FAO knowledge product on water
Methods of vulnerability assessment and adaptation planning and practices

1. FAO Report on “Climate change, water and food security” – Assessment and policy support

Climate change will significantly impact agriculture by increasing water demand, limiting crop productivity and by reducing water availability in areas where irrigation is most needed or has comparative advantage. In response to global warming, the hydrological cycle is expected to accelerate as rising temperatures increase the rate of evaporation from land and sea. Thus rainfall is predicted to rise in the tropics and higher latitudes, but decrease in the already dry semi-arid to arid mid-latitudes and in the interior of large continents. Water-scarce areas of the world will generally become drier and hotter. Both rainfall and temperatures are predicted to become more variable, with a consequent higher incidence of droughts and floods, sometimes in the same place. Substantial reductions (up to -40 percent) in regional runoff have been modelled in southeastern Australia and in other areas where annual potential evapotranspiration exceeds rainfall. Relatively small reductions in rainfall will translate into much larger reductions in runoff, for example, a 5 percent fall precipitation in Morocco will result in a 25 percent reduction in runoff. In glacier-fed river systems, the timing of flows will change, although mean annual runoff may be less affected.

Climate change will impact the extent and productivity of both irrigated and rainfed agriculture across the globe. Reductions in river runoff and aquifer recharge are expected in the Mediterranean basin and in the semi-arid areas of the Americas, Australia and southern Africa, affecting water availability in regions that are already water-stressed. In Asia, the large contiguous areas of irrigated land that rely on snowmelt and high mountain glaciers for water will be affected by changes in runoff patterns, while highly populated deltas are at risk from a combination of reduced inflows, increased salinity and rising sea levels. Everywhere, rising temperatures will translate into increased crop water demand. Estimates of incremental water requirement to meet future demand for agricultural production under climate change vary from 40 to 100 percent of the extra water needed without global warming.

The main agricultural water management systems that climate change is expected to impact are depicted in Fig.1. It is projected that Africa and South Asia are the most vulnerable to climate change and expected to cause food insecurity. The poor existing levels of food security in Africa and the low level of economic development conspire with high levels of climatic risk, whereas large populations, heavily exploited natural resources and climate risk threaten South Asia’s poor.

Both the livelihoods of rural communities and the food security of a predominantly urban population are therefore at risk from water-related impacts linked primarily to climate variability. The rural poor, who are the most vulnerable, are likely to be
disproportionately affected. Various adaptation measures that deal with climate variability and build upon improved land and water management practices have the potential to create resilience to climate change and to enhance water security. They imply a good understanding of the impact of climate change on available water resources and on agricultural systems, and a set of policy choices, and investments and managerial changes to address them.

![Main agricultural water management systems that climate change is expected to impact](image)

Fig.1 Main agricultural water management systems that climate change is expected to impact

The FAO report on “Climate Change, Water and Food Security” summarizes current knowledge of the anticipated impacts of climate change on water availability for agriculture. The implications for local and national food security are examined; and the methods and approaches to assess climate change impacts on water and agriculture are discussed. The report emphasizes the need for a closer alignment between water and agricultural policies and makes the case for immediate implementation of ‘no-regrets’ strategies which have both positive development outcomes and make agricultural systems resilient to future impacts. It is hoped that policy makers and planners will find in this report the elements of information and guidance that are needed to assess and respond to the challenge that climate change is expected to impose on agricultural water management and food security.

**Further Details:** Jacob Burke ([burke.jacob@fao.org](mailto:burke.jacob@fao.org)) and Jean-Marc Faurès ([JeanMarc.Faures@fao.org](mailto:JeanMarc.Faures@fao.org)), FAO Land and Water Division, FAO

**2. FAO-MOSAICC (MOdelling System for Agriculture Impacts of Climate Change)**
The FAO Climate Impact Team within the Climate, Energy and Tenure Division (NRC) is developing an integrated toolbox called FAO-MOSAICC (for MOdelling System for Agricultural Impacts of Climate Change) to assess climate change impacts on agriculture at national levels in a view of decision-making support. The MOSAICC is an integrated system of models designed to carry out each step of the impact assessment from climate scenarios downscaling to economic impact analysis at national level. The four main components of the system are 1) tools for climate data downscaling and processing, 2) hydrological model for estimating water resources, 3) two crop models to simulate future crop yields and 4) CGE (Computable General Equilibrium) model to assess the effect of changing yields on national economies. The system is designed to be deployed at national level among different institutions with relevant competences. A multidisciplinary working group is constituted to manage the system and lead impact assessment projects. Trainings are provided to support the utilization and the maintenance of the system. The modelling system also comprises documentation on methods and tools, as well as user manuals and sample data.

The hydrological model integrated in MOSAICC is an enhanced version of STREAM model, developed at the Free University of Amsterdam. STREAM is a spatially distributed precipitation-runoff model aimed at simulating flow accumulation and discharge rate in large water catchments areas. In the framework of this project, several major improvements have been made to the original model: major dams can be now included in the simulations, an automatic calibration module has been developed, the algorithm has been optimized to reduce processing time and the model can run on both Windows and Linux platforms.

