CHAPTER 1

INTRODUCTION

The United Nations Framework Convention on Climate Change (UNFCCC) provides that all Parties must formulate and implement national or regional programmes containing measures to facilitate adequate adaptation to climate change (Art. 4.1.b). It lists specific domains in particular need of adaptation, namely coastal zones, water resources, agriculture, and areas affected by drought and desertification, as well as floods. Article 4.8 complements this list with e.g. small island countries, countries with forest areas liable to forest decay, countries prone to natural disasters, and countries with fragile ecosystems, including mountain ecosystems.

The croplands, pastures and forests that occupy 60 percent of the Earth's surface are progressively being exposed to threats from increased climatic variability and, in the longer run, to climate change. Abnormal changes in air temperature and rainfall and resulting increases in frequency and intensity of drought and flood events have long-term implications for the viability of these ecosystems.

As climatic patterns change, so also do the spatial distribution of agro-ecological zones, habitats, distribution patterns of plant diseases and pests, fish populations and ocean circulation patterns which can have significant impacts on agriculture and food production.

CLIMATE CHANGE IMPACTS IN AGRICULTURE

Increased intensity and frequency of storms, drought and flooding, altered hydrological cycles and precipitation variance have implications for future food availability. The potential impacts on rainfed agriculture *vis-à-vis* irrigated systems are still not well understood.

The developing world already contends with chronic food problems. Climate change presents yet another significant challenge to be met. While overall food production may not be threatened, those least able to cope will likely bear additional adverse impacts (WRI, 2005). The estimate for Africa is that 25–42 percent of species habitats could be lost, affecting both food and non-food crops. Habitat change is already underway in some areas, leading to species range shifts, changes in plant diversity which includes indigenous foods and plant-based medicines (McClean, Colin *et al.*, 2005). In developing countries, 11 percent of arable land could be affected by climate change, including a reduction of cereal production in up to 65 countries, about 16 percent of agricultural GDP (FAO Committee on Food Security, Report of 31st Session, 2005).

Changes in ocean circulation patterns, such as the Atlantic conveyer belt, may affect fish populations and the aquatic food web as species seek conditions suitable for their lifecycle. Higher ocean acidity (resulting from carbon dioxide absorption from the atmosphere) could affect the marine environment through deficiency in calcium carbonate, affecting shelled organisms and coral reefs.

Climate change impacts can be roughly divided into two groups:

biophysical impacts:

- physiological effects on crops, pasture, forests and livestock (quantity, quality);
- changes in land, soil and water resources (quantity, quality);
- increased weed and pest challenges;
- shifts in spatial and temporal distribution of impacts;
- sea level rise, changes to ocean salinity;
- sea temperature rise causing fish to inhabit different ranges.

socio-economic impacts:

- decline in yields and production;
- reduced marginal GDP from agriculture;
- fluctuations in world market prices;
- changes in geographical distribution of trade regimes;
- increased number of people at risk of hunger and food insecurity;
- migration and civil unrest.

Table 1 shows the possible direction of changes from negative to positive for most regions when assuming adaptation. For Europe, the Former Soviet Union and Centrally Planned China, impacts could be mostly positive. Concerning the adaptation scenario, Tol *et al.* comment that former studies often assumed “limited capacities of farmers to adapt to changing circumstances”. (Tol 2002, p. 52). Perfect adaptation is less realistic as imperfect information, limited access to technology and institutional weaknesses reduce the extent and effectiveness of adaptation.

The results presented in Fischer *et al.* (2002) are different but also derived from a different approach - an integrated assessment of biophysical, economic and social impacts. In comparing and weighing the results from these different modelling exercises, the integrated assessment (mentioned above) rates higher in the hierarchy of models. The GIS-based framework integrates crop-specific environmental limitations with crop modelling under varying input and management conditions.

TABLE 1: **GLOBAL IMPACTS ON AGRICULTURE* FOR A 2.5 DEGREE CELSIUS INCREASE IN GLOBAL MEAN TEMPERATURE**

REGIONS	WITHOUT ADAPTATION		WITH ADAPTATION		MEAN
	Best Guess	SD	Best Guess	SD	
Latin America	-0,8	0,6	0,6	0,7	-0,1
South & South-east Asia	-0,7	0,3	0,6	0,3	0,0
Middle East	-0,4	0,4	0,6	0,5	0,1
Africa	-0,2	0,2	0,5	0,3	0,1
OECD-P	-0,2	1,6	0,8	1,6	0,3
OECD-A	-0,3	1,3	1,0	1,3	0,4
OECD-E	0,6	1,0	2,1	1,1	1,3
Eastern Europe & Former SU	0,9	1,2	2,7	1,1	1,8
Centrally planned Asia	1,7	1,0	3,1	1,0	2,4

