 2002. Participatory Workshops: A Source Book of 21 Sets of Ideas and Activities. Earthscan. Available from http://www.earthscan.co.uk/. Good source book of information about how to run workshops including lots of practical advice and common mistakes. Coalition for Agrarian Reform and Rural Development (ANGOC) and International Institute of Rural Reconstruction (IIRR). 2001. Enhancing Ownership and Sustainability: A Resource Book on Participation. International Fund for Agricultural Development (IFAD). e-mail: publications@iirr.org. A collection of short reviews of participatory approaches and experiences. Pretty, J.N., I. Guijt, I. Scoones and J. Thompson. 1995. Participatory Learning and Action: A Trainers Guide. International Institute for Environment and Development (IIED). Available from www.earthprint.com. A valuable collection of advice, tips, and methods for participatory approaches. The focus is mostly on participatory rural appraisal but much would also be relevant to APF workshops. Kaner, S., L. Lind, C. Toldi, S. Fisk and D. Berger. 1996. Facilitator's Guide to Participatory Decision-Making. New Society Publishers. An introduction to how to build consensus and make sustainable agreements with groups. Also gives advice on how to handle difficult group dynamics and individuals.

Global Sustainability Scenarios

Description	Scenarios of future vulnerability are poorly framed by existing scenarios developed for bracketing future greenhouse gas emissions. Alternative scenarios of sustainability have been developed in various forms, and these correspond to many of the conditions of vulnerability and adaptive capacity that are of concern to development planners and practitioners. A major suite of sustainability scenarios was developed by the Global Scenarios Group (GSG). These include a conventional wisdom of market forces, a world of increasing degradation and impoverishment, and a sustainability transition. They are similar to scenarios developed for the UNEP Geo assessment. The GSG suite of scenarios includes storylines and quantified indicators for major world regions using the PoleStar scenario tool developed by SEI-Boston.
Appropriate Use	The GSG and PoleStar data can be used to frame national or local scenarios of vulnerability, or to place national development scenarios in context.
Scope	Global to regional; with some extensions they can be used to frame more local scenarios.
Key Output	Quantitative indicators of environmental change, economic conditions, and social welfare that can be linked to climatic vulnerability.
Key Input	The storylines and overview are described in an SEI monograph, Great Transitions (see References below).
Ease of Use	Very little effort is required to appreciate the storylines. PoleStar is not a simple model to understand, although it is well documented. It may take several days to extract the quantitative data and format for specific purposes; it is possible to create new subregions within PoleStar, but that will require additional time and possibly training.
Training Required	None necessary, although further training in PoleStar may be warranted.
Training available	SEI has used this tool in many contexts — contact SEI-Boston for training in PoleStar and the GSG scenarios; SEI Oxford has developed explicit links to climate vulnerability using South Africa and India as examples.
Computer Requirements	PC Windows.
Documentation	GSG web site, monograph and PoleStar software and manual are available through the SEI Boston office: see www.sei.se.
Applications	Global to local socioeconomic scenarios of future climate vulnerability and adaptive capacity.
Contacts for Framework, Documentation, Technical Assistance	Paul Raskin, SEI-Boston for the GSG and PoleStar, 11 Arlington Street, Boston, MA 02116-3411, USA; Tel: +1.617.266.8090; e-mail: praskin@tellus.org. For application to climate change: Dr. Thomas Downing, Stockholm Environment Institute, Oxford Office, 10B Littlegate Street, Oxford, OX1 1QT, United Kingdom; Tel: +44.1865.202070; e-mail: tom.downing@sei.se.
Cost	PoleStar is available for free in a demonstration version, which includes the GSG scenarios. The GSG monograph is available free in an electronic version.
References	P. Raskin, et al. 2002. Great Transition. Stockholm Environment Institute, Boston. http://www.tellus.org/seib/publications/Great_Transitions.pdf

MPPACC (Model of Private Proactive Adaptation to Climate Change)

Description	The Model of Private Proactive Adaptation to Climate Change (MPPACC) is a psychological model, which helps to understand the psychological determinants of individual adaptation behavior. MPPACC separates out the psychological steps to taking action in response to climate change, and allows one to see where the most important bottlenecks occur—including risk perception and perceived adaptive capacity.
Appropriate Use	MPPACC mainly qualifies as a theoretical model, which helps to address the important determinants of individual adaptive behavior in campaigns that have the objective to foster individual adaptation behavior. In taking actions to promote particular adaptations, it would be worthwhile for policy makers to focus on the cognitive barriers mentioned in MPPACC. In addition, MPPACC can offer predictive power to the task of assessing individual adaptive capacity (i.e., the probability of individual adaptation behavior) by measuring the psychological determinants of adaptation behavior through surveys (e.g., by asking people for their perceived ability to avoid damage from climate change impacts). MPPACC is not a tool to assess climate change impacts or vulnerability.
Scope	MPPACC can be applied worldwide, but individual determinants of adaptation behavior vary from culture to culture. Therefore, in most cases MPPACC has to be checked for cultural adequacy.
Key Output	MPPACC is an analytical tool to understand the determinants of individual adaptation behavior.
Key Input	When MPPACC is used as a theoretical tool to understand the determinants of individual adaptation behavior there are no data required.
Ease of Use	Every user who can think psychologically can use the MPPACC.
Training Required	No training is required.
Training Available	No training is required.
Computer Requirements	None.
Documentation	Grothmann, T. and A. Patt. 2005. Adaptive Capacity and Human Cognition: The Process of Individual Adaptation to Climate Change. *Global Environmental Change* 15 (3):199-213.
Applications	No further cases or projects where MPPACC has been applied despite the project presented in Grothmann and Patt (2005).
Contacts for Tools, Documentation, Technical Assistance	Torsten Grothmann; e-mail: Torsten.Grothmann@web.de.
Cost	None.
References	Grothmann, T. and A. Patt. 2005. Adaptive Capacity and Human Cognition: The Process of Individual Adaptation to Climate Change. *Global Environmental Change* 15 (3):199-213.

3.4 Other Multisector Tools

The tools described in this part of the compendium, listed in Table 3.4, are applicable to more than one sector. They provide a general evaluation of adaptation options, are easily adapted to numerous regions and situations, and are frequently used in conjunction with sector-specific tools to develop a comprehensive analysis or in support of a complete framework. Some are focused and produce specific information (e.g., M-CACES provides the user with estimates of the cost of particular adaptations, while CCAV provides insight into impacts of climate variability). Others are more general approaches that can be applied to more than one step of a vulnerability and adaptation assessment (e.g., uncertainty and risk analysis, forecasting by analogy, expert judgment). Several of the tools listed below are disaster risk reduction tools that have been developed in response to numerous climate-related hazards. The application of these tools can provide an effective framework for identifying risks and vulnerabilities, and to build adaptive capacity.

Table 3.4. Other multisector tools

Climatic Change and Variability (CCAV)
Expert Judgment
Historical or Geographic Analogs: Forecasting by Analogy
Uncertainty and Risk Analysis
Estimating Adaptation Costs: M-CACES
Impacts Database
PAGE2002 (Policy Analysis for the Greenhouse Effect)
Resource Approach to Assessment of Climate Change Impact on Human Activity
Comprehensive Hazard and Risk Management (CHARM)
Community-Based Disaster Risk Management Field Practitioners' Handbook
Guidelines for Emergency Assessment
Guidelines on Climate Watches
Natural Disaster Mitigation in Drinking Water and Sewerage Systems: Guidelines for Vulnerability Analysis
Handbook for Estimating the Socio-Economic and Environmental Effects of Disasters
The Good Practice Guide: Community Awareness and Education in Emergency Management

Climatic Change and Variability (CCAV)

Description	A methodology of descriptive statistics to illustrate the changing average conditions and the variability in conditions over time. Climate time-series data can be described according to their average conditions, but of particular importance for vulnerability are the impacts of adaptation to the variability of conditions from year to year. Within the range of climatic conditions is a range of conditions with which humans can cope. This range can be changed with adaptive responses. The climatic conditions can also be described and compared according to the variation of conditions over a particular time period (indicated by the variance).
Appropriate Use	To assess climate change and variability in the context of the coping capacity of human systems.
Scope	All locations; all levels of analysis.
Key Output	Allows user to understand changes not only in average climate conditions but also in extreme conditions.
Key Input	Climate time-series data.
Ease of Use	Easy.
Training Required	No formal training required, although an understanding of climatic data and descriptive statistics is an asset.
Training Available	None identified.
Computer Requirements	None identified.
Documentation	Smit, B., D. McNabb, and J. Smithers. 1996. Agricultural adaptation to climatic variation. *Climatic Change* 33:7-29. Smit, B., I. Burton, R.J.T. Klein, and J. Wandel. 2000. An anatomy of adaptation to climate change and variability. *Climatic Change* 45(1):223-251. Smit, B., I. Burton, R.J.T. Klein, and R. Street. 1999. The science of adaptation: A framework for assessment. *Mitigation and Adaptation Strategies for Global Change* 4(3-4):239-252. Smit, B. 1999. Agricultural Adaptation to Climate Change in Canada. A Report to the Adaptation Liaison Office.
Applications	Applied by Environment Canada's Environmental Adaptation Research Group, and in other climate change and variability research in Canada and Germany.
Contacts for Framework, Documentation, Technical Assistance	Elizabeth Harvey, University of Guelph, Department of Geography, Guelph, ON N1G 2W1; Tel: 519.824.4120 ext. 8961; Fax: 519.837.2940; e-mail: eharvey@uoguelph.ca. Dr. Barry Smit, University of Guelph, Department of Geography, Guelph, ON N1G 2W1 Canada; Tel: 519.824.4120 ext. 3279; Fax: 519.837.2940; e-mail: bsmit@uoguelph.ca. Ian Burton, Adaptation and Impacts Research Division (AIRD), Meteorological Service of Canada, 4905 Dufferin Street, Downsview, ON M3S 5T4, Canada; Tel: 416.739.4314; Fax: 416.739.4297; e-mail: ian.burton@ec.gc.ca.
Cost	None identified.
References	See Documentation above.

Expert Judgment

Description	Expert judgment is an approach for soliciting informed opinions from individuals with particular expertise. This approach is used to obtain a rapid assessment of the state of knowledge about a particular aspect of climate change. It is frequently used in a panel format, aggregating opinions to cover a broad range of issues regarding a topic. Expert judgment is frequently used to produce position papers on issues requiring policy responses and is integral to most other decision-making tools.
Appropriate Use	This approach is most useful either in conjunction with a full research study or when there is insufficient time to undertake a full study. It is important to be aware, however, of the subjective nature of expert judgment and the need to select a representative sample of experts to cover the full spectrum of opinion on an issue.
Scope	All locations; all sectors; national or site-specific.
Key Output	Current information on any area of climate change and subjective assessment of potential adaptation options.
Key Input	Knowledge of experts' respective areas of expertise.
Ease of Use	Easy to apply.
Training Required	Requires knowledge of policy issues and available experts. More training may be required to assemble an expert panel, formulate questionnaires, and interpret and aggregate expert opinions.
Training Available	Informal training offered; contact Ian Burton (see below) for information.
Computer Requirements	None.
Documentation	Not applicable.
Applications	UK, Mackenzie Basin in Canada, Finland.
Contacts for Tools, Documentation, Technical Assistance	Ian Burton, Adaptation and Impacts Research Division (AIRD), Meteorological Service of Canada, 4905 Dufferin Street, Downsview, ON M3S 5T4, Canada; Tel: 416.739.4314; Fax: 416.739.4297; e-mail: ian.burton@ec.gc.ca.
Cost	Cost depends on the fee charged by the experts.
References	Cohen, S.J. (ed.). 1997. Mackenzie Basin Impact Study. No. En 50_118/1997_IE. Environment Canada, Downsview, Ontario. Smith, J.B. and D.A. Tirpak. 1990. The Potential Effects of Global Climate Change on the United States. Report to Congress, U.S. EPA, Washington, DC.

Historical or Geographic Analogs: Forecasting by Analogy

Description	This qualitative tool is a method for evaluating the effectiveness of potential adaptation strategies by comparing observed adaptations to past climate extremes in different geographic locations, sectors, or time periods. This method compares events that have had a similar effect in the recent past to the likely impact of future events associated with climate change, assuming that lessons can be learned from such past experience and then applied to future situations. These compared situations can generally share several important characteristics such as time scale, severity, reversibility, impacted sector, or aggravating factors, and point out how well actual adaptation response worked or did not work.
Appropriate Use	This approach is useful during the initial survey stages of evaluating adaptation strategies to avoid duplicating research or to narrow the list of feasible options, and is generally used in conjunction with a quantitative evaluation of adaptation options. This approach does not provide a method to weigh the trade-offs among different adaptation options, but instead provides insight into how the adaptation process may work. Also, an example of adaptation in one place at a particular time is not always applicable to a future adaptation at a different place. This approach has not seen extensive use recently.
Scope	All locations; all sectors; national or site-specific.
Key Output	A broad perspective on previous research and attempted strategies used to address similar situations.
Key Input	General information on other adaptation issues: research done, approaches used, problems encountered. Often performed by a multidisciplinary panel of experts, including relevant members of the research community such as climatologists, meteorologists, hydrologists, entomologists, and epidemiologists.
Ease of Use	Relatively easy to use, although the robustness of the comparison depends on the extent of the user's knowledge of the situations being compared.
Training Required	Requires a background understanding of the adaptation issues being compared.
Training Available	Contact Michael Glantz for more information (see Contacts below).
Computer Requirements	None.
Documentation	Glantz, M., and J. Ausubel. 1998. Impact assessment by analogy: Comparing the impacts of the ogallala aquifer depletion and CO_2 induced climate change. In *Societal Responses to Regional Climate Change: Forecasting by Analogy.* M. Glantz (ed.). Westview Press, Boulder, CO, USA.
Applications	Used in U.S. EPA-supported project on analogous forecasting of the societal responses to the regional impacts of global warming. Also used to evaluate fisheries in Poland, Mexico, and the Far East.
Contacts for Tools, Documentation, Technical Assistance	Michael Glantz, University Corporation for Atmospheric Research, P.O. Box 3000, Boulder, CO 80303 USA; Tel: +1.303.497.8117; e-mail: glantz@ucar.edu.
Cost	Low cost to obtain documentation.

Historical or Geographic Analogs: Forecasting by Analogy (cont.)

References	Glantz, M. (ed.). 1998. *Societal Responses to Regional Climatic Change: Forecasting by Analogy*. Westview Press, Boulder, CO, USA. Coastal: Hands, E.B. 1983. The Great Lakes as a test model for profile responses to sea level changes. In *CRC Handbook of Coastal Processes and Erosion,* Komar, P.D. (ed.). CRC Press, Boca Raton, pp. 167-189. N. Mimura and H. Nobuoka. 1995. Verification of the Bruun Rule for the estimation of shoreline retreat caused by sea-level rise. In *Coastal Dynamics* 95, W.R. Dally and R.B. Zeidler (eds.). American Society of Civil Engineers, New York, pp. 607-616. Parkinson, R.W. (ed.) 1994. Sea-level rise and the fate of tidal wetlands. *Journal of Coastal Research* 10:987-1086. Health: FAO. 1998. *An El Niño Primer*. FAO Rome. (http://www.fao.org/). Jury, M.R. 1996. Malaria forecasting project. In *Workshop on Reducing Climate-Related Vulnerability in Southern Africa. Victoria Falls, Zimbabwe, October 1-4, 1996*. SADC/NOAA/NASA. NOAA, OGP, Silver Spring, MD, USA.

Uncertainty and Risk Analysis

Description	This approach can be applied through critical review of available literature and data or through data analysis using software programs. Uncertainty and risk analysis allows the user to address the errors and unknowns often associated with data and information used to evaluate climate change adaptation measures. A key element of uncertainty and risk analysis is defining the decision criterion that is most appropriate for the question at hand. Uncertainty and risk can be assessed qualitatively, using probability ratings such as slight, moderate, and high. Uncertainty can also be assessed quantitatively, using decision analysis tools (e.g., decision trees) or sensitivity analyses such as Monte Carlo analysis. This method is often used in conjunction with other assessment techniques.
Appropriate Use	This tool is an important step in any assessment of climate change adaptation measures. Quantitative analyses using decision theory or simulation techniques are most useful when evaluating the data used for benefit-cost or similar quantitative analyses.
Scope	All locations; all sectors; national or site-specific.
Key Output	Depending on the method used, a quantitative or qualitative estimate of the uncertainty or risk associated with data being used to evaluate an adaptation measure.
Key Input	Information and data used for other analyses of an adaptation measure.
Ease of Use	Relatively easy to apply.
Training Required	Requires an understanding of the policy objectives and adaptation measures being considered. Monte Carlo and other quantitative analyses require training in specific techniques and uses of statistical software.
Training Available	Contact Stratus Consulting for more information (see below).
Computer Requirements	IBM-compatible 286; Lotus 1-2-3 or Excel spreadsheet software; @Risk, Crystal Ball software applications.
Documentation	U.S. EPA. Guidelines for Preparing Economic Analyses. U.S. Environmental Protection Agency, Washington, DC. Available at http://yosemite.epa.gov/ee/epa/eed.nsf/webpages/Guidelines.html.
Applications	Used to help determine total programmatic effectiveness of the Global Environment Facility (GEF).
Contacts for Tools, Documentation, Technical Assistance	Joel Smith, Stratus Consulting, P.O. Box 4059, Boulder, CO 80306 USA; Tel: +1.303.381.8000; Fax: +1.303.381.8200; e-mail: jsmith@stratusconsulting.com; website: http://www.stratusconsulting.com/.
Cost	Documentation is free. Cost of analysis varies depending on type of analysis used; quantitative analyses are more time consuming and costly.
References	Brklacich, M. and B. Smit. 1992. Implications of changes in climatic averages and variability on food production opportunities in Ontario, Canada. *Climatic Change* 20:1-21. Katz, R.W. 2002. Techniques for estimating uncertainty in climate change scenarios and impact studies. *Climate Research* 20:167-185.

Estimating Adaptation Costs: M-CACES

Description	M-CACES, a Windows-based software program, is required by the U.S. Army Corps of Engineers for the preparation of water resources construction and rehabilitation cost estimates for projects with federal costs exceeding US$2 million. The Unit Price Book associated with M-CACES provides production rates, unit costs, and crew composition for the United States. Price escalation for inflation is used to adjust pricing to the project schedule and to fully fund the estimate.
Appropriate Use	Useful for estimating the costs of large natural resources construction projects (including dams, shoreline protection, and ecosystem rehabilitation). Best used for final rather than initial cost analyses due to the amount of time and data required to complete.
Scope	Designed for the United States, but can be adapted to other countries; multiple sectors; site-specific.
Key Output	Cost estimate for natural resources projects.
Key Input	Quantity take-offs from drawings, specifications and references.
Ease of Use	Requires extensive data on the costs associated with the project. Relatively easy to apply if data are available; more rigorous results require more analysis.
Training Required	Training is suggested to acquire skill in developing quality cost estimates and customizing databases for site-specific or project-specific elements.
Training Available	Building Systems Design (see Contacts below) offers monthly training classes.
Computer Requirements	IBM compatible computer with Windows 95 or later operating system.
Documentation	Supplemental construction cost information is published in USA by R.S. Means Company, Inc., Publishers & Consultants, +1.617.585.7880, or Dodge Cost Systems, McGraw Hill Information Systems Company, +1.800.544.2678.
Applications	Used as an internal tool by the U.S. Army Corps of Engineers to estimate construction and rehabilitation costs of water resources projects. Also used by the U.S. Department of Defense, the U.S. Department of Energy, and the U.S. Environmental Protection Agency.
Contacts for Tools, Documentation, Technical Assistance	*Tools and Documentation:* Roy Braden, Cost Engineering Branch, Headquarters, U.S. Army Corps of Engineers, USA; Tel: +1.202.761.1495; e-mail: Roy.E.Braden@usace.army.mil. *Technical Assistance:* Building Systems Design, Inc., 1175 Peachtree St., 100 Colony Square, Suite 1900, Atlanta, GA 30361 USA; Tel: +1.404.876.4700; Fax: +1.404.876.0006.
Cost	Cost of obtaining and running the model depends on scale of project.
References	None available.

Impacts Database

Description	The impacts database is a web-based database of climate / weather-related impacts as reported in the media. It enables the user to assess the impacts of a particular climatic event thereby enabling them to plan for future events of its kind.
Appropriate Use	The tool is useful in assessing what impacts may result from extreme weather events. It is not for use in distinguishing whether a particular weather event was a result of climate change
Scope	The majority of impacts documented in the impacts database are UK-based. However, there are certain instances of impacts outside of the UK.
Key Output	User-specified search results supplied in the form of a summary for each example plus the source of the full document.
Key Input	A user-specified sector or searchable field.
Ease of Use	Extremely easy to use.
Training Required	None.
Training Available	None.
Computer Requirements	Access to the internet.
Documentation	All documentation is supplied within the database.
Applications	Use in UKCIP presentations - this tool has only recently become available.
Contacts for Tools, Documentation, Technical Assistance	Anna Steynor, Scientific Officer, UK Climate Impacts Programme; e-mail: anna.steynor@ukcip.org.uk.
Cost	None.
References	None.

PAGE2002 (Policy Analysis for the Greenhouse Effect)

Description	PAGE2002 is a spreadsheet probabilistic model written in Excel with the @RISK add-in. The model calculates regional and global impacts of climate change, and social costs of different greenhouse gases. It also calculates the costs of abatement and adaptation. It is an Integrated Assessment Model starting from emission projections, and carrying uncertainties throughout the calculations.
Appropriate Use	The model is designed to explore the impacts and social costs under any user-specified emission scenarios. It can be used to calculate optimal abatements.
Scope	The model is global in scope, with a user-defined focus region. It calculates to 2200 by default.
Key Output	The model and the results obtained with it are the key outputs.
Key Input	Emission scenarios and about 80 parameter probability distributions covering both scientific and economic inputs.
Ease of Use	Designed to be transparent and easy to use.
Training Required	A single session with the model developer is all that is normally required.
Training Available	The model developer will offer advice and support under contract.
Computer Requirements	PC running Excel and @RISK.
Documentation	PAGE2002 is described in detail in Hope C, 2006, "The marginal impact of CO2 from PAGE2002: An integrated assessment model incorporating the IPCC's five reasons for concern", Integrated Assessment, 6, 1, 19-56.
Applications	Several analyses performed for the GB Office of Gas and Electricity Markets who paid for the development of the model. PAGE2002 was the main model used for the impact calculations in the UK Government's Stern report.
Contacts for Tools, Documentation, Technical Assistance	Dr Chris Hope, Judge Business School, University of Cambridge.
Cost	The model is free to use, on the condition that any publications resulting from the use of the model include Dr Chris Hope as an author. The model developer will provide advice and support under contract.

PAGE2002 (Policy Analysis for the Greenhouse Effect) (cont.)

References	Alberth, S. and C. Hope. 2007. Climate modelling with endogenous technical change: Stochastic learning and optimal greenhouse gas abatement in the PAGE2002 model. *Energy Policy* 35: 1795-1807. Dietz S, C. Hope and N. Patmore. 2007. Some Economics of 'Dangerous' Climate Change: Reflections on the Stern Review. *Global Environmental Change* 17(3-4):311-325. Dietz, S., C. Hope, N. Stern and D. Zenghelis. 2007. Reflections On The Stern Review (1), A Robust Case for Strong Action to Reduce the Risks of Climate Change. *World Economics* 8(1):121 - 168. Hope, C. and D. Newbery. 2007. Calculating the social cost of carbon. Chapter 2 of Grubb, M., T. Jamasb and M. Pollitt (eds.), *Delivering a Low Carbon Electricity System: Technologies, Economics and Policy*, Cambridge University Press. Hope, C. 2005. Integrated Assessment Models. Chapter 4 in Helm, D. (ed.), *Climate Change Policy*, Oxford University Press. Hope, C. 2006. The marginal impacts of CO2, CH4 and SF6 emissions. *Climate Policy* 6(5):537 - 544. Hope, C. 2006. The marginal impact of CO2 from PAGE2002: An integrated assessment model incorporating the IPCC's five reasons for concern. *Integrated Assessment* 6(1):19-56. Hope, C. 2006. The social cost of carbon: what does it actually depend on? *Climate Policy* 6(5):566 - 572. Hope, C. 2007. Discount rates, equity weights and the social cost of carbon. *Energy Economics*. Available online 12 January 2007 at www.sciencedirect.com. Hope, C. 2007. PAGE Modeling system. Chapter 2 of the Yale Symposium on the Stern Review, Yale Center for the Study of Globalization, http://www.ycsg.yale.edu/climate/stern.html. Wahba, M. and C. Hope. 2006. The marginal impact of carbon dioxide under two scenarios of future emissions. *Energy Policy* 34(17):3305-3316.

Resource Approach to Assessment of Climate Change Impact on Human Activity

Description	Resource approach allows decision makers to include information on climate conditions and their change directly in economic analysis. The climate resources estimation helps to represent spatial distribution of climate resources for given field of human activity and to evaluate total climate resources for concrete region and to compare them over the whole country. This methodology creates opportunities to compare climate resources for different economic sectors in various regions at present and in the future and to choose the regions that could be optimal for development of specific activity taking into account probable climate change. Particularly, this approach provides some tools to assess vulnerability of regions and economic sectors to climate change in terms of climate resources change. Resource approach involves 5 steps: (1) to select specific indexes of climate impact on objects and processes in a given economy sector, (2) to calculate these impact indexes both at present and for the future using results regional climate projections, (3) to convert climate impact indexes from initial physical units to relative (non-dimensional) units, (4) to estimate climate resource for a given economy sector in each region of the country, and (5) to compare climate resource values in different regions and choose the optimal ones.
Appropriate Use	Resource approach is relevant to decision makers who are responsible for regional planning of economic activity, strategic planning of a given economy sector, ensuring the sustainable development of the region's economy. This information can be also used for concrete applications including the estimation of economic value for land.
Scope	All regions, all economic sectors.
Key Output	The values of climate resources and evaluation of adaptation potential to climate change for various economic branches in all regions of a given country expressed in relative and monetary (for some sectors) units.
Key Input	Meteorological data for specific climate impact index calculations, results of regional climate projections.
Ease of Use	Relatively easy to apply, only basic computer skills are needed.
Training Required	Requires little training, but it requires expert knowledge to choose appropriate climate impact indexes.
Training Available	No formal training currently offered. Sources of assistance / consulting can be obtained from contacts listed below.
Computer Requirements	Personal computer.
Documentation	Encyclopedia of climate resources of Russia. 2005, 319 pp., Gidrometeoizdat, St. Petersburg.
Applications	Applications across a wide range of regions in Russian Federation in the following sectors: building construction, land use planning, power grid planning.
Contacts for Tools, Documentation, Technical Assistance	Nina Kobysheva, Voeikov Main Geophysical Observatory, 194021 Karbyshev Str. 7, St. Petersburg, Russian Federation; Tel: +7.812.2974390; Fax: +7.812.297.8661; e-mail: director@main.mgo.rssi.ru or kobyshnv@main.mgo.rssi.ru.
Cost	Depends on breadth of assessment.

Resource Approach to Assessment of Climate Change Impact on Human Activity (cont.)

References	Akentyeva, E.M. 2005. New approaches to the climate resource estimation. In Proceedings - *GCOS Regional Workshop for Eastern and Central Europe, Leipzig, Germany* [CD-ROM computer file]. Kobysheva, N.V. and O.B. Iljina. 2001. Methodology of climate resource estimation in Leningrad region. *Meteorology and climatology* 9:17-24. Kobysheva, N.V. 2005. Climate as a Natural Resource for Integrated Planning and Management. In Proceedings - *Technical Conference "Climate as a Resource", Beijing, China* [CD-ROM computer file].

Comprehensive Hazard and Risk Management (CHARM)

Description	CHARM is defined as a comprehensive hazard and risk management tool for use within an integrated national development planning process. It aims to facilitate greater collaboration between risk reduction projects at all levels (though mostly at the national level with participation from stakeholders for decision-making) and across sectors to enhance sustainable development. CHARM takes all hazards into account across the whole country.
Appropriate Use	This tool can be used for mainstreaming disaster risk reduction into ongoing national development planning processes. It aims to address all hazards including natural and human-induced, and also to help identify measures that can be implemented in all phases of disaster management (prevention, preparedness, response, and recovery). The emphasis is on bringing a wide range of stakeholders together for risk reduction to enhance effectiveness of the combined efforts.
Scope	National level.
Key Output	The immediate output of the CHARM process is to develop a matrix summarizing national risks and risk reduction measures (or "treatment options") that considers the activities of all agencies. Planners then target the gaps identified in the matrix. Step 1 – Context established Step 2 – Risks identified Step 3 – Risks analyzed Step 4 – Risks evaluated Step 5 – Risks treated and results evaluated
Key Input	Step 1 – Identification of national development priorities, organizational issues, and initial risk evaluation criteria Step 2 – Identification of hazard, vulnerable sectors, and impacts Step 3 – Assessment of risks with stakeholders based on agreed indicators, such as frequency of hazards, potential impacts, etc. Step 4 – Determination of acceptable levels of risks and priorities for action Step 5 – Selection of risk reduction measures; assignment of roles and responsibilities for all partners; evaluation against agreed criteria
Ease of Use	Readily usable by those with experience in policy analysis, developing work plans, and inter-agency planning.
Training Required	Knowledge of tools for each step is needed (e.g. to rank development challenges, develop budgets).
Training Available	Training is available through broad stakeholder consultation workshops involving both national and regional stakeholders. SOPAC has also developed a manual.
Computer Requirements	Word processing and spreadsheets
Documentation	SOPAC. 2001. Comprehensive Hazard Risk Management Regional Guidelines for Pacific Island Countries. Suva: South Pacific Applied Geosciences Commission. Guideline and manual available in print or on CD (see Contacts below).
Applications	CHARM has been used for planning in Palau, Kiribati, Vanuatu, Fiji, and Tonga, and it has also been aligned to the Joint Australia-New Zealand Risk Management Standard.
Contacts for Tools, Documentation, Technical Assistance	SOPAC Secretariat, Private Mail Bag, GPO, Suva, Fiji Islands; Tel: +679.338.1377; Fax: +679. 3370040. Atu Kaloumaira, Community Risk Programme Advisor; e-mail: atu@sopac.org. Noud Leenders, Community Risk Management Advisor; e-mail: noud@sopac.org.

Comprehensive Hazard and Risk Management (CHARM) (cont.)

Cost	Free.
References	See Documentation.

Community-Based Disaster Risk Management Field Practitioners' Handbook

Description	The handbook briefly explains the concept of community-based disaster risk management (CBDRM) and provides practical tools that can be applied in community-level programming. The Handbook is divided into four parts: (1) an introduction to CBDRM, (2) specific step-by-step exercises, (3) cross-cutting issues of gender and communication, and (4) disaster risks in Southeast Asia. The tools in Section 2 cover seven types of activities in CBDRM: (1) Selecting the community (2) Rapport building and understanding the community (3) Participatory disaster risk assessment (4) Participatory disaster risk management planning (5) Building/training a community disaster risk management organization (CDRMO) (6) Community-managed implementation (7) Participatory monitoring and evaluation The resource pack for risk identification (Step 3) includes instructions and guiding questions for the most commonly used participatory assessment tools, e.g. constructing timelines, hazard maps, rankings, and calendars.
Appropriate Use	This handbook is a comprehensive how-to guide that can be used to assist project teams working at the local level to ensure the participation of community members in reducing disaster risks. Each of the seven steps, particularly Step 3, is clearly outlined, along with simple instructions for group exercises, information to gather, and stakeholders to involve.
Scope	Community level.
Key Output	Overall: "The CBDRM process should lead to progressive improvements in public safety and community disaster resilience. It should contribute to equitable and sustainable community development in the long term." Step 1 – Priority vulnerable communities identified Step 2 – Trust between community and project members; understanding of community needs among project members Step 3 – Disaster risks identified and community members understand these risks Step 4 – Community disaster risk management plan Step 5 – CDRMO established and equipped with skills to implement their disaster risk management plan Step 6 – Planned activities implemented effectively and on time, with participation of stakeholders Step 7 – Appropriate indicators of program success developed and progress measured, with participation of stakeholders

Community-Based Disaster Risk Management Field Practitioners' Handbook (cont.)

Key Input	Step 1 – Information on various criteria developed by decision makers Step 2 – Information about the community and efforts to develop relationships/understanding with community members Step 3 – Range of qualitative and quantitative data about the hazards, vulnerabilities, and capacities in the community Step 4 – Dialogue among stakeholders to identify needed measures Step 5 – Identification of CDRMO members and training Step 6 – Responsibilities carried out by members; periodic reviews Step 7 – Range of qualitative and quantitative data about activities' impacts; dialogue between stakeholders
Ease of Use	Readily usable.
Training Required	Some training or experience in working at the local level would be useful.
Training Available	Contact Zubair Murshed at mzubair@adpc.net or adpc@adpc.net.
Computer Requirements	• None for community risk identification exercises • Word processing and spreadsheet skills for program planning and implementation, depending on complexity of local activities • GIS optional for community disaster risk assessment (Step 3)
Documentation	Abarquez, I. and Z. Murshed. 2004. Community-Based Disaster Risk Management: Field Practitioners' Handbook. Bangkok: Asian Disaster Preparedness Center. Can be downloaded from http://www.adpc.net/pdr-sea/publications/12Handbk.pdf.
Applications	This methodology has been used in several communities throughout South and Southeast Asia.
Contacts for Tools, Documentation, Technical Assistance	Information Manager, PDR SEA, Asian Disaster Preparedness Center (ADPC), P.O. Box 4, Klong Luang, Pathumthani 12120, Thailand; Tel: +66.2.516.5900 to 5910; Fax: +66.2.524.5360; e-mail: adpc@adpc.net; website: www.adpc.net.
Cost	Free.
References	Arcilla, M.J.D., Z.G. Delica et al. (eds.). 1998. 4B: Project Development, Monitoring and Evaluation in Disaster Situations. Quezon City, Philippines, Citizen's Disaster Response Center. Gutteling and Wiegman, 1996. Exploring Risk Communication: Advances in natural and technological hazards research, Kluwer Academic Publishers, Dordrecht, The Netherlands.