Within MOSAICC, STREAM has been integrated to model the hydrology of river basins under climate change scenarios in order to derive water resources for agriculture and in particularly irrigation at basin or (sub-) national levels. STREAM runs on historical and projected climate data, prepared using the climate processing tools such as the statistical downscaling method and the interpolation tool. The results of stream can be used in the Computable General Equilibrium to constrain the production of irrigated crops.

The hydrological model can have other applications for climate change impact studies in the agricultural sector. At the scale of a watershed, STREAM can be used to estimate the availability of water for irrigation schemes under climate change scenarios. At the scale of a country, the model can be used to evaluate the total actual renewable water resources (TARWR). Using current climate data, the model could also be used for river discharge monitoring.

The MOSAICC suite of models will be tested in Morocco in 2011 based on FAO-World Bank study on “Impact of climate change agriculture in Morocco” (http://www.fao.org/nr/climpag/pub/FAO_WorldBank_Study_CC_Morocco_2008.pdf). Further Details: Michele Bernardi (Michele.Bernardi@fao.org) and Francois Delobel (Francois.Delobel@fao.org), Climate, Energy and Tenure Division, FAO, Rome.
3. Groundwater Management in India – Adaptive Action on the ground

The Andhra Pradesh Farmer Managed Groundwater Systems Project (APFaMGS) was implemented in the state of Andhra Pradesh in India with technical support from Food and Agriculture Organisation (FAO) of the United Nations. FAO supported this novel project for improved water use efficiency by empowering farmers in monitoring and managing groundwater resources in their hydrological unit.

The Andhra Pradesh Farmer Managed Groundwater Systems (APFaMGS) initiative included analysis of a 900 farmer sample survey; remote sensing of cropping patterns, and pumping behavior of farmers. Assessments based on these diverse data indicate that more than 500 communities in different agroeconomic settings across the project area have begun to bring their water use in line with groundwater availability, which includes reduction in groundwater abstractions in the years when the recharge is low.

Picture title: A trained women farmer showing fellow farmers the method of measuring static water level in a monitoring well
The APFaMGS experience is a field evidence of viability of community-led groundwater management in certain hydrogeologic conditions in India. The salient findings and key lessons of APFaMGS assessments are:

- The sustainable management of groundwater is feasible only if users understand its occurrence, cycle, and limited availability. Unlike the standard practice whereby the targeted community is a mostly passive recipient of technical information on the status of their local resources, the APFaMGS approach engages the farmers in data collection and analysis, thereby building their understanding of the dynamics and status of groundwater in the local aquifers. An estimate of the aquifer budget gives the farmers an important element of information on the risk to their cropping systems, and provides this information in time before the planting of post monsoon crops (rabi crops in Adhra Pradesh, India.

![A groundwater manager presenting groundwater recharge, draft and balance at the annual gathering of groundwater users](image)

- Approximately 6 533 farmers were trained to collect data that are important for understanding the local aquifers. Farmers donate the land for installation of rain gauges, and at each of the 191 rain gauge stations a farmer records. At more than 2,119 observation wells, farmers carry out daily and fortnightly measurements of groundwater levels, and also conduct fortnightly measurements of pump well discharges in 1022 wells. In all, more than 4 644 farmers, men and women, are voluntarily collecting data in 634 habitations across the project area. The data are
maintained in registers kept at the groundwater management committee offices and are also entered on village display boards.

- Complement to participatory hydrological monitoring, crop water budgeting was introduced, whereby the quantity of water required for the proposed post-monsoon (winter) planting is assessed at the aquifer level, and compared with the amount of groundwater actually available. The groundwater budget, arrived at through broad-based collective action in the aquifer community and disseminated similarly through the community, crystallizes in one number the state of the aquifer and the gap between what is available and what is cumulatively desired.

- The main vehicle for education and capacity building in APFaMGS is the farmer water school, a meeting of around 25–30 farmers once every 15 days, with the learning process grounded in the farmers’ own fields. Following the hydrological cycle centered around the monsoons, the farmer water school runs from June to May. In addition to education on groundwater (participatory hydrological monitoring and crop water budgeting), the curriculum includes exposure to techniques and interventions that can enable farmers to get higher returns from agriculture by switching crops, improving yields, and reducing input costs. The farmers accordingly learn about vermicomposting, green manuring, biofertilizers, mulching, intercropping, improved irrigation methods, and the system of rice intensification for paddy. The farmer water school employs multiple learning cycles, and trained farmers learn further by becoming farmer facilitators and instructors for the school in their respective habitations. The farmer water schools have turned out 19,974 graduates who are equipped with skills to train and guide other farmers.

- APFaMGS has succeeded in establishing strong community processes by formally engaging all groundwater users and using traditional and well-established vehicles of community mobilization. The project is rooted in a strong participatory, capacity-