* expressed in percent change from reference projection of GDP

Source: Tol (2002)

The assessment of agro-ecosystem sensitivity to climate change (under the different socio-economic IPCC scenarios) by the FAO/IIASA Agro-Ecological Zones (AEZ) model is combined with a model of the global food system (IIASA Basic Linked System, BLS). The BLS is "a representation of all major economic sectors, and views national agricultural systems as embedded in national economies, which in turn interact with each other at the international level."(Fischer *et al*., 2002, p.vi)[1]

Results for impacts on production are generally simulated in two different ways. Either climate-induced yield changes are projected without agronomic (farm-level) and economic (sector-level) adjustment (Harrison *et al.*, 2000; Adams *et al*., 1999) or different static cases are compared, with a given level of climatic change and a fixed adaptation factor (Darwin *et al*., 1999; Parry *et al*., 2004). In the integrated assessment, using the BLS, decreases or gaps in food production lead to a rise in world market prices and create incentives for capital and resource re-distribution. Consumption patterns are adjusted accordingly.

The general findings from the impacts on yields and production are mirrored in the results of the economic analysis:

1. Globally aggregated impacts are small (-1.5% – +2.6%) in terms of changes in GDP from agriculture (similar to Tol *et al*. 2002): -0.8 – +3.1% over all regions).
2. The agricultural GDP in developed countries would likely benefit from climate change.

[1] For more detailed discussion of methodology, models and scenarios, see Fischer *et al*., 2002, pp.15-37.

3. With the exception of Latin America, developing countries would face a decrease of GDP from agriculture due to climate change. Asia (-4% for high emission scenarios) and Africa (-2 – -9% for 3 of the 4 GCMs) would generally be negatively affected.
4. North America could gain in all scenarios, as could the former USSR, from climate-induced changes in production conditions. Western Europe though, would lose in all scenarios.

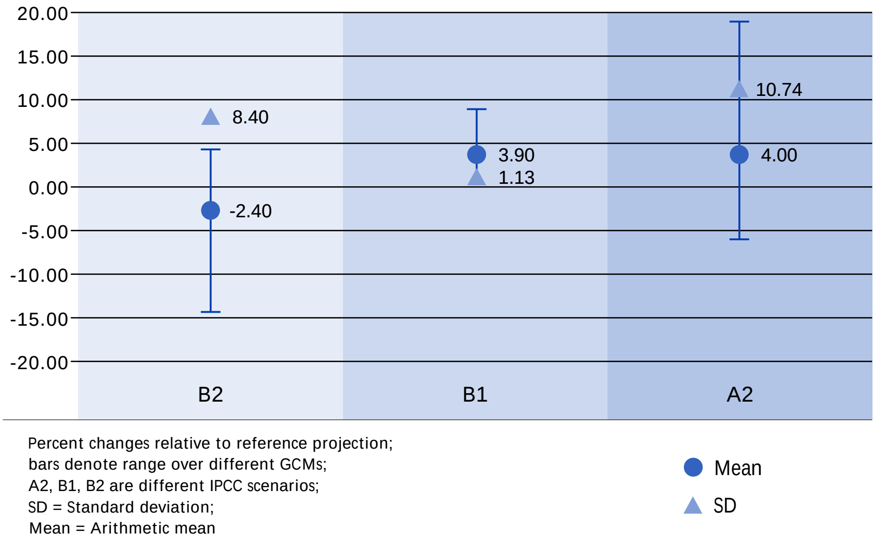

FIGURE 1: Impacts of climate change on world market prices for cereals, year 2080

Source: Juergens 2002, based on data from Fischer *et al.* (2002)

The considerable efforts needed to prepare for climate-related impacts and the time required for agriculture, forestry and fishery production systems to adapt is the crucial point. Success depends on factors relating to biology, ecology, technology and management regimes. Those countries with limited economic resources and insufficient access to technology will be least able to keep up with the changes.

CHAPTER 2

A FRAMEWORK FOR CLIMATE ADAPTATION IN AGRICULTURE, FORESTRY AND FISHERIES

APPROACHES TO CLIMATE CHANGE ADAPTATION

Two main types of adaptation are autonomous and planned adaptation. Autonomous adaptation is the reaction of, for example, a farmer to changing precipitation patterns, in that s/he changes crops or uses different harvest and planting/sowing dates.