Guidelines for Emergency Assessment

Description	These guidelines provide advice on the organization of emergency assessments, starting with an introduction of key concepts and then outlining each step. The steps are roughly laid out in the order required during an assessment. The chapter on fieldwork notes some basic principles that should underlie activities, such as participation, inclusion or marginal groups, looking out for biases, etc. Results of the general assessment can indicate where more technical assessment is needed. The framework can be easily adapted to incorporate climate change issues as it provides fairly general guidelines on the assessment process.
Appropriate Use	Aimed at generalists in the Red Cross Red Crescent community conducting an assessment to provide an overview of the situation. The guidelines cover the following steps, some of which may overlap: (1) Planning (2) Office tasks (3) Fieldwork (organization and management) (4) Analysis (5) Reporting The chapter on fieldwork includes detailed descriptions of various types of information gathering exercises and issues to consider for each one, including tips on establishing trust, cultural sensitivities, suggested questions, and extensive checklists that were compiled by sector specialists. It gives very clear, easily understandable directions for carrying out activities. The chapter on analysis provides worksheets team members may use to synthesize information. These are largely based on IFRC's vulnerability and capacity framework (see References).
Scope	Local affected areas.
Key Output	• Planning – Determination of whether an assessment is needed, objectives and terms of reference, and type of assessment (rapid/detailed/continual). • Office tasks – Arrangements for coordination, required resources identified, team assembled and briefed, key locations identified. • Fieldwork – Sufficient information gathered in selected locations on issues identified during planning phase. • Analysis – Identification of the main problems, affected populations, and local capacity; recommendations for further action. • Reporting – Clear, concise reports following a recommended format: summary; background information; details and assumptions; needs, coping strategies, and assistance; program proposals.

Guidelines for Emergency Assessment (cont.)

Key Input	The guidelines recommend that each of these steps are generally undertaken sequentially, so that the output of the planning phase is used as an input to the office-based tasks, and so on. • Planning – Information from secondary sources on the nature of the emergency and urgency of an assessment • Office tasks – Objectives and terms of reference; information on potential team members' skills • Fieldwork – Secondary information, interviews with community members and authorities, group exercises, household visits, etc. • Analysis – Summaries of information that have been checked for consistency, discussion among team members. • Reporting – Results of the analysis.
Ease of Use	Readily usable by anyone conducting an assessment.
Training Required	None.
Training Available	Contact regional and country offices: http://www.ifrc.org/who/delegations.asp
Computer Requirements	None, although word processing and spreadsheets may be useful for analysis and reporting.
Documentation	IFRC. 2005. Guidelines for Emergency Assessment. Geneva: International Federation of the Red Cross and Red Crescent Societies.
Applications	Based on IFRC's experience in conducting assessments following disasters around the world.
Contacts for Tools, Documentation, Technical Assistance	International Federation of Red Cross and Red Crescent Societies, PO Box 372, CH-1211, Geneva 19, Switzerland; Tel: +41.22.730.4222; Fax: +41.22.733.0395; e-mail: secretariat@ifrc.org; website: www.ifrc.org.
Cost	Free.
References	IFRC. 1999. Code of conduct for the International Red Cross and Red Crescent Movement and Non-Governmental Organizations in Disaster Relief. Geneva: International Federation of the Red Cross and Red Crescent Societies, http://www.ifrc.org/publicat/conduct/code.asp. IFRC. 1999. Vulnerability and capacity assessment: an International Federation guide. Geneva: International Federation of the Red Cross and Red Crescent Societies, http://www.ifrc.org/what/disasters/dp/planning/vcaguidelines.asp . IFRC. 2000. Better Programming Initiative: options for better aid programming in post-conflict settings. Geneva: International Federation of the Red Cross and Red Crescent Societies. Sphere Project. 2003. Humanitarian Charter and Minimum Standards in Disaster Response. Geneva: Sphere Project, http://www.sphereproject.org/handbook/index.htm.

Guidelines on Climate Watches

Description	These guidelines describe how to establish a climate watch system and the information required in a climate watch. Governments typically react to extreme climate events through "crisis management" rather than through continuous risk reduction. Decision makers have cited the lack of information about approaching climate hazards with sufficient notice to take action. Climate watches aim to deliver this necessary, accurate information to end-users through the National Meteorological Services (NMSs) in a timely and useful manner.
Appropriate Use	This tool targets "the special situation and needs of smaller NMSs, which have limited resources" in establishing the system and issuing climate watches. The process is based on continuous collaboration with climate information users, and it should serve as a mechanism to initiate preparedness activities to limit impacts from climate anomalies (e.g. excessive rainfall over several months). The guidelines discuss the rationale for a climate watch system, current activities and capacity in NMSs, characteristics and operation of a climate watch system, format and criteria for issuing a climate watch, and various annexes, including examples of climate watches. Climate watch format: • A standard heading, issuing authority, and time and date of issue • Areas for which the advice is current (the appropriate regions) • Period during which the climate watch is valid • Where appropriate, an indication of the reason for the climate watch, which may include graphical information • Relevant skill of long range forecasts • Possible follow-on effects of the climate anomaly • Date at which the next update will be issued
Scope	National level; meteorological services.
Key Output	Information about significant climate anomalies for the forthcoming season(s) that may have substantial impacts on a sub-national scale. (1) Establishment of national climate watch system (2) Capacity built for the climate watch system (3) Operation of national climate watch (4) Climate watch system evaluated
Key Input	• A network of observation stations; an understanding of the current and recent past climate of the region in question; linkage with regional/global monitoring systems; dissemination channels to reach users; partnerships with key stakeholders • Understanding of users' needs; criteria for issuing a Climate Watch defined (e.g. average rainfalls below a certain level for the season); technical training; strengthening of communication links • Monitoring and analysis of climate data; communication with other organizations that maintain their observation systems; communication with intermediaries to translate information for user groups • Periodic reviews of the system and process; dialogue with users on their needs to identify gaps in dissemination or content
Ease of Use	Usable by national meteorological services.
Training Required	Requires expertise in meteorology/climatology and understanding of climate information users' needs.

Guidelines on Climate Watches (cont.)

Training Available	See Contacts.
Computer Requirements	Software for forecasting and word processing.
Documentation	WMO. 2005. Guidelines on Climate Watches. Geneva: World Meteorological Organization.
Applications	None identified.
Contacts for Tools, Documentation, Technical Assistance	Omar Baddour, Chief, World Climate Data and Monitoring Programme, WMO, 7bis Ave. de la Paix, C.P. 2300, CH-1211, Geneva 2, Switzerland; Tel: 41.22.730.8268 or 41.22.730.8214; Fax: 41.22.730.8042; e-mail: obaddour@wmo.ch.
Cost	Free.
References	Technical documents published under the WMO World Climate Data and Monitoring Programme (WCDMP).

Handbook for Estimating the Socio-Economic and Environmental Effects of Disasters

Description	One of the problems following disasters is that damaged areas are often reconstructed quickly and without adequate resources. The result is that vulnerability is reconstructed rather than reduced. This tool helps to assess the direct and indirect socio-economic impacts of disasters, and to identify the most affected areas and priority areas for recovery. It outlines the conceptual and general methodological aspects of estimating the asset damage, losses in the flows of goods and services, as well as any effects on the macroeconomy. The handbook is divided into five sections: 1. Methodological and conceptual framework 2. Assessing impacts in social sectors 3. Assessing impacts on infrastructure 4. Assessing impacts in economic sectors 5. Assessing impacts in cross-sectoral areas, such as the environment, gender, and employment
Appropriate Use	This type of assessment should follow the emergency phase of a man-made or natural disaster, so it will not interfere with urgent humanitarian activities. Sufficient quantitative information on damages is also more likely to be available after that period. The tool is good for organizations that want to understand a wider range of disaster risks. By assessing the direct and longer-term indirect socio-economic impacts, organizations then have a better idea of how to reduce the risks in future programs that may have development or environmental goals. The tool can be adapted to comprehensively assess socio-economic impacts of climate change. Sections 2-5 include a definition of the sector, an overview of likely direct and indirect damages, the quantitative and qualitative information needed, possible information sources, general instructions on analyzing the data, and issues to consider in assessing macroeconomic impacts arising from damages in that sector. It is not a step-by-step guide, but rather gives an overview of general steps to be taken in each assessment.
Scope	National or sub-national level; sectoral.
Key Output	A measurement, summarized in table form and in monetary terms where possible, of the impacts of disasters on the society, economy and environment of the affected country or region. Results are divided into direct, indirect and macroeconomic effects (employment, the balance of payments, public finances, and prices and inflation). The disaster may also have benefits, so the assessment refers to the net effect. The assessment identifies the key geographical areas and sectors affected, together with corresponding reconstruction priorities. It can provide a way to estimate the country's capacity to undertake reconstruction on its own and the extent to which financial and technical cooperation are needed. For the longer term, it may identify the public policy changes and development programs to address these needs.
Key Input	Quantitative and qualitative information on conditions both before and following the disaster. The assessment team must decide on the balance between precision and speed in conducting the assessment. "Shadow prices" may be used to try to take into account the indirect effects and externalities of disasters.
Ease of Use	Experience with economic valuation and assessing damage in specific sectors required. The use of market vs. social prices will depend on the availability of information and time to conduct the assessment.
Training Required	Specialist knowledge in each sector.

Handbook for Estimating the Socio-Economic and Environmental Effects of Disasters (cont.)

Training Available	Instituto Latinoamericano y del Caribe de Planificación Económica y Social (ILPES), ECLAC's training division, offers courses on various economic and social issues of the region. ILPES, Av. Dag Hammarskjöld 3477, Vitacura, Casilla 179-D, Santiago, Chile; Tel: +56.2.210.2506/7; Fax: +56.2.206.6104; e-mail: cursosilpes-cepal@eclac.cl.
Computer Requirements	Various software programs are recommended for some assessments, e.g. Redatam by CELADE (see References) or other GIS programs (ArcView, MapInfo, IDRISI, or GISMAP)
Documentation	ECLAC. 2003. Handbook for Estimating the Socio-Economic and Environmental Effects of Disasters. Santiago, Chile: Economic Commission for Latin America and the Caribbean. www.proventionconsortium.org/toolkit.htm Hardcopies available at: ECLAC Publications, Casilla 179D, Santiago, Chile; Fax: +56.2.210.2069; e-mail: publications@eclac.cl.
Applications	The handbook has been used throughout Latin America and the Caribbean. Assessments following the Indian Ocean disaster also used the methodology, particularly in the cases of Indonesia and India.
Contacts for Tools, Documentation, Technical Assistance	Ricardo Zapata-Martí, Focal Point for Disaster Evaluations, Economic Commission for Latin America and the Caribbean, Av. Presidente Masaryk 29, 11570 México, D.F., Apartado Postal 6-718, México D.F.; Tel: +52.55.5263.9600; Fax: +52.55.5531.1151; e-mail: cepal@un.org.mx , izapata@un.org.mx.
Cost	Free.
References	Redatam software: http://www.eclac.cl/redatam/default.asp?idioma=IN The Handbook, sample reports, and case studies: http://siteresources.worldbank.org/INTDISMGMT/Resources/guidelines.htm

Natural Disaster Mitigation in Drinking Water and Sewerage Systems: Guidelines for Vulnerability Analysis

Description	These guidelines provide the basic tools to evaluate the vulnerability of a drinking and sewerage system to various natural hazards. These systems are vital to development, as well as to ensuring a return to normalcy following a disaster. Conducting this vulnerability analysis helps identify preparedness and mitigation measures to limit risks. It also identifies the response mechanisms that should be put into action in the event of a disaster. The risk of damage to water systems increases with factors such as uncontrolled growth in urban areas, deficiencies in infrastructure, and climate change. The guide is divided into four sections: (1) Planning (2) Principles of vulnerability analysis (3) Description of hazards and impacts (4) Conducting a vulnerability analysis for specific hazards
Appropriate Use	The tool is ideally used during the disaster preparedness phase to identify and implement mitigation measures. It is aimed at engineers and technical personnel of water service companies to project how the water systems will perform in the event of the disaster and to minimize damage. Vulnerability and probabilities of damage are expressed as various formulae. The guide provides an overview for each section with issues to consider at each step. It also includes checklists (e.g. characteristics of an emergency operations center and the emergency committee; components of an emergency response plan), matrices to describe system vulnerabilities (formats provided in annexes), and extensive information on impacts on water systems from earthquakes, volcanoes, hurricanes, floods, etc. in Chapter 3 and annexes.
Scope	Water systems (with coverage being sub-national, municipal, etc.)
Key Output	• Planning – Emergency committee established within the water company, with roles and responsibilities defined; emergency operations center established; partnerships with national organizations established. • Vulnerability analysis – Identification and quantification of deficiencies in the physical system and the organization’s capacity to provide services in a disaster; strengths of the physical system and the organization identified; recommendations for mitigating disaster impacts. • Mitigation and emergency response plans for administration/operational aspects – Identification of roles and responsibilities, resources required, and measures to reduce vulnerability. Measures may include: improvements in communication systems, provision of auxiliary generators, frequent line inspections, detection of slow landslides, repair of leaks and planning for emergency response. • Mitigation and emergency response plans for physical aspects – Identification of roles and responsibilities, resources required, and measures to reduce vulnerability. Measures may include: retrofitting, substitution, repair, placement of redundant equipment, improved access, etc.

Natural Disaster Mitigation in Drinking Water and Sewerage Systems: Guidelines for Vulnerability Analysis (cont.)

Key Input	• Planning – Information on: national standards, institutional coordination, and resources available for preparedness and response; and dialogue with partners • Vulnerability analysis – Information on: organizational and legal aspects, availability of resources, hazards and likely impacts on the water system, current state of system and operating requirements, sensitivity of components to hazards, and the response capacity of the services. • Mitigation and emergency response plans – Information from the vulnerability analysis, priorities for implementing measures, and resources available.
Ease of Use	Can be used as an overview for the emergency committee, although the vulnerability analysis should be conducted by a team of specialists.
Training Required	Vulnerability analysis requires extensive experience in the design, operation, maintenance, and repair of a drinking water and sewerage system's components.
Training Available	The Virtual Campus of Public Health is a consortium of institutions led by PAHO/WHO for continuing education. http://www.campusvirtualsp.org/eng/index.html.
Computer Requirements	Various specialized software, word processing, and spreadsheets.
Documentation	PAHO. 1998. Natural Disaster Mitigation in Drinking Water and Sewerage Systems: Guidelines for Vulnerability Analysis. Washington, DC: Pan American Health Organization, Regional Office of the World Health Organization, http://www.paho.org/English/DD/PED/natureng.htm.
Applications	Used throughout Latin America and the Caribbean. Case study in documentation from Limon, Costa Rica, to assess earthquake vulnerability.
Contacts for Tools, Documentation, Technical Assistance	Emergency Preparedness and Disaster, Relief Coordination Program, Pan American Health Organization, 525 Twenty-third Street, N.W., Washington, D.C. 20037, USA; Fax:+1.202.775.4578; e-mail: disaster@paho.org. Contact lists for the Americas during a disaster: http://www.paho.org/english/DD/PED/contactos.htm
Cost	Free.
References	Bibliography available in document.

The Good Practice Guide: Community Awareness and Education in Emergency Management

Description	During the emergency period, a well-prepared community can reduce the impacts from the disaster. Community members often play a large role in providing relief for each other. This tool presents best practices, ideas, plans, and suggestions for educating the community on disaster preparedness, rather than a how-to guide on communications. The broad framework can be easily adapted for specific communities. The guide provides the following information: 1. Introduction to the issue and how to get people's attention 2. Planning a campaign, with information on a range of communication tactics 3. Evaluating a campaign 4. Working with the media, partners and sponsors, and the community 5. Information resources
Appropriate Use	The guide aims to assist in planning and implementing community awareness and education campaigns. It is aimed at local government authorities, health services, police, fire services, schools, and other community organizations. It lays out the basic steps of an awareness campaign, describes communication tactics (e.g. print/electronic communications, giveaways, special events, etc.), and outlines a method for evaluating the campaign's performance.
Scope	Local level
Key Output	Step 1 – Target audience identified Step 2 – Target audience's needs and wants identified Step 3 – Key message developed Step 4 – Measurable objectives identified Step 5 – Tactics chosen Step 6 – Required resources secured Step 7 – Awareness and education campaign implemented Step 8 – Awareness and education campaign evaluated and documented results available
Key Input	Step 1 – Information on vulnerable groups and potential partners in reaching them Step 2 – Discussions with community representatives and members; review of existing sources of information (newspapers, radio, etc.) Step 3 – Identification of hazards and priority messages Step 4 – Development of campaign objectives and concrete indicators to measure changes Step 5 – Identification of effective information sources and delivery methods for the target audience, as well as the required resources Step 6 – Partnerships developed; information on available staff and financial resources Step 7 – Commitment of staff and volunteers; definition of roles, responsibilities, and a timetable for activities Step 8 – Review of the campaign against indicators, e.g. through surveys, observation, or discussions
Ease of Use	Readily usable.
Training Required	None.
Training Available	See Contacts below.

The Good Practice Guide: Community Awareness and Education in Emergency Management (cont.)

Computer Requirements	None.
Documentation	EMA. 2000. The Good Practice Guide: Community awareness and education in emergency management. Canberra: Emergency Management Australia. http://www.crid.or.cr/digitalizacion/pdf/eng/doc12728/doc12728.htm
Applications	Based on EMA's experience in Australia, but easily adaptable to other contexts.
Contacts for Tools, Documentation, Technical Assistance	Emergency Management Australia, PO Box 1020 Dickson, Australian Capital Territory 2602, Australia; Tel: 61.2.6256.4600; Fax: 61.2.6256.4653; e-mail: ema@ema.gov.au.
Cost	Free.
References	References included in document on case studies, additional methodologies, communication tips, etc. Documents on local risk management, community education, community preparedness, and related sites (mostly in Spanish): http://www.crid.or.cr/crid/MiniKitCommunityParticipation/documentos_interes_participacion_comunitaria_ing.html#capacitacion EMA publications on community evacuation coordination, flood warnings, and other response activities at: www.ema.gov.au

4. Sector-Specific Tools

The tools described in this section of the compendium are examples of tools that an analyst might consider employing within a given sector and tend to be applicable to only one sector. However, the tools described in each section here should by no means be considered a comprehensive listing of tools that are available. The following sectors are included: agriculture, water, coastal resources, and human health.

4.1 Agricultural Sector Tools

The agricultural sector tools described in this compendium, listed in Table 4.1, range from sector-wide economic analyses to farm-level crop models. The crop process models address the impact of various management and climate change scenarios on single crops (e.g., WOFOST, ICASA, ALFALFA, ORYZA), multiple crops (e.g., APSIM), and entire ecosystems (e.g., CENTURY). Other tools can be used to examine particular ecological factors or processes (e.g., ACRU) or support bigger picture strategic adaptation decisions (e.g., MAACV, RRI, CLOUD, CRAM). The economic models (e.g., Ricardian analysis and input-output accounting) assist the user in evaluating the economic impacts of changing land values, supply and demand, and commodity production resulting from climate change. There are substantially more agricultural sector tools than there are tools in other sectors. This is because many agricultural models are crop specific or are applicable only to particular regions, whereas models in other sectors tend to be more generally applicable.

Table 4.1. Tools covered in agricultural sector

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
Model of Agricultural Adaptation to Climatic Variation (MAACV)
Relative Risk Index (RRI)
Government Support in Agriculture for Losses due to Climatic Variability
AgroMetShell
Agroclimatic Water Stress Mapping
Local Climate Estimator (New_LocClim)
FAOClim 2.0
CLIMWAT 2.0
CM Box
CLOUD (Climate Outlooks and Agent-based Simulation of Adaptation in Africa)
CRAM (Canadian Regional Agriculture Model)
Process Crop Models: Decision Support System for Agrotechnology Transfer (DSSAT) developed under the International Consortium for Agricultural Systems Applications (ICASA)
Process Crop Models: General-Purpose Atmospheric Plant Soil Simulator (GAPS 3.1)
Process Crop Models: Erosion Productivity Impact Calculator (EPIC)
Irrigation Model: CROPWAT
Irrigation Model: AquaCrop
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)

APSIM (Agricultural Production Systems sIMulator)

Description	APSIM is a modeling framework with the ability to integrate models derived in fragmented research efforts. This enables research from one discipline or domain to be transported to the benefit of some other discipline or domain. It also facilitates comparison of models or submodels on a common platform. This functionality uses a "plug-in-pull-out" approach to APSIM design. The user can configure a model by choosing a set of submodels from a suite of crop, soil, and utility modules. Any logical combination of modules can be simply specified by the user "plugging in" required modules and "pulling out" any modules no longer required. Its crop simulation models share the same modules for the simulation of the soil, water, and nitrogen balances. APSIM can simulate more than 20 crops and forests (e.g., alfalfa, eucalyptus, cowpea, pigeonpea, peanuts, cotton, lupin, maize, wheat, barley, sunflower, sugarcane, chickpea, tomato). APSIM outputs can be used for spatial studies by linking with geographic information systems (GIS).
Appropriate Use	The APSIM environment is an effective tool for analyzing whole-farm systems, including crop and pasture sequences and rotations, and for considering strategic and tactical planning. APSIM allows users to improve understanding of the impact of climate, soil types, and management on crop and pasture production. It is a powerful tool for exploring agronomic adaptations such as changes in planting dates, cultivar types, fertilizer/irrigation management, etc.
Scope	Site-specific but can be extrapolated to national and regional levels using GIS.
Key Output	Changes in crop and pasture yields, yield components, soil erosion losses, for different climate change scenarios.
Key Input	Soil properties, daily climate data, cultivar characteristics, and agronomic management.
Ease of Use	For trained agronomists. Requires advanced knowledge of plant growth and soil processes.
Training Required	APSIM training takes approximately one week to acquire minimum skills to conduct simple simulations.
Training Available	Training courses are offered by APSRU (see Contacts below).
Computer Requirements	Windows-based PC.
Documentation	Available at: http://www.apsim.info/apsim/Publish/Docs/Documentation.xml.
Applications	Used in Australia, APN projects in Asia, and AIACC activities in South America.
Contacts for Framework, Documentation, Technical Assistance	Christopher Murphy, APSRU, PO Box 102, Toowoomba, QLD, 4350, Australia; Tel: +61.07.4688.1394; e-mail: Christopher.Murphy@dpi.qld.gov.au. Support desk: http://www.apsim.info/apsim/default.asp.
Cost	Not identified.

APSIM (Agricultural Production Systems sIMulator) (cont.)

References	Keating, B.A., P. S. Carberry, G. L. Hammer, M. E. Probert, M. J. Robertson, D. Holzworth, N. I. Huth, J. N. G. Hargreaves, H. Meinke, Z. Hochman, G. McLean, K. Verburg, V. Snow, J. P. Dimes, M. Silburn, E. Wang, S. Brown, K. L. Bristow, S. Asseng, S. Chapman, R. L. McCown, D. M. Freebairn and C. J. Smith. 2003. An overview of APSIM, a model designed for farming systems simulation. *European Journal of Agronomy* 18(3-4):267-288.
	McCown, R.L., G.L. Hammer, J.N.G. Hargreaves, D.P. Holzworth, and D.M. Freebairn. 1996. APSIM: A novel software system for model development, model testing and simulation in agricultural systems research. *Agricultural Systems* 50:255-271.
	Yunusa, I.A.M., W.D. Bellotti, A.D. Moore, M.E. Probert, J.A. Baldock and S.M. Miyan. 2004. An exploratory evaluation of APSIM to simulate growth and yield processes for winter cereals in rotation systems in South Australia. *Australian Journal of Experimental Agriculture* 44(8):787–800.

WOFOST

Description	WOFOST simulates the daily growth of a specific crop, given the selected weather and soil data. Each simulation is conducted for selected specific boundary conditions, which comprise the crop calendar and the soil's water and nutrient status. WOFOST follows the hierarchical distinction between potential and limited production. Light interception and CO_2 assimilation are the growth driving processes, and crop phenological development is the growth controlling process. WOFOST can be used to estimate crop production, indicate yield variability, evaluate effects of climate changes or soil fertility changes, and determine limiting biophysical factors. The following crop models are available: wheat, grain maize, barley, rice, sugar beet, potato, field bean, soybean, oilseed rape, and sunflower.
Appropriate Use	WOFOST considers only ecological factors under the assumption that optimum management practices are applied.
Scope	WOFOST is one-dimensional, mechanistic, and site-specific. Its application to regions relies on the selection of representative points, followed by spatial aggregation or interpolation (e.g., linked to a GIS).
Key Output	Crop yield and variability for different climate change scenarios.
Key Input	Rainfall, temperature, wind speed, global radiation, air humidity, soil moisture content at various suction levels, and data on saturated and unsaturated water flow. Data on site-specific soil and crop management.
Ease of Use	For trained agronomists.
Training Required	No formal training required, but advanced knowledge of plant growth and soil processes is needed.
Training Available	Training and support is available for a fee.
Computer Requirements	Windows-based PC.
Documentation	Hijmans R.J., I.M. Guiking-Lens, and C.A. van Diepen. 1994. WOFOST 6.0: User's Guide for the WOFOST 6.0 Crop Growth Simulation Model. Technical Document 12. ISSN 0928-0944. DLO Winand Staring Centre, Wageningen, The Netherlands.
Applications	WOFOST has been used to study the impact of climate change on crop yield potentials and water use in the Rhine basin. WOFOST has also been incorporated in the European Crop Growth Monitoring System (CGMS) of the MARS project (Monitoring Agriculture with Remote Sensing).
Contacts for Framework, Documentation, Technical Assistance	Kees van Diepen, Department of Land Evaluation Methods, The Winand Staring Centre for Integrated Land, Soil and Water Research (SC-DLO), Marijkeweg 11/22 P.O. Box 125, 6700 AC Wageningen, The Netherlands; Tel: +31.317.474230; e-mail: diepen@sc.dlo.nl.
Cost	Not identified.

WOFOST (cont.)

References	Boogaard, H.L., C.A. van Diepen, R.P. Rötter, J.M.C.A. Cabrera, and H.H. van Laar. 1998. User's Guide for the WOFOST 7.1 Crop Growth Simulation Model and WOFOST Control Center 1.5. DLO-Winand Staring Centre, Wageningen, Technical Document 52. Eitzinger, J., M. Trnka, J. Hösch, Z. Žalud and M. Dubrovský. 2004. Comparison of CERES, WOFOST and SWAP models in simulating soil water content during growing season under different soil conditions. *Ecological Modelling* 171(3):223-246. Supit, I., A.A. Hooijer, and C.A. van Diepen (eds.). 1994. System Description of the WOFOST 6.0 Crop Simulation Model Implemented in CGMS. Volume 1: Theory and Algorithms. Catno: CL-NA-15956-EN-C. EUR 15956, Office for Official Publications of the European Communities, Luxembourg.

ACRU (Agricultural Catchments Research Unit)

Description	The ACRU model has its origins in a catchment evapotranspiration based study carried out in Natal in the early 1970s. The agrohydrological component of ACRU first came to the fore during research on an agrohydrological and agroclimatological atlas for Natal. ACRU is a multipurpose model that integrates water budgeting and runoff components of the terrestrial hydrological system with risk analysis, and can be applied in crop yield modeling, design hydrology, reservoir yield simulation and irrigation water demand/supply, regional water resources assessment, planning optimum water resource allocation and utilization, climate change, land use and management impacts, and resolving conflicting demands on water resources. The ACRU model uses daily multilayer soil water budgeting and has been developed essentially into a versatile total evaporation model. It has therefore been structured to be highly sensitive to climate and to land cover/use changes on the soil water and runoff regimes, and its water budget is responsive to supplementary watering by irrigation, to changes in tillage practices, or to the onset and degree of plant stress.
Appropriate Use	ACRU can be used at the catchment or subcatchment level to study the impact of climate change and enhanced CO_2 conditions on crop yield and water balances.
Scope	ACRU can operate as site-specific or as a lumped small catchments model. However, for large catchments or in areas of complex land uses and soils, ACRU can operate as a distributed cell-type model.
Key Output	Crop yield and water balances (including irrigation needs, runoff, etc.) for different climate change scenarios.
Key Input	Weather data: maximum and minimum temperatures, rainfall. Catchment: location, area, configuration, altitude. Other data: land cover, soil properties (texture, depth).
Ease of Use	For trained hydrologists and agronomists.
Training Required	No formal training required, but advanced knowledge of plant and soil processes as well as hydrology is needed.
Training Available	Training and support is available from the School of Bioresources Engineering and Environmental Hydrology, University of Natal, Pietermaritzburg, South Africa.
Computer Requirements	Windows-based PC.
Documentation	Smithers, J. and R. Schulze. 1995. ACRU: Hydrological Modelling System . User Manual Version 3. Available at: http://www.beeh.unp.ac.za/acru.
Applications	ACRU has been used to assess the potential impact of elevated CO_2 and temperature levels and possible changes in precipitation and potential evaporation on crop and runoff production in southern Africa. The model has also been used to study shifts in maize production regions in southern Africa as a consequence of global climate change. A version of ACR linked to the CERES Maize model was used to simulate possible changes in maize production under different fertilizer scenarios over southern Africa.
Contacts for Framework, Documentation, Technical Assistance	Professor Roland E Schulze. School of Bioresources Engineering and Environmental Hydrology, University of Natal, Private Bag X01, Scottsville 3209, Pietermaritzburg, South Africa; Tel: 033.260.5490; e-mail: schulzeR@nu.ac.za.

ACRU (Agricultural Catchments Research Unit) (cont.)

Cost	Not identified.
References	Schulze, R.E., G. Kiker, and R.P. Kunz. 1993. Global climate-change and agricultural productivity in Southern Africa. *Global Environmental Change* 3:330-349. Schulze, R. 1989. ACRU: Background, Concepts and Theory. Report 35, Agricultural Catchments Research Unit, Department of Agricultural Engineering, University of Natal, Pietermaritzburg, South Africa. Tarboton, K.C. and R.E. Schulze. 1991. The ACRU modeling system for large catchment water resources management. *Int. Assoc. Hydrol. Sci. Publ.* 201:219-232.

Process Soil and Crop Models: CENTURY

Description	The CENTURY version 5 agroecosystem model is the latest version of the soil organic model developed by Parton et al. (1987). This model simulates C, N, P, and S dynamics through an annual cycle over time scales of centuries and millennia. The producer submodel may be a grassland/crop, forest or savanna system, with the flexibility of specifying potential primary production curves representing the site-specific plant community. CENTURY was especially developed to deal with a wide range of cropping system rotations and tillage practices for system analysis of the effects of management and global change on productivity and sustainability of agroecosystems. Note: CENTURY is also described under terrestrial vegetation.
Appropriate Use	To study the impact of climate change on net primary production (crops, pastures, forests) as well as carbon and nutrient dynamics (including carbon sequestration), and to explore adaptive agricultural and natural resource management options (tillage, fertilizer, different species and sequences, etc.).
Scope	Site-specific but has been used at watershed, drainage basin, and regional scales using GIS.
Key Output	Changes in soil carbon and nutrient balances, as well as in crop, pasture and forest production, for different climate change scenarios.
Key Input	Monthly average maximum and minimum air temperature; monthly precipitation; soil texture; plant nitrogen; phosphorus and sulfur content; lignin content of plant material; atmospheric and soil nitrogen inputs; initial soil carbon; nitrogen (phosphorus and sulfur optional).
Ease of Use	For trained agronomists and ecologists. Requires advanced knowledge of soil and plant growth processes.
Training Required	CENTURY basic training requires at least 1-2 weeks to acquire minimum skills to conduct simple simulations.
Training Available	Training is offered at NREL, Colorado State University (see Contacts below).
Computer Requirements	PC-based stand alone version, Linux cluster for regional simulations.
Documentation	http://www.nrel.colostate.edu/projects/century5/. http://www.nrel.colostate.edu/projects/century5/reference/index.htm.
Applications	CENTURY has been used in the Loch Vale Watershed Project, a long-term research program designed to assess the effect of global climate change on the Front Range of the Colorado Rockies. Specifically, CENTURY was used to assess the abiotic and biotic controls on forest distribution and productivity as a basis for assessing potential vegetation change for projected climate scenarios.
Contacts for Framework, Documentation, Technical Assistance	Dr William Parton, NREL at Colorado State University, 1499 Campus Delivery Fort Collins, CO 80523-1499, USA; Tel: 970.491.1987; e-mail: billp@nrel.colostate.edu. Cindy Keough, Natural Resource Ecology Laboratory, Colorado State University, Fort Collins, CO 80523-1499 USA; Tel: 970.491.2195; Fax: 970.491.1965; e-mail: cindyk@nrel.colostate.edu.

Process Soil and Crop Models: CENTURY (cont.)

Cost	Not identified.
References	See http://nrel.colostate.edu/projects/century5/reference/html/bibliography.htm#parton1987 for more references. Hall, D.O., J.M.O. Scurlock, D.S. Ojima, and W.J. Parton. 2000. Grasslands and the global carbon cycle: Modelling the effects of climate change. In *The Carbon Cycle*. T.M.L. Wigley and D.S. Schimel (eds.). Cambridge University Press, Cambridge, UK, pp. 102-114. Kelly, R.H., W.J. Parton, G.J. Crocker, P.R. Grace, J. Klír, M. Körschens, P.R. Poulton, and D.D. Richter. 1997. Simulating trends in soil organic carbon in long-term experiments using the Century model. *Geoderma* 1258. Melillo, J.M., J. Borchers, J. Chaney, H. Fisher, S. Fox, A. Haxeltine, A. Janetos, D.W. Kicklighter, T.G.F. Kittel, A.D. McGuire, R. McKeown, R. Neilson, R. Nemani, D.S. Ojima, T. Painter, Y. Pan, W.J. Parton, L. Pierce, L. Pitelka, C. Prentice, B. Rizzo, N.A. Rosenbloom, S. Running, D.S. Schimel, S. Sitch, T. Smith, and I. Woodward. 1995. Vegetation/ecosystem modeling and analysis project: comparing biogeography and biogeochemistry models in a continental-scale study of terrestrial ecosystem responses to climate change and CO_2 doubling. *Global Biogeochemical Cycles* 9:407-437. Ojima, D.S., W.J. Parton, D.S. Schimel, T.G.F. Kittel, and J.M.O. Scurlock. 1993. Modeling the effects of climatic and CO_2 changes on grassland storage of soil C. *Water, Air, and Soil Pollution* 70:643-657. Parton, W.J., D.S. Schimel, C.V. Cole and D.S. Ojima. 1987. Analysis of factors controlling soil organic matter levels in Great Plains grasslands. *Soil Science Society of America Journal* 51:1173-1179. Parton, W.J., D.S. Schimel, D.S. Ojima, and C.V. Cole. 1994. A general model for soil organic matter dynamics: sensitivity to litter chemistry, texture and management. Pages 147-167 *in* Bryant, R. B. and R.W. Arnold (eds.). Quantitative modeling of soil forming processes. SSSA Spec. Publ. 39. ASA, CSSA and SSA, Madison, WI, USA.