Planned adaptation measures are conscious policy options or response strategies, often multisectoral in nature, aimed at altering the adaptive capacity of the agricultural system or facilitating specific adaptations. For example, deliberate crops selection and distribution strategies across different agriclimatic zones, substitution of new crops for old ones and resource substitution induced by scarcity (Easterling 1996).

Farm level analyses have shown that large reductions in adverse impacts from climate change are possible when adaptation is fully implemented (Mendelsohn and Dinar 1999). Short-term adjustments are seen as autonomous in the sense that no other sectors (e.g. policy, research etc.) are needed in their development and implementation.

Long-term adaptations are major structural changes to overcome adversity such as changes in land-use to maximize yield under new conditions; application of new technologies; new land management techniques; and water-use efficiency related techniques. Reilly and Schimmelpfennig (1999, p. 768ff.) define the following “major classes of adaptation”:

- seasonal changes and sowing dates;
- different variety or species;
- water supply and irrigation system;
- other inputs (fertilizer, tillage methods, grain drying, other field operations);
- new crop varieties;
- forest fire management, promotion of agroforestry, adaptive management with suitable species and silvicultural practices (FAO, 2005).

Accordingly, types of responses include (*ibid*., p. 770-771):

- reduction of food security risk;
- identifying present vulnerabilities;
- adjusting agricultural research priorities;
- protecting genetic resources and intellectual property rights;
- strengthening agricultural extension and communication systems;
- adjustment in commodity and trade policy;
- increased training and education;
- identification and promotion of (micro-) climatic benefits and environmental services of trees and forests (FAO, 2005).

With changes in precipitation and hydrology, temperature, length of growing season and frequency of extreme weather events, considerable efforts would be required to prepare developing countries to deal with climate-related impacts in agriculture. Among the key challenges will be to assist countries that are constrained by limited economic resources and infrastructure, low levels of technology, poor access to information and knowledge, inefficient institutions, and limited empowerment and access to resources.

Managed carefully, climate adaptation strategies could have environmental benefits for some countries. The Canadian agricultural sector has identified 96 different adaptation measures, including: change in topography of land (11 measures), use of artificial systems to improve water use/availability and protect against soil erosion (29), change farming systems (21), change timing of farm operations (2), use of different crop varieties (7), governmental and institutional policies and programmes (16), and research into new technologies (10). Many of these involve improved resource management – an option with benefits that extend beyond adaptation. These “additional” benefits should not be underestimated.

Climate change and variability are among the most important challenges facing Least Developed Countries because of their strong economic reliance on natural resources and rain-fed agriculture. People living in marginal areas such as drylands or mountains face additional challenges with limited management options to reduce impacts. Climate adaptation strategies should reflect such circumstances in terms of the speed of the response and the choice of options.

In view of the above, a framework for climate change adaptation needs to be directed simultaneously along several interrelated lines:

- *Legal and institutional* elements – decision making, institutional mechanisms, legislation, implementing human right norms, tenure and ownership, regulatory tools, legal principles, governance and coordination arrangements, resource allocation, networking civil society.

- *Policy and planning* elements – risk assessment and monitoring, analysis, strategy formulation, sectoral measures.
- *Livelihood* elements – food security, hunger, poverty, non-discriminatory access.
- *Cropping, livestock, forestry, fisheries and integrated farming system* elements – food crops, cash crops, growing season, crop suitability, livestock fodder and grazing management, non-timber forest products, agroforestry, aquaculture, integrated crop-livestock, silvo-pastoral, water management, land use planning, soil fertility, soil organisms.
- *Ecosystem* elements – species composition, biodiversity, resilience, ecosystem goods and services.
- *Linking climate change adaptation* processes and technologies for promoting carbon sequestration, substitution of fossil fuels, promoting use of bioenergy.

Closely related is the UNFCCC Subsidiary Body for Scientific and Technological Advice (SBSTA) Five-year Programme of Work on Impacts, Vulnerability and Adaptation to Climate Change, now renamed as "Nairobi Work Programme on Impacts, Vulnerability and Adaptation to Climate Change". Its indicative list of topics proposed for initial activities include: Methods and tools, Data and observations, Climate modelling, scenarios and downscaling, Climate related risks and extreme events, Socio-economic information, Adaptation planning and practices, Research, Technologies, Economic diversification. Effort is needed to further develop and integrate these groups and to estimate the expected marginal costs related to adaptation.