ORYZA 2000

Description	ORYZA 2000 is the successor to a series of rice growth models. It is an update and integration of the models ORYZA1 for potential production, ORYZA-W for water-limited production, and ORYZA-N for nitrogen-limited production. The model combines several modules: aboveground crop growth, evapotranspiration, nitrogen dynamics, soil-water balance, and others.
Appropriate Use	To study the impact of climate change rice yields and to explore adaptive management options (fertilizer, cultivar type, irrigation strategy, sowing date, etc.).
Scope	Site-specific, but can be used at regional scales using GIS.
Key Output	Rice yield for different climate change scenarios.
Key Input	Daily climate data (irradiation or sunshine hours, minimum temperature, maximum temperature, early morning vapor pressure, mean wind speed, and precipitation), soil properties, and crop management.
Ease of Use	For trained agronomists. Requires advanced knowledge of plant growth processes.
Training Required	ORYZA 2000 training requires 1-2 weeks to acquire minimum skills to conduct simple simulations.
Training Available	Training is offered online at: http://www.knowledgebank.irri.org/oryza2000/whgdata/whlstt0.htm
Computer Requirements	Windows-based PC.
Documentation	Available at: http://www.knowledgebank.irri.org/oryza2000/.
Applications	Detailed physiological analysis of field experiments, estimation of crop performance and crop management optimization for a given biophysical environment (climate, soil), including expected climate change, breeding and germplasm evaluation.
Contacts for Framework, Documentation, Technical Assistance	Dr. B.A.M. Bouman, Crop, Soil and Water Sciences Division, International Rice Research Institute (IRRI), DAPO Box 7777, Metro Manila, Philippines; e-mail: b.bouman@cgiar.org. H.H. van Laar, Crop and Weed Ecology Group, Wageningen University and Research Centre (WUR), P.O. Box 430, 6700 AK Wageningen, The Netherlands; e-mail: gon.vanlaar@wur.nl.
Cost	Not identified.
References	Bannayan, M., K. Kobayashi, H.-Y. Kim, M. Lieffering, M. Okada and S. Miura. 2005. Modeling the interactive effects of atmospheric CO_2 and N on rice growth and yield. *Field Crops Research* 93(2-3):237-251. Bouman, B.A.M., M.J. Kropff, T.P. Tuong, M.C.S. Wopereis, H.F.M. ten Berge, and H.H. Van Laar. 2001. ORYZA2000: Modeling Lowland Rice. International Rice Research Institute, Los Baños, Philippines and Wageningen University and Research Centre, Wageningen, The Netherlands. Matthew, R.B., D. Bachelet, and H.H. van Laar (eds.). 1995. *Modeling the Impact of Climate Change on Rice Production in Asia*. CAB International, Wallingford, United Kingdom.

Information and Decision Support System for Climate Change Studies in South East South America (IDSS-SESA Climate Change)

Description	The IDSS SESA is based on the linking and integration of (a) maps and associated databases of soils, weather, land use, and political divisions; (b) national and regional statistics (production, socioeconomic, demographic); (c) prices of inputs and products; (d) remotely sensed information (crops, pastures, natural resources, climate); (e) simulation models of crop, pasture and forest growth, development and production (DSSAT, APSIM); (f) climate change scenarios (GCMs, RCMs, and statistical methods); (g) a statistical package for analyzing climate data and generating synthetic weather (LARS and MARKSIM); (h) methods for land use evaluation and for defining land use feasibility classes; (i) a simulation model of soil carbon and nutrient dynamics (CENTURY); (j) tools for agricultural applications of global positioning systems (GPS); and (k) geographic information systems (GIS) to process and analyze maps and databases and to generate information that can be easily understandable and applied by agricultural stakeholders. Climate change scenarios are defined using three methods: (1) studying the changes in climate during the last 100 years and projecting those changes for the near future; (2) using sensitivity analyses, i.e., modifying observed weather data with combinations of changes in temperatures max and min and rainfall and generating synthetic weather data; and (3) using GCMs to estimate monthly anomalies of weather (temperatures and rainfall) or atmospheric variables (SLP, geopotential at 850 mb, etc.) and modifying the observed climatic data.
Appropriate Use	To study the impacts of possible climate change scenarios on different agricultural production systems (livestock, crops, mixed) and on the natural resource base, and explore adaptive technological options (crop/pasture management, input use, mixes of crop and pasture types).
Scope	Agro-ecological zone level (national, regional).
Key Output	Changes in agricultural productivity and economic results, variation in agricultural and environmental risks, etc., for different climate change scenarios. Produces outputs (e.g., maps, tables, etc.) in formats easily understood by non-specialist users such as policy makers and farmers.
Key Input	Soils, weather, and land use data; national and regional statistics of crop/livestock production; prices of inputs and products.
Ease of Use	For trained agronomists.
Training Required	Requires training on the basic tools included in the IDSS: simulation models, GIS, weather generators, and statistical analyses.
Training Available	Training is available for some of the IDSS components (DSSAT, APSIM, CENTURY).
Computer Requirements	Windows-based PC.
Documentation	http://sedac.ciesin.columbia.edu/aiacc/methods.html.
Applications	Used in INIA-Uruguay, INTA-Argentina, IAPAR-Brazil, EMBRAPA-Trigo, Brazil, and the AIACC project LA 27.

Information and Decision Support System for Climate Change Studies in South East South America (IDSS-SESA Climate Change) (cont.)

Contacts for Tools, Documentation, Technical Assistance	Walter E. Baethgen IFDC-Uruguay, Juan M. Perez 2917 Apt. 501, Montevideo, Uruguay; Tel: 598.2.712.0838; e-mail: wbaethgen@undpfim.org.uy. Agustín Giménez, INIA La Estanzuela, Colonia, Uruguay 70000; Tel: 598.574.8000. Graciela Magrin, INTA Castelar, Buenos Aires; Tel: 54.11.4621.1684.
Cost	Not identified.
References	Baethgen, W.E., R. Faría, A. Giménez, and P. Wilkens. 2001. Information and decision support systems for the agricultural sector. In *Proceedings — Third International Symposium on Systems Approaches for Agricultural Development, Lima, Peru, 8-10 November 1999* [CD-ROM computer file]. International Potato Center (CIP), Lima, Peru.

Decision Support Systems Linking Agro-Climatic Indices with GCM-Originated Climate Change Scenarios

Description	Key agro-climatic indices for the crops under study are defined (e.g., crop heat units, growing degree-days, effective growing degree-days, precipitation deficits, seasonal crop coefficients of water demand). Typically these indices are calculated using gridded monthly observed climatic normals for average daily maximum and minimum air temperature, total precipitation, and solar radiation. Climate change scenarios are then obtained from the outputs of GCMs and different statistical packages are used for interpolating and downscaling the results (e.g., PRISM, ANUSPLIN). The agro-climatic indices are then recalculated for the climate change scenarios, and adaptive management options are explored (different crop species, different cultivars, sowing dates, etc.).
Appropriate Use	To study expected shifts in the agro-climatic zones for different crop types under possible climate change scenarios, and to explore the adaptive ability of crop types and management options (planting date, cultivar types).
Scope	Agro-ecological zone level (national, regional).
Key Output	Changes in crop yields, shifts in agro-ecological zones, relative to different climate change scenarios.
Key Input	Gridded observed climate data, agro-climatic indices for different crop species and cultivars.
Ease of Use	For trained agronomists and agro-climatologists.
Training Required	Requires knowledge of agro-climatic indices, and methods for climatic data interpolation and downscaling (e.g., ANUSPLIN, PRISM).
Training Available	See Contacts below.
Computer Requirements	Windows-based PC.
Documentation	PRISM: Daly, C., R.P. Neilson, and D.L. Phillips. 1994. A statistical-topographic model for mapping climatological precipitation over mountainous terrain. *Journal of Applied Meteorology* 33:140-158. ANUSPLIN: Information on ANUSPLIN Version 4.3 available at http://cres.anu.edu.au/outputs/anusplin.php#1
Applications	Used by Canadian Climate Change Action Projects.
Contacts for Tools, Documentation, Technical Assistance	Climate Change Impacts & Adaptation Directorate, Natural Resources Canada; e-mail: adaptation@nrcan.gc.ca, Dr. A. Bootsma, Agriculture and Agri-Food Canada; Tel: 613.759.1526; e-mail: bootsmaa@em.agr.ca. Dr. D. Neilsen, Agriculture and Agri-Food Canada; Tel: 250.494.6417; e-mail: NeilsenD@em.agr.ca.
Cost	Not identified.

Decision Support Systems Linking Agro-Climatic Indices with GCM-Originated Climate Change Scenarios (cont.)

References	Bootsma1, S.G. and D.W. McKenney. 2001. Adaptation of Agricultural Production to Climate Change in Atlantic Canada. Report for Climate Change Action Fund Project A214. Neilsen, D., S. Smith, W. Koch, G. Frank, J. Hall, and P. Parchomchuk. 2001. Impact of Climate Change on Crop Water Demand and Crop Suitability in the Okanagan Valley, BC. Technical Bulletin 01-15. Pacific Agri-Food Research Centre, Summerland, British Columbia, Canada. http://adaptation.nrcan.gc.ca/projdb/pdf/4_e.pdf.

Model of Agricultural Adaptation to Climatic Variation (MAACV)

Description	Computer and numerical models require assessment of system forces and responses to adaptation in order to understand the context for the variables being considered. This model illustrates the endogenous and exogenous forces that influence adaptation responses and classifies those responses into various farm and regional level responses. The biophysical environment, government programs, economic conditions, and other forces are the exogenous considerations and factors such as the attributes of the farmer, the farm family, and the farm, including their experiences, perceptions, location, scale, and finances, are the endogenous considerations made in this model. Farm responses include tactical and strategic decisions.
Appropriate Use	Provides structure and hypotheses for numerical impact assessments in agriculture; particularly for developed economies.
Scope	All locations; farm and regional level analyses of commercial farming systems.
Key Output	Classification of range of forces and responses to adaptation to climatic variation.
Key Input	System and human agency influences on adaptation responses.
Ease of Use	Easy.
Training Required	No formal training required, although an understanding of farming systems is an asset.
Documentation	Smit, B., D. McNabb, and J. Smithers. 1996. Agricultural adaptation to climatic variation. *Climatic Change* 33:7-29.
Applications	Applied in research of corn hybrid adaptation in Ontario, Canada, and in the University of Guelph's Farming Systems Research.
Contacts for Tools, Documentation, Technical Assistance	Dr. Barry Smit and Dr. John Smithers, University of Guelph, Department of Geography, Guelph, ON N1G 2W1 Canada; Tel: (519) 824-4120 ext. 3279; Fax: (519) 837-2940; e-mail: bsmit@uoguelph.ca. D. McNabb, Carleton University, Impact Assessment Centre, Ottawa, ON K1S 5B6 Canada; Tel: 613.520.2547; Fax: 613.520.2551.
Cost	Not identified.
References	Smit, B., D. McNabb, and J. Smithers. 1996. Agricultural adaptation to climatic variation. *Climatic Change* 33:7-29. Smit, B. 1999. Agricultural Adaptation to Climate Change in Canada. A Report to the Adaptation Liaison Office.

Relative Risk Index (RRI)

Description	RRI illustrates the overall level of risk a farmer faces in light of various cropping decisions and climatic variation. In the study referenced here, various levels of risk are categorized and rated and then the proportion of the total farm area planted to each category of risk is calculated. The index is determined on the basis of the proportion of relatively risky versus relatively conservative crops planted.
Appropriate Use	To illustrate the relative risk positions of individuals (before or after adaptation) and begin to explain changes in cropping practices.
Scope	All locations; farm or regional level analyses.
Key Output	A relative risk index.
Key Input	Data on annual variations in cropping practices.
Ease of Use	Easy.
Training Required	No formal training required, although an understanding of various agronomic practices is an asset.
Documentation	Smit, B., R. Blain, and P. Keddie. 1997. Corn hybrid selection and climatic variability: Gambling with nature? *The Canadian Geographer* 41(4):429-438.
Applications	Used in research of commercial cash crop farming in Ontario, Canada.
Contacts for Tools, Documentation, Technical Assistance	Dr. Barry Smit, University of Guelph, Department of Geography, Guelph, ON N1G 2W1 Canada; Tel: 519.824.4120 ext. 3279; Fax: 519.837.2940; e-mail: bsmit@uoguelph.ca.
Cost	Not identified.
References	See Documentation above.

Government Support in Agriculture for Losses due to Climatic Variability

Description	A methodology using descriptive statistics to summarize data on government supports for extreme weather and climate variability in agriculture. Government sponsored programs such as Crop Insurance and Ad hoc Disaster Payment programs are considered in terms of their changing value over time.
Appropriate Use	To describe and evaluate the sustainability of government support programs that are provided in response to climate variability and weather extremes.
Scope	All locations; provincial and national level analyses.
Key Output	Value of government programs providing payments to farmers directly related to climatic variability.
Key Input	Farm income and government support data.
Ease of Use	Easy.
Training Required	No formal training required, although an understanding of government support programs, farming systems and descriptive statistics is an asset.
Computer Requirements	Spreadsheet software package.
Documentation	See Smit, B., 1994, in References below.
Applications	Used by the Environmental Adaptation Research Group of Environment Canada, Ontario Ministry of Agriculture, Food and Rural Affairs and Canada's National Implementation Strategy.
Contacts for Tools, Documentation, Technical Assistance	Dr. Barry Smit, University of Guelph, Department of Geography, Guelph, ON N1G 2W1 Canada; Tel: 519.824.4120 ext. 3279; Fax: 519.837.2940; e-mail: bsmit@uoguelph.ca.
Cost	Not identified.
References	Smit, B. 1994. Climate, compensation and agriculture. In *Improving Responses to Atmospheric Extremes: The Role of Insurance and Compensation. Workshop Proceedings.* J. McCulloch and D. Etkin (eds.).The Climate Institute, Environment Canada, Toronto. Smit, B. 1999. Agricultural Adaptation to Climate Change in Canada. A Report to the Adaptation Liaison Office.

AgroMetShell

Description	AgroMetShell is an integrated toolbox of several software packages which helps professionals in National Agrometeorological Services, agronomic research and food security units etc. to assess the impact of climatic conditions on crops, to analyze climate risks and to perform regional crop forecasting using statistical and crop modelling approaches. It allows an integrated analysis of ground data and low resolution satellite information under a common interface.
Appropriate Use	Applicable to the assessment of current and future climatic impacts on crops, derivation of management options for the growing season possible.
Scope	All locations; agricultural sector.
Key Output	Crop-specific soil water balance, agronomic/agrometeorological indicators to assess crop conditions, e.g. crop water consumption (potential evapotranspiration), rainfall probabilities, growing season characteristics.
Key Input	Climate, crop and soils data sets.
Ease of Use	Relatively easy to use for qualified experts with appropriate background.
Training Required	Yes.
Training Available	Included in CM Box training modules offered by FAO.
Computer Requirements	PC Windows 98 and above.
Documentation	http://www.fao.org/nr/climpag/aw_6_en.asp http://www.hoefsloot.com/agrometshell.htm
Applications	National Early Warning Systems for Food Security. National Agrometeorological Services. See also: http://www.hoefsloot.com/agrometshell.htm.
Contacts for Tools, Documentation, Technical Assistance	René Gommes, Michele Bernardi; Environment, Climate Change and Bioenergy Division (NRC), FAO, Viale delle Terme di Caracalla, 00153 Rome, Italy; e-mail: Rene.Gommes@fao.org, Michele.Bernardi@fao.org.
Cost	No cost to obtain software and documentation.
References	http://www.hoefsloot.com/agrometshell.htm http://www.fao.org/nr/climpag/aw_6_en.asp

Agroclimatic Water Stress Mapping

Description	The agroclimatic water stress mapping tool provides a global, near real-time warning of current and future agricultural emergencies indicating areas where excess or deficit rainfall is likely to produce serious damage to rainfed agriculture or pastures. Furthermore, the tool can use seasonal forecast data to produce maps identifying the probability of water deficit or surplus conditions in the coming months.
Appropriate Use	Global assessment of current and future areas with excess and deficit rainfall allows early warning for the on-going growing season.
Scope	Global, agricultural sector.
Key Output	Digital water stress maps by comparing actual and average monthly precipitation digital maps at 0.5° of resolution during the periods when agricultural activities are more "sensitive" to water stress.
Key Input	Long-term average rainfall. Long-term temperature and potential evapotranspiration to identify the regions with active growing seasons. Real-time rainfall data provided by the German Weather service (DWD). Real-time seasonal forecast provided by DEMETER project.
Ease of Use	Centralized server driven by FAO, the water stress maps can be downloaded from the FAO website (see documentation). There is no stand-alone version available.
Training Required	None.
Training Available	None.
Computer Requirements	None.
Documentation	See http://www.fao.org/nr/climpag/hot_2_en.asp.
Applications	Drought and flood monitoring over agricultural areas. Currently, internal use by FAO for global assessments of water stress. See also: http://www.fao.org/nr/climpag/hot_2_en.asp.
Contacts for Tools, Documentation, Technical Assistance	René Gommes, Michele Bernardi; Environment, Climate Change and Bioenergy Division (NRC), FAO, Viale delle Terme di Caracalla, 00153 Rome, Italy; e-mails: Rene.Gommes@fao.org, Michele.Bernardi@fao.org
Cost	None.
References	See http://www.fao.org/nr/climpag/hotspots/maps_en.asp.

Local Climate Estimator (New_LocClim)

Description	New_LocClim (Local Climate Estimator) is a software tool for spatial interpolation of agroclimatic data. It can estimate climatic conditions at locations for which no observations are available and provides nine different spatial interpolation methods (IDW, kriging, Shepard, thin-plate splines, etc.). It allows users to optimize interpolation by investigating interpolation errors and the influence of different settings on the results. Users can also interpolate their own data and prepare grid maps at any spatial resolution.
Appropriate Use	New_LocClim is appropriate for the preparation and investigation of agroclimatic maps from point to regional scale based on the FAOClim database or user data. The tool determines the average growing season as the period during a year when precipitation exceeds half the potential evapotranspiration. However, the user can also modify this definition.
Scope	All scales, agricultural sector.
Key Output	Climate maps at any spatial resolution of the average monthly climate conditions (8 variables). Export of data for further processing. Display graphs showing the annual cycle of monthly climate and the crop calendar.
Key Input	Climate data (from user or from FAOClim database).
Ease of Use	Relatively easy to use for qualified experts with appropriate background. On-line help is available.
Training Required	No.
Training Available	None.
Computer Requirements	PC Windows 98 and above.
Documentation	FAO. 2005. New_LocClim CD-ROM. Available at http://www.fao.org/nr/climpag/pub/en3_051002_en.asp.
Applications	All applications requiring climatic data. Agricultural planning.
Contacts for Tools, Documentation, Technical Assistance	René Gommes, Michele Bernardi; Environment, Climate Change and Bioenergy Division (NRC), FAO, Viale delle Terme di Caracalla, 00153 Rome, Italy; e-mail: Rene.Gommes@fao.org, Michele.Bernardi@fao.org.
Cost	No cost.
References	FAO. 2005. New_LocClim (incl. CD-ROM), Environment and Natural Resources Working paper No. 20. Available at http://www.fao.org/nr/climpag/pub/en3_051002_en.asp.

FAOClim 2.0

Description	FAOClim 2.0 is a global agroclimatic database containing data from almost 32,000 stations for up to 14 observed and computed agroclimatic parameters. The database includes both long-term averages (1961-90) and time series for rainfall and temperatures. The database is linked to real-time daily meteorological data flow and allows users to browse and retrieve basic data. The user can select data by geographic area, time period and parameter and can export and visualize the information in map and graph form.
Appropriate Use	The agroclimatic database is a valuable tool to analyze the variability of agroclimatic parameters and serves as a basis for risk studies. FAOClim provides a crucial resource in understanding how climate is changing and in establishing the baselines from which climate is being perturbed.
Scope	Global.
Key Output	Agroclimatic parameters for selected regions and time periods.
Key Input	User can add data for additional stations.
Ease of Use	Easy to use. On-line help is available.
Training Required	No.
Training Available	None.
Computer Requirements	PC Windows 98 and above.
Documentation	FAOClim 2.0 Agroclimatic Database CD-ROM. Available at http://www.fao.org/nr/climpag/pub/en1102_en.asp.
Applications	All applications requiring climatic data. Agricultural planning and climate risk assessment.
Contacts for Tools, Documentation, Technical Assistance	René Gommes, Michele Bernardi; Environment, Climate Change and Bioenergy Division (NRC), FAO, Viale delle Terme di Caracalla, 00153 Rome, Italy; e-mail: Rene.Gommes@fao.org, Michele.Bernardi@fao.org.
Cost	No cost.
References	FAO. 2001. FAOClim 2.0. Agroclimatic Database CD-ROM + Users Manual (72 pp.) Environment and Natural Resources Working paper No. 5. Available at http://www.fao.org/nr/climpag/pub/en1102_en.asp.

CLIMWAT 2.0

Description	CLIMWAT 2.0 is an extensive climatic database of more than 5,000 stations worldwide which is directly linked to the irrigation model AQUACROP. The combination of both allows users to calculate crop water requirements, irrigation supply and irrigation scheduling for various crops for a range of climatological stations.
Appropriate Use	CLIMWAT, in combination with AQUACROP, can be used for planning and management of irrigated and rainfed agriculture.
Scope	Global, agricultural sector.
Key Output	Climate data: maximum and minimum temperature, mean daily relative humidity, sunshine hours, windspeed, precipitation and calculated values for reference evapotranspiration and effective rainfall as input data for AQUACROP.
Key Input	FAOClim database.
Ease of Use	Easy to use. On-line help is available.
Training Required	No.
Training Available	None.
Computer Requirements	PC Windows 98 and above.
Documentation	See http://www.fao.org/nr/water/infores_databases_climwat.html.
Applications	To be used in conjunction with CropWat software. See http://www.fao.org/nr/water/infores_databases_cropwat.html.
Contacts for Tools, Documentation, Technical Assistance	René Gommes, Michele Bernardi; Environment, Climate Change and Bioenergy Division (NRC), FAO, Viale delle Terme di Caracalla, 00153 Rome, Italy; e-mail: Rene.Gommes@fao.org, Michele.Bernardi@fao.org.
Cost	No cost.
References	See http://www.fao.org/nr/water/infores_databases_climwat.html.

CM Box

Description	A national turn-key crop monitoring system, the CM Box is a training package for FAO crop monitoring and forecasting software. Interested countries receive a combination of training, hardware and software customized for local use, as well as the real-time data required to operate the system in-country. The CM Box is fed in real time with weather, satellite and crop information and generates a set of indicators that are relevant for food security. The training covers the operation of a national crop yield monitoring and forecasting system in a food security context, in particular the interpretation of the maps and other outputs produced by the various tools.
Appropriate Use	It strengthens the capacity of national experts to analyze weather data and to assess their current and future impact on crop production and food security. CM Box consists of individual modules which countries can select.
Scope	Global, agricultural sector.
Key Output	Output of the software tools: indicators related to food security as text, maps and tables by provinces or districts. Output of the training: Trainees can prepare crop and weather reports for the national food security system. Trainees are capable of operating the software independently, including the input of crop and weather data and the integration of ground and satellite information.
Key Input	National datasets prepared by the trainees before the training.
Ease of Use	Relatively easy to use for qualified experts with appropriate background.
Training Required	It is part of the package.
Training Available	Yes.
Computer Requirements	PC Windows 98 and above.
Documentation	CM Box User Guide. Available at http://www.fao.org/nr/climpag/aw_6_en.asp.
Applications	Tailored training sessions performed in several countries, e.g. Cambodia, Congo DRC, Ethiopia, Malawi, Lao PDR.
Contacts for Tools, Documentation, Technical Assistance	René Gommes, Michele Bernardi; Environment, Climate Change and Bioenergy Division (NRC), FAO, Viale delle Terme di Caracalla, 00153 Rome, Italy; e-mail: Rene.Gommes@fao.org, Michele.Bernardi@fao.org.
Cost	Software used is free (see AgroMetShell). The cost of training sessions varies according to local needs.
References	CM Box User Guide: http://www.fao.org/nr/climpag/aw_6_en.asp

CLOUD (Climate Outlooks and Agent-based Simulation of Adaptation in Africa)

Description	CLOUD developed a proto-type multi-agent simulation (MAS) model that is coupled to information about farming activity and climate data. MAS is a general computational technique that can be used for simulating societies and their interactions with the environment. It is a processed-based modelling approach arising from artificial intelligence research: Individual agents in a given system are identified and sets of behavioural rules are used to evolve the system state forward in time, taking into account the interactions between agents and the feedbacks between agent actions and the changes in state of their environment. For social-system models, agents may represent individual people, households, social groups or larger institutions. Environmental models can be coupled to the MAS in a variety of ways, depending on the type of physical or ecological system under consideration. In a climate context, such a model forms a test-bed for hypotheses about how environmental change and its perception within society may affect both adaptation to change and the future climate, in much the same way that a physical model allows testing of hypotheses about the physics of the atmosphere and ocean.
Appropriate Use	The model is as yet exploratory in nature and not sufficiently sophisticated to use for policy advice. For models that examine forecasting and climate, the CLOUD model has been applied to small subsistence farming villages in dryland farming regions where some seasonal forecast skill might be available.
Scope	The model focus was originally Southern Africa and specific to a single village. With appropriate social survey, crop and climate data it could be applied to other regions. However, MAS itself has in principle much broader applicability for social simulation.
Key Output	An exploratory model for examining “What if” scenarios. In the case of CLOUD, how belief in seasonal forecasts might affects crop returns and benefit (or otherwise) subsistence farmers.
Key Input	For forecast simulations, time series rainfall and temperature data at monthly resolution, crop coefficients suitable for CROPWAT, social information regarding agricultural practice and conditions under which crop choices are made, price and distribution information for crop sales, and climate forecast skill information.
Ease of Use	Requires expert programming knowledge in C++ or Java and experience in multi-agent simulation.
Training Required	See above.
Training Available	None currently available.
Computer Requirements	Platform- independent self-contained code. For single village simulations, any modern computer has sufficient power to run the model.
Documentation	Documentation is currently available as comments within the code.

CLOUD (Climate Outlooks and Agent-based Simulation of Adaptation in Africa) (cont.)

Applications	Subsistence farmers are particularly vulnerable to fluctuations in climate, particularly rainfall. Seasonal, inter-annual and longer-term changes in availability of water all affect their ability to survive. One way in which they might improve their circumstances would be to have access to seasonal forecast information, so as to be able to anticipate the right crops to plant, both for food and for marketing. Dry-land farmer success therefore depends on the availability of rain, and on the prices they can get at market, both of which are also dependent on the climate. The model was applied to two Southern African villages, Ha Thlaku, where adaptation of practice to planting either maize or sorghum was examined (Ziervogel et al. 2005), and Mangondi (Bharwani et al. 2005), where computer-aided knowledge-elicitation tools were used to determine a set of strategies that the farmers could use to plant crops in a market garden. An agent-based model was developed that captured these strategies and allowed us to couple them to a crop model (CROPWAT) driven with rainfall and temperature derived from 140-year runs of the UK Met Office coupled climate model. The agents changed their behaviour according to their memory of past climate, their interaction with other farmers, and their belief in a seasonal forecast. The projects studied how these factors influenced the success of the farming community as the climate varied over annual, decadal and longer timescales, including the effect of changes in the accuracy of the seasonal forecasts.
Contacts for Tools, Documentation, Technical Assistance	Dr. M. Bithell, Dept. of Geography, University of Cambridge, England (see www.geog.cam.ac.uk).
Cost	Software is regarded as pre-release at present. Future development envisages a MAS model that will be freely available and open source.
References	Bharwani, S., M. Bithell, T.E. Downing, M. New, R. Washington and G. Ziervogel. 2005. Multi-Agent Modelling of Climate Outlooks and Food Security on a community Garden Scheme in Limpopo, South Africa. Phil *Trans. Roy. Soc. London Ser. B* 360:2183-2194. Bithell, M., J. Brasington and K. Richards. 2006. Discrete-element, individual-based and agent-based models: tools for interdisciplinary enquiry in geography? *Geoforum*. doi:10.1016/j.geoforum.2006.10.014. Ziervogel, G., M. Bithell, R. Washington and T. Downing. 2005. Agent-based social simulation: a method for assessing the impact of seasonal climate forecast applications among smallholder farmers. *Agricultural Systems* 83:1-26.

CRAM (Canadian Regional Agriculture Model)

Description	The Canadian Regional Agriculture Model (CRAM) is a sector (i.e. partial) equilibrium, static model for Canadian agriculture written in General Algebraic Modeling System (GAMS, details available at http://www.gams.com/). The model has approximately 2300 variables, and 1300 equations. It consists of a main file with small files that can be "called" when running the model. The model is disaggregated across both commodities and space (55 crop regions and 10 livestock regions). The basic commodity coverage is grains and oilseeds, forage, beef, hogs, dairy and poultry (horticulture is excluded). For crops, data in CRAM include: yield, areas, cost of production, prices, quantity demanded, input requirements (price and quantity of fertilizers, chemicals and fuels), repair costs, management practice (tillage, summerfallow etc.). On the livestock side, data include: number of animals, input requirements (feed, forage, pasture), variable costs, prices of live animals (steers, bulls, cows etc.), prices and quantity of the different types of meat (high quality beef, low quality beef, veal, pork). Dairy (i.e. types of milk and usage, butter, cream, etc.) and Poultry (chicken, turkeys, eggs.) data are also included in CRAM. Other inputs include shipment cost of commodities to ports, and demand information (price, quantity, and elasticities), population per province etc. CRAM is a non-linear optimization model maximizing producer plus consumer surplus less transport costs. A Positive Mathematical Programming (PMP) approach is applied to crops, hogs and beef, and input demand, feed demand, crop area and livestock numbers. Through a calibration process, the model duplicates the observed allocation of a fixed and allocable resource (land) by positioning an unobserved marginal cost curve in a manner that ensures the classic conditions for constrained profit maximization are obtained. The model is processed through MINOS, that is, a general purpose nonlinear programming (NLP) solver. More recently, experiments for more complex analysis have been done with CONOPT. Both solvers are available under license (http://www.gams.com/sales/sales.htm).
Appropriate Use	The model currently reflects the baseline conditions for 2006 and 2010. Work is underway to determine conditions for a longer baseline. The current CRAM model is static and is not intended for dynamic application, although theoretically this could be possible.
Scope	CRAM has a national coverage where there are agricultural activities in Canada (Newfoundland and Labrador, Prince-Edward-Island, Nova Scotia, New Brunswick, Quebec, Ontario, Manitoba, Saskatchewan, Alberta and British Columbia).
Key Output	The key outputs are: Consumer and producer surplus (CPS) in dollar terms; crop areas; livestock production; quantities demanded; exports and imports. The model also indicates shifts (or needs) in land resources in optimizing the CPS, when analyzing the impact of a policy (or a shock). It also generates information on net income changes between the baseline and the scenario analysed (policy). Results are given at CRAM regions level, but can be aggregated to reflect provincial and national impacts.
Key Input	See Description, above. The main sources for data are: • Statistics Canada, for *Census of Agriculture* and various data. • Agriculture and Agri-Food Canada, for the *Medium Term Policy Baseline* (internal document) • USDA, for international data Other sources of data might be needed depending on the relevancy of the information.

CRAM (Canadian Regional Agriculture Model) (cont.)

Ease of Use	In general, medium level of effort is required and, with time, CRAM is easier to use. Because most of the economists who use CRAM have the necessary background on microeconomics theory, and in optimization theory, most of the effort is in learning GAMS language. A period of up to six months would suffice to gain familiarity with the language and the CRAM model itself. Furthermore, because 70 % of the raw series are available electronically, the data transformation part of the work with CRAM might require a medium level, or less, of effort.
Training Required	See above
Training Available	There is no formal training available.
Computer Requirements	A Pentium-based computer with a minimum of 512 MB is required. However, for more complex analysis, 1GB is definitely better. The operating system used is Windows XP SP2 (for GAMS and solver requirement on various platforms, please see http://www.gams.com/solvers/index.htm)
Documentation	Description of the CRAM structure can be found in some of the early publications (such as Webber et al, 1986). CRAM contains information on updates made, however this doesn't constitute a how-to manual for the models. There are on-going efforts with the CRAM Team to develop a separate documentation that could fill (partially) the role of a manual. GAMS documentation is available at http://www.gams.com/docs/document.htm.
Applications	One of the first applications of CRAM was to look at the implications of the introduction of medium quality wheat on the Prairies (1986). Since then it has been used to examine the impact of the 1985 U.S. Food Security Act on the Canadian Grains sector (1988) and the impact of direct government assistance programs on the beef and hogs sectors (1989). CRAM has been employed within AAFC to examine the implications of the Canada-U.S. Trade Agreement (CUSTA), the Multilateral Trade Negotiations (MTN) (1990), changing the Western Grain Transportation Act (WGTA) (1991 and 1994) and licensing BST for dairy cows (1990). It has been used for the environmental assessment of the crop insurance program (1998) and return on research investment studies for wheat (1995), potatoes (1996), hogs (1998), and forages (2000). CRAM has been used to calculate greenhouse gas emissions of the agriculture sector (with the Canadian Economic and Emissions Model for Agriculture, CEEMA, 2000-2004), to track the environmental performance of the agriculture sector (through agri-environmental indicators), and to assess the expanded use of biofuels (2000). Furthermore, CRAM is currently used in an on-going analysis of climate change impacts and adaptation.
Contacts for Tools, Documentation, Technical Assistance	Bob MacGregor, Chief, Agricultural & Environmental Policy Analysis, Agriculture and Agri-Food Canada, 930 Carling Avenue, room 689, Ottawa, Ontario, Canada K1A 0C9; Tel: 613.759.7196; e-mail: macgrbo@agr.gc.ca.
Cost	The incremental costs are for GAMS program and solver licences purchases. For the most up-to-date information on costs, please consult http://www.gams.com/sales/sales.htm.
References	Agriculture and Agri-Food Canada. 2000. Options Report – Reducing Greenhouse Gas Emissions From Canadian Agriculture, Public Works and Government Services Canada. Publication 2028/E, Ottawa, ON. Agriculture and Ari-Food Canada. Agricultural Policies and Soil Degradation In Western Canada: An Agro-ecological Economic Assessment (Reports 1-5 http://www2.agr.gc.ca).

CRAM (Canadian Regional Agriculture Model) (cont.)

References continued	Fox, G., G. Brinkman and G. Thomas. 1998. The Economic Benefits of Canadian Swine Research. Agriculture and Agri-Food Canada, Ottawa, ON. Giraldez, J., R.J. MacGregor, B. Junkins, R. Gill, I. Campbell, G.Wall, I. Shelton, G. Padbury and B. Stephen. 1998. The Federal-Provincial Crop Insurance Program: An Integrated Environmenal-Economic Assessment. Agriculture and Agri-Food Canada, Ottawa, ON. Graham, J.D., B. Stennes, R.J. MacGregor, K. Meilke and G. Moschini. 1990. The Effects of Trade Liberalization on Canadian Dairy and Poultry Sectors. Agriculture Canada, Working Paper Number 3, Ottawa, ON. Heigh, L. and B. Junkins. 2005. Quantitative Analysis of the Impact of Agricultural Management Strategies on Environmental Indicators. Agriculture and Agri-Food Canada. Horner, G.L., J. Corman, R.E. Howitt, C.A. Carter and R.J. MacGregor. 1992. The Canadian Regional Agriculture Model – Structure, Operation and Development. Agriculture Canada, Technical Report 1/92. Huffman, E.. 2000. Soil cover by Crops and Residue, pp. 33-40 in T. McRae, C.A.S. Smith and L.J. Gregorich (eds.), 2000 Environmental Sustainability of Canadian Agriculture: Report of the Agri-Environmental Indicator Project. Agriculture and Agri-Food Canada, Ottawa, ON. Klein, K.K., G. Fox, W.A. Kerr, S.N. Kulshreshtha and B. Stennes. 1991. Regional Implications of Compensatory Freight Rates for Prairie Grains and Oilseeds. Agriculture Canada Working Paper, Number 3, Ottawa. Klein, K.K. and B. Freeze. 1995. Economics of Loss Avoidance Research on Wheat in Canada. Report submitted to Research Branch, Agriculture and Agri-Food Canada, Ottawa, ON. Klein, K.K., B. Freeze and A.M. Wallbuger. 1995. Economic Returns to Yield Increasing Research on Wheat in Canada, Report submitted to Research Branch. Agriculture and Agri-Food Canada, Ottawa, ON. Klein, K., D. Le Roy, A.Walburger, S. Clark, and E. Yiridoe. 2004. Revisions to Crop Module in the Canadian Regional Agricultural Model (CRAM) - Final Report. Agriculture and Agri-Food Canada, Ottawa, ON. MacGregor, R.J. and J.D. Graham. 1988. The impact of Lower Grains and Oilseed Prices on Canada's Grain Sector: A Regional Programming Approach. *Canadian Journal of Agricultural Economics* 36:51-67. Oxley, J., B. Junkins, C. Dauncy and R.J. MacGregor. 1996. The Economic Benefits of Public Potato Research in Canada, Report submitted to Research Branch. Agriculture and Agri-Food Canada, Ottawa, ON. Stennes, B.K., R.R Barichello and J.D. Graham. 1990. Bovine Somatotropin and the Canadian Dairy Industry: An Economic Analysis. Agriculture Canada Working Paper No 1-91, Ottawa, ON. Thompsen, J.G., R. Ewing and K. Shukla. 2000. Documentation and Analysis of the Economic Benefits of Public Research of Forages in Canada. Report submitted to Agriculture and Agri-Food Canada, Ottawa, ON. Webber, C.A., J.D. Graham and R.J. MacGregor. 1988. A Regional Analysis of Direct Government Assistant Programs in Canada and Their impacts on the Beef and Hog Sectors, Agriculture Canada, Working Paper No. **6/88**, Ottawa, ON. Webber, C.A., J.D. Graham and K.K. Klein. 1986. The Structure of CRAM: A Canadian Regional Agricultural Model. Department of Agricultural Economics, University of British Columbia.

Process Crop Models: Decision Support System for Agrotechnology Transfer (DSSAT) developed under the International Consortium for Agricultural Systems Applications (ICASA)

Description	The Decision Support System for Agrotechnology Transfer (DSSAT) is decision support system that encompasses process-based computer models that predict growth, development and yield as a function of local weather and soil conditions, crop management scenarios and genetic information. The crops that are covered include grain cereals such as rice, wheat, maize, barley, sorghum, and millet, grain legumes, such as soybean, peanut, dry bean, chickpea, tuber crops, such as potato and cassava, cotton, sugarcane, vegetables, and various other species. DSSAT also includes a basic set of tools to prepare the input data, as well as application programs for seasonal, crop rotation and spatial analysis. The crop models not only predict crop yield, but also resource dynamics, such as for water, nitrogen and carbon, and environmental impact, such as nitrogen leaching. DSSAT includes an economic component that calculates gross margins based harvested yield and byproducts, the price of the harvested products, and input costs. The models use daily weather data, soil profile information, and basic crop management data as input. Model outputs are normally compared with local experimental data in order to evaluate model performance and determine the genetic characteristics of local varieties.
Appropriate Use	DSSAT can be used at a farm level to determine the impact of climate change on production and potential adaptation practices that should be developed for farmers. It can also be used at a regional level to determine the impact of climate change at different spatial scales, the main consideration being availability of accurate input data.
Scope	DSSAT can be used for any region across the world, as long as the local input data are available. DSSAT has been distributed to over 2,000 users in more than 90 countries and has been tested in most regions of the world.
Key Output	Key outputs are the impact of climate change on crop production, resource use and environmental pollution and management options for adaptation.
Key Input	The crop simulation models require daily weather data, including maximum and minimum temperature, solar radiation, and precipitation, a description of the soil physical and chemical characteristics of the local, and crop management, including crop, variety, planting date, plant spacing, and inputs such as fertilizer and irrigation.
Ease of Use	DSSAT has been developed in Windows environment and can be easily used after installation. For all crops considered (over 25 spp.), example data based on real experiments are provided. For local implementation, access to weather and soil data, crop management information and some crop measurements are needed.
Training Required	For proper use, some training is required, especially with respect to the preparation of the input files, determination of the genetic coefficients and for evaluation with local data. Familiarity with the Windows operating system, spread sheet tools, and text editors is desirable.
Training Available	The University of Georgia in collaboration with the International Consortium for Agricultural Systems Applications (ICASA) offers a two week training workshop on DSSAT every other year. In addition, training is often provided for groups of scientists in a country or region, depending on available resources and research interests.
Computer Requirements	DSSAT runs on a Pentium 4 or higher computer with at least 521 MByte of memory and 0.5 GByte of hard disk space. The preferred operating system is Windows XP.

Process Crop Models: Decision Support System for Agrotechnology Transfer (DSSAT) developed under the International Consortium for Agricultural Systems Applications (ICASA) (cont.)

Documentation	Hoogenboom, G., J.W. Jones, P.W. Wilkens, C.H. Porter, W.D. Batchelor, L.A. Hunt, K.J. Boote, U. Singh, O. Uryasev, W.T. Bowen, A.J. Gijsman, A. du Toit, J.W. White, and G.Y. Tsuji. 2004. Decision Support System for Agrotechnology Transfer Version 4.0 [CD-ROM]. University of Hawaii, Honolulu, HI. Tsuji, G. Y., G. Hoogenboom, and P. K. Thornton [Editors]. 1998. Understanding Options for Agricultural Production. Systems Approaches for Sustainable Agricultural Development. Kluwer Academic Publishers, Dordrecht, the Netherlands. ISBN 07923-4833-8. 400 pp.
Applications	The software has been used extensively in many different projects funded by US AID, US EPA, Asian Pacific Network, and other organizations to determine the impact of climate change on agricultural production and food security. It was also used by numerous countries in the U.S. Country Studies Program, including Egypt, Japan, Kazakhstan, and Uruguay.
Contacts for Tools, Documentation, Technical Assistance	For tools and documentation, please contact: International Consortium for Agricultural Systems Applications (ICASA), 2440 Campus Rd., Box 527, Honolulu, HI 96822, USA, e-mail: ICASA@ICASA.net; website; www.ICASA.net. For technical assistance, please contact Dr. Gerrit Hoogenboom, Department of Biological and Agricultural Engineering, the University of Georgia, Griffin, Georgia 30223, USA; e-mail: Gerrit@uga.edu.
Cost	The cost of the software is $195+ shipping expenses. The registration costs for attending a training workshop are $1,500. Additional costs include hotel and per diem, and travel to and from the workshop.
References	Alexandrov, V.A., and G. Hoogenboom. 2000. The impact of climate variability and change on major crops in Bulgaria. *Agricultural and Forest Meteorology* 104(4):315-327. Alexandrov, V.A., and G. Hoogenboom. 2000. Vulnerability and adaptation assessments of agricultural crops under climate change in the Southeastern USA. *Theoretical and Applied Climatology* 67:45-63. Baethgen, W. E. 1997. Vulnerability of the agricultural sector of Latin America to climate change. *Climate Research* 9(1-7). Hatch, U., S. Jagtap, J. Jones, and M. Lamb. 1999. Potential effects of climate change on agricultural, water use in the southeast US. *Journal of the American Water Resources Association* 35: 1551-1561. Iglesias, A., Rosenzweig, C., and Pereira, D. 2000. Agricultural impacts of climate change in Spain: Developing tools for a spatial analysis. *Global Environmental Change* 10:69-80. Jones, J.W., G. Hoogenboom, C.H. Porter, K.J. Boote, W.D. Batchelor, L.A. Hunt, P.W. Wilkens, U. Singh, A.J. Gijsman, and J.T. Ritchie. 2003. DSSAT Cropping System Model. *European Journal of Agronomy* 18:235-265. Jones, P.G., and P.K. Thornton. 2003. The potential impacts of climate change on maize production in Africa and Latin America in 2055. *Global Environmental Change*13:51-59. Mearns, L. O., T. Mavromatis, E. Tsvetsinskaya, C. Hays, and W. Easterling. 2001. Comparative responses of EPIC and CERES crop models to high and low spatial resolution climate change scenarios. *Journal of Geophysical Research* 104(d4): 6623-6646. Tsuji, G. Y., G. Hoogenboom, and P. K. Thornton [eds.]. 1998. Understanding Options for Agricultural Production. Systems Approaches for Sustainable Agricultural Development. Kluwer Academic Publishers, Dordrecht, the Netherlands. ISBN 07923-4833-8. 400 pp. White, J.W, G. Hoogenboom, and L.A. Hunt. 2005. A structured procedure for assessing how crop models respond to temperature. *Agronomy Journal* 96(2):426-439.

Process Crop Models: General-Purpose Atmospheric Plant Soil Simulator (GAPS 3.1)

Description	GAPS is a dynamic DOS or Windows-based simulation software package of the soil-plant-atmosphere continuum, with crop management explicit in the model. It can simulate a sequence of crops and climates in a single simulation run. Used to examine the influence of climate on different aspects of crop management (e.g., the effects of climate variability on the number of field-days for getting equipment into fields).
Appropriate Use	For use in research and teaching the principles and practice of dynamic simulation modeling of the soil-plant-atmosphere system.
Scope	All locations; agricultural sector; site-specific, although can be extrapolated using GIS to a national level.
Key Output	Crop yield and yield components.
Key Input	Data on the site's soils, climate, and management.
Ease of Use	High skill-level and time commitment required to prepare and run GAPS.
Training Required	Requires extensive training in crop management and computer modeling.
Training Available	Self-instruction using manual.
Computer Requirements	Any PC that uses DOS or Windows 95 (or better). A batch version for large numbers of repetitive simulations is available.
Documentation	Buttler, I.W. and S. Riha. 1989. GAPS: A General Purpose Simulation Model of the Soil-Plant-Atmosphere System, Version 3.1. User's Manual. Dept. of Agronomy, Cornell University, Ithaca, NY.
Applications	Used to examine farm-level impacts of climate change on agriculture in the midwestern U.S.
Contacts for Tools, Documentation, Technical Assistance	Dr. Susan J. Riha, Dept. of Soil, Crop, and Atmospheric Sciences, Cornell University, 140 Emerson Hall, Ithaca, NY 14853 USA; Tel: +1.607.255.6143; e-mail: sjr4@cornell.edu.
Cost	No cost for model.
References	Kaiser, H., S. Riha, D. Wilks, D. Rossiter, and R. Sampath. 1993. A farm-level analysis of economic and agronomic impacts of gradual climate warming. *American Journal of Agricultural Economics* 75:387-398.

Process Crop Models: Erosion Productivity Impact Calculator (EPIC)

Description	EPIC is an IBM, Macintosh, or Sun based generalized crop model that simulates daily crop growth on a hectare scale. Like most process plant growth models, it predicts plant biomass by simulating carbon fixation by photosynthesis, maintenance respiration, and growth respiration. Several different crops may be grown in rotation within one model execution. It uses the concept of light-use efficiency as a function of photosynthetically available radiation (PAR) to predict biomass. EPIC has been modified to simulate the direct effects of atmospheric carbon dioxide on plant growth and water use. Crop management is explicitly incorporated into the model.
Appropriate Use	This approach is useful for evaluating a limited number of agronomic adaptations to climate change, such as changes in planting dates, modifying rotations (i.e., switching cultivars and crop species), changing irrigation practices, and changing tillage operations. The parameter files are extremely sensitive to local conditions and EPIC can give grossly misleading results when relying on default settings as it is being tailored to different locations and cropping systems.
Scope	All locations; agricultural; site-specific.
Key Output	Response of crop yields, yield components, and irrigation requirements to climate change adaptations.
Key Input	Quantitative data on climate, soils, and crop management.
Ease of Use	Data intensive and difficult to use without sufficient qualifications. A person trained in general crop systems science with moderate programming skills should be able to use EPIC reliably with 3-4 days of intensive training.
Training Required	Requires technical modeling skills and a basic knowledge of agronomic principles.
Training Available	Informal training available; see below.
Computer Requirements	IBM-compatible PC 486 with 4k of RAM and 80MB.
Documentation	Williams, J.R., C.A. Jones, and P.T. Dyke. 1990. The EPIC model documentation. USDA-ARS Technical Bulletin No. 1768. U.S. Department of Agriculture, Washington, DC. pp. 3-92.
Applications	RAC analysis, drought assessment, soil loss tolerance tool, Australian sugarcane model (AUSCANE), pine tree growth simulator, global climate change analysis, farm level planning, drought impacts on residue cover, and nutrient and pesticide movement estimates for alternative farming systems for water quality analysis. Also used in combination with socio-economic model CRAM (Canadian Regional Agriculture Model) as part of an integrated assessment of agriculture production in the Canadian prairies.
Contacts for Tools, Documentation, Technical Assistance	Dr. Susan J. Riha, Dept. of Soil, Crop, and Atmospheric Sciences, Cornell University, 140 Emerson Hall, Ithaca, NY 14853 USA; Tel: +1.607.255.6143; e-mail: sjr4@cornell.edu.
Cost	No cost for model.

Process Crop Models: Erosion Productivity Impact Calculator (EPIC) (cont.)

References	Easterling, W.E., N.J. Rosenberg, M.S. McKenney, C.A. Jones, P.T. Dyke, and J.R. Williams. 1992. Preparing the erosion productivity impact calculator (EPIC) model to simulate crop response to climate change and the direct effects of CO_2. *Special Issue: Methodology for Assessing Regional Agricultural Consequences of Climate Change, Agricultural and Forest Meteorology* 59(1-2):17-34. Izaurralde, R.C., J.R. Williams, W.B. McGill, N.J. Rosenberg and M.C. Quiroga Jakas. 2006. Simulating soil C dynamics with EPIC: Model description and testing against long-term data. *Ecological Modelling* 192(3-4):362-384. Williams, J.R., C.A. Jones, and P.T. Dyke. 1984. A modeling approach to determining the relationship between erosion and soil productivity. *Transamerican Society of Agricultural Engineering* 27:129-144.

Irrigation Model: CROPWAT

Description	CROPWAT is a DOS or Windows based decision support system designed as a tool to help agro-meteorologists, agronomists, and irrigation engineers carry out standard calculations for evapotranspiration and crop water use studies, particularly the design and management of irrigation schemes. It allows the development of recommendations for improved irrigation practices, the planning of irrigation schedules under varying water supply conditions, and the assessment of production under rainfed conditions or deficit irrigation.
Appropriate Use	As a tool for testing the efficiency of different irrigation strategies (e.g., irrigation scheduling, improved irrigation efficiency) under climate change. Does not have the capacity of simulating the direct effects of rising atmospheric carbon dioxide concentrations on crop water use.
Scope	All locations; agricultural sector; site-specific.
Key Output	Reference evapotranspiration, crop water requirements, and crop irrigation requirements.
Key Input	Climatic and crop data (CLIMWAT database, included with the program) for calculations of crop water requirements and irrigation requirements. The development of irrigation schedules and the valuation of rainfed and irrigation practices are based on a daily soil-water balance using various options for water supply and irrigation management conditions.
Ease of Use	Relatively easy to use for qualified experts with appropriate background.
Training Required	Intended for use by agricultural professionals because it requires background and training in agricultural modeling. Using the manual, an expert can learn how to use this tool within 1-2 days.
Training Available	No formal training currently offered beyond the training manual.
Computer Requirements	IBM-compatible PC 486 with 4k of RAM and 80MB supporting DOS or Windows. CROPWAT version 5.7, issued in 1992, is written in BASIC and runs in the DOS environment. The program is available in English, French and Spanish. The English version of CROPWAT 5.7 has since been replaced by CROPWAT version 7.0. CROPWAT for Windows contains a CROPWAT version in Visual Basic to operate in the Windows environment.
Documentation	CROPWAT for Windows and its manual are available in Acrobat format and can be downloaded from http://www.fao.org/nr/water/infores_databases_cropwat.html.
Applications	The CROPWAT database contains data for six continental regions and 144 countries. It has been used to develop irrigation schedules under various management conditions to evaluate rainfed production and drought effects and efficiency of irrigation practices.
Contacts for Tools, Documentation, Technical Assistance	Martin Smith, Senior Irrigation Management Officer, Water Resources, Development, and Management Service, FAO, Viale delle Terme di Caracalla, 00100 Rome, Italy; Tel: 39.06.57053818; Fax: 39.06.57056275; e-mail: Martin.Smith@fao.org.
Cost	No cost to obtain model documentation or software.
References	Doria, R., C.A. Madramootoo and B.B. Mehdi. 2006. Estimation of Future Crop Water Requirements for 2020 and 2050, Using Cropwat. EIC Climate Change Technology, 2006 IEEE pp 1-6. FAO Irrigation and Drainage Paper No. 46. Food and Agriculture Organization, Rome. FAO. 1992. CROPWAT — A Computer Program for Irrigation Planning and Management.

Irrigation Model: AquaCrop

Description	AquaCrop, a new version of CROPWAT, is a Windows-based software programme designed to simulate biomass and yield responses of field crops to various degrees of water availability. Its application encompasses rain fed as well as supplementary, deficit and full irrigation. It is based on a water-driven growth-engine that uses biomass water productivity (or biomass water use efficiency) as key growth parameter (WP_b). The model runs on daily time-steps using either calendar time or thermal time. It accounts for three levels of water-stress responses (canopy expansion rate, stomatal closure and senescence acceleration), for salinity build-up in the root zone and for fertility status. AquaCrop is a tool for: (1) predicting crop production under different water-management conditions (including rain fed and supplementary, deficit and full irrigation) under present and future climate change conditions, and (2) investigating different management strategies, under present and future climate change conditions.
Appropriate Use	AquaCrop is useful for cropping planning and management and is mainly intended for practitioners such as those working for extension services, governmental agencies, NGOs and various kinds of farmers' associations. It is useful for developing irrigation strategies under water deficit conditions. AquaCrop is particularly useful for perspective studies as it includes biomass and yield predictions under global warming and elevated CO_2, i.e., it is suitable for climate change types of studies.
Scope	AquaCrop can be applied to any field condition worldwide (once calibrated, it can be extrapolated in space and time). The "field-plot" scale should be the most appropriate spatial scale, while the "day" time-step is the time scale.
Key Output	AquaCrop is a crop-growth model predicting biomass and yield response to water under any climatic and soil conditions, including climate change cases.
Key Input	AquaCrop requires weather data (air temperature, reference evapotranspiration and rainfall), soil texture data (sand, clay, loam, in %) and crop parameters (initial, final and rate of change in % Canopy Cover; initial, final and rate of deepening in root depth; biomass water productivity; harvest index; typical management conditions such as irrigation dates and amounts, sowing and harvest dates, mulching, etc.).
Ease of Use	AquaCrop is user-friendly. The degree of difficulty can be rated very low.
Training Required	AquaCrop comes with documentation and people do not require training to use it. Nevertheless, it is generally recommended to participate in periodic training workshops that are offered for special applications.
Training Available	Training sessions are periodically organized based on demand.
Computer Requirements	AquaCrop runs on PCs with Microsoft Windows operating systems and requires 5 Mb of Hard Disk space.
Documentation	AquaCrop includes a "User's Guide" and "Technical Manual" for the calculation procedures and algorithms.
Applications	AquaCrop is at prototype level. Applications, tests and validations are under publication (first official document will be available in 2008).
Contacts for Tools, Documentation, Technical Assistance	Pasquale Steduto, Chief of Water Unit, Land and Water Division, Food and Agricultural Organization of the United Nations (FAO), Viale delle Terme di Caracalla, 00153 Rome, Italy; e-mail: pasquale.steduto@fao.org.

Irrigation Model: AquaCrop (cont.)

Cost	AquaCrop will be downloadable from the Internet. It is intended to be free of charge. The hard-copies of the documentation and the CD with the software will be inexpensive (to cover the hardcopy production cost).
References	AquaCrop is new and has not yet developed publications that have critically discussed its use.

Process Crop Models: Alfalfa 1.4

Description	Alfalfa 1.4 is a DOS, Windows, or Macintosh based model that simulates growth and development of the alfalfa plant, based on integrative plant physiology and morphology. The model permits simulation of the diurnal patterns of production processes and growth for studying the influences of temperature, radiation, water deficit, and carbon supply. Beginning with tissue and organ level information, the growth of shoots is simulated for up to five age classes of stems. Perennial, underground structures (crown, taproot, and fibrous roots) are simulated over 10 soil layers. The model includes variations in plant population so that overwintering and stand persistence can be simulated.
Appropriate Use	Suited to a wide range of management issues and for coupling to insect and disease models. Several usual adaptation strategies for coping with climate change (changes to cultivars, planting dates) may be tested.
Scope	All locations; agricultural sector; site-specific.
Key Output	Total above-ground biomass (edible yield).
Key Input	Daily weather data from standard meteorological reports.
Ease of Use	Relatively easy to use with sufficient background.
Training Required	Advanced programming skills (knowledge of FORTRAN language) helpful, agronomic background required.
Training Available	No formal training currently offered beyond the training manual.
Computer Requirements	DOS, Windows, or Macintosh environments. Instructions for downloading given at the website below in Contacts.
Documentation	Denison, R.F. and B. Loomis. 1989. An Integrative Physiological Model of Alfalfa Growth and Development. UC ANR Publication 1926, University of California, Davis.
Applications	Used by farmers in the U.S.
Contacts for Tools, Documentation, Technical Assistance	R. Ford Denison, Agronomy and Range Science, University of California, Davis, 95616, USA; Tel: +1.530.752.9688; e-mail: rfdenison@ucdavis.edu.
Cost	Program and manual available for US$25. Order form can be accessed at http://www.ipm.ucdavis.edu/IPMPROJECT/order.html.
References	Denison, F. and B. Loomis. 1989. An Integrative Physiological Model of Alfalfa Growth and Development. UC ANR Publication 1926. University of California, Davis.

Process Crop Models: AFRC-Wheat

Description	AFRC-Wheat is a FORTRAN-based mechanistic model that incorporates crop response to water and nitrogen constraints. Model processes include phenological development, partitioning of photosynthesis, growth of leaf and stems, senescence, biomass accumulation, and root system dynamics. The model uses a threshold of accumulated growing degree days above a base and below a ceiling temperature to regulate growth.
Appropriate Use	Used to investigate the interannual variation in the length of vegetative and floral development and grain filling periods driven by historic climate data. Results of experiments with the AFRC-Wheat model run with climate change can be extrapolated to national-scale crop potential estimations using GIS technology.
Scope	All locations; agricultural sector; national or site-specific.
Key Output	Yield and yield components.
Key Input	Weather data such as daily values of maximum, minimum, dry and wet bulb temperature, solar radiation, sunshine hours, rainfall, wind, etc.
Ease of Use	For experts with sufficient background, the model is easy to use.
Training Required	Requires basic knowledge of climate, crop agronomy, crop physiology, and soils.
Training Available	See web site in Contacts below for details.
Computer Requirements	VAX computers (in FORTRAN 77) or IBM PC-compatibles (DOS v3.3 or higher).
Documentation	
Applications	AFRC-Wheat has been used in the United Kingdom by several institutions including AFRC and University of Oxford, in Italy by the University of Florence, in France by INRA Avignon, in Hungary by the University of Budapest, in Germany by the University of Bonn, in New Zealand by Crop and Food Research Limited, and in Syria by ICRISAT.
Contacts for Tools, Documentation, Technical Assistance	Dr. John R. Porter, Dept. of Agricultural Services, Royal Agricultural and Veterinary University, agrovej 10, 2630 Taastrup, Denmark; Tel: 45.28.77.35.60; Fax: 45.35.28.21.75; e-mail: john.r.porter@agsci.kvl.dk.
Cost	Free for anyone in Global Change and Terrestrial Ecosystems (GCTE) Wheat Network.
References	Addiscott, T.M. and A.P. Whitmore. 1987. Computer simulation of changes in soil mineral nitrogen and crop nitrogen during autumn, winter, and spring. *Journal of Agriculture Science* 109:141-157. Addiscott, T.M., P.J. Heys, and A.P. Whitmore. 1986. Application of simple leaching models in heterogeneous soils. *Geoderma* 38:185-194. Atkinson, M.D., P.S. Kettlewell, P.D. Hollins, D.B. Stephenson and N.V. Hardwick. 2005. Summer climate mediates UK wheat quality response to winter North Atlantic Oscillation. *Agriculture and Forest Meteorology* 130(1-2):27-37. Miglietta, F. and J.R. Porter. 1992. The Effects of Climatic Change on Development in Wheat: Analysis and Modelling. Journal of Experimental Biology 43(8):1147-1157. Weir, A.H., P.L. Bragg, J.R. Porter, and J.H. Rayner. 1984. A winter wheat model without water or nutrient limitations. *Journal of Agricultural Science* 102:371-383.

Process Crop Models: RICEMOD

Description	RICEMOD is a FORTRAN and BASIC based ecophysiological model for irrigated rice production. It includes a number of physical parameters, including accommodation of subroutines dealing with soil and plant chemistry as well as physical processes of the atmospheric environment. The model is very sensitive to soil parameters and has been expanded to consider soil water deficit. Model components include maximum leaf area index, timings of plant growth initiation and harvest, radiation-use efficiency (RUE), and harvest index (HI).
Appropriate Use	To study the relative constraining effects of radiation, leaf blade nitrogen content, respiration rate, and assimilate partitioning on rice plant growth. Useful for predicting future production scenarios. Does not include the influence of CO_2.
Scope	All locations; agricultural sector; site-specific.
Key Output	Total area index (LA1, leaves and stem), growth rates, dry weights, dry matter partitioning, grain yield, number of grains, CO_2 assimilation, amount of radiation absorbed by the canopy.
Key Input	Data intensive; requires soil, plant, and atmospheric data (rainfall, pan evaporation, radiation, minimum and maximum temperature, day length).
Ease of Use	Relatively easy to use, although requires some expertise and is fairly data intensive.
Training Required	Requires knowledge of soil physical properties and some background in agronomics.
Training Available	IRRI (see Contacts below) offers training.
Computer Requirements	Programmed in FORTRAN IV and BASIC. Requires an IBM-compatible PC 370/135.
Documentation	McMennary, J. and J.C. O'Toole. 1985. RICEMOD: A Physiologically-Based Rice Growth Model. IRRI research paper series #87. 1099 Manila, The Philippines.
Applications	Used to indicate leaf water stress and predict the growth and yield component of different rice varieties in a number of rice-producing countries, including the Philippines.
Contacts for Tools, Documentation, Technical Assistance	Dr. John Sheehy, Chairman of the GCTE Rice Working Group, IRRI, PO Box 933, 1099 Manila, The Philippines; Tel: 63.2.8181926/884869; Fax: 63.2.8178470/8182087; e-mail: irri@cgiar.com; websites: http://www.cgiar.org/ and http://www.irri.org/
Cost	Contact IRRI for information.
References	See Documentation above.

Process Crop Models: GOSSYM/COMAX

Description	GOSSYM/COMAX is a mechanistic cotton growth model and expert system that simulates cotton growth given selected weather, soil, and management practices. Management options include fertilizer and irrigation strategies. GOSSYM operates on daily time steps and calculates material balances for water and nitrogen using weather and soil data to predict crop growth and crop yield. The model also calculates material balances and soil nitrogen uptake.
Appropriate Use	Effective aid to cotton growers, crop consultants, and researchers in the management of irrigation water, nitrogen, plant growth regulators, and crop termination chemicals. Useful in computing irrigation, planting time, and fertilization strategies for farmers; can be used in conjunction with GCMs or WGEN to examine the effects of changes in climate on crop production. Does not work well with intersecting insect data.
Scope	All locations; agricultural sector; site-specific.
Key Output	Crop yield and yield components.
Key Input	Soil moisture and bulk density for each soil horizon, and weather data (temperature, wind speed, solar radiation, and humidity).
Ease of Use	Relatively easy to use despite significant data requirements.
Training Required	Requires some knowledge of soil and plant physiology, although a user with sufficient background can gain proficiency with a few days of training.
Training Available	Short training course offered (see Contacts below).
Computer Requirements	An IBM-compatible 486 with 4K of RAM and 80MB.
Documentation	Application manual available (see Cost below).
Applications	Has been used in Spain, Greece, China, The Philippines, Australia (modified), Cameroon, and Thailand as well as many states in the U.S.
Contacts for Tools, Documentation, Technical Assistance	Dr. James McKinion, USDA-ARS, Crop Simulation Unit, PO Box 536, Mississippi State, MS 39762, USA; Tel: +1.601.324.4375; Fax: +1.601.324.4371; e-mail: mckinion@csrumsu.ars.ag.gov.
Cost	Can be obtained free of charge by e-mailing sturner@ra.msstate.edu.
References	Doherty, R.M., L.O. Mearns, K.R. Reddy, M.W. Downton and L. McDaniel. 2003. Spatial Scale Effects of Climate Scenarios on Simulated Cotton Production in the Southeastern U.S.A. *Climatic Change* 60(1-2):99-129. McKinion, J.M., D.N. Baker, F.D. Whisler, and J.R. Lambert. 1989. Application of GOSSYM/COMAX system to cotton crop management. *Agricultural Systems* 31:55-65. Watkins, K.B., Y.C. Lu, and V.R. Reddy. 1998. An economic evaluation of alternative pix application strategies for cotton production using GOSSYM/COMAX. *Computers and Electronics in Agriculture* (20)3:251.

Process Crop Models: GLYCIM

Description	GLYCIM is a dynamic soybean simulation model with hourly time steps. It predicts growth and yield of a soybean crop in response to climate, soil, and management practices by deterministic simulation of organ-level processes such as photosynthesis, transpiration, carbon partitioning, and organ growth and development.
Appropriate Use	Farmers use GLYCIM for pre-plant planning decisions like the selection of cultivar/soil type combination, planting date, and row spacing, and post-plant decisions like irrigation scheduling, harvest timing, and yield prediction. The use of the model for crop management, decision making, and input optimization shows promise in increasing profits to growers and improvements to environment and groundwater quality. Amendable to the testing of management adjustments to climate variation.
Scope	All locations; agricultural sector; site-specific.
Key Output	Plant height, water stress, nitrogen stress, stages of maturity, water content data, yield, and yield components.
Key Input	Requires daily maximum and minimum temperature, precipitation, and solar radiation data as input. Soil data are also required to execute the model (e.g., soil horizons, organic matter, and nitrogen content).
Ease of Use	GLYCIM demands more data inputs than many crop models, but once data input requirements are met at the user level, it is simple to use.
Training Required	Requires some knowledge of agronomy and soil science.
Training Available	Mississippi State University can provide training.
Computer Requirements	Requires an IBM-compatible 486, with 4K of RAM and 80MB.
Documentation	http://eco.wiz.uni-kassel.de/model_db/mdb/glycim.html.
Applications	Currently being used by farmers and several extension services in nine states in the U.S.
Contacts for Tools, Documentation, Technical Assistance	Dr. James McKinion, USDA-ARS, Crop Simulation Unit, PO Box 536, Mississippi State, MS 39762 USA; Tel: +1.601.324.4375; Fax: +1.601.324.4371; e-mail: mckinion@csrumsu.ars.ag.gov.
Cost	Can be downloaded free from website (see Documentation above).
References	http://eco.wiz.uni-kassel.de/model_db/mdb/glycim.html.