CHAPTER 3

FAO WORK RELATED TO CLIMATE CHANGE ADAPTATION

Climate change adaptation will be needed in a variety of ecosystems, including agro-ecosystems (crops, livestock, grasslands), forests and woodlands, inland waters and coastal and marine ecosystems. FAO's multidisciplinary expertise in agriculture, forestry and fisheries and involvement with farmers, scientists and policy-makers could facilitate an integrated approach to climate change adaptation.

Adaptation options where FAO has a comparative advantage include rural areas and household livelihoods; national policies in agriculture, forestry and fisheries; and national and regional assessments for food security. Although adaptation measures in any given area ought to be considered holistically, including trade-offs among biophysical and socio-political factors, the action areas described below are presented by subsector for ease of reference.

Agrobiodiversity

Biodiversity in all its components (e.g. genes, species, ecosystems) increases resilience to changing environmental conditions and stresses. Genetically-diverse populations and species-rich ecosystems have greater potential to adapt to climate change. FAO promotes use of indigenous and locally-adapted plants and animals as well as the selection and multiplication of crop varieties and autochthonous races adapted or resistant to adverse conditions.

The selection of crops and cultivars with tolerance to abiotic stresses (e.g. high temperature, drought, flooding, high salt content in soil, pest and disease resistance) allows harnessing genetic variability in new crop varieties if national programmes have the required capacity and long-term support to use them. To strengthen capacity of developing countries to implement plant breeding programmes and develop locally-adapted crops, FAO and other like-minded institutions are planning the Global Initiative on Plant Breeding Capacity Build (GIPB) initiative, to be launched at the governing body meeting of the International Treaty on Plant Genetic Resources for Food and Agriculture (Madrid, June 2007).

The linkage of GIPB to the Treaty will assist its members to address their commitments to implementation of Article 6 of the Treaty for supporting the development of capacities in plant breeding. It emphasizes: conserving diversity (6.2.b); adapting varieties to diverse and marginal conditions (6.2.c); broadening the genetic base of crops (6.2.d); promoting locally adapted crops and underutilized species (6.2.e); and reviewing breeding strategies and regulations concerning variety release and seed distribution (6.2.g). FAO's work on adapted crops includes decision-support tools such as EcoCrop to identify alternative crops for specific ecologies.

Work on adapted crops cannot be separated from other management options within agro-ecosystems. A specific example is rice, which is both impacted by and impacts climate. Climate change is expected to significantly impact the productivity of rice systems and thus the nutrition and livelihood of millions of people. Rice varieties have different abilities to tolerate high temperature, salinity, drought and floods. Rice varieties with salinity tolerance have been used to expedite the recovery of production in areas damaged by the 2004 Asian tsunami.

The selection of appropriate rice varieties deserves consideration for adaptation to climate change taking into account more than high yielding potential. Emission of methane from flooded rice soils has been identified as a contributor to global warming. Water regimes, organic matter management, temperature and soil properties as well as rice plant are factors determining the production and flux of methane (CH_4) in rice fields.

Varietal differences could be used to lessen the methane emission in rice production. Also, intermittent irrigation and/or alternating dry-wet irrigation could reduce methane emission from rice fields, while the transfer and adoption of the Rice Integrated Crop Management (RICM) system, such as the Australian RiceCheck, would increase the efficiency of nitrogen fertilizer in rice production, thus reducing the nitrous oxide (a greenhouse gas) emission. Upland rice cultivation under slash-and-burn shifting cultivation, especially in sub-Saharan Africa, has resulted in destruction of forest vegetation. The development of wetland rice in sub-Saharan Africa could reduce deforestation in these areas.

Soil and land management

Climate change adaptation for agricultural cropping systems requires a higher resilience against both excess of water (due to high intensity rainfall) and lack of water (due to extended drought periods). A key element to respond to both problems is soil organic matter, which improves and stabilizes the soil structure so that the soils can absorb higher amounts of water without causing surface run off, which could result in soil erosion and, further downstream, in flooding. Soil organic matter also improves the water absorption capacity of the soil for during extended drought.

FAO promotes low tillage and maintenance of permanent soil cover that can increase soil organic matter and reduce impacts from flooding, erosion, drought, heavy rain and winds. Among areas being explored are conservation agriculture, organic agriculture and risk-coping production systems that incorporate crop rotations, agroforestry, crop-livestock associations, crop-fish systems and the use of hedges, vegetative buffer strips and other farm landscaping practices.

While intensive soil tillage reduces soil organic matter through aerobic mineralization, low tillage and the maintenance of a permanent soil cover (through crops, crop residues or cover crops and the introduction of diversified crop rotations) increases soil organic matter. A no- or low-tilled soil conserves the structure of soil for fauna and related macrospores (earthworms, termites and root channels) to serve as drainage channels for excess water. Surface mulch cover protects soil from excess temperatures and evaporation losses and can reduce crop water requirements by 30 percent.

Conservation agriculture and organic agriculture that combine zero or low tillage and permanent soil cover are promising adaptation options promoted by FAO for their ability to increase soil organic carbon, reduce mineral fertilizers use and reduce on-farm energy costs. Special attention will be given to the situation of indigenous communities

Risk-coping production systems, resilient to land and water modifications, require diversified structures in space and time such as crop rotations, agroforestry, crop-livestock associations, crop-fish systems and the use of hedges, vegetative buffer strips and other farm landscaping practices. Accomplishing this can have an enormous impact on adaptation to drought, heavy rains and winds.

Land and water management techniques have been developed under the FAO partnership of the World Overview of Conservation Approaches and Techniques (WOCAT), which identify which methods have proven workable under specific biophysical and socio-economic conditions. Land use planning approaches have been developed that stress participatory approaches for identifying priority areas at district and national level and identifying where investments are most needed under changing climatic conditions. Special attention will be given to pastoralists and indigenous people and their relation to natural resources.

Land cover assessment and monitoring of its dynamics are essential for sustainable management of natural resources, assessing the vulnerability of ecosystems and planning food security and humanitarian programmes. However, there is still a lack of reliable or comparable baseline data. The Global Land Cover Network (GLCN) led by FAO and UNEP works to harmonize land cover definitions, standardize land cover baseline datasets, facilitate data acquisition and build capacity at the national and regional levels.

The Global Terrestrial Observing System (GTOS) is hosted by FAO and co-sponsored with ICSU, UNEP, UNESCO and WMO. Its joint panel with the Global Climate Observing System (GCOS) on terrestrial climate observations has identified core variables for terrestrial climate monitoring which have been endorsed by the UNFCCC Conference of Parties. For each variable, analysis has been carried out on its use, required resolution, methodology and equipment required, and requirements for recordkeeping.

Global observing systems are generally under-represented in developing country regions, especially in least developed countries. FAO, through GTOS, is responding to this and working with the multilateral environmental agreements to expand global observing systems in these regions. For example, the CarboAfrica project will expand the existing flux network for carbon, water and fire monitoring in sub-Saharan Africa. It includes a major component on capacity building and information dissemination and will generate emission estimates from fires combining burned area and fire intensity using an approach based on Fire Radiative Power.

Water management

A broad range of agricultural water management practices and technologies are available to spread and buffer production risks. Enhancing residual soil moisture through land conservation techniques assists significantly at the margin of dry periods while buffer strips, mulching and zero tillage help to mitigate soil erosion risk in areas where rainfall intensities increase.

The inter-annual storage of excess rainfall and the use of resource efficient irrigation remain the only guaranteed means of maintaining cropping intensities. Beyond the direct agricultural interventions, water resource management responses for river basins and aquifers, which are often transboundary, will be forced to become more agile and adaptive (including near real-time management), as variability in river flows and aquifer recharge becomes apparent. Competing sectoral demands for water will place more pressure on allocations to agriculture to account for its dominant use of raw water. Additionally there may be increased water demand for irrigated systems.

Forestry

Forests cover 30 percent of the total land surface. Forests in the ten most forest-rich countries account for two-thirds of total forest area, while 57 countries have less than 10% of their land area in forests. In addition to adapting forests to climate change, forests can play a role in adaptation by helping human societies to adapt to climate change.

Adaptive management of forests will contribute to sustaining the livelihood of over two billion people worldwide.

Many existing forests and most newly established stands will experience climatic conditions that deviate from conditions today. Compared to agriculture, decisions taken today for managed forests (e.g. tree species choice) remain irreversible for decades or even centuries. On the other hand, selection of seed provenances for altered climatic conditions will require time.

Worldwide, only 34% of forests are intensely managed for wood production. An equal proportion fulfils multiple functions at lower management intensity, the remainder is managed at low intensity or for protection, conservation or social services.