Economic Models: Econometric (Ricardian-Based) Models

Description	Econometric models are manipulated with climate change scenarios to predict the economic costs of adaptation. They estimate structural relations between historical climate and agricultural land values under the presumption that such relations reflect a steady-state level of adaptation of regional farming systems to local climate characteristics. These relations are cross-sectional (i.e., units of observation are geographic areas) and the geographic variation in land values is assumed to be partly regulated by differences in the quality of climate inputs. Parameter estimates embed the relative efficiency of current adaptation to a range of climate conditions (cold and warm).
Appropriate Use	Econometric models can capture the full range of economic adaptations that farmers and supporting institutions are likely to use in response to climate change. They are particularly suited to analysis that assumes no change in real crop prices in response to climate change. These tools do not estimate the cost of adaptation.
Scope	All locations; agricultural sector; national or regional.
Key Output	Potential changes in regional or national cropping patterns, land prices, production, revenues, and profits.
Key Input	Historical climate and land values.
Ease of Use	Because no established or "canned" models exist, each application requires development of a unique, region-specific model.
Training Required	Expertise in principles of econometric modeling.
Training Available	No formal training offered.
Computer Requirements	IBM-compatible PC.
Documentation	See Mendelsohn et al., 1994, in References below.
Applications	Econometric models have been used to estimate the economic cost/benefit of climate change for agriculture and forestry in the United States, Brazil, and India.
Contacts for Tools, Documentation, Technical Assistance	Dr. Robert Mendelsohn, Yale University, 360 Prospect St., New Haven, CT 06511 USA; Tel: +1.203.432.5128; Fax: +1.203.387.0766; e-mail: robert.mendelsohn@yale.edu.
Cost	Varies, depending on data needs and resources required for developing a unique model.
References	Dinar, A., R. Mendelsohn, R. Evenson, J. Parikh, A. Sanghi, K. Kumar, J. McKinsey, and S. Lonergon. 1998. Measuring the Impact of Climatic Change on Indian Agriculture. World Bank Technical Report No. 409, The World Bank, Washington, DC. Mendelsohn, R. and J. Neumann (eds.). 1999. *The Impacts of Climate Change on the U.S. Economy*. Cambridge University Press, Cambridge, England. Mendelsohn, R., W. Nordhaus, and D. Shaw. 1994. The impact of global warming on agriculture: A Ricardian analysis. *American Economic Review* 84(4):753-751. Seo, S. and R. Mendelsohn. 2006. The impact of climate change on livestock management in Africa: a structural Ricardian analysis. CEEPA Discussion Paper No. 23, Centre for Environmental Economics and Policy in Africa, University of Pretoria.

Economic Models: Input-Output Modeling (with IMPLAN)

Description	Input-output accounting (using the IMPLAN model as an example) describes commodity flows from producers to intermediate and final consumers. The total industry purchases of commodities, services, employment compensation, value added, and imports are equal to the value of the commodities produced. Industries producing goods and services for final use and purchases for final use (final demand) drive the model. Industries producing goods and services for final demand purchase goods and services from other producers. These other producers, in turn, purchase goods and services. This buying of goods and services continues until leakages from the region stop the cycle. The resulting sets of multipliers describe the change of output for every regional industry caused by a US$1.00 change in final demand for any given industry.
Appropriate Use	Serves three functions: data retrieval, data reduction and model development, and impact analysis. Comprehensive and detailed data coverage of the entire U.S. by county and the ability to incorporate user-supplied data at each stage of the model building process provide a high degree of flexibility in terms of both geographic coverage and model formulation. Can be used to look at the effects of adaptations such as changes in economic policies (e.g., removal or imposition of subsidies) toward agriculture. Designed specifically for the U.S., but basic model structure can be adapted and applied to other countries where data are available.
Scope	Agricultural sector; national or regional-specific.
Key Output	Being demand-driven, most input-output models are structured to trace changes in the flows of capital and labor between industries in response to a change in final demand. Climate change impact analysis often uses input-output models to trace the interindustry flows in response to climate-induced changes in supply.
Key Input	The IMPLAN database consists of (1) a U.S. level technology matrix and (2) estimates of sectoral activity for final demand, final payments, industry output and employment for each county in the U.S., along with state and national totals.
Ease of Use	Commercially available input-output models like IMPLAN are relatively easy to use, although modification from demand to supply driven models is facilitated with an economics background.
Training Required	Training in the use of these models, along with a background in economic analysis, is essential.
Training Available	MIG Workshops (see Contacts below) provide training on the use of IMPLAN in economic analysis. Workshops are held either in MIG's Minnesota USA office or at user's site.
Computer Requirements	Requires a PC, Windows, and the IMPLAN software package. Adobe Acrobat needed to download user manual from the website.
Documentation	A user manual for IMPLAN, available from the MIG, Inc. website listed in Contacts below, may be downloaded to a PC using Adobe software.
Applications	Applied by numerous state, federal, academic, and private institutions in the U.S., such as U.S. Department of Agriculture Forestry Service, the Illinois Department of Natural Resources, and Cornell University.

Economic Models: Input-Output Modeling (with IMPLAN) (cont.)

Contacts for Tools, Documentation, Technical Assistance	Tools and Documentation: MIG, Inc., 1725 Tower Drive West, Suite 140, Stillwater, MN 55082 USA; Tel: +1.651.439.4421; Fax: +1.651.439.4813; e-mail: info@implan.com; website: http://www.implan.com/. Product Support: http://www.implan.com/support.html.
Cost	IMPLAN costs vary depending on scope of study (county, state, or national). County-level software costs $150 per county. State-level software averages about $1,500 per state.
References	Bowes, M. and P. Crosson. 1993. Consequences of climate change for the MINK economy: Impacts and responses. *Climatic Change* 24:131-158.

4.2 Water Sector Tools

The water sector tools described in this compendium, listed in Table 4.2, are mathematical models for assessing water resource adaptations to climate change, focusing on regional water supply and demand analysis of managed water systems. The models summarized here include long-range simulation tools such as WEAP and IRAS, short-range simulation models like RiverWare and WaterWare, and economic optimization models like Aquarius. RIBASIM allows for the assessment of infrastructure, and operational and demand management measures. MIKEBASIN provides basin scale solutions for optimizing water allocations, conjunctive water use, reservoir operation, and water quality issues, emphasizing results visualization through a GIS interface. CALVIN helps identify integrated water management strategies covering surface water, ground water, water conservation, water market, water reuse, and desalination water management options. OSWRM, which simulates water resource supply and demand, was developed to support a stakeholder dialogue process that focuses on the potential role of climate change in water resource management. The European Flood Alert System, on the other hand, is a flood forecasting system that provides medium-range flood forecasting information for trans-national river basins across Europe.

Table 4.2. Tools covered in water sector

WaterWare
Water Evaluation and Planning System (WEAP)
RiverWare
Interactive River and Aquifer Simulation (IRAS)
Aquarius
RIBASIM
MIKE BASIN
Spatial Tools for River Basins and Environment and Analysis of Management Options (STREAM)
CALVIN (CALifornia Value Integrated Network)
OSWRM (Okanagan Sustainable Water Resources Model)
European Flood Alert System (EFAS)

WaterWare

Description	This UNIX based software package is an advanced water resource simulation tool that incorporates numerous models and analyses for easy access to advanced tools for data analysis, simulation modeling, rule-based assessment, and multicriteria decision support for a broad range of water resources management problems. WaterWare is implemented in an open, object-oriented architecture; it supports the seamless integration of databases, GIS, models, and analytical tools into a common sense, easy-to-use framework. This includes a multimedia user interface with Internet access, a hybrid GIS with hierarchical map layers, object data bases, time series analysis, reporting functions, an embedded expert system, and a hypermedia help-and-explain system. Real-time data management, modeling, forecasting, and reporting, and support for operational management are provided with a real-time expert system. Designed to be a highly detailed operation analysis tool at shorter timesteps (hourly to daily). Strongly linked to water quality modeling of instream flows to determine optimal wastewater loading strategies as well as related engineering, environmental, and economic aspects. WaterWare includes a number of simulation and optimization models and related tools, including a rainfall-runoff and water budget model, an irrigation water demand estimation model, dynamic and stochastic water quality models, a groundwater flow and transport model, a water resources allocation model, and an expert system for environmental impact and assessment.
Appropriate Use	Analysis and planning of complex, large-scale water resource management problems. Could be used to investigate realistic adaptation strategies under various hydrologic conditions. System includes both a rainfall/runoff model and a rule-based water resource system simulation tool, so a consistent hydrologic and water resource assessment could be made.
Scope	All locations; ground- and surface water systems; national or site-specific.
Key Output	Water allocations at demand nodes, flows in river reaches, water quality constituents throughout water system, aquifer dynamics, and other water system components.
Key Input	Extensive data requirements. Geographic: background maps with administrative boundaries, land use; river network (geometry) graph and segment geometry (cross sections, roughness) for all channel based models. River Basin Objects: these include classes such as subcatchments, aquifers, lakes and reservoirs, cities, industries, agricultural areas and irrigation districts, representing the nodes in the river network; for each object, and depending on the type of object, data on water demand, use, consumptive use, and wastewater generation (pollution loads) are required. For aquifers, basic hydrogeological data are required; for reservoirs, morphometry and operating rules. Hydrological and Meteorological: Time series of basic hydrometeorological data (hourly to daily) covering at least one year or the period of interest for the long-term models), temperature and precipitation, optionally relative humidity, wind speeds,. cloud cover and solar radiation, potential evapotranspiration. Water Quality: hourly to daily observation data from one or more water quality observation stations; station location and regular time series for each parameter. Economic: Discrete cost functions (investment and operational costs) for a set of alternative waste water treatment technologies.
Ease of Use	Fairly difficult to use given its broad scope.

WaterWare (cont.)

Training Required	Significant training in computer modeling and the engineering, environmental, and economic aspects of water systems.
Training Available	Software purchase includes on-site installation. Training courses and on-site training available (see Contacts below).
Computer Requirements	WaterWare is currently supported for UNIX servers (SUN Sparc/Solaris, IBM RS6000/AIX, HP Risc/HP-UX, Intel Pentium/Linux), with a minimum of 64 MB RAM and 128 MB of swap space. About 2 GB disk space is required; disk space requirements depend on the amount of geographical data (in particular satellite images) and monitoring data. A graphics resolution of 1280*1024 (256 simultaneous colors) is required for the X11 platforms.
Documentation	Documentation available from Environmental Software and Services, GmbH (see Contacts below).
Applications	River Thames in England, Lerma Chapala in Mexico, West Bank and Gaza in Palestine, Kelantan River in Malaysia and Yangtze River in China. River basins and coastal zones in Turkey, Lebanon, Jordan, Egypt, and Tunisia.
Contacts for Framework, Documentation, Technical Assistance	Environmental Software and Services, GmbH, P.O. Box 100 A-2352 Gumpoldskirchen, Austria; Tel: 43225263305; Fax: 432252633059; website: http://www.ess.co.at/WATERWARE/.
Cost	ECU30,000 for initial installation, support, and one-year license.
References	WaterWare: A Water Resources Management Information System — Palestinian case study. Available from Environmental Software and Services, GmbH, P.O. Box 100 A-2352 Gumpoldskirchen, Austria.

Water Evaluation and Planning System (WEAP)

Description	This is a PC based surface and groundwater resource simulation tool, based on water balance accounting principles, which can test alternative sets of conditions of both supply and demand. The user can project changes in water demand, supply, and pollution over a long-term planning horizon to develop adaptive management strategies. WEAP is designed as a comparative analysis tool. A base case is developed, and then alternative scenarios are created and compared to this base case. Incremental costs of water sector investments, changes in operating policies, and implications of changing supplies and demands can be economically evaluated.
Appropriate Use	What-if analysis of various policy scenarios and long-range planning studies. Adaptive agriculture practices such as changes in crop mix, crop water requirements, canal linings; changes in reservoir operations; water conservation strategies; water use efficiency programs; changes in instream flow requirements; implications of new infrastructure development. Strengths include detailed demand modeling.
Scope	All locations, surface- and groundwater systems; national, international or site-specific.
Key Output	Mass balances, water diversions, sectoral water use; benefit/cost scenario comparisons; pollution generation and pollution loads.
Key Input	Configuration of system (can use GIS layers for background) and component capacities and operating policies. Water demand: Spatially explicit demographic, economic, crop water requirements; current and future water demands and pollution generation. Economic data: Water use rates, capital costs, discount rate estimates. Water supply: Historical inflows at a monthly timestep; groundwater sources. Scenarios: Reservoir operating rule modifications, pollution changes and reduction goals, socioeconomic projections, water supply projections.
Ease of Use	Relatively easy to use. Requires significant data for detailed analysis.
Training Required	Moderate training/experience in resource modeling required for effective use.
Training Available	On-line tutorial available at http://www.weap21.org/. Contact SEI for details regarding available training (see below).
Computer Requirements	200 MHz or faster Pentium class PC with Microsoft Windows 95 or later (a 400 MHz PC with Windows 98 or later is recommended). A minimum of 32 MB of RAM and 50 MB of free hard disk space is also required (64 MB of RAM recommended). In addition Microsoft Internet Explorer version 4.0 is required for viewing WEAP's HTML Help. Monitor should be set to a minimum resolution of 800x600, but preferably even higher (e.g., 1024x768 or 1280x1024), to maximize the presentation of data and results.
Documentation	WEAP21 User Guide; available online at http://www.weap21.org/downloads/WEAP_User_Guide.pdf.
Applications	Has been used for projects in the Aral Sea; Beijing, China; Rio San Juan, Mexico; Rajasthan, India; South Africa; West Africa; California, Texas, and Southeast, USA; Central Asia; India; Nepal; Korea; and Cairo, Egypt. Has also been used in Uzbekistan to assess water resource capacity with regard to irrigation needs.
Contacts for Framework, Documentation, Technical Assistance	Jack Sieber, Senior Software Scientist, Stockholm Environment Institute (SEI), Boston; SEI-Tellus Institute, 11 Arlington St., Boston, MA 02116-3411 USA; Tel: +1.617.266.5400; e-mail: weap@tellus.com; website: http://www.weap21.org/.

Water Evaluation and Planning System (WEAP) (cont.)

Cost	2-year license fee ranges from US$1000-2500, depending on type of user. Free to developing countries. See http://www.weap21.org for more information.
References	Arranz, R. and M. McCartney. 2007. Application of the Water Evaluation And Planning (WEAP) model to assess future water demands and resources in the Olifants catchment, South Africa. Colombo, Sri Lanka: International Water Management Institute. 103 pp. (IWMI Working Paper 116). Hansen, E. 1994. WEAP — A system for tackling water resource problems. In *Water Management Europe 1993/94: An Annual Review of the European Water and Wastewater Industry*. Stockholm Environment Institute: Stockholm. *U.S. Water News*, Oct. 1992. Aral Sea is classic example of ecological suicide. No. V4, p. 12. Huber-Lee, A., D. Yates, D. Purkey, W. Yu, and B. Runkle. 2003. Water, climate, food, and environment in the Sacramento Basin — contribution to ADAPT: Adaptation strategies to changing environment. Stockholm Environment Institute, Boston, MA, USA. Raskin, P., E. Hansen, Z. Zhu, and D. Stavisky. 1992. Simulation of water supply and demand in the Aral Sea region. *Water International* 17(2):55-67.

RiverWare

Description	A general UNIX based river and reservoir modeling application with both operational and planning applications. This system offers multiple solution methodologies that include simulation, simulation with rules, and optimization. RiverWare can accommodate a variety of applications, including daily scheduling, operational forecasting, and long-range planning. Modeling framework is non-spatial (not GIS based). Because of its object-oriented nature, the modeling framework allows for the generation of new modeling methods that could include economically driven demand modeling.
Appropriate Use	The tool is most appropriately used to model resource demands on complex water systems governed by water law and intricate operating rules. For broader, water resource-related activity, WEAP or IRAS tools are preferable (less expensive, easier to implement, less data required). Uncertainty modeling related to parameter variance provides estimates of uncertainty in model output.
Scope	All locations; surface water systems; national or site-specific.
Key Output	Mass balances, detailed flow descriptions throughout the water system, water diversions, hydropower generation, hydropower tradeoffs to other operating objectives. Water quality descriptions of dissolved solids and water temperature.
Key Input	Water demand: Description of diversion requirements (no explicit, economically driven demand modeling at this time). Water supply: Historical inflows at multiple timesteps, reservoir characteristics, stream reach routing characteristics. No groundwater components currently available. Scenarios: Operating rules of system given as prioritized operating policy described through a rule-based computer programming language. Water quality: Return water temperatures from thermal plants.
Ease of Use	The flexibility of the system makes it a more difficult model to use. Ideally designed for detailed analysis, requiring significant data.
Training Required	Requires extensive knowledge of the physical characteristics of water systems. Knowledge of water systems modeling helpful.
Training Available	CADSWES regularly holds training workshops in Boulder, CO, USA (see Contacts below).
Computer Requirements	Sun Solaris (Unix) workstation with Solaris 2.7 or higher operating system, or Windows NT/2000/XP; system memory requirements depend on river/reservoir model size and data; a minimum of 256MB is recommended. CPLEX, a third-party solver, is required to run the RiverWare Optimization module.
Documentation	Detailed documentation available through CADSWES; RiverWare description at http://cadswes.colorado.edu/riverware/.
Applications	Currently, modeling applications have focused on operational strategies of current systems. In the U.S., the model has been used to develop operational strategies for the Tennessee Valley Authority's (TVA) river/reservoir system at short time scales (daily). Used for evaluating operating policies on the Colorado River at longer timesteps (monthly). The model has also been applied in the San Juan Basin and Upper Rio Grande.

RiverWare (cont.)

Contacts for Framework, Documentation, Technical Assistance	Center for Advanced Decision Support in Water and Environmental Systems (CADSWES), University of Colorado, Campus Box 428, Boulder, CO 80309-0428 USA; e-mail: rwinfo@cadswes.colorado.edu; website: http://cadswes.colorado.edu/riverware/.
Cost	Single node license US$6500 for first year; US$2500 annual renewal fee; additional fees for optimization solver. See http://cadswes.colorado.edu/riverware/LicensingRW/ for more information.
References	See http://cadswes.colorado.edu/riverware/publications.html for a list of references. Zagona, E.A., T.J. Fulp, R. Shane, T. Magee, and H.M. Goranflo. 2001. RiverWare: A generalized tool for complex reservoir systems modeling. *Journal of the American Water Resources Association* 37(4):913-929.

Interactive River and Aquifer Simulation (IRAS)

Description	This tool is a PC based surface water resource simulation tool, based on water balance accounting principles that can test alternative sets of conditions of both supply and demand. The river system is represented by a network of nodes and links, with the nodes representing aquifers, gauges, consumption sites, lakes, reservoirs, wetlands, confluences, and diversions. Links are river reaches or water transfers to the nodes. The model can simulate up to 10 independent or interdependent water quality factors at a submonthly timestep. Through data interfacing, IRAS can link to various external modules such as rainfall-runoff and to economic and ecological impact prediction programs.
Appropriate Use	Used in long-range planning to evaluate the performance or impacts of alternative designs and operating policies of regional water resource systems, ranging from simple to complex systems. It has more significant water quality modeling ability than WEAP, but does not include a detailed demand modeling environment. Strengths include modeling capability of groundwater, natural aquatic systems and water quality. Includes wetland analysis.
Scope	All locations; surface water systems; national or site-specific.
Key Output	System performance in meeting demand requirements; flows, storage volumes, energy, and water quality throughout system.
Key Input	Configuration of system and component capacities and operating policies. Water demand: Demand requirements at various nodes. Water supply: Historical inflows at various time steps, evaporation and seepage losses from system, aquifer recharge rates, wetland characteristics. Water quality: Waste loads. Scenarios: Reservoir operating rule modifications, pollution changes and reduction goals.
Ease of Use	Relatively easy to use. Detailed analysis requires significant data.
Training Required	Moderate training/experience in resource modeling and demand analysis required for effective use.
Training Available	Contact RPA for details regarding available training (see Contacts below).
Computer Requirements	IBM-compatible PC with Windows 95 or higher. Recommended Pentium processor with 24MB RAM, 100MB disk space, and color monitor.
Documentation	Detailed users guide is available from RPA in Contacts, below.
Applications	Has been applied to evaluate designs and policies of river-aquifer systems in North America, Europe, Africa, and Asia.
Contacts for Framework, Documentation, Technical Assistance	Marshall Taylor, Resources Planning Associates, Inc., 231 Langmuir Bldg., 95 Brown Road, Ithaca, NY 14850 USA; Tel: +1.607.257.4305; Fax: +1.607.257.4306.
Cost	Relatively low cost to obtain model documentation and software.
References	Brandão, C. and R. Rodrigues. 2000. Hydrological simulation of the international catchment of Guadiana River. *Physics and Chemistry of the Earth, Part B: Hydrology, Oceans and Atmosphere* 25(3):329-339. CH2M Hill, 1993. New Jersey Statewide Water Supply Master Plan, Task 4 Report: Preliminary Development of Water Supply Initiatives. CH2M Hill, Parsippany, NJ, USA. Loucks, D.P., P.N. French and M.R. Taylor. 1995. IRAS — Interactive River-Aquifer Simulation: Program Description and Operation. Resources Planning Associates, Incorporated, Ithaca, NY, USA.

Aquarius

Description	A computer model depicting the temporal and spatial allocation of water flows among competing traditional and nontraditional water uses in a river basin. The model focuses on optimization of a nonlinear system, where supplies and requested demands are prescribed on the system. Water resource systems are described in a node-link architecture, with river reaches, reservoirs, lakes, and demand objects describing the system. A drag and drop user interface helps define the system layout, which is then translated into a quadratic objective function with linear constraints.
Appropriate Use	Determining economically efficient water destination strategies. Can be used in a full deterministic optimization mode, for general planning purposes, or in a quasi-simulation mode, with restricted foresight capabilities. Supports the following water uses (system components): storage reservoir, hydropower plants, agricultural water use, municipal and industrial water use, instream recreation water use, reservoir recreation use, and instream flow protection. For a water use with a predetermined level of allocation but without a defined economic demand function, the analyst can either constrain the model to meet the specified allocation or experiment with surrogate demand curves until the required level of water allocation is reached. The latter approach indicates the level of economic subsidy required to provide the incremental increases of flow to sustain the use in open competition with other uses. The interactive nature of Aquarius facilitates such experimentation.
Scope	All locations; surface and groundwater systems; cost-effectiveness; national or site-specific.
Key Output	Economically efficient allocations that meet prescribed demands.
Key Input	The model's input data have been divided into physical and economic data. The physical data include the information associated with the dimensions and operational characteristics of the system components, such as maximum reservoir capacity, percent of return flow from an offstream demand area, and power plant efficiency. The economic data consist mainly of the demand functions of the various water uses competing for water.
Ease of Use	Fairly easy to use. Straightforward user interface with limited modeling scope makes model setup time relatively short.
Training Required	Minimal training required. Requires some knowledge of optimization theory.
Training Available	Questions regarding software availability and training can be directed to Gustavo E. Diaz (see below).
Computer Requirements	PC Windows 95, 98, NT, or Windows 2000 operating system.
Documentation	Model documentation is available on line at http://www.fs.fed.us/rm/value/docs/aquadoc01.pdf.
Applications	Authors are not aware of existing applications in developing countries.
Contacts for Framework, Documentation, Technical Assistance	Gustavo E. Diaz, Department of Civil Engineering, Colorado State University, Fort Collins, CO, 80523, USA; Tel: +1.970.491.5048; Fax: +1.970.491.7721; e-mail: gdiaz@lamar.colostate.edu; website: http://www.fs.fed.us/rm/value/aquariusdwnld.html.

Aquarius (cont.)

Cost	Model documentation and software is free for government agencies and for teaching and research purposes.
References	Diaz, G.E., T.C. Brown, and O. Sveinsson. 2005. Aquarius: A Modeling System for River Basin Water Allocation. General Technical Report RM-GTR-299-revised. U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station, Fort Collins, CO.

RIBASIM

Description	RIBASIM is a generic model package for simulating the behavior of river basins under various hydrological conditions. The model package is a comprehensive and flexible tool that links the hydrological water inputs at various locations with the specific water users in the basin. RIBASIM enables the user to evaluate a variety of measures related to infrastructure and operational and demand management, and to see the results in terms of water quantity and flow composition. RIBASIM can also generate flow patterns that provide a basis for detailed water quality and sedimentation analyses in river reaches and reservoirs. Demands for irrigation, public water supply, hydropower, aquaculture, and reservoir operation can be taken into account. Surface- and groundwater resources can be allocated. Minimum flow requirements and flow composition can be assessed.
Appropriate Use	Evaluation of the options and potential for development of water resources in a river basin. Assessment of infrastructure, and operational and demand management measures.
Scope	All locations, surface- and groundwater systems; national or site-specific.
Key Output	Water balance providing the basic information on the available quantity of water as well as the composition of the flow at every location and any time in the river basin. This takes into account drainage from agriculture, discharges from industry and the downstream re-use of water in the basin.
Key Input	Configuration of system (can use GIS layers for background) and component capacities and operating policies. Water demand: Spatially explicit demographic, economic, crop water requirements; current and future water demands and pollution generation. Economic data: Water use rates, capital costs, discount rate estimates. Water supply: Historical inflows at a monthly timestep; groundwater sources. Scenarios: Reservoir operating rule modifications, pollution changes and reduction goals, socioeconomic projections, water supply projections.
Ease of Use	Relatively easy to use. Requires significant data for detailed analysis.
Training Required	Moderate training/experience in resource modeling required for effective use.
Training Available	Contact Delft Hydraulics for details regarding available training (see Contacts below).
Computer Requirements	200 MHz Pentium processor; 64 Mb RAM; 400 Mb free disk space; Super VGA graphics card with matching monitor; mouse; CD-ROM drive; RIBASIM requires MICROSOFT WINDOWS 95, 98, 2000, NT or XP.
Documentation	User manual and technical reference manual are provided with RIBASIM software. Brochure and other materials are available at http://www.wldelft.nl/soft/ribasim/doc/index.html.
Applications	RIBASIM has been applied for more than 20 years in a wide variety of projects and countries. Water management organizations worldwide use it to support their management and planning activities. See http://www.wldelft.nl/soft/ribasim/cases/index.html for more details.
Contacts for Framework, Documentation, Technical Assistance	WL Delft Hydraulics Rotterdamseweg 185, P.O. Box 177, 2600 MH Delft, The Netherlands. Tel: +31.0.15.285.8585; Fax: +31.0.15.285.8582; e-mail: ribasim.info@wldelft.nl; website: http://www.wldelft.nl/soft/ribasim/int/index.html.
Cost	Relatively low cost to obtain model and documentation.
References	Contact Delft Hydraulics for references.

MIKE BASIN

Description	For addressing water allocation, conjunctive use, reservoir operation, or water quality issues, MIKE BASIN couples the power of ArcView GIS with comprehensive hydrologic modeling to provide basin-scale solutions. The MIKE BASIN philosophy is to keep modeling simple and intuitive, yet provide in-depth insight for planning and management. In MIKE BASIN, the emphasis is on powerful simulation result visualization in both space and time, making it the perfect tool for building understanding and consensus. For hydrologic simulations, MIKE BASIN builds on a network model in which branches represent individual stream sections and the nodes represent confluences, diversions, reservoirs, or water users. The ArcView GIS interface has been expanded accordingly, e.g., such that the network elements can be edited by simple right-clicking. Technically, MIKE BASIN is a quasi-steady-state mass balance model, however, allowing for routed river flows. The water quality solution assumes purely advective transport; decay during transport can be modeled. The groundwater description uses the linear reservoir equation.
Appropriate Use	Water availability analysis: conjunctive surface and groundwater use, optimization thereof. Infrastructure planning: irrigation potential, reservoir performance, water supply capacity, waste water treatment requirements. Analysis of multisectoral demands: domestic, industry, agriculture, hydropower, navigation, recreation, ecological, finding equitable trade-offs. Ecosystem studies: water quality, minimum discharge requirements, sustainable yield, effects of global change. Regulation: water rights, priorities, water quality compliance.
Scope	All locations; surface- and groundwater systems; national or site-specific.
Key Output	Mass balances, detailed flow descriptions throughout the water system, water diversions, hydropower generation, hydropower tradeoffs to other operating objectives. Water quality descriptions of dissolved solids and water temperature.
Key Input	Overall system: Digitized river system layout, withdrawal and reservoir locations. Water demand: Time series of water demand, percentage of ground abstraction, return flow ratio, linear routing coefficient (irrigation only). Water supply: Unit naturalized runoff (time series), initial groundwater elevation, linear reservoir time constant, groundwater recharge time series. Hydropower: time series of withdrawal for hydropower, installed effect, tail water level, machine efficiency. Reservoir: Initial water level, operational rule curves, stage-area-volume curve, time series of rainfall and evaporation, linkages to users, priority of delivery, linkages to upstream nodes. Water quality: rate parameters, temperature, non-point loads, weir constant for re-aeration, transport time and water depth or Q-h relationship, concentrations in effluent.
Ease of Use	Relatively easy to use if user is familiar with ArcView software. Requires significant data for detailed analysis.
Training Required	Moderate training/experience in resource modeling required for effective use. Also requires working knowledge of ESRI's ArcView software.
Training Available	MIKE BASIN courses are arranged both regularly and upon request (see http://www.dhigroup.com/Software/Training/CourseTopics/WaterResources.aspx).
Computer Requirements	ArcView 3.2 or 3.2a; Windows 98, NT, 2000, or XP operating system (MIKE BASIN may also run on Windows 95 and ME, but those operating systems are not officially supported by DHI); minimum 64 MB RAM (recommended); high resolution monitor, minimum 800x600 pixels; minimum 200 MB free disk space.

MIKE BASIN (cont.)

Documentation	Detailed documentation including on-line tours of the model available through their website: http://www.dhigroup.com/Software/WaterResources/MIKEBASIN.aspx.
Applications	Has been used in Peru; Sabah, Malaysia; Gold Coast, Australia; Idaho and North Carolina, USA; Italy; Poland; Thailand; Sri Lanka; Senegal; Czech Republic; Zambia; and Tanzania.
Contacts for Framework, Documentation, Technical Assistance	DHI's Software Support Centre; Tel: +45.45.16.93.33 Fax: +45.45.16.92.92; e-mail: software@dhi.dk; website: http://www.dhigroup.com/Software/WaterResources/MIKEBASIN.aspx.
Cost	Licensed software cost US$3000 per class set, US$300 to update each set.
References	See http://www.dhigroup.com/Software/WaterResources/MIKEBASIN/References/Publications.aspx for references.

Spatial Tools for River Basins and Environment and Analysis of Management Options (STREAM)

Description	STREAM is a spatial hydrological model that allows for assessing hydrological impacts due to changes in climate and socio economic drivers. STREAM is set up according to a policy analysis framework and ensures a structured approach for an entire river basin including the coastal zone. STREAM uses hydrological input data, scenarios, and adaptive strategies and provides output data on water availability and (salt water) quality. It integrates within this frame several types of interactions between effects of river management on the coastal zone, land and water uses such as short term deforestation and dam building, and long term impacts of climate change. STREAM is a spatial model and uses data from digital GIS maps and satellite observations, in particular land-use related data. The basis of the instrument is a grid or raster-based water balance approach. Water use and withdrawals can be simulated such as the spatial distribution of agriculture and urbanization use and the storage of water in the open flood plain and groundwater aquifers. The main advantage of STREAM is that it primarily uses public domain data from the internet providing a very first order of estimates on impacts. This makes the STREAM instrument very flexible for future extensions and adjustments. The next stage of development, calibration and validation, is usually performed in close cooperation with local stakeholders, using local time series of in and output data increasing the level of reliability.
Appropriate Use	The STREAM can be applied to entire river basins with different sizes for which it considers the full year hydrological cycle. For example, in large river basins, a grid size of 1 x 1 km2 can be applied while in the lower regions a 100 x 100 m2 grid size is applicable. Time steps can vary from 1 month as an overall step to either decades or 5-day steps for specific periods of interest during the hydrological cycle, such as the flood season.
Scope	STREAM has been primarily applied to studies to assess impacts of climate change, climate variability and land use changes (including dams and reservoirs) to water resources in river basins. For these issues, STREAM enables calculation of the impacts of changes in temperature and precipitation on the regional hydrology. Based on these impacts, different management strategies can be assessed by providing a quantitative assessment of water availability under various scenarios.
Key Output	Key output is spatial hydrological information on water availability in the form of (monthly) soil-humidity and river discharges. The latter outputs can be in either a hydrograph or a spatial GIS based map.
Key Input	The required input data is: temperature, precipitation, soil types, elevation. And for calibration and validation: runoff data.
Ease of use	The model is easy to use for non technical users. However, it is best used within a team of both hydrological experts and policy makers. Some GIS knowledge is required.
Training Required	Some GIS knowledge and training is required to prepare the input data of the model. Also some basic hydrological knowledge is an advantage but is not necessary.

Spatial Tools for River Basins and Environment and Analysis of Management Options (STREAM) (cont.)

Training Offered	A setup manual is delivered with the model. It is recommended, however, that users follow a short introductory course by the distributor and RIKZ.
Computer Requirements	The minimum hardware requirement is a PIII – 500MhZ computer with 256 MB internal memory
Documentation	STREAM software and user manual are available at http://www.geo.vu.nl/users/ivmstream/.
Applications	STREAM has been applied to the following river basins: Rhine (Europe), Meuse (Europe), Amu Darya (Central Asia), Syr Darya (Central Asia), Nile (Africa), Niger (Africa), Incomati (Africa), Zambezi (Africa), Ganges/Brahmaputra (Asia), Yangtze (China), Krishna (India), Perfume (Vietnam).
Contacts for Framework, Documentation and Technical Assistance	Dr. Robbert Misdorp, Coastal Zone Management Centre/National Institute for Coastal and Marine Management (RIKZ),Ministry of Transport, Public Works and Water Management Kortenaerkade 1, PO BOX 20907, 2500EX The Hague. The Netherlands; Tel: +31.70.3114311, Fax: +31.70.3114300, e-mail: R.Misdorp@chello.nl; website: http://www.netcoast.nl. Dr. Jeroen Aerts, Senior Researcher Water Resources, Climate Change Institute for Environmental Studies (IVM), Vrije Universiteit Amsterdam De Boelelaan 1087, 1081 HV Amsterdam, The Netherlands, Tel. +31.20.4449528 / 9555; Fax. +31.20.4449553, e-mail: jeroen.aerts@ivm.vu.nl; website: http://www.falw.vu.nl/home/index.cfm.
Cost	A STREAM-DEMO tool can be acquired for free. After registering, a free copy of the Model can be obtained through the IVM – STREAM Website. The development of a first order Internet-based STREAM for a new river basin can be accomplished within a month.
References	See http://www.geo.vu.nl/users/ivmstream/ for list of STREM references.