The first harbingers of forest climate change impacts are visible as forest decline on former permafrost soils in Canada and Alaska, as decline of cloud forests in the tropics, the global frequency and severity of forest fires, altered timing of seeding and as increased pest and disease outbreaks.

Preliminary analysis indicates that concepts and contingency plans for adapting forests are rarely included in national plans for adaptation. FAO has begun systematically informing forestry administrations in regional organizations and member countries about climate change, the vulnerabilities of their forest sector and possible adaptive options.

Projected long-term impacts of climate change on forests, ranging from pronounced increases in productivity in some northern countries to die-back of some tropical forests are available. FAO can offer decision models for managing forests under uncertainty, and management options for intensively managed forests in regeneration, tending, harvesting, protection, conservation and management planning.

Unfortunately, in forests which are managed at low intensity or not at all, particularly the tropical forests, fewer options exist and uncertainty is more pronounced regarding climate change adaptation. Intensifying assessment and monitoring, establishing new tools and indicators to rate vulnerability and targeting research efforts appear most promising to cope with climate change in these forests.

FAO is closely involved with UNFCCC efforts to reduce emissions from deforestation in developing countries. While this might be seen as primarily aimed at mitigating climate change, it has an adaptive component of preserving species richness, continuity of forest ecosystems and resilience. It is estimated that adverse climate change impacts will contribute to the destruction of forests and thereby promote the emission of greenhouse gases, which in turn will enhance global warming.

Interfaces with agriculture and food security

Trees and shrubs in farming systems (including agroforestry) can play a significant role in mitigating the impacts of extreme events and the resulting threats to food security. In addition to benefits such as the provision of wood and non wood forest products, restoration of soil fertility, and the conservation of biological diversity, trees and forests improve the microclimate by buffering winds, regulating the water table, providing shade to crops and animals, and stabilizing coastal areas (e.g. through mangrove rehabilitation and reforestation). They thus contribute to sustainable agricultural production and food security.

Crop yield forecasting

The knowledge and technology required for adaptation includes understanding the patterns of variability of current and projected climate, seasonal forecasts, hazard impact mitigation methods, land use planning, risk management, and resource management.

Adaptation practices require extensive high quality data and information on climate, and on agricultural, environmental and social systems affected by climate, with a view to carrying out realistic vulnerability assessments and looking towards the near future. Vulnerability assessment observes impacts of variability and changes in mean climate (inter-annual and intra-seasonal variability) on agricultural systems. However, agricultural production systems have their own dynamics and adaptation has a particular emphasis on future agriculture.

Early warning and risk management systems are obvious and efficient contributors that can facilitate adaptation to climate variability and change, including:

- a historical climate data archive; an archive on climate impacts on agriculture;
- monitoring tools using systematic meteorological observations;
- climate data analysis (to determine the patterns of inter-annual and intra-seasonal variability and extremes);
- information on the characteristics of system vulnerability and adaptation effectiveness such as resilience, critical thresholds and coping mechanisms

(this information is required to identify opportunities for adaptation measures, and the potential of particular practices);

- crop weather insurance indices to reduce the risk of climate impacts for lower-income farmers.

FAO has a long tradition in crop forecasting and monitoring technology based on field data, satellite based indices and software. Since 1974, FAO Agrometeorology has developed and improved its crop forecasting methodology to supply updated information on crop conditions mainly in sub-Saharan countries through the Global Information and Early Warning System on Food and Agriculture and to various national Food Security Information and Early Warning Systems worldwide. Building from such national systems, which are known and used by countries is a more effective starting point than trying to launch new, possibly improved but largely untested, analytical tools.

FAO has been a leader in the use of new data types (in particular rainfall, crop phenology and remotely sensed data) and specific tools (methods and software) such as crop specific water balance, data interpolation in time and space and analysis tools either at continental / regional level or national, district and local levels. FAO agrometeorological tools are designed with scale independence in mind to monitor patterns of climate variability at global, continental, regional, national, subnational and farm level. They have been tested and used extensively by countries and are appropriate for vulnerability risk assessment and to define best practices for climate change adaptation.

Adaptation activities need also to focus on securing agricultural productivity in a sustainable manner. The improved use of Early Warning and Information Systems (EWIS) and Disaster Information Management Systems (DIMS), the short- and long-term impact of (extreme) events on agriculture livelihoods can be assessed while contributing to disaster preparedness and mitigation of potential risks.