CALVIN (CALifornia Value Integrated Network)

Description	This is an economic-engineering optimization model of California's inter-tied water supply system, based on the US Army Corps of Engineers HEC-PRM software. Data on surface and ground water hydrology, infrastructure connectivity and capacities, operating costs, economic values for water deliveries, and environmental flow constraints are combined with an optimization solver to identify promising integrated water management strategies coving surface water ground water, water conservation, water market, water reuse, and desalination water management options.
Appropriate Use	This is a screening model for planning and policy purposes.
Scope	Models for US California, its sub-regions, and Baja California, Mexico.
Key Output	Costs, marginal economic values, and monthly water management decisions are provided for the time series of hydrologic data provided.
Key Input	Surface and ground water inflows (time series), system connectivities and infrastructure capacities, operating costs, economic values for water deliveries, water loss coefficients, evaporation rates.
Ease of Use	Not easy.
Training Required	3-4 day course, plus prior modeling experience and familiarity with water management systems
Training Available	Short courses are available from UC Davis, UABC-Ensenada, and several California consultants.
Computer Requirements	Regular desktop computer.
Documentation	See http://cee.engr.ucdavis.edu/faculty/lund/CALVIN/.
Applications	Statewide and regional water models of US California and Baja California, Mexico. Applications include: valuing infrastructure expansions, water markets and transfers, conjunctive use, integrated resource management, climate warming adaptation, adaptation to a repeat of a severe and sustained paleodrought, Hetch Hetchy dam removal, Colorado River restoration, etc.
Contacts for Tools, Documentation, Technical Assistance	See http://cee.engr.ucdavis.edu/faculty/lund/CALVIN/.
Cost	Software is free.

CALVIN (CALifornia Value Integrated Network) (cont.)

References	Thirteen peer-reviewed publications, a few included below. See http://cee.engr.ucdavis.edu/faculty/lund/CALVIN/ for these and reports and non-peer-reviewed publications. Draper, A.J., M.W. Jenkins, K.W. Kirby, J.R. Lund and R.E. Howitt. 2003. Economic-Engineering Optimization for California Water Management. *Journal of Water Resources Planning and Management* 129(3):155-164. Jenkins, M.W., J.R. Lund, R.E. Howitt, A.J. Draper, S.M. Msangi, S.K. Tanaka, R.S. Ritzema and G.F. Marques. 2004. Optimization of California's Water System: Results and Insights. *Journal of Water Resources Planning and Management* 130(4): 271-280. Medellin-Azuara, J., J.J. Harou, M.A. Olivares, K. Madani-Larijani, J.R. Lund, R.E. Howitt, S.K. Tanaka, M.W. Jenkins and T. Zhu. In press. Adaptability and Adaptations of California's Water Supply System to Dry Climate Warming. *Climatic Change*. Medellín-Azuara, J., J.R. Lund and R.E. Howitt. 2007. Water Supply Analysis for Restoring the Colorado River Delta, Mexico," *Journal of Water Resources Planning and Management* 133(5): 462-471. Null, S. and J.R. Lund. 2006. Re-Assembling Hetch Hetchy: Water Supply Implications of Removing O'Shaughnessy Dam. *Journal of the American Water Resources Association* 42(4):395 – 408. Pulido-Velázquez, M., M.W. Jenkins, and J.R. Lund. 2004. Economic Values for Conjunctive Use and Water Banking in Southern California. *Water Resources Research* 40(3). Tanaka, S.K., T. Zhu, J.R. Lund, R.E. Howitt, M.W. Jenkins, M.A. Pulido, M. Tauber, R.S. Ritzema and I.C. Ferreira.2006. Climate Warming and Water Management Adaptation for California. *Climatic Change* 76(3-4):361-387.

OSWRM (Okanagan Sustainable Water Resources Model)

Description	OSWRM is created in system dynamics software (STELLA). The model simulates water resource supply and demand, including residential (municipal), agricultural, and instream flow requirements. Included are population growth and climate change and how they affect both supply and demand. The tool was developed in 2005 within a stakeholder dialogue process that focused on the potential role of climate change in management of their water resources. The tool helped to combine scientifically-generated plausible scenarios with on-the-ground knowledge of water management operations and policies, as well as the social acceptability of potential adaptation options. The tool supported dialogue by providing a common focal point and testing participants' assumptions about the current and future state of the water resources.
Appropriate Use	The purpose of the tool is to explore and learn about the system, particularly in group settings among stakeholders. The tool is not intended for policy design, but to support dialogue on which policies may be most effective and warrant more detailed study (and also, which ones will not be effective).
Scope	The tool is specifically designed for the Okanagan Basin, British Columbia, Canada.
Key Output	The results of the process are the OSWRM (model), analysis of future scenarios, and the experience of those who participated in the model development workshops.
Key Input	The model is populated with data for hydrologic and crop water demand scenarios based on Merritt and Alila 2006, Neilsen et al. 2006, Neale et al., in press, Neale 2005, along with an array of population growth scenarios, so no additional information is required to run the model. The user has the option to select the climate and population scenario, and then to test a number of adaptation options.
Ease of Use	The model was designed for use by stakeholders of different backgrounds. The user interface is separate from the model design layer and is relatively easy for the lay-person to use.
Training Required	It is possible for individuals to use the model without training; however, the model was intended for use within group settings for the purpose of stimulating dialogue.
Training Available	See documentation.
Computer Requirements	STELLA software is needed to run the model. You may download either a demo version or a model viewer from the company's website: www.iseesystems.com
Documentation	A quick user guide and model documentation references are available in the appendices of both Cohen and Neale 2006 (Final report) and Langsdale 2007 (Dissertation).
Applications	OSWRM was developed within a year-long stakeholder engagement process. Five workshops were held to engage the Okanagan Basin's water resource community (professionals and other interested parties) in guiding model development and in exploring plausible futures. This process is described in the references listed below.
Contacts for Tools, Documentation, Technical Assistance	Stacy Langsdale, NRC Research Fellow, Institute for Water Resources, Alexandria, VA; e-mail: slangsdale@gmail.com. Stewart Cohen, Adaptation and Impacts Research Division (AIRD), Environment Canada, located at Dept. of Forest Resources Management, University of British Columbia, Vancouver BC; e-mail: Stewart.Cohen@ec.gc.ca. Jeff Carmichael, Adjunct Faculty, Institute for Resources Environment & Sustainability, University of British Columbia, Vancouver; e-mail: Jeff.Carmichael@gvrd.bc.ca.

OSWRM (Okanagan Sustainable Water Resources Model) (cont.)

Cost	STELLA software is available from ISEE for US$650 (price for educators/researchers). The price for professionals is US$1900. Documentation for the software costs US$50. Current information on prices is available from the ISEE website (www.iseesystems.com). Regarding the research study that supported Dr. Langsdale (Cohen and Neale, 2006), the study was two years in duration, but was built on previous work that extended over 5 years. The study included direct support for Dr. Langsdale's time and for the group-based process (workshops, facilitation, and travel to the study area). Costs to develop a similar tool will depend on availability of information on the system of interest, scenario-based projections of impacts, and information on locally available adaptation measures. The current version of OSWRM is freely available.
References	Beall, A., L. Zeoli, et al. 2006. Participatory Modeling for Adaptive Management: Reports from the Field. Proceedings of the 24th International Conference of the System Dynamics Society, Nijmegen, The Netherlands. Beall, A. and A. Ford. 2007. Participatory Modeling for Adaptive Management: Reports from the Field II. Proceedings of the 25th International Conference of the System Dynamics Society, Boston. Beall, A. 2007. Participatory Environmental Modeling and System Dynamics: Integrating Natural Resource Science and Social Concerns. Ph.D. Thesis. Washington State University, Pullman Washington. Cohen, S. and T. Neale (eds.). 2006. Participatory integrated assessment of water management and climate change in the Okanagan Basin, British Columbia. Final report, Project A846. Submitted to Natural Resources Canada, Ottawa. Environment Canada and University of British Columbia, Vancouver, 188p. Langsdale, S. M. 2007. Participatory Model Building for Exploring Water Management and Climate Change Futures in the Okanagan Basin, BC, Canada. PhD Dissertation. University of British Columbia. Langsdale, S. 2007. Communication of Climate Change Uncertainty to Stakeholders Using the Scenario Approach. *J. of Contemporary Water Research & Education*: 138. Langsdale, S., A. Beall, J. Carmichael, S. Cohen, and C. Forster. In Press. An Exploration of Water Resources Futures under Climate Change using System Dynamics Modeling. *Integrated Assessment Journal.* The Integrated Assessment Society. Langsdale, S., A. Beall, J. Carmichael, S. Cohen, and C. Forster. 2006. Managing water resources and climate change using group model building. Proceedings of the Adaptive Management of Water Resources Summer Specialty Conference. American Water Resources Association, Missoula, MT. Langsdale, S. A. Beall, J. Carmichael, S. Cohen, C. Forster, and T. Neale. In review. Participatory Modeling to Explore the Implications of Climate Change on Water Resources in the Okanagan River Basin, British Columbia, Canada. *Journal of Water Resources Planning and Management*. Langsdale, S., A. Beall, et al. 2006. Ch. 5: Exploring Water Resources Futures with a System Dynamics Model. Participatory Integrated Assessment of Water Management and Climate Change in the Okanagan Basin, British Columbia, Canada: Final Report. S. Cohen and T. Neale (eds.). Vancouver, Environment Canada and UBC.

OSWRM (Okanagan Sustainable Water Resources Model) (cont.)

References continued	Langsdale, S., A. Beall, et al. 2006. Ch. 4: Shared Learning Through Group Model Building. Participatory Integrated Assessment of Water Management and Climate Change in the Okanagan, British Columbia, Canada: Final Report. S. Cohen and T. Neale (eds.). Vancouver, Environment Canada and UBC. Langsdale, S., A. Beall, et al. 2006. Managing water resources and climate change using group model building. Proceedings of the Adaptive Management of Water Resources Summer Specialty Conference, American Water Resources Association (AWRA), Missoula, Montana. Merritt, W. S., Y. Alila, et al. 2006. Hydrologic response to scenarios of climate change in the Okanagan Basin, British Columbia. *Journal of Hydrology* 326:79-108. Neale, T. 2005. Impacts of Climate Change and Population Growth on Residential Water Demand in the Okanagan Basin, British Columbia. School of Environment and Sustainability. Victoria, B.C., Royal Roads University. Neale, T., J. Carmichael and S. Cohen. In press. Urban Water Futures: A multivariate analysis of population growth and climate change impacts on urban water demand in the Okanagan Basin, BC. *Canadian Water Resources Journal*. Neilsen, D., C. A. S. Smith, et al. 2006. Potential impacts of climate change on water availability for crops in the Okanagan Basin, British Columbia. *Canadian Journal of Soil Science* 86: 921-936. Winz, I., G. Brierley and R. Cavana. The Use of System Dynamics Simulation in Integrated Water Resource Management. Proceedings of the 25th International Conference of the System Dynamics Society, Boston.

European Flood Alert System (EFAS)

Description	The European Flood Alert System is a flood forecasting system currently under development and testing at the European Commission DG Joint Research Centre in close collaboration with National Hydrological and Meteorological Services. The system was launched by the European Commission following the devastating Elbe and Danube floods in 2002 with the aim to provide National Hydrological Services with medium-range flood forecasting information on river basin scale across Europe. Technically, EFAS is based on the physically-based distributed hydrological model LISFLOOD and is driven by observed meteorological data and medium-range weather forecasts including full sets of Ensemble Prediction System. Its output consists of probabilistic information on floods in the medium-range (3-10 days) for trans-national river basins in Europe. In case that a high probability of flooding is forecasted in 3-10 days, the partner organizations are contacted with detailed information from the EFAS system. EFAS outputs are also evaluated against historic observations and skill is assessed through case study analysis and statistical skill score assessments. One important objective of EFAS is to further research in probabilistic flood forecasting in operational applications. It is planned that the pre-operational system will be transferred to an operational entity by 2010.
Appropriate Use	EFAS results are not public information but provided only to experts, e.g. hydrological experts in the National Hydrological Services, as early flood warning information. EFAS ensures that the partners are informed about EFAS output through training documents and workshops and understand how to understand the probabilistic results.
Scope	EFAS covers medium-large trans-national river basins in Europe.
Key Output	Medium-range flood probability maps, ensemble streamflow output, meteorological rainfall information, media-monitoring on floods made accessible through a web-based interface.
Key Input	Key input can be split into dynamic data, e.g. observed meteorological data, rainfall, temperature, evaporation, weather forecast data including EPS, observed discharge data, and static data, e.g. maps of topography, land-use, soil, river network.
Ease of Use	EFAS information consists of specific products for flood forecasting experts and therefore requires a good understanding of flood forecasting and hydrological processes. The information is made accessible through a web-interface which is easy to use. Concise manuals and training documents guide the user through the different applications and online explanation is also provided directly through the web interface.
Training Required	Expert knowledge on hydrological forecasting is required to understand the specific products and how to use them. Training is provided through documents, meetings and discussions.
Training Available	Training documents, manuals, meetings.
Computer Requirements	In order to run EFAS as a system a Linux cluster is needed, a database and a substantial file storage system for model input/output (capacity in the order of several TBytes). The system is programmed in a dynamic GIS language (PCRaster) and Python scripting. In order to view the results, the EFAS web-interface is based on Windows and accessible through any web browser.
Documentation	Documentation can be found on the EFAS webpage http://efas.jrc.it.
Applications	Since 2005 EFAS information is provided to about 24 National hydrological services across Europe in case flooding is forecasted more than 3 days in advance. The system was active and successful during a number of serious floods in the past, including the Danube floods in 2005 and 2006, the Elbe floods in 2006, Rhine floods 2007. Medium-smaller scale floods were also covered by EFAS and reported to the partner organizations.

European Flood Alert System (EFAS) (cont.)

Contacts for Tools, Documentation, Technical Assistance	General information can be found at http://efas.jrc.it . Contact points for specific questions on EFAS at the Joint Research Centre are ad.de-roo@jrc.it and jutta.thielen@jrc.it.
Cost	General Information on EFAS and its research results are provided free of charge. Flood forecast information can only be provided on formal agreement to experts in National Hydrological Services and are free of charge.
References	For an updated list of references find information on the EFAS webpage: http://efas.jrc.it. De Roo, A., B., Gouweleeuw, J. Thielen, P. Bates, A. Hollingsworth, et al. 2003. Development of a European Flood Forecasting System. *International Journal of River Basin Management* 1(1):49-59. De Roo, A., J. Thielen and B. Gouweleeuw. 2002. LISFLOOD, a distributed water balance, flood simulation and flood inundation model. User manual. Version 1.0. Report of the European Commission, Joint Research Centre, Special Publications No. I.02.131. De Roo, A., M.H. Ramos, J. Thielen, G. Franchello, J. Bartholmes, K. Wachter, S. Niemeyer, M. Kalas, G. Laguardia and J. van der Kniff. 2006. The Alpine floods of August 2005. What did EFAS forecast, what was observed, which feedback was received from end-users? EFAS Post-event summary report, European Commission, EUR 22154 EN, 94pp. Feyen, L., J.A. Vrugt, B. Ó Nualláinc, J. van der Knijff and A. de Roo. 2007. Parameter optimisation and uncertainty assessment for large-scale streamflow simulation with the LISFLOOD model. *Journal of Hydrology* 332(3-4):276-289. Gouweleeuw, B., J. Thielen, G. Franchello, A. de Roo and R. Buizza. 2005. Flood forecasting using medium-range probabilistic weather prediction. *Hydrological and Earth System Sciences* 9(4):365-380. Gouweleeuw, B., P. Reggiani and A. De Roo (eds.). 2004. A European Flood Forecasting System EFFS. Full Report. European Report EUR 21208, EC DG JRC & WL Delft Hydraulics, 304pp. Kalas M., M.H- Ramos, J. Thielen and G. Babiakova. In press. Evaluation of the medium-range European flood forecasts for theMarch - April 2006 flood in the Morava River. *Journal of Hydrology and Hydromechanics*. Ramos. M.H., J. Bartholmes, J. Thielen-del Pozo. Development of decision support products based on ensemble forecasts in the European Flood Alert System, submitted to *Atmospheric Science Letters.* Thielen, J., J. Bartholmes, M.-H. Ramos, M. Kalas, J. van der Knijff and A. de Roo. 2006. Added value of ensemble prediction system products for medium-range flood forecasting on European scale. In: Proceedings of the workshop “Ensemble Predictions and Uncertainties in Flood Forecasting”, International Commission for the Hydrology of the Rhine Basin (CHR), Bern Switzerland, 30-31 March 2006, p.77-82. Thielen J., M.H. Ramos, J. Bartholmes, A. de Roo H. Cloke, F. Pappenberger and D. Demeritt. 2005. Summary report of the 1st EFAS workshop on the use of Ensemble Prediction System in flood forecasting, 21-22nd November 2005, Ispra. European Report EUR 22118 EN, European Commission 2005, 23pp. Van Der Knijff, J. and A. de Roo .2006. LISFLOOD – distributed water balance and flood simulation model. User manual (2006), European Commission Report EUR 22166 EN, 60pp.

4.3 Coastal Resources Tools

Sea level rise is now accepted as an inevitable consequence of global warming. In addition, the impacts of climate change will include possible increases to sea surface temperatures, greater variability in the patterns of rainfall and runoff, possible changes to wave climate, changes to the frequency, intensity and duration of storms, and changes to ocean chemistry. In light of this, the coast is regarded as one of the most vulnerable areas on the planet and is increasingly the focus for assessments of vulnerability and adaptation to climate change. This compendium describes a range of the tools and methods applied globally to support this activity.

Tools can also be described as 'first', 'second' and 'new generation' tools. First generation are older tools that have, in many cases, been superseded by more recent techniques. Second generation tools are relatively recent and are still widely applied in the process of coastal V&A assessment whereas those described as 'new generation' are in the early stages of application and have yet to be thoroughly validated.

The evolution of assessment techniques is marked by:

- Improved consideration of uncertainties involved in climate and impact projections;
- Increased integration of climatic and non climatic stressors;
- More realistic recognition of the potential for and limitations to societal responses;
- Increased importance of stakeholder involvement; and
- A purposeful shift form science driven vulnerability assessment to policy driven vulnerability reduction[1].

Many criteria can be used to classify vulnerability assessments. Tools described here are considered within three categories:

1. Qualitative
2. Semi qualitative
3. Quantitative & specific

In general, methods employed are concerned with establishing the current physical condition of the coast, considering variability of each condition in the face of ongoing natural environmental factors, and evaluating the likely response to climate change and associated sea level rise.

[1] Abuodha, PA & Woodroffe, CD, 2006. International assessments of the vulnerability of the coastal zone to climate change, including an Australian perspective Final Report submission to Australian Greenhouse Office in response to RFQ 116/2005DEH

Table 4.3. Tools covered in coastal sector

Inter-governmental Panel on Climate Change (IPCC) Common Methodology (CM)
UNEP Handbook Methodology
Bruun Rule
SURVAS
DIVA and DINAS-COAST
CoastClim of Simulator of Climate Change Risks and Adaptation Initiatives (SimClim)
Community Vulnerability Assessment Tool (CVAT)
Decision Support Models: COSMO (Coastal Zone Simulation Model)
The South Pacific Island Methodology (SPIM)
Shoreline Management Planning (SMP)
RamCo and ISLAND MODEL
ReefResilience Toolkit
Smartline

Inter-governmental Panel on Climate Change (IPCC) Common Methodology (CM)

Description	Widely used framework for vulnerability assessment first proposed in 1991. CM incorporates expert judgment and data analysis of socioeconomic and physical characteristics to assist the user in estimating a broad spectrum of impacts from sea-level rise, including the value of land and wetlands lost. It presents a list of analyses that should be done, but does not explicitly instruct the user on how to perform the analyses. Information from this methodology is generally used as a basis for further physical and economic modelling. The user follows seven steps: (1) delineate the case study area; (2) inventory study area characteristics; (3) identify the relevant socioeconomic development factors; (4) assess the physical changes; (5) formulate response strategies; (6) assess the Vulnerability Profile; (7) identify future needs. Adaptation focuses around three generic options: retreat, accommodate or protect.
Appropriate Use	This approach is most useful as an initial, baseline analysis for country level studies where little is known about coastal vulnerability.
Scale	CM can be used in sub-national, national, regional and global analysis.
Key Output	Vulnerability profile and the list of future policy needs to adapt both physically and economically. A range of impacts of sea-level rise, including land loss and associated value and uses, wetland loss, etc.
Key Input	Physical and socioeconomic characteristics of the study area.
Ease of Use	Requires considerable knowledge on a range of techniques for estimating biophysical and socioeconomic impacts of sea level rise and adaptation. It has been criticised and redesigned by several groups of researchers.
Training Required	Significant training required to complete the seven steps (weeks or months); often performed by external consultants rather than in-country experts.
Training Available	No formal training currently offered.
Computer Requirements	Methodology does not explicitly state how to perform analyses; analytical method chosen by the user will determine the computer needs.
Documentation	Original documentation from 1991 is unavailable. Update provided in IPCC CZMS (1992)
International studies	IPCC CZMS (1992), Nicholls (1995, 1998a, 1998b) Bijlsma et al. (1996) Nicholls and Mimura (1998) Klein and Nicholls. (1999)
Contacts for Tools, Documentation, Tech. Assistance	Coastal Zone Management Centre, P.O. Box 20907, NL-2500 EX, The Hague, The Netherlands; Tel: 1.70.311.4364, Fax: 31.70.311.4380.
Cost	No cost to obtain documentation.
Validity	Used in many coastal countries. Examples of studies: Harvey et al.(1999a), Harvey et al (1999b), Kay et al. (1996), Kay et al. (1992), McLean and Mimura (1993), Morvell (1993a, 1993b), Waterman (1996), Woodroffe and McLean (1993)

UNEP Handbook Methodology

Description	The UNEP methodology establishes a generic framework for thinking about and responding to the problems of sea level rise and climate change. The user goes through the following seven guiding steps: (1) define the problem, (2) select the method, (3) test the method, (4) select scenarios, (5) assess the biogeophysical and socioeconomic impacts, (6) assess the autonomous adjustments, and (7) evaluate adaptation strategies. The last step is itself split into seven substeps. At each step, methods are suggested but the choice is left up to the user.
Appropriate Use	This approach is useful in a range of situations, including subnational, or national level studies. It could comprise the first study, or follow earlier studies such as those completed using the IPCC Common Methodology. The possibility of a quick screening assessment followed by a more detailed vulnerability assessment has been suggested (Klein and Nicholls, 1999). Information gathered with this methodology can then be used as input for future modeling.
Scope	Coastal; and scale; sub-national, national, regional and global analysis.
Key Output	Evaluation of a range of user-selected impacts of sea level rise and potential adaptation strategies according to both socioeconomic and physical characteristics.
Key Input	Qualitative or quantitative physical and socioeconomic characteristics of the national coastal zone.
Ease of Use	Fairly simple framework. As the level of analysis is not prescribed, the ease of use will depend on the level of analysis that is attempted.
Training Required	Depends on user expertise and the level of analysis that is attempted, but it is likely that some training is required to complete the seven steps.
Training Available	No formal training currently offered, although technical assistance is available for countries within the UNEP program.
Computer Requirements	No explicit requirements, although using information in this framework for future modeling will require computers.
Documentation	Feenstra, J., I. Burton, J. Smith, and R. Tol (eds.). United Nations Environment Programme, Nairobi, and Institute for Environmental Studies, Vrije Universiteit, Amsterdam. (Version 2.0). http://www.falw.vu.nl/images_upload/151E6515-C473-459C-85C59441A0F3FB49.pdf. Klein, R.J.T. and R.J. Nicholls. 1998. Coastal zones. Chapter 7 in *Handbook on Methods for Climate Change Impact Assessment and Adaptation Strategies* (Version 2.0).
Applications	Used in several countries, including the Cameroon, Antigua and Barbuda, Estonia, Pakistan, Cuba, Grenada, Guyana and Barbados.
Contacts for Tools, Documentation, Technical Assistance	Dr. Michiel van Drunen, Institute for Environmental Studies, Vrije Universiteit, Amsterdam; Tel: +31.20.5989534; e-mail: michiel.van.drunen@ivm.falw.vu.nl.
Cost	No cost to obtain documentation.

UNEP Handbook Methodology (cont.)

References	Klein, R.J.T. and R.J. Nicholls. 1999. Assessment of coastal vulnerability to climate change. *Ambio*, 28(2):182-187. Klein, R.J.T., R.J. Nicholls, and N. Mimura. 1999. Coastal adaptation to climate change: Can the IPCC Technical Guidelines be applied? *Mitigation and Adaptation Strategies for Global Change,* 4:51-64. Klein, R.J.T., R.J. Nicholls, S. Ragoonaden, M. Capobianco, J. Aston, and E.N. Buckley. 2001. Technological options for adaptation to climate change in coastal zones. *Journal of Coastal Research* 17(3):531-543. Nicholls, R.J. 1998. Coastal Vulnerability Assessment for Sea-Level Rise: Evaluation and Selection of Methodologies for Implementation. Technical Report TR098002, Caribbean Planning for Adaptation to Global Climate Change (CPACC) Project.

Bruun Rule

Description	The first and best known model relating shoreline retreat to an increase in local sea level is that proposed by Per Bruun (1962). The IPCC reports that 1 cm rise in sea level erodes beaches about 1 m horizontally. This becomes a large issue for developed beaches that are less than 5 m from the ocean (IPCC, 1998). The Bruun rule states that a typical concave-upward beach profile erodes sand from the beach face and deposits it offshore to maintain constant water depth. The Bruun rule can be applied to correlate sea-level rise with eroding beaches. The Bruun rule estimates the response of the shoreline profile to sea-level rise. This simple model states that the beach profile is a parabolic function whose parameters are entirely determined by the mean water level and the sand grain size. The analysis by Bruun assumes that with a rise in sea level, the equilibrium profile of the beach and shallow offshore moves upward and landward. The analysis is two-dimensional and assumes that (1) the upper beach is eroded due to the landward translation of the profile and (2) The material eroded from the upper beach is transported immediately into the offshore and deposited, such that the volume eroded is equal to the volume deposited; and (3) The rise in the nearshore bottom as a result of deposition is equal to the rise in sea level, thus maintaining a constant water depth in the offshore (SCOR, 1991).
Appropriate Use	The Bruun rule is only applicable for small scale local sites.
Scale	Over long stretches of coast, the Bruun rule and associated cross-shore transport models become complex. There has been a number of critiques e.g. Cooper and Pilkey (2004)
Key Output	Shoreline recession (in metres relative to sea-level rise).
Key Input	An increase in sea level, (S), cross shore distance (L) to the water depth (h) taken by Bruun as the depth to which nearshore sediments exist (depth of closure), and B is the height of the dune.
Ease of Use	Easy to use with numerous assumptions.
Training Required	Familiarity with the coastal zone being investigated.
Training Available	None.
Computer Requirements	None, unless it is incorporated into a model.
Documentation	Originally proposed by Per Bruun in 1962
International studies	Bruun (1962, 1988)
Contacts for Tools, Documentation, Technical Assistance	See applications above.
Cost	No cost to use the Bruun rule.
Validity	Bruun rule has been applied but caution needs to be exercised where other factors influence sediment budget or control profile.

SURVAS

Description	The SURVAS (Synthesis and Upscaling of Sea-level Rise Vulnerability Assessment Studies) project developed a global assessment of vulnerability of the coastal zone using a common assessment methodology, identifying key indicators for the assessment of coastal natural susceptibility and socio-economic vulnerability and resilience to the impact of climate change, particularly accelerated sea-level rise.
Appropriate Use	For the assessment of coastal natural susceptibility and socio-economic vulnerability and resilience to the impact of climate change, particularly accelerated sea-level rise.
Scale	SURVAS can be applied in sub-national, national, regional and global analysis.
Key Output	Workshop reports (see international references).
Key Input	Expert knowledge in workshop context.
Ease of Use	Depends upon consensus between experts.
Training Required	Expert judgement required.
Training Available	None.
Computer Requirements	Is required when modeling.
Documentation	The SURVAS database http://www.survas.mdx.ac.uk/sitemap.htm
International studies	Workshops held in Egypt, Germany and UK. Examples of studies: SURVAS (2000a, 2000b, 2001) Nicholls (2000)
Contacts for Tools, Documentation, Technical Assistance	See documentation above.
Cost	No cost to use the approach.
Validity	During a SURVAS overview workshop in UK in 2001 it was reported that geological, historical and current sea-level data exists. Other data include those from UNFCCC and NC as well as data on present coastal erosion and storminess climate variability.

DIVA and DINAS-COAST

Description	Dynamic Interactive Vulnerability Assessment (DIVA) is a tool for integrated assessment of coastal zones produced by the EU-funded DINAS-Coast consortium in 2004. It is specifically designed to explore the vulnerability of coastal areas to sea-level rise. It comprises a global database of natural system and socioeconomic factors, relevant scenarios, a set of impact-adaptation algorithms and a customized graphical-user interface. Factors that are considered include erosion, flooding salinisation and wetland loss. DIVA is inspired by the paper-based Global Vulnerability Assessment (Hoozemans et al., 1993), but it represents a fundamental improvement in terms of data, factors considered (which include adaptation) and use of PC technology.
Appropriate Use	DIVA is designed for national, regional and global scale analysis of coastal vulnerability, including consideration of broad adaptation issues.
Scale	DIVA covers all 180+ coastal nations in 12,148 coastal segments at national, regional, and global scales.
Key Output	The impacts of sea-level rise under a range of different user-defined scenarios, including some adaptation options. For each SRES the program produces a table, a map and chart.
Key Input	The user's chosen scenarios.
Ease of Use	The software is explicitly intended to be easy to use, and draws on extensive experience in graphical user interfaces.
Training Required	Designed to be used without significant training — an interested user should be able to explore this tool without any training.
Training Available	If required, contact DINAS-COAST consortium — see contacts below.
Computer Requirements	Windows 2000/XP, 2 GHz Pentium, 512 MB memory, 5 GB free hard drive.
Documentation	Included with the DIVA tool.
International studies	DIVA has been used to develop assessments of wetland loss and the effects of mitigation. Examples of studies are; Hoozemans et al. 1993 Nicholls (2002) Hinkel and Klein. (2003) Vafeidis et al. (2003, 2004a, 2004b)
Contacts for Tools, Documentation, Technical Assistance	http://diva.demis.nl/ Jochen Hinkel Potsdam Institute for Climate Impact Research, Germany; e-mail: hinkel@pik-potsdam.de.
Cost	Free download from http://diva.demis.nl/
Validity	DINAS-Coast database contains limited segments for many areas.

CoastClim of Simulator of Climate Change Risks and Adaptation Initiatives (SimClim)

Description	The Simulator of Climate Change Risks and Adaptation Initiatives (SimClim) software enables examination of future climate scenarios in several contexts. The method features a separate consideration for sea-level rise (sea-level generator) due to climate change and global warming and that resulting from local land movements. One of the distinct advantages of using the generator is that it allows rapid generation of place-based sea-level scenarios, which account for some uncertainties associated with emissions scenario, but may not account for isostatic change. SimClim also includes a set of developed impact models. For the coastal zone, the focus is on erosion and flooding. The simple erosion model is a modified version of the Bruun Rule, which takes into account storm effects, local sea-level trends and lag effects in order to provide time-dependent response of the shoreline to sea-level rise at selected sites. The coastal flood model is spatial and allows the user to examine changes in the areas of potential inundation from the combined effects of sea-level rise and extreme storm events. The purpose of SimClim is to link and integrate complex arrays of data and models in order to simulate, temporally and spatially, bio-physical impacts and socio-economic effects of climatic variations, including extreme climatic events. In this way, it provides the foundation for assessing options for adapting to the changes and reducing the risks. SimClim is designed to support decision-making and climate proofing in a wide range of situations where climate and climate change pose risk and uncertainty.
Appropriate Use	A tool to aid decision-making under changed climate conditions.
Scale	SimClim can be applied in sub-national, national, regional and global analysis.
Key Output	Current shoreline (m).
Key Input	For the coastal erosion model part of SimClim, one requires; shoreline response time, closure distance (m), depth of material exchange (m), dune height (m) and residual movement (m/year) and well as storm parameters.
Ease of Use	The distinctive advantage of the SimClim open system, as opposed to the hard-wired system, is the flexibility afforded to users for importing their own data and models in order to customise the system for their own purposes – much like a GIS.
Training Required	Training is useful.
Training Available	Training can be arranged by contacting Peter Urich at management@climsystems.com or www.climsystems.com/site/home
Computer Requirements	Knowledge of computer is required.
Documentation	Included with the SimClim software.
International studies	Kenny et al (1999, 2000) Warrick et al (1996, 2005)
Contacts for Tools, Documentation, Technical Assistance	Climsystems Ltd, P. O. Box 638, Hamilton, New Zealand. Climsystems Home. http://www.climsystems.com/site/home/
Cost	There is a cost to the use of the software. Contact Peter Urich (see documentation).
Validity	The coastal impact model of SimClim is a possible tool to use in coastal zones.