Livestock systems

Climate change has direct effects on livestock productivity as well as indirectly through changes on the availability of fodder and pastures. Climate determines the type of livestock most adapted to different agro-ecological zones and therefore the animals that are able to sustain rural communities. Climate change is expected to affect livestock at the species level. For example, if the Himalayas turn warmer, the yak could be restricted to higher altitudes where grass and fodder is less available. Communities will seek other species for production, relying on their own knowledge.

Since changes are relatively slow, there is need to rely more on continuous observations and experience of farmers and their local knowledge. Climate changes will also affect nomadic and transhumant livestock keepers. New routes and pastures will have to be found. The negative impact of ruminants on greenhouse gases emissions can be addressed through changes in animal husbandry including ruminant diets and animal stocking ratios to avoid nitrous oxides emissions.

Larger changes in climate can increase costs exponentially (Hahn and Morgan 1999, cited in IPCC 2001a). Historical success in coping with climate variability suggests that some livestock systems could adapt to climate change successfully. Benefits that might be realized during cooler seasons may be less than (negative) hot weather impacts (Hahn *et al.*, 1992, cited *ibid.*). However, adaptation could entail dislocation costs for certain producers.

FAO can assist in monitoring both the direct (animal genetic resources) and indirect (availability of fodder and pastures) effect of climate change on livestock, provide early warnings to the various climatic zones and assist countries in adapting livestock policies. In addition, FAO can work with farmers who know by experience which types of animal breeds or varieties can best resist changing conditions, to mitigate the negative impact of ruminants on greenhouse gas emissions through recommending animal husbandry changes such as ruminant diets and stocking ratios.

Fisheries

Variability on a range of time-scales has always been a feature of fisheries, especially capture fisheries. Recruitment and productivity in most fisheries vary from year to year and are superimposed on longer scale variability which typically occurs on a scale of decades. Inter-annual and decadal scale variability, often involving shifts in productivity patterns and dominant species, of populations of small pelagic fish in upwelling systems, are examples of multiscale variability.

Where there is effective management in place, fishery systems have developed adaptive strategies and through monitoring and feedback, fishing effort and catches are regularly modified according to the state of the stock. In these cases, the fishers must have either the robustness or flexibility (or both) to absorb the changes in resource abundance so as to avoid negative ecological, social or economic impacts.

Robustness is typically associated with factors such as total fishing capacity being commensurate with the productive capacity of the resource during its lower productivity phases, the availability of alternative fishery resources, investments in flexible technologies such as multipurpose boats (as opposed to specialized vessels) and flexible processing chains, or the ability and opportunity for alternative livelihoods during lean periods.

FAO supported development and practice of resilient and adaptive fishery management systems and fisheries to implement the FAO Code of Conduct for Responsible Fisheries and ecosystem approaches to fisheries. So far, it is not clear what the project priorities will be under the Adaptation Fund (AF), however countries could also seek support through other funding avenues.

The impact of long-term trends in climate change, in particular related to global warming, is less well-understood in fisheries but is beginning to receive attention. FAO is monitoring and participating in this work and has developed expertise and experience in rapid appraisal of the impacts of disasters on local fishing communities and aquatic ecosystems and the immediate and longer-term remedial action required. Long-term climate change has important feedback loops to global ocean circulation patterns, sea level rise and changes in ocean salinity all of which affect the biological properties and distribution of species.

At present FAO is giving priority an Ecosystem Approach to Fisheries which requires addressing impacts of the wider environment in order to manage fishery resources and the ecosystems on which they depend.

The Organization monitors developments in these areas by participating in the Scientific Steering Committee of the Global Ecosystem Dynamics (GLOBEC) programme of the International Geosphere Biosphere Programme. Interaction with those structures, amongst others, could lead to better science-based guidance to countries.

Rural livelihoods

The risks and vulnerabilities of the poor who live in insecure places and need to build their resilience to cope with climatic fluctuations are among the more important challenges in adapting to increasing climate variability and climate change.

FAO has developed and tested a livelihood-based approach to promote climate change adaptation processes at grass root level building on the assumption that most rural communities in LDCs (as well as in other developing countries) work on the basis of day-to-day priorities rather than for the longer-term. The basic processes associated with the approach to working with farmers, fishermen and livestock keepers at local level therefore involve:

- assessing and understanding current livelihood systems, indigenous knowledge, adaptive capacities and vulnerabilities;
- starting work on the issues that matter today and, based on that:
  - identifying and promoting options to adapt to climate variability, jointly with local agricultural producers and research institutes and extension;
  - enhancing local adaptive capacities by linking multiple stakeholders, and

- adding a longer-term perspective to the above;
- ensuring non-discriminatory adaptation policies.