Community Vulnerability Assessment Tool (CVAT)

Description	Community Vulnerability Assessment Tool (CVAT) supports the linking of environmental, social and economic data in the coastal zone. It is a static GIS map overlay procedure that enables a relative risk or vulnerability analysis of coastal communities to a series of existing threats. The CVAT procedure comprises 7 steps; (1) Hazard identification and prioritisation, (2) Hazard analysis, (3) Critical Facilities analysis, (4) Social analysis, (5) Economic analysis, (6) Environmental analysis and (7) Mitigation opportunities analysis. A CD-ROM provides a step-by-step guide for conducting community-wide risk and vulnerability assessments. It also provides an illustrative case study demonstrating the process for analysing physical, social, economic and environmental vulnerability to hazards at the local level. It contains a detailed case study on New Hanover county, North Carolina, which illustrates the use of the Community Vulnerability Methodology Assessment methodology in a specific community.
Appropriate Use	Used to conduct a community vulnerability assessment to a range of hazards (not specifically addressing climate change).
Scale	The assessment focuses on the community level.
Key Output	Relative risk or vulnerability analysis of coastal communities to a series of existing threats.
Key Input	Environmental, social and economic data for the coastal zone in GIS format.
Ease of Use	The CD-ROM is relatively easy to use.
Training Required	It provides a framework for vulnerability and risk assessment, which allows communities to carry out the assessment. CVAT is most useful for people who wish to gain an understanding of how to conceptualise community vulnerability.
Training Available	The NOAA coastal services offers training on how to do a risk and vulnerability assessment. More information on this training is available at www.csc.noaa.gov/training/cvat-tool.html
Computer Requirements	The following options are available for using the information on the CD-ROM (1) Web-Browser for viewing text, images, and static maps and (2) ArcExplorer GIS Data Explorer (free software included). ArcView GIS (ArcView 3.0 or higher required to interact with one component of the case study on the CD-ROM)
Documentation	See below for contacts. The CD-ROM contains a number of tutorials designed to assist in hazard planning activities. These tutorials include vulnerability assessment tutorials, LIDAR tutorials and extensions and damage assessment tool tutorial.
International studies	National Oceanic and Atmospheric Administration (NOAA) Coastal Services Center (CSC) (1997, 1999) Albury (2004) Clark et al. (1998) Cutter (1996) Cutter et al. (2000, 2003) Emrich (2000) Morrow (1999)
Contacts for Tools, Documentation, Technical Assistance	To receive a copy of the CD-ROM or any assistance contact: NOAA Coastal Services Center, 2234 South Hobson Avenue, Charleston, South Carolina 29405-2413.e-mail: clearinghouse@csc.noaa.gov . Resource persons are Tashya Allen at Tashya.Allen@noaa.gov and Cindy Fowler at Cindy.Fowler@noaa.gov
Cost	There is no cost for the CD-ROM (File size: 0.3MB).
Validity	The CVAT tool would require customising to a given environment where there is a different suite of hazards and access to appropriate data is not as centralised.

Decision Support Models: COSMO (Coastal Zone Simulation Model)

Description	COSMO is a decision-support model that allows coastal zone managers to evaluate potential management strategies under different scenarios, including long-term climate change. COSMO demonstrates the main steps in the preparation, analysis and evaluation of Coastal Zone Management (CZM) plans. The program is an interactive tool that allows coastal zone managers to explore the impacts of development projects and environmental and coastal protection measures. It calculates various criteria, including long term effects of climate change, reflecting the use of the coastal zone. The user can explore a number of predefined cases as an educational tool, or specify new development scenarios and combinations of measures as a decision-making tool. A more complex version of COSMO has been developed to demonstrate some more realistic characteristics, constraints and limitations of institutional arrangements for CZM. The program simulates day-to-day management of a coastal zone from the perspective of four organizations: (1) the city government, (2) the public works department, (3) the environment department and (4) the private sector. Each of these four roles takes annual decisions, within their means/budget and mandate, to further their own objectives.
Appropriate Use	Useful as educational tools about relationship of adaptation to climate change in coastal zone management. Helps determine the advantages and disadvantages of adaptation alternatives, either as an educational or decision-support tool, in conjunction with other, more quantitative analyses.
Scale	COSMO can be applied in site-specific case studies or at national scale.
Key Output	The outcome of a range of different management options.
Key Input	The user's chosen management strategy.
Ease of Use	Easy to use for educational purposes, although unsuitable for analysis of actual management plans by itself. Might be used within other frameworks, such as studies based on the UNEP Handbook Methodology.
Training Required	For educational purposes it requires little training, although as a decision support tool it requires more knowledge of physical and socioeconomic characteristics of the situation.
Training Available	For training and education services contact: Coastal Zone Management Centre, P.O. Box 20907, NL-2500 EX, The Hague, The Netherlands; Tel: (1-70)311.4364; Fax: (31-70)311-4380; E-mail. f.vdmenlen@rikz.rws.minvenw.nl
Computer Requirements	Standard PC (Pentium or better).
Documentation	See international studies below
International studies	Used in training for CZM, including adaptation to climate change. Examples of studies: Resource Analysis and Coastal Zone Management Centre, Hoozemans et al. (1993)
Contacts for Tools, Documentation, Technical Assistance	Coastal Zone Management Centre, The Hague; Tel: 31.70.3114.364.
Cost	US$150 from Coastal Zone Management Centre.
Validity	A valid model but is yet to be applied.

The South Pacific Island Methodology (SPIM)

Description	The South Pacific Island Methodology is an index-based approach that uses relative scores to evaluate different adaptation options in a variety of scenarios. The coastal zone is viewed as six interacting systems. There are three “hard” systems, the natural environment, the people, and infrastructure, and three “soft” systems, which encompass the less tangible elements of the coastal system, the institutions, the socio-cultural factors, and the economic system. These are further divided into subsystems. The user gives each subsystem a vulnerability and a resilience score from -3 to +3, based on expert judgment, for the following scenarios: (1) today’s situation, (2) the future with sea level rise and no management, and (3) the future with sea level rise and optimum management. For each subsystem, the two values are combined to produce a sustainable capacity index for each scenario.
Appropriate Use	Particularly useful in coastal settings with limited quantitative data but considerable experience and qualitative knowledge. Can be used during initial evaluation phases to analyse a range of possible adaptation options. Should be followed by a more quantitative analysis of the chosen option.
Scale	SPIM is regional in scale and most relevant to the South Pacific Islands.
Key Output	Defines a sustainable capacity index for the subsystems defined.
Key Input	Expert judgment and qualitative information on the relative performance of various adaptation options.
Ease of Use	Relatively easy to use because it requires very little quantitative data.
Training Required	Limited training is required, although background knowledge of physical, social, and economic characteristics of the area is helpful.
Training Available	No formal training currently.
Computer Requirements	None.
Documentation	Documented in Yamada et al, 1995.
International studies	Used in several Pacific Island countries, including Fiji. Yamada et al (1995) Kay and Hay (1993) Nunn et al (1994a, 1994b, 1996) Mimura and Harasawa (2000)
Contacts for Tools, Documentation, Technical Assistance	Prof. N. Mimura, CWES, Ibaraki University 4-12-1 Nakanarusawa, Hitachi, Ibaraki 316, Japan; Tel: 81.294.38.5169. Prof. P. Nunn, University of the South Pacific, Suva, Fiji; Tel: 679.313.900; Fax: 679.301.305.
Cost	No cost for documentation, although cost of the analysis itself will depend on the availability and cost of data and local experts.
Validity	Most valid for Island states.

Shoreline Management Planning (SMP)

Description	Shoreline Management Planning is a generic approach to the strategic management of the combined hazards of erosion and flooding hazards in coastal areas, which are key concerns under climate change and sea-level rise. New approaches to shoreline management have developed in the United Kingdom over the last 10 years. This involves dividing the coast of England and Wales into a series of natural units (cells and sub-cells). Based on these units, a number of shoreline management plans are then developed which collectively cover the entire coastal length. Each shoreline management plan further divides the coast based on land use and selects a series of strategic options to be applied over the next 50 to 100 years: (1) advancing the line; (2) holding the line; (3) managed realignment; (4) limited intervention; and (5) no active intervention. The practical implementation of these options is not directly considered — this is considered at lower levels of planning. Whatever is proposed must be consistent with a suite of Project Appraisal Guidance Notes (PAGN) that provide guidance (listed at http://www.defra.gov.uk/environ/fcd/pubs/pagn/default.htm). The Eurosion consortium have taken these approaches and developed them for application across the European Union (http://www.eurosion.org/).
Appropriate Use	SMP has been designed for developed countries with extensive coastal defence infrastructure. However, these approaches should find widespread application around the world's coasts, especially if slightly adapted to local circumstances. SMPs are designed as "living" plans, including regular update, so the whole process will stimulate the development of long-term coastal management appropriate to responding to climate change and sea-level rise.
Scale	SMP is applied typically at sub- national to national scales pertinent to strategic flood and erosion management.
Key Output	Strategic approaches for flood and erosion management for the next 50 to 100 years.
Key Input	A range of information is required, including, ideally, historical shoreline change, contemporary coastal processes, coastal land use and values, and appropriate scenarios of change. However, the first generation of SMPs in England and Wales was conducted with incomplete datasets.
Ease of Use	The methods are designed assuming significant expertise and would be best implemented by consultants.
Training Required	With appropriate consultants this would not be necessary.
Training Available	None offered at present.
Computer Requirements	Depends on the approach adopted.
Documentation	See International studies.
International studies	Department for Environment, Food and Rural Affairs DEFRA (2001) Ministry of Agriculture, Fisheries and Food (MAFF, 1995) Leafe et al (1998) Burgess and Hosking (2002) http://www.eurosion.org/
Contacts for Tools, Documentation, Technical Assistance	DEFRA, Flood and Coastal Defence Division (http:/www.defra.gov.uk/). Stephane Lombardo, National Institute for Coastal and Marine Environment/RIKZ, Kortenaerkade, 1, 2500 EX The Hague, The Netherlands; Tel: + 31.70.3114.369; Fax: +31.70.3114.380; e-mail: S.Lombardo@rikz.rws.minvenw.nl.
Cost	Free download of DEFRA (2001) from http://www.defra.gov.uk/environ/fcd/pubs/smp/revisedsmpguidancefinal.pdf.

RamCo and ISLAND MODEL

Description	RamCo and ISLAND MODEL are cell-based decision support tools designed as a means of asking structured questions about how external and internal components of coastal zone management problems interact. The socioeconomic system is explicitly defined and can interact with the physical effects of climate change, as well as regional and global changes to boundary conditions, such as global trade patterns. These are the prototypes of more general information systems for decision support.
Appropriate Use	Because they are part of an evolving approach, they are excellent educational tools, although they have been used in analytical situations (see Applications below). Scope of applicability is currently limited by data availability, although new applications could be developed with the originators.
Scope	All locations where GIS data are available; coastal; regional.
Key Output	The outcome of a range of different user-defined scenarios and management options.
Key Input	The user's chosen scenarios and management strategies.
Ease of Use	The Demo Guides are easy to follow without training — development of new applications would be much more difficult.
Training Required	Requires little training for educational purposes, although the documentation is only for demonstration and does not explain how to set up another site for analysis.
Training Available	Coastal Zone Management Centre, The Hague, The Netherlands, Tel: 31.70.3114.364.
Computer Requirements	Pentium or better, Windows 95 or better, Microsoft Excel (version 7.0), IDRISI for Windows. See page 15 of documentation.
Documentation	Uljee, I., G. Engelen, and R. White. 1996. ISLAND-Demo User Guide, Version 3, Research Institute for Knowledge Systems, P.O. Box 463, Tongersestraat 6, 6200 AL Maastricht, The Netherlands. Uljee, I., G. Engelen, and R. White. 1996. RamCo Demo Guide Version 1.0, Coastal Zone Management Centre, National Institute for Coastal and Marine Management, PO Box 20907, 2500EX The Hague, The Netherlands.
Applications	St. Lucia, Sulawesi.
Contacts for Tools, Documentation, Technical Assistance	Coastal Zone Management Centre, National Institute for Coastal and Marine Management, PO Box 20907, 2500EX The Hague, The Netherlands; Tel: 31.70.3114.364. Modeling and Simulation Research Group, Research Institute for Knowledge Systems BV, PO Box 463, Tongerstraat 6, 6200 AL Maastricht, The Netherlands.
Cost	US$150 from Coastal Zone Management Centre.

RamCo and ISLAND MODEL (cont.)

References	de Kok, J.L., G. Engelen, R. White, and H. Wind. 2001. Modelling land-use change in a decision-support system for coastal-zone management. Environmental Monitoring and Assessment 6:123-133. Engelen, G., R. White, and I. Uljee. 1993. Exploratory modelling of socio-economic impacts of climatic change. In Climatic Change in the Intra-Americas Sea. G.A. Maul (ed.). Edward Arnold, London, pp. 350-368. Engelen, G., R. White, I. Uljee, and P. Drazen. 1995. Using cellular automata for integrated modelling of socio-environmental systems. Environmental Monitoring and Assessment 34:203-214. Engelen, G., R. White, I. Uljee, and S. Wargnies. 1996. Numerical modeling of small island socio-economics to achieve sustainable development. In Small Islands: Marine Science and Sustainable Development, Coastal and Estuarine Studies Volume 51, G.A. Maul, (ed.). American Geophysical Union, Washington, DC. pp. 437-463. White, R., G. Engelen, and I. Uljee. 2000. Modelling land use change with linked cellular automata and socio-economic models: A tool for exploring the impact of climate change on the island of St. Lucia. In Spatial Information for Land Use Management, M. Hill and R. Aspinall (eds.). Gordon and Breach, pp. 189-204.

Reef Resilience Toolkit

Description	The R2 Toolkit is a 'living' toolkit that provides practitioners with the latest tools, strategies, and protocols to address coral bleaching, conservation of reef fish spawning aggregations, and general principles of adaptive management that are critical to respond to climate change. The toolkit is designed primarily for use by Marine Protected Area (MPA) managers, trainers, and policymakers. Entrusted with protecting coral reefs, they face significant challenges because these ecosystems are highly vulnerable to the demographic, economic, and environmental changes expected during the next century. R2 builds on the principle that effective management is fundamental to ensure reef survival. Currently comprised of two extensive streams – Coral Bleaching and Reef Fish Spawning Aggregations – the toolkit will help practitioners begin to build resilience into their coral reef conservation programs so that these valuable natural systems can survive anticipated rapid changes and provide for escalating human needs. During 2007 and 2008, the R2 Toolkit is undergoing a major revision, with new developments in science and management being added, as well as topics relating to other tropical habitats and social issues. The next version will be launched at the IUCN World Conservation Congress in Barcelona in October 2008.
Appropriate Use	The R2 Toolkit is most appropriate for tropical coastal and marine resource managers, and especially helpful to coral reef managers and fisheries managers. The R2 Toolkit includes a great deal of information that is helpful to those designing protected areas and networks, as well as information on developing monitoring programs, engaging stakeholders, and more. The R2 Toolkit can be useful to managers at any time/stage as it addresses both the beginnings of protected area work as well as adaptive management and monitoring.
Scope	Although this tool is designed primarily with tropical coral reef systems in mind, the principles can be applied to almost any marine system. The information is relevant at both local and regional scales.
Key Output	There is no specific output or final product from the R2 Toolkit, given that it is a series of steps and information that helps to guide managers to design and develop sound management practices that are flexible and support adaptive management in the face of climate change.
Key Input	There are no inputs or information required to use the tool. In cases where there is limited or no data, expert and local knowledge can be used. There is always a 'low-tech' option for places that have limited information and resources when one is trying to build resilience to climate change into management activities and strategies.
Ease of Use	The R2 Toolkit is easy to maneuver and understand, and is supported by a range of practitioners and experts that can be consulted for advice and lessons learned. However, to effectively apply the principles to resource management requires skill, experience, and a commitment to developing a robust management structure to adapt to climate change and other unpredictable changes at a site or in a region.
Training Required	There is no training required to use these resources. The R2 Toolkit is in a website format so any person familiar with the internet should be able to navigate the tool.
Training Available	A series of regional training sessions have been held in the Caribbean, Southeast Asia, Western Pacific, South Asia, and Western Indian Ocean. Additional training has occurred in American Samoa, Australia, MesoAmerican Reef, and the Red Sea. These training sessions covered the application of resilience principles to real-world situations and problems. There are no sessions currently scheduled. Future training may occur once the toolkit is revised (Oct 2008) and a demand for the training develops.

Reef Resilience Toolkit (cont.)

Computer Requirements	Certain applications will be needed to view the Toolkits rich-media including: QuickTime, Adobe Acrobat Reader, Arc Explorer, and Microsoft Office (Word and PowerPoint). The CD-ROM includes these media applications. For specific questions on web browser requirements please contact Stephanie Wear (swear@tnc.org). System requirements for: MAC OS X A 400 MHz PowerPC G3 or faster Macintosh computer, at least 128 MB of RAM, Mac OS X v10.2.5-10.3.x. Mac OS 8.6/9 A PowerPC processor-based Macintosh computer, at least 128 MB of RAM, Mac OS 8.6 or later. Windows A Pentium processor-based PC or compatible computer, at least 128 MB of RAM, Win 98/Me/2000/XP.
Documentation	There is no user guide, but there is help embedded within the R2 Toolkit.
Applications	The principles of resilience highlighted in the R2 Toolkit have been applied in numerous tropical locations around the globe. Examples of applying resilience principles to the design of marine protected area network include Kimbe Bay - Papua New Guinea, MesoAmerican Reef, and the British Virgin Islands. Examples of developing resilience and bleaching monitoring programs include the Florida Keys, MesoAmerican Reef, and Australia's Great Barrier Reef. The toolkit currently includes case study examples and continues to add new examples on a monthly basis. All of these can be found at www.reefresilience.org. (As of March 2008)
Contacts for Tools, Documentation, Technical Assistance	The tool was developed by The Nature Conservancy in collaboration with numerous partners. Please contact Stephanie Wear at swear@tnc.org or resilience@tnc.org for further information or assistance.
Cost	Free. CD ROM set available on request and also available at www.reefresilience.org Please note: user must have reasonable internet connection to use some features of the website (e.g., video).
References	Publications discussing the use of the tool are expected in the early part of 2008. Some related documents can be found at: http://www.iucn.org/dbtw-wpd/edocs/2006-042.pdf IUCN Publication: Coral Reef Resilience and Resistance to Bleaching. http://www.iucn.org/dbtw-wpd/edocs/2006-041.pdf IUCN Publication: Managing Mangroves for Resilience to Climate Change. http://www.iucn.org/dbtw-wpd/edocs/2006-043.pdf Joint Partner Publication: Reef Manager's Guide to Coral Bleaching.

SmartLine

Description	The "Smartline" approach is a method of capturing geographical data in a segmented line within a Geographical Information System (GIS). The model builds on over six years experience using a similar approach in the Australian state of Tasmania. The approach allows: • Extraction of data from a range of different existing geomorphic maps (in different formats and with different classifications) and translation of these into a single, nationally consistent classification; and • Rapid identification of shores sensitive to physical change or instability resulting from climate change and sea level rise.
Appropriate Use	A key advantage of the model is its ability to rapidly capture a very wide range of information for a coastal zone at different levels of detail. It also allows many types of data analysis to be undertaken efficiently. Consequently, the "Smartline" approach is ideal for first pass assessments of coastal vulnerability.
Scope	The information captured is useful for a wide range of management and research purposes in addition to vulnerability assessment, for example oil spill sensitivity assessments and coastal natural asset inventories. As such, the methodology provides a very practical means of mapping useful coastal geomorphic data for countries that do not have the capacity to undertake major (polygon) geomorphic mapping exercises.
Key Output	GIS based geomorphic map of coastal sensitivity.
Key Input	The majority of input data may be sourced through aerial photograph and cartographic analsysis; this includes data on morphology of coast and geographic setting.
Ease of Use	The Smartline tools is easy to maneuver and understand, and is supported by a range of practitioners and experts that can be consulted for advice and lessons learned. However, initial development of a Smartline mapping systems requires expert input and training.
Training Required	There is no training required to use these resources. The R2 Toolkit is in a website format so any person familiar with the internet should be able to navigate the tool.
Training Available	A series of regional training sessions have been held in the Caribbean, Southeast Asia, Western Pacific, South Asia, and Western Indian Ocean. Additional training has occurred in American Samoa, Australia, MesoAmerican Reef, and the Red Sea. These training sessions covered the application of resilience principles to real-world situations and problems. There are no sessions currently scheduled. Future training may occur once the toolkit is revised (Oct 2008) and a demand for the training develops.
Computer Requirements	Certain applications will be needed to view the Toolkits rich-media including: QuickTime, Adobe Acrobat Reader, Arc Explorer, and Microsoft Office (Word and PowerPoint). The CD-ROM includes these media applications. For specific questions on web browser requirements please contact Stephanie Wear (swear@tnc.org). System requirements for: MAC OS X A 400 MHz PowerPC G3 or faster Macintosh computer, at least 128 MB of RAM, Mac OS X v10.2.5-10.3.x. Mac OS 8.6/9 A PowerPC processor-based Macintosh computer, at least 128 MB of RAM, Mac OS 8.6 or later. Windows A Pentium processor-based PC or compatible computer, at least 128 MB of RAM, Win 98/Me/2000/XP.
Documentation	There is a user guide provided and help embedded within the application.

4.4 Human Health Sector Tools

The health tools described in this compendium, listed in Table 4.4, differ significantly in their scope and application. Some facilitate the investigation of multiple or overall disease burden and how this burden responds to a number of environmental stressors, including climate change (MIASMA and Environmental Burden of Disease Assessment). Others are more narrowly focused and model the health impacts or transmission dynamics of particular diseases (CIMSiM and DENSiM, LymSim, and MARA LITe). They aid in identifying areas of high risk, and are particularly useful for areas currently endemic to diseases like malaria, dengue fever, and Lyme disease or in close proximity to such areas. Modeling adaptation strategies in the health sector is an emerging field, so the number of tools and approaches available explicitly designed for this purpose is still limited. The UNFCCC Guidelines is one such example. However, all the human health tools detailed in this section are suited to examining impacts of climate change on human health and potential adaptations.

Table 4.4. Tools covered in human health sector
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)

MIASMA (Modeling Framework for the Health Impact Assessment of Man-Induced Atmospheric Changes)

Description	MIASMA is a Windows-based modeling application that models several health impacts of global atmospheric change and include simulation for several modules: (1) vector-borne diseases, including malaria, dengue fever, and schistosomiasis; (2) thermal heat mortality; and (3) UV-related skin cancer due to stratospheric ozone depletion. The models are driven by both population and climate/atmospheric scenarios, applied across baseline data on disease incidence and prevalence, climate conditions, and the state of the stratospheric ozone layer.
Appropriate Use	MIASMA can be used to link GCM output of climate change or scenarios of stratospheric ozone depletion to any of the human health outcomes mentioned above. Applicability of this model is limited only by the scope of available data.
Scope	Health; regional and global analysis.
Key Output	For the thermal stress module: cardiovascular, respiratory, and total mortality; for skin cancer module: malignant melanoma and non-melanoma skin cancer; for vector-borne disease modules: cases and fatalities from malaria, and incident cases for dengue fever and schistosomiasis.
Key Input	Climate input is module or disease specific. For thermal stress, maximum and minimum temperature are required. For skin cancer, the column loss of the stratospheric ozone over the site is required to determine the level of UV-B radiation potentially reaching the ground. Requires maximum and minimum temperature and rainfall. Vector-borne diseases also require other baseline data, determinable by local experts. For example, for malaria it would help to know the level of partial immunity in the human population and the extent of drug resistant malaria in the region.
Ease of Use	After a short training, the computer simulations should not be difficult.
Training Required	Requires familiarity with computer modeling; some mathematical skills may be beneficial.
Training Available	Dr. Pim Martens (see Contacts below).
Computer Requirements	Pentium PC, 16 MB RAM, Windows 95 or NT4 or higher. For hard drive installation: 20 MB free disk space. A monitor resolution of 1074 x 768 is recommended. To view the documentation and help files, either Netscape Navigator (version 4 or higher) or Microsoft Internet Explorer (version 4 or higher) is recommended.
Documentation	Martens, P. 1998. Health and Climate Change: Modeling the Impacts of Global Warming and Ozone Depletion. Earthscan Publications, London. Additional information can be found at http://www.m.rivm.nl/usr/miasma/miasma.htm.
Applications	Thermal stress module has been applied to 20 international cities. Skin cancer module has been applied to The Netherlands and Australia. Vector-borne disease module has been used globally, malaria module in Zimbabwe, and dengue module for Bangkok, San Juan, Mexico City, Athens, and Philadelphia.
Contacts for Tools, Documentation, Technical Assistance	Dr. Pim Martens, ICIS, P.O. Box 616, 6200 MD Maastricht, The Netherlands; Tel: 31.43.388.3555; Fax: 31.43.321.1889; e-mail: p.martens@icis.unimaas.nl.
Cost	Low cost (price of shipping CD-ROM and documentation).

MIASMA (Modeling Framework for the Health Impact Assessment of Man-Induced Atmospheric Changes) (cont.)

References	Martens, W.J.M., T.H. Jetten et al. 1995. Climate change and vector-borne diseases: A global modelling perspective. *Global Environmental Change* 5(3):195-209. Martens, W.J.M., T.H. Jetten et al. 1997. Sensitivity of malaria, schistosomiasis, and dengue to global warming. *Climatic Change* 35:145-156. Martens, W.J.M. 1998. Climate change, thermal stress and mortality changes. *Soc. Sci. Med.* 46(3):331-344. Martens, W. 1997. Health Impacts of Climate Change and Ozone Depletion: An Eco-Epidemiological Modelling Approach. Dept. Mathematics. Maastricht, University of Maastricht.

Environmental Burden of Disease Assessment

Description	The global burden of disease attributable to climate change was recently estimated as part of a comprehensive World Health Organization (WHO) project. The project sought to use standardized methods to quantify disease burdens attributable to 26 environmental, occupational, behavioral, and life-style risk factors in 2000 and at selected future times up to 2030. The Environmental Burden of Disease (EBD) tools include guidelines on how to estimate the approximate magnitude of the health impacts of various environmental factors, including climate change, at the national or regional level, to help determine priorities for action.
Appropriate Use	An EBD assessment for climate change will indicate which impacts could be greatest and in which regions, and how much of the climate-attributable disease burden could be avoided by emissions reduction. It also will guide health-protective strategies.
Scope	An EBD assessment is usually conducted on a national or regional scale.
Key Output	Comparative risk assessment attempts to answer the following questions: (1) How much disease is caused by climate change (attributable burden of disease)? (2) How much could be avoided by making plausible reductions in the exposure (avoidable burden of disease)? The outputs can be defined by the user, but are usually in DALYs (disability adjusted life years) or avoided deaths that can be compared between populations and between specific health impacts of climate change.
Key Input	The following are needed to determine the amount of climate-sensitive disease that is attributable to climate change: (1) the baseline burden of climate-sensitive diseases, (2) the estimated increase in the risk of disease/disability per unit increase in exposure to climate change, and (3) the current or estimated future population distribution of exposure. The avoidable burden of climate-sensitive diseases is estimated by comparing projected burdens under alternative exposure scenarios. The global assessment used WHO estimates of the baseline burden of cardiovascular deaths associated with thermal extremes, diarrhea episodes, cases of malaria, malnutrition, and deaths due to natural disasters.
Ease of Use	Requires familiarity with comparative risk assessment methods, disease modeling, and estimation of DALYs.
Training Required	Depends on individual familiarity with comparative risk assessment methods, disease modeling, and estimation of DALYs.
Training Available	Occasional training workshops on EBD methods, by WHO.
Computer Requirements	Standard PC, GIS, and spreadsheet software; access to outputs of climate prediction models.
Documentation	Examples of global and regional assessments previously published by the WHO and Australian National University. Guidelines for comparative risk assessment methods have been published by WHO, with guidelines for national and regional assessments forthcoming in early 2004. The WHO guides on assessing the environmental burden of disease are available at http://www.who.int/quantifying_ehimpacts/publications/en/9241546204chap1.pdf. Publications on Environmental burden of disease are available at http://www.who.int/quantifying_ehimpacts/publications/en/. Research tools are available at http://www.who.int/research/en/.

Environmental Burden of Disease Assessment (cont.)

Applications	See http://www.who.int/quantifying_ehimpacts/en/..
Contacts for Framework, Documentation, Technical Assistance	Environmental Burden of Disease Assessment, Occupational and Environmental Health, Protection of the Human Environment (PHE), World Health Organization, 20, Avenue Appia, CH-1211 Geneva 27, Switzerland; e-mail: EBDAssessment@WHO.
Cost	Not identified.
References	WHO. 2003. The World Health Report 2002. World Health Organization, Geneva. McMichael, A.J. et al. 2003. Climate change. In *Global Burden of Disease*. C.J. Murray and A.D. Lopez (eds.). World Health Organization, Geneva.

CIMSiM and DENSiM (Dengue Simulation Model)

Description	CIMSiM is a dynamic life-table simulation entomological model that produces mean-value estimates of various parameters for all cohorts of a single species of Aedes mosquito within a representative 1 ha area (Focks et al., 1993a and b). For each cohort, depending on the life stage, CIMSiM maintains information on abundance, age, development with respect to temperature and size, weight, fecundity, and gonotrophic status. With few exceptions, the various processes are simulated mechanistically. The accounting is made dynamic by calculating on a daily basis the number of each cohort that will pass to the next age or stage as a function of a number of variables and relationships. For example, development times of eggs, larvae, pupae, and gonotrophic cycle are based on temperature using an enzyme kinetics approach. The bases of larval weight gain, food depletion, and fasting are differential equations modified to compensate for the influence of temperature. Fecundity is modeled as a function of pupal size, which in turn is a function of the recent history of larval abundance, food, temperature and, fasting in the larval habitat. All survivals are tied to temperature, and, for adults and eggs, saturation deficit as well; larval survival is also a function of fasting and body fat reserves. Because microclimate is a key determinant of survival and development for all stages, CIMSiM also contains an extensive database of daily weather information. DENSiM (Focks et al., 1995) is essentially the corresponding account of the dynamics of a human population driven by country- and age-specific birth and death rates. An accounting of individual serologies is maintained, reflecting infection and birth to seropositive mothers. The entomological factors passed from CIMSiM are used to create the biting mosquito population. The survival and emergence values dictate the dynamic size of the vector population within DENSiM while the gonotrophic development and weight estimates influence the rate at which these females bite. Temperature and titer of virus in the human influence the extrinsic incubation period in the mosquito; titer is also seen as influencing the probability of transfer of virus from human to mosquito. The infection model accounts for the development of virus within individuals and its passage between the vector and human populations.
Appropriate Use	The models can be used to (1) optimize dengue control strategies using multiple control measures; (2) develop transmission thresholds in terms of *Ae. aegypti pupae* per person as a function of temperature and herd immunity; and (3) evaluate the impact of climate change.
Scope	The models are site-specific and require local surveys and weather to parameterize them.
Key Output	Parameters estimated by DENSiM include demographic, entomologic, serologic, and infection information on a human age-class and/or time basis.
Key Input	A pupal/demographic survey is required to estimate the productivities of the various local water-holding containers. Daily weather is required — maximum/minimum temperature, rainfall, and saturation deficit.
Ease of Use	The front ends of the models are Windows-based and easy to use. However, because the models are site-specific, there is a substantial upfront investment in parameterization.
Training Required	Usually, 3-4 days of training in the context of a grant where Dana A. Focks is either the PI or a collaborator with responsibilities for simulation analysis.
Training Available	Interested parties should contact Dana A. Focks.

CIMSiM and DENSiM (Dengue Simulation Model) (cont.)

Computer Requirements	IBM PC compatible computers are required. Memory 512 MB, processor speed useful, 1 GHz rough minimum.
Documentation	Documentation for the DOS versions is available from Dana A. Focks.
Applications	Use of the models has permitted the development of targeted source reduction/control strategies; WHO's TDR is now funding pilot evaluations in 10 countries. To project the impact of climate change on dengue prevalence in the Caribbean, Mexico, USA (Texas), and multiple locations in South and Central America, and Asia.
Contacts for Framework, Documentation, Technical Assistance	Dana A. Focks, Infectious Disease Analysis, P.O. Box 12852, Gainesville, FL 32604 USA; Tel: 352.375.3520; Fax: 352.372.1838; e-mail: DAFocks@ID-Analysis.com.
Cost	Depends on end user. Many dengue-endemic countries have copies.
References	Burke, D., A. Carmichael, D. Focks et al. 2001. *Under the Weather: Exploring the Linkages Between Climate, Ecosystems, Infectious Disease, and Human Health*. National Research Council, National Academy Press, Washington, DC 146 pp. Ebi, K.L., N.D. Lewis and C. Corvalan. 2006. Climate Variability and Change and Their Potential Health Effects in Small Island States: Information for Adaptation Planning in the Health Sector. *Environ Health Perspect* 114(12):1957-1963. Focks, D.A., D.H. Haile, E. Daniels, and G.A. Mount. 1993a. Dynamic life table model of a container-inhabiting mosquito, Aedes aegypti (L.) (Diptera: Culicidae). Analysis of the literature and model development. *J Med Entomol* 30:1003-1017. Focks, D.A., D.H. Haile, E. Daniels, and G.A. Mount. 1993b. Dynamic life table model of a container-inhabiting mosquito, Aedes aegypti (L.) (Diptera: Culicidae). Simulation Results and Validation. *J Med Entomol* 30:1018-1028. Focks, D.A., E. Daniels, D.H. Haile, and J.E. Keesling. 1995. A simulation model of the epidemiology of urban dengue fever: Literature analysis, model development, preliminary validation, and samples of simulation results. *Am J Trop Med Hyg* 53:489-506. Focks, D.A., R.J. Brenner, D.D. Chadee, and J. Trosper. 1998. The use of spatial analysis in the control and risk assessment of vector-borne diseases. *Am Entomologist* 45:173-183. Focks, D.A., R.J. Brenner, E. Daniels, and J. Hayes. 2000. Transmission thresholds for dengue in terms of Aedes aegypti pupae per person with discussion of their utility in source reduction efforts. *Am J Trop Med Hyg* 62:11-18. Focks, D.A. 2003a. A Review of Entomological Sampling Methods and Indicators for Dengue Vectors. Tropical Disease Research, World Health Organization. Geneva. Jetten, T.H. and D.A. Focks. 1997. Changes in the distribution of dengue transmission under climate warming scenarios. *Am J Trop Med Hyg* 57:285-297.