Considerable "expert judgment" or accumulated experiences are available in farming communities who live with climate risks over time. The availability of usable science-based climate prediction information needs to be tailored to farmer needs by matching it with traditional practices and incorporating existing local knowledge.

To facilitate this process science-society integrators who orient climate modelling research to meet farmers' need and vice versa can provide feedback to the climate science community on the application value of their research. These integrators need to be part of the initial institutional set-up, with specific responsibilities and terms of reference.

An important aspect in the above is to analyse the dimensions of climate change impacts and adaptation patterns on gender and the implementation of human rights including issues such as: how does climate change aggravate existing problems in the areas of food and water security; does this affect women's and men's lives differently; what are women's needs for improving their access to education, labour markets, and participation in decision-making. Issues include, for example, effects of irrigation water scarcity on women in different regions and the economic and health effects of climate-related food insecurity.

FAO advocates strengthening the capacity of rural institutions to use appropriate tools and strategies such as:

- participatory identification of current vulnerabilities and risk reduction measures, and implementation of prioritized community-based disaster risk reduction activities (e.g. national and sub-national early warning systems);
- strengthening capacity of communities to manage their resources (e.g. savings, credit schemes, agricultural inputs, agricultural production, land use, etc.);
- enhancing the use of technological options to manage climate variability associated risks (e.g. disaster information management system);
- raising awareness of farmers and building capacities of local institutions in support of national disaster management policy;
- advocacy by policy makers on natural disaster risk management and climate change;
- introducing the additional layer of accountability provided by the rights-based approach, and
- partnerships between regional and national research institutions, extension systems and farmers/fishermen.

Legislation and policy

A regulatory framework needs to be in place to support and implement adaptation policies and programmes, across the spectrum of renewable natural resources which come within the scope of FAO's mandate. This will be founded on the Voluntary Guidelines on the Right to Food and the fundamental human rights principles of participation, non-discrimination and accountability, taking the perspectives of groups most likely to be affected by adaptation. The right to food may serve as a tool to mitigate potential trade-offs between different adaptation requirements (e.g. climate coping strategies and food security needs).

Furthermore, FAOLEX is an online source of specialized information and data, accessible and searchable through climate change-relevant keywords. Taking FAOLEX as a point of departure, more focused research is possible into legal issues raised by adaptation and into legislative and regulatory responses to the adaptation challenge. The outputs include guidance on the nature, scope and content of an adequate legal response to the adaptation challenge. Capacity-building and technical assistance work in the legislative domain would complement this research effort and be underpinned by its results.

FAO provides advice to countries with regards to their agriculture, forestry, fisheries and rural development policies, based on exchange of experiences and cooperation within and between countries. Adaptation strategies, planning and management could be integrated within this function.

Capacity-building and technology transfer

Technical and organizational training has been traditionally FAO's vocation in all areas falling under its mandate, from improving skills at the rural community level (to sustain livelihoods), through the national level (to improve policies and incentive measures) to the international decision-making sphere (to assist developing countries negotiating their needs).

One longstanding example is the FAO Farmers-Field-School experience that has been recently used as means to transfer knowledge on adaptation in agriculture for farmers: simplified soil carbon sequestration models have been developed that permit to evaluate win-win situations for carbon trading while maintaining agricultural production at acceptable levels.

Knowledge management

FAO has, since its inception, been in the forefront of gathering land resource information through its member countries and its field project execution in support to land resource planning and management. Thematic knowledge networks, best practices and numerous databases have been developed and stored in land information systems and made available via the internet or CD-Rom are among the tools available to address climate change adaptation.

These include, at a global level, the digital soil map of the world and derived soil properties (FAO/UNESCO), the global agro-ecological zones study (FAO/IIASA), regular Forest Resource Assessments, annual production, consumption and trade of forest products, land cover information such as AfriCover and its expansion under the Global Land Cover Network, FAOSTAT, and Agro-Maps on national and subnational crop/livestock production and land use statistics. Global agrometeorological data are made available via internet and CD-Rom, as well as software for climate analysis and impact assessment on agriculture.

At regional level, FAO can draw on networks dealing with problems such as salt affected soils to provide online the status of land resources in selected countries through its Land Resources gateway. Other data systems include Soil and Terrain Database (SOTER), global irrigation statistics (AQUASTAT) and information generated by the Land Degradation Assessment in Drylands (LADA) project.