UNFCCC Guidelines: Methods of Assessing Human Health Vulnerability and Public Health Adaptation to Climate Change

Description	Provides information on qualitative and quantitative methods of assessing human health vulnerability and public health adaptation to climate change. Objectives and the steps for assessing vulnerability and adaptation are described. For a range of health outcomes, methods are presented for evaluation of evidence that climate change could affect morbidity and mortality; projection of future impacts; and identification of adaptation strategies, policies, and measures to reduce current and future negative effects. The health outcomes considered are morbidity and mortality from heat and heat-waves, air pollution, floods and windstorms, and food insecurity; vector-borne diseases; water- and food-borne diarrheal diseases; and adverse health outcomes associated with stratospheric ozone depletion.
Appropriate Use	To conduct an assessment of current and future human health vulnerability of specific populations to climate change and to develop appropriate responses.
Scope	National or regional scales.
Key Output	Description of the current distribution and burden of climate-sensitive diseases; description of the adaptation baseline; evaluation of the health implications of the potential impact of climate change on other sectors; estimates of the future potential health impact of climate change using scenarios of future climate change, population growth, and other factors; and identification of additional adaptation measures to reduce current and future vulnerability.
Key Input	A basic assessment can be conducted using readily available information and data such as previous assessments, literature reviews by the IPCC and others, and available region-specific data. A more comprehensive assessment could include a literature search focused on the goals of the assessment, some quantitative assessment using available data, some quantification of effects, and a formal peer review of results. An even more comprehensive assessment could include a detailed literature review, collecting new data and/or generating new models to estimate impacts, extensive analysis of quantification and sensitivity, formal uncertainty analysis, and formal peer review.
Ease of Use	Can be used by anyone familiar with epidemiological and risk assessment methods.
Training Required	Little.
Training Available	In discussion for Central Asia.
Computer Requirements	Depends on level of assessment, from none to computers with adequate power to run models.
Documentation	See References below.
Applications	Assessment of the potential burden of climate-sensitive diseases and identification of response options to reduce vulnerability. Still being tested so examples of existing applications are few.

UNFCCC Guidelines: Methods of Assessing Human Health Vulnerability and Public Health Adaptation to Climate Change (cont.)

Contacts for Framework, Documentation, Technical Assistance	Bettina Menne, WHO European Centre for Environment and Health, Via Francesco Crispi, 10 I-00187 Rome, Italy; e-mail: bme@who.it. Jacinthe Seguin, Climate Change and Health Office, Health Canada Ottawa, Ontario, Canada; website: http://hc-sc.gc.ca/cc. Sari Kovats, LSHTM, Dept of Public Health and Policy, Keppel St., London WC1E 7HT, England; e-mail: sari.kovats@lshtm.ac.uk. Kristie L. Ebi, Exponent, 1800 Diagonal Road, Suite 355, Alexandria, VA 22314, USA; e-mail: kebi@exponent.com.
Cost	First 2000 copies free; additional reprints will have marginal costs.
References	WHO. 2003. Methods of Assessing Human Health Vulnerability and Public Health Adaptation to Climate Change. World Health Organization, Geneva. Available at http://www.euro.who.int/document/e81923.pdf.

LymSiM

Description	LymSiM simulates the population dynamics of the blacklegged tick, *Ixodes scapularis*, and the dynamics of transmission of the Lyme disease agent, *Borrelia burgdorferi,* among ticks and vertebrate hosts. LymSiM models the effects of ambient temperature, saturation deficit, precipitation, habitat type, and host type and density on tick populations. The model accounts for epidemiological parameters, including host and tick infectivity, transovarial and transstadial transmission, such that the model realistically simulates the transmission of the Lyme disease spirochete between vector ticks and vertebrate hosts. The software features a dynamic life table model of *I. scapularis* with a weekly time step; rates of development, survival, fecundity, and host finding are based on weather or other environmental variables and vary with time. The relationships used were based on the literature and unpublished field studies.
Appropriate Use	Optimize control of Lyme disease and its vectors; and climate change impact studies.
Scope	The models are site-specific and require local surveys and weather data to parameterize them.
Key Output	Seasonal and geographical distributions of the Lyme disease agent and its vectors as a function of climate.
Key Input	Required inputs are (1) proportions of forested, meadow, and ecotone; (2) weekly average temperature, rainfall total, relative humidity, and saturation deficit; and (3) density of the four to six types of hosts.
Ease of Use	The model is Windows based and is easy to use.
Training Required	One or two days.
Training Available	Yes; contact Dana A. Focks at DAFocks@ID-Analysis.com.
Computer Requirements	IBM-compatible, minimal processor/memory required.
Documentation	Documentation exists for the earlier, DOS version. See Contacts below.
Applications	A principal use of LymSiM has been to simulate and optimize the effects of management technologies on populations of tick vector, *I. scapularis*, and *B. burgdorferi* in eastern North America. The model was used to evaluate area-wide acaricide treatments, acaricide self-treatment of white-footed mice and white-tailed deer, vegetation reduction, and white-tailed deer density reduction. Simulations demonstrated that area-wide acaricide, vegetation reduction, or a combination of these technologies would be useful for short-term seasonal management of ticks and disease in small recreational or residential sites. Moreover, acaricide self-treatment of deer appears to be the most cost-effective technology for use in long-term management programs in large areas. Simulation results also suggested that deer density reduction should be considered as a management strategy component. Finally, the model was used to develop integrated management strategies for operational tick and tick-borne disease control programs. Based on the previous studies, the U.S. Centers for Disease Control and Prevention used LymSiM to evaluate various Lyme disease control techniques as a function of various degrees of compliance by the public involved in anti-tick measures. This assessment comparing the effectiveness of alternative community-based prevention strategies illuminates the limitations and distributive effects of interventions and helped clarify the actual available prevention options for community residents.

LymSiM (cont.)

Contacts for Framework, Documentation, Technical Assistance	Dana A. Focks, Infectious Disease Analysis, P.O. Box 12852, Gainesville, FL 32604 USA; Tel: 352.375.3520; Fax: 352.372.1838; e-mail: DAFocks@ID-Analysis.com.
Cost	A function of user and application.
References	Hayes, E.B., G.O. Maupin, G.A. Mount, and J. Piesman. 1999. Assessing the prevention effectiveness of local Lyme disease control. *J Public Health Manag Pract* 5(3):84-92. Mount, G.A., D.G. Haile, and E. Daniels. 1997. Simulation of management strategies for the blacklegged tick (Acari: *Ixodidae*) and the Lyme disease spirochete, *Borrelia burgdorferi*. *J Med Entomol* 34(6):672-663.

Mapping Malaria Risk in Africa (MARA) Low-end Information Tool (LITe)

Description	MARA is a biological model of *Falciparum* malaria transmission that sets decision rules which govern how minimum and mean temperature constrain the development of the parasite and the vector and how precipitation affects survival and breeding. MARA determined the decision rules by reviewing laboratory and field studies throughout Sub-Saharan Africa and looking at current malaria distribution maps. This biological model approximates the current boundaries of malaria distribution across the continent quite well. The model uses three variables to determine any geographic location's climatic suitability: mean monthly temperature, winter minimum temperature, and total cumulative monthly precipitation. An important distinction between this model and others is that the MARA decision rules were developed using fuzzy logic to resolve the uncertainty in defining distinct boundaries dividing malarious from nonmalarious regions. The MARA/ARMA decision rules stipulate that both temperature and precipitation have to be favorable at the same time of the year to allow transmission, and suitable conditions have to continue long enough for the transmission cycle to be completed. Five months were considered a sufficient length of time for conditions to be suitable for stable transmission. MARA LITe is a stand-alone query system of the MARA database. MARA LITe converts the MARA relational database (29 separate tables) into a flat structure.
Appropriate Use	MARA LITe can be used to create a baseline against which future increases or decreases in malaria can be quantified. These baselines can be used in conjunction with climate change scenarios to project possible populations at risk and future prevalence of *Falciparum* malaria for a given region.
Scope	MARA has not been validated outside of Sub-Saharan Africa.
Key Output	Calculations of populations at risk and graphic display of regions showing areas with potential *Falciparum* malaria transmission.
Key Input	Specified regions.
Ease of Use	Relatively easy to use.
Training Required	None.
Training Available	Comprehensive online help files exist for all aspects of the tool.
Computer Requirements	MARA is implemented in GIS format.
Documentation	MARA LITe and resources are available at http://www.mara.org.za/lite/download.htm.
Applications	See References (below) for examples of applications.
Contacts for Framework, Documentation, Technical Assistance	See http://www.mara.org.za/.

Mapping Malaria Risk in Africa (MARA) Low-end Information Tool (LITe) (cont.)

Cost	MARA LITe available in CD-ROM.
References	See http://www.mara.org.za/ for references. Craig M.H., R.W. Snow, and D. le Sueur. 1999. A climate-based distribution model of malaria transmission in sub-Saharan Africa. *Parasitology Today* 15:105-111. Snow R.W., M. Craig, U. Deichmann, and K. Marsh. 1999. Estimating mortality, morbidity, and disability due to malaria among Africa's non-pregnant population. *Bull. WHO* 77:624-640. Hartman, J., K.L. Ebi, J.K. McConnell, N. Chan, and J. Weyant. 2002. Climate suitability for stable malaria transmission in Zimbabwe under different climate change scenarios. *Global Change and Human Health* 3:2-14. Kleinschmidt, I., J. Omumbo, O. Briet, N. van de Giesen, N. Sogoba, N.K. Mensa, P. Windmeijer, M. Moussa, and T. Teuscher. 2001. An empirical malaria distribution map for West Africa. *Trop Med Int Health* 6:779-786. Gemperli A., P. Vounatsou, I. Kleinschmidt, M. Bagayoko, C. Lengeler, and T. Smith. 2004. Spatial patterns of infant mortality in Mali: The effect of malaria endemicity. *Am J Epidemiol* 159:64-72. MARA/ARMA. 1998. *Towards an atlas of malaria risk in Africa.* Durban, South Africa.

4.5 Terrestrial Vegetation Sector Tools

The terrestrial vegetation models presented in this compendium (listed in Table 4.5) represent a broad sample of the sorts of models that might be useful in considering the impacts of climate change as well as the potential for adaptation. Some of the models are global in scale (e.g., IBIS, IMAGE, and MC1, among others) while some are regional in their focus (e.g., Medrush). Some take a process based approach (e.g., LPJ, CASA, TEM, and CENTURY) while models such as AEZ rely on assessing the suitability of vegetation growth according to a number of productivity parameters. While most models allow for the investigation of a number of environmental parameters, models such as IMAGE were developed explicitly with climate change in question.

Table 4.5. Tools covered in terrestrial vegetation sector
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)

LPJ (Lund-Postdam-Jena) Model

Description	The LPJ model combines process-based, large-scale representations of terrestrial vegetation dynamics and land-atmosphere carbon and water exchanges in a modular framework. Features include feedback through canopy conductance between photosynthesis and transpiration, and interactive coupling between these "fast" processes and other ecosystem processes, including resource competition, tissue turnover, population dynamics, soil organic matter and litter dynamics, and fire disturbance.
Appropriate Use	Photosynthesis, evapotranspiration, and soil-water dynamics are modeled on a daily time step, and vegetation structure and PFT population densities are updated annually.
Scope	Global at 0.5° latitude and longitude resolution.
Key Output	Vegetation structure, biomass carbon.
Key Input	Latitude, longitude, climate, soil texture, CO_2.
Ease of Use	Expert ecosystem vegetation scientist.
Training Required	Yes.
Training Available	Training occurs for young scientists developing masters or Ph.D. theses on the basis of LPJ.
Computer Requirements	Linux cluster.
Documentation	http://www.pik-potsdam.de/lpj/lpj_researchvt1.html#furtherinfo.
Applications	Being applied in many different contexts, LPJ has been able to show multiple aspects of biospheric vulnerability to climate and land use change, as well as the feedbacks that will likely arise from broad-scale alteration of the land surface.
Contacts for Framework, Documentation, Technical Assistance	Dr. I. Colin Prentice, Max Planck Institute for Biogeochemistry, Jena, Germany; Tel: +49.3641.643.774; Fax: +49.3641.643.775; e-mail: colin.prentice@bgc-jena.mpg.de.
Cost	Not identified.
References	Bondeau A., P.C. Smith, S. Zaehle, S. Schaphoff, W. Lucht, W. Cramer, D. Gerten, H. Lotze-Campen, C. Müller, M. Reichstein and B. Smith. 2007. Modelling the role of agriculture for the 20th century global terrestrial carbon balance. *Global Change Biology* 13(3):679-706. Cramer, W. and 16 others. 2001. Global response of terrestrial ecosystem structure and function to CO_2 and climate change: Results from six dynamic global vegetation models. *Global Change Biology* 7:357-373. Prentice, I.C., M. Heimann, and S. Sitch. 2000. The carbon balance of the terrestrial biosphere: Ecosystem models and atmospheric observations. *Ecological Applications* 10:1553-1573. Sitch, S., B. Smith, I.C. Prentice, A. Arneth, A. Bondeau, W. Cramer, J. Kaplan, S. Levis, W. Lucht, M. Sykes, K. Thonicke, and S. Venevski. 2003. Evaluation of ecosystem dynamics, plant geography and terrestrial carbon cycling in the LPJ Dynamic Vegetation Model. *Global Change Biology* 9:161-185.

IBIS (Integrated BIosphere Simulator)

Description	IBIS performs integrated assessments of water balance, carbon balance, and vegetation structure on both global and regional scales based on an integrated modeling approach that explicitly represents competition between plant functional types (competition for light and water) and characterizes their responses to global change drivers (land use changes, climate variability and change, atmospheric CO2). IBIS is designed around a hierarchical conceptual framework, and includes several submodels (or "modules") that are organized with respect to their characteristic temporal scale: land surface processes (energy, water, carbon and momentum balance); soil biogoechemistry (carbon and nitrogen cycling from plant through soil); vegetation dynamics (plant competition for light, water, and eventually nutrients); vegetation phenology (based on a growing degree day approach); and atmospheric coupling (IBIS is now directly coupled to GENESIS and CCM3 GCMs).
Appropriate Use	IBIS represents a wide range of ecosystem and land surface processes in a single, physically consistent framework. In this way, IBIS can simulate the dynamic behavior of land surface and ecosystem processes, and their consequences for vegetation composition and structure.
Scope	Global; spatial: 0.5°, 1.0°, 2.0° and 4.0°; temporal: hourly.
Key Output	GPP, above and belowground NPP, NEP, fine root and heterotrophic respiration, nitrogen mineralization, latent, sensible heat, aet, evaporation, transpiration, snow temperature, extension and depth. Carbon and nitrogen: (a) vegetation: fine roots, leaves, and wood for upper canopy (trees) and fine roots and leaves for lower canopy (shrubs and grasses); (b) litter: above and belowground (fine root) separated in 3 distinct pools (decomposable, structural and resistant); (c) soil organic matter: microbial biomass, protected and unprotected "slow" C pools, and passive C pool.
Key Input	Climatic, site, vegetation, soils and resolution (e.g., daily, monthly).
Ease of Use	Expert ecosystem vegetation scientist.
Training Required	Yes.
Training Available	No formal training offered.
Computer Requirements	High performance cluster.
Documentation	http://www.sage.wisc.edu/download/IBIS/ibis.html and http://gaim.unh.edu/Structure/Intercomparison/EMDI/models/ibis.html.
Applications	Global climate impacts.
Contacts for Framework, Documentation, Technical Assistance	Jonathan Andrew Foley, Center for Sustainability and the Global Environment (SAGE), Institute for Environmental Studies, University of Wisconsin, 1225 West Dayton Street, Madison, Wisconsin 53706 USA; Tel: 608.265.9119; Fax: 608.265.4113; e-mail: jfoley@facstaff.wisc.edu.
Cost	Not provided.

IBIS (Integrated BIosphere Simulator) (cont.)

References	Foley, J.A., I.C. Prentice, N. Ramunkutty, S. Levis, D. Pollard, S. Sitch, and A. Haxeltine. 1996. An integrated biosphere model of land surface processes, terrestrial carbon balance and vegetation dynamics. *Global Biogeochemical Cycles* 10:603-628. Delire, C. and J.A. Foley. 1999. Evaluating the performance of a land surface/ecosystem model with biophysical measurements from contrasting environments. *Journal of Geophysical Research (Atmospheres)* 104(D14):16:895-16,909. Kucharik, C.J., J.A. Foley, C. Delire, V.A. Fisher, M.T. Coe, J. Lenters, C. Young-Molling, N. Ramankutty, J.M. Norman, and S.T. Gower. 2000. Testing the performance of a dynamic global ecosystem model: Water balance, carbon balance and vegetation structure. *Global Biogeochemical Cycles* 14(3):795-825. Wang, G., E.A.B. Eltahir, J.A. Foley, D. Pollard and S. Levis. 2004. Decadal variability of rainfall in the Sahel: results from the coupled GENESIS-IBIS atmosphere-biosphere model. *Climate Dynamics* 22(6-7):625-637.

Medrush Vegetation Model

Description	Landscape-scale model of vegetation structure and productivity, hydrology and soil erosion. Simulation of structure, productivity, and water relations of Mediterranean vegetation using a mechanistic (process-based) approach.
Appropriate Use	Applied to simulating the effects of recent historical changes in climate and CO2 in evergreen sclerophyllous shrubland.
Scope	Regional applications.
Key Output	Vegetation productivity, vegetation composition, soil erosion, and hydrology.
Key Input	Climatic, atmosphere CO_2, and soil texture data.
Ease of Use	Ecosystem-vegetation community expertise needed.
Training Required	Yes.
Training Available	Not indicated.
Computer Requirements	PC-based stand-alone.
Documentation	None identified.
Applications	Regional.
Contacts for Framework, Documentation, Technical Assistance	Professor Ian Woodward, Centre for Terrestrial Carbon Dynamics (CTCD), University of Sheffield, Dept. of Animal and Plant Sci., Alfred Denny Building, Western Bank, Sheffield S10 2TN, United Kingdom.
Cost	Not indicated.
References	Osborne, C.P., P.L. Mitchell, J.E. Sheehy, and F.I. Woodward. 2000. Modelling the recent historical impacts of atmospheric CO_2 and climate change on Mediterranean vegetation. *Global Change Biology* 6:445-458.

CENTURY

Description	The CENTURY version 5 agroecosystem model is the latest version of the soil organic model developed by Parton et al. (1987). This model simulates C, N, P, and S dynamics through an annual cycle over time scales of centuries and millennia. The producer submodel may be a grassland/crop, forest or savanna system, with the flexibility of specifying potential primary production curves representing the site-specific plant community. CENTURY was especially developed to deal with a wide range of cropping system rotations and tillage practices for system analysis of the effects of management and global change on productivity and sustainability of agroecosystems. Note CENTURY is also described under agriculture.
Appropriate Use	To study the impact of climate change on net primary production (crops, pastures, forests) as well as carbon and nutrient dynamics (including carbon sequestration), and to explore adaptive agricultural and natural resource management options (tillage, fertilizer, different species and sequences, etc.).
Scope	Site-specific but has been used at watershed, drainage basin, and regional scales using GIS.
Key Output	Changes in soil carbon and nutrient balances, as well as in crop, pasture and forest production, for different climate change scenarios.
Key Input	Monthly average maximum and minimum air temperature; monthly precipitation; soil texture; plant nitrogen; phosphorus and sulfur content; lignin content of plant material; atmospheric and soil nitrogen inputs; initial soil carbon; nitrogen (phosphorus and sulfur optional).
Ease of Use	For trained agronomists and ecologists. Requires advanced knowledge of soil and plant growth processes.
Training Required	CENTURY basic training requires at least 1-2 weeks to acquire minimum skills to conduct simple simulations.
Training Available	Training is offered at NREL, Colorado State University (see Contacts below).
Computer Requirements	PC-based stand alone version, Linux cluster for regional simulations.
Documentation	http://www.nrel.colostate.edu/projects/century5/. http://www.nrel.colostate.edu/projects/century5/reference/index.htm.
Applications	CENTURY has been used in the Loch Vale Watershed Project, a long-term research program designed to assess the effect of global climate change on the Front Range of the Colorado Rockies. Specifically, CENTURY was used to assess the abiotic and biotic controls on forest distribution and productivity as a basis for assessing potential vegetation change for projected climate scenarios.
Contacts for Framework, Documentation, Technical Assistance	Dr William Parton, NREL at Colorado State University, 1499 Campus Delivery Fort Collins, CO 80523-1499, USA; Tel: 970.491.1987; e-mail: billp@nrel.colostate.edu. Cindy Keough, Natural Resource Ecology Laboratory, Colorado State University, Fort Collins, CO 80523-1499 USA; Tel: 970.491.2195; Fax: 970.491.1965; e-mail: cindyk@nrel.colostate.edu.
Cost	Not identified.

CENTURY (cont.)

References	See http://nrel.colostate.edu/projects/century5/reference/html/bibliography.htm#parton1987 for more references. Hall, D.O., J.M.O. Scurlock, D.S. Ojima, and W.J. Parton. 2000. Grasslands and the global carbon cycle: Modelling the effects of climate change. In *The Carbon Cycle*. T.M.L. Wigley and D.S. Schimel (eds.). Cambridge University Press, Cambridge, UK, pp. 102-114. Kelly, R.H., W.J. Parton, G.J. Crocker, P.R. Grace, J. Klír, M. Körschens, P.R. Poulton, and D.D. Richter. 1997. Simulating trends in soil organic carbon in long-term experiments using the Century model. *Geoderma* 1258. Melillo, J.M., J. Borchers, J. Chaney, H. Fisher, S. Fox, A. Haxeltine, A. Janetos, D.W. Kicklighter, T.G.F. Kittel, A.D. McGuire, R. McKeown, R. Neilson, R. Nemani, D.S. Ojima, T. Painter, Y. Pan, W.J. Parton, L. Pierce, L. Pitelka, C. Prentice, B. Rizzo, N.A. Rosenbloom, S. Running, D.S. Schimel, S. Sitch, T. Smith, and I. Woodward. 1995. Vegetation/ecosystem modeling and analysis project: comparing biogeography and biogeochemistry models in a continental-scale study of terrestrial ecosystem responses to climate change and CO_2 doubling. *Global Biogeochemical Cycles* 9:407-437. Ojima, D.S., W.J. Parton, D.S. Schimel, T.G.F. Kittel, and J.M.O. Scurlock. 1993. Modeling the effects of climatic and CO_2 changes on grassland storage of soil C. *Water, Air, and Soil Pollution* 70:643-657. Parton, W.J., D.S. Schimel, C.V. Cole and D.S. Ojima. 1987. Analysis of factors controlling soil organic matter levels in Great Plains grasslands. *Soil Science Society of America Journal* 51:1173-1179. Parton, W.J., D.S. Schimel, D.S. Ojima, and C.V. Cole. 1994. A general model for soil organic matter dynamics: sensitivity to litter chemistry, texture and management. Pages 147-167 *in* Bryant, R. B. and R.W. Arnold (eds.). Quantitative modeling of soil forming processes. SSSA Spec. Publ. 39. ASA, CSSA and SSA, Madison, WI, USA.

MC1

Description	MC1 consists of three linked modules simulating biogeography, biogeochemistry, and fire disturbance. The main functions of the biogeography module are to (1) predict the composition of deciduous/evergreen tree and C3/C4 grass lifeform mixtures, and (2) classify the predicted biomass from the biogeochemistry module into different vegetation classes. The biogeochemistry module simulates monthly carbon and nutrient dynamics for a given ecosystem. Above- and below-ground processes are modeled in detail, and include plant production, soil organic matter decomposition, and water and nutrient cycling. Parameterization of this module is based on the lifeform composition of the ecosystems, which is updated annually by the biogeography module.
Appropriate Use	Climate change effects on vegetation changes.
Scope	Regional to global.
Key Output	Vegetation structure, fire events, plant productivity, vegetation carbon, soil carbon and nitrogen, evapotranspiration.
Key Input	Monthly precipitation, mean monthly average minimum and maximum temperatures, vapor pressure, wind speed, solar radiation, soil depth, soil texture, bulk density.
Ease of Use	Ecosystem and vegetation science expertise.
Training Required	Yes.
Training Available	See Contacts below.
Computer Requirements	Linux cluster or multiple processor.
Documentation	http://www.fsl.orst.edu/dgvm/mcgtr508.pdf.
Applications	Regional to global applications.
Contacts for Framework, Documentation, Technical Assistance	Ronald P. Neilson, BioClimatologist, USDA Forest Service, Pacific Northwest Research Station, Corvallis Forestry Sciences Laboratory, 3200 SW Jefferson Way, Corvallis, OR 97331 USA; Tel: 541.750.7303; e-mail: rneilson@fs.fed.gov.
Cost	Depends on application.
References	Bachelet, D., J.M. Lenihan, C. Daly, and R.P. Neilson. 2000. Climate, fire and grazing effects at Wind Cave National Park, SD. Ecological Modelling 134(2-3):229-244. Bachelet, D., J.M. Lenihan, C. Daly, R.P. Neilson, D.S. Ojima, and W.J. Parton. 2001. MC1. A dynamic vegetation model for estimating the distribution of vegetation and associated ecosystem fluxes of carbon, nutrients and water. Technical Documentation Version 1.0. General Technical Report PNW-GTR-508. Corvallis, OR. USDA Forest Service, Pacific Northwest Research Station. Daly, C., D. Bachelet, J.M. Lenihan, R.P. Neilson, W.J. Parton, and D. Ojima. 2000. Dynamic simulation of tree-grass interactions for global change studies. *Ecological Applications* 10(2):449-469. Lenihan, J.M., C. Daly, D. Bachelet, and R.P. Neilson. 1998. Simulating broad-scale fire severity in a dynamic global vegetation model. *Northwest Science* 72:91-103.

IMAGE (Integrated Model to Assess the Greenhouse Effect)

Description	IMAGE was developed at RIVM in the Netherlands (Alcamo, 1994). It takes a global approach with the entire earth system as the subject of investigation. Its main use is scenario analysis of the issue of anthropogenic climate change due to the greenhouse effect. It is *Integrated* because it is designed to simulate the dynamics and interconnections between three major subsystems of the globe, namely, climate, biosphere, and society.
Appropriate Use	Land use and climate change effects on land productivity.
Scope	Global and national level responses.
Key Output	Cumulative greenhouse gas emissions, the resulting atmospheric concentrations, global warming, sea level rise, changing patterns of land use and cover, agricultural impacts, ecosystem risks, and also the costs of policies for emissions reduction or control.
Key Input	Climate, soil, land use and cover, regional demands for cropland and rangeland and fuelwood demand, and "local" potential for land.
Ease of Use	Expertise of ecosystem and land use science.
Training Required	Yes.
Training Available	No formal training offered.
Computer Requirements	PC-based.
Documentation	http://sedac.ciesin.columbia.edu/mva/image-2.0/image-2.0-toc.html
Applications	Regional and global use.
Contacts for Framework, Documentation, Technical Assistance	Joseph Alcamo, Environmental Systems Engineering, Executive Director, Center for Environmental Systems Research, Kurt-Wolters-Straße 3, Room 2116, 34109 Kassel, Germany; Tel: +49.561.804.3898; Fax: +49.561.804.3176; e-mail: alcamo@usf.uni-kassel.de.
Cost	Not specified.
References	Alcamo, Joseph (ed.). 1994. *IMAGE 2.0: Integrated Modeling of Global Climate Change*. Dordrecht, The Netherlands: Kluwer Academic Publishers.

AEZ (Agro-ecological Zones) Methodology

Description	The Food and Agriculture Organization of the United Nations (FAO) with the collaboration of the International Institute for Applied Systems Analysis (IIASA), has developed this system, which enables rational land-use planning on the basis of an inventory of land resources and evaluation of biophysical limitations and potentials. It is anticipated that the AEZ process will be crucial in identifying agricultural and natural resource baselines, and in monitoring how these baselines are being altered. The AEZ methodology also provides a means of identifying how natural resources and agricultural production is likely to be perturbed under future climate scenarios and in identifying suitable crops and locations under future climate scenarios. Recent availability of digital global databases of climatic parameters, topography, soil and terrain, vegetation, and population distribution has called for revisions and improvements in calculation procedures and in turn has allowed for expanding assessments of AEZ crop suitability and land productivity potentials to temperate and boreal environments.
Appropriate Use	Climate change analysis of crop production. It is recommended that users access model results.
Scope	AEZ methodology and supporting software packages can be applied at global, regional, national and sub-national levels.
Key Output	Maximum potential and agronomically attainable crop yields for basic land resources units (usually grid-cells in the recent digital databases).
Key Input	Climate, topography and soil characteristics, and is to a large extent determined by demographic, socioeconomic, cultural, and political factors, such as population density, land tenure, markets, institutions, and agricultural policies.
Ease of Use	Expertise in crop systems.
Training Required	Yes.
Training Available	See Contacts below.
Computer Requirements	Web-based PC tools.
Documentation	http://www.iiasa.ac.at/Research/LUC/GAEZ/index.htm?sb = 6.
Applications	Climate change assessments of agricultural production.
Contacts for Framework, Documentation, Technical Assistance	Günther Fischer, International Institute for Applied Systems Analysis (IIASA), A-2361 Laxenburg, Austria; Tel: +43.2236.807.0; Fax: +43.2236.71.313; e-mail: fisher@iiasa.ac.at.
Cost	Depends on application.

AEZ (Agro-ecological Zones) Methodology (cont.)

References	Batjes, N.H., G. Fischer, F.O. Nachtergaele, V.S. Stolbovoi, and H.T. van Velthuizen. 1997. Soil Data Derived from WISE for Use in Global and Regional AEZ Studies. FAO/IIASA/ ISRIC Report IR-97-025. International Institute for Applied Systems Analysis, Laxenburg, Austria. Fischer, G. and H.T. van Velthuizen. 1996. Climate Change and Global Agricultural Potential Project: A Case Study of Kenya. International Institute for Applied Systems Analysis, Laxenburg, Austria, 96 pp. Fischer, G. and H.T. van Velthuizen. 1999. Agro-ecological zones of China, the former Soviet Union and Mongolia. International Institute for Applied Systems Analysis, Laxenburg, Austria. Fischer, G and G.K. Heilig. 1997. Population momentum and the demand on land and water resources. *Phil. Trans. R. Soc. Land.* B 352:869-889. Fischer, G., S. Prieler and H. van Velthuizen. 2005. Biomass potentials of miscanthus, willow and poplar: results and policy implications for Eastern Europe, Northern and Central Asia. *Biomass and Bioenergy* 28(2):119-132.

CASA (Carnegie-Ames-Stanford Approach) Model

Description	Calculation of monthly terrestrial NPP is based on the concept of light-use efficiency, modified by temperature and moisture stress scalars. Soil carbon cycling and Rh flux components of the model are based on a compartmental pool structure, with first-order equations to simulate loss of CO2 from decomposing plant residue and surface soil organic matter (SOM) pools. Model outputs include the response of net CO2 exchange and other major trace gases in terrestrial ecosystems to interannual climate variability (1983 to 1988) in a transient simulation mode.
Appropriate Use	Climate change analysis of ecosystem productivity.
Scope	Global to regional.
Key Output	Global gridded estimates of primary production, above and below ground biomass, leaf area index (LAI), and trace gas fluxes.
Key Input	Air surface temperature and precipitation are used together with long-term (30-year) mean values, and surface solar irradiance measurements.
Ease of Use	Expertise of ecosystem and biogeochemistry science.
Training Required	Yes.
Training Available	No formal training offered.
Computer Requirements	High end workstation.
Documentation	http://geo.arc.nasa.gov/sge/casa/index4.html.
Applications	Estimate of current ecosystem productivity.
Contacts for Framework, Documentation, Technical Assistance	Christopher Potter, Ecosystem Science and Technology, NASA Ames Research Center, Moffett Field, CA USA; Tel: 650.604.6164; Fax: 650.604.4680; e-mail: cpotter@gaia.arc.nasa.gov.
Cost	Not specified.
References	See http://geo.arc.nasa.gov/sge/casa/pubs.html for full publication list.

TEM (Terrestrial Ecosystem Model)

Description	The TEM is a process-based ecosystem model that describes carbon and nitrogen dynamics of plants and soils for terrestrial ecosystems of the globe. The TEM uses spatially referenced information on climate, elevation, soils, vegetation, and water availability as well as soil- and vegetation-specific parameters to make monthly estimates of important carbon and nitrogen fluxes and pool sizes of terrestrial ecosystems. The TEM operates on a monthly time step and at a 0.5° latitude/longitude spatial resolution.
Appropriate Use	Regional to global simulation of climate effects on ecosystem dynamics.
Scope	Regional to global.
Key Output	GPP, NPP, evapotranspiration, soil carbon and nitrogen, vegetation carbon and nitrogen.
Key Input	Vegetation, soil texture, elevation, solar radiation, precipitation, air temperature.
Ease of Use	Expertise in ecosystem science and biogeochemistry.
Training Required	Yes.
Training Available	See Contacts below.
Computer Requirements	High-end workstation.
Documentation	http://www.mbl.edu/eco42/.
Applications	Examined the time-dependent responses of terrestrial carbon storage and the net carbon exchange with the atmosphere as influenced by historical climate CO_2, land use and soil thermal regime.
Contacts for Framework, Documentation, Technical Assistance	Jerry M. Melillo, A. David McGuire, David W. Kicklighter, Yude Pan, Hanqin Tian, The Ecosystems Center, Marine Biological Laboratory, Woods Hole, MA 02543 USA; e-mails: jmelillo@lupine.mbl.edu, ffadm@aurora.alaska.edu, dkick@mbl.edu.
Cost	Not specified.
References	See http://www.mbl.edu/eco42/tempub.html for additional references. McGuire, A.D., C. Wirth, M. Apps, J. Beringer, J. Clein, H. Epstein, D.W. Kicklighter, J. Bhatii, F.S. Chapin III, B. de Groot, D. Efremov, W. Eugster, M. Fukuda, T. Gower, L. Hinzman, B. Huntley, G.J. Jia, E. Kasischke, J.M. Melillo, V. Romanovsky, A. Shvidenko, E. Vaganov, and D. Walker. 2002. Environmental variation, vegetation distribution, carbon dynamics, and water/energy exchange in high latitudes. *Journal of Vegetation Science* 13:301-314. Pan, Y., A.D. McGuire, J.M. Melillo, D.W. Kicklighter, S. Sitch, and I.C. Prentice. 2002. A biogeochemistry-based dynamic vegetation model and its application along a moisture gradient in the continental United States. *Journal of Vegetation Science* 13:369-382. Tian, H., J.M. Melillo, D.W. Kicklighter, S. Pan, J. Liu, A.D. McGuire, and B. Moore III. 2003. Regional carbon dynamics in monsoon Asia and its implications for the global carbon cycle. *Global and Planetary Change* 37:201-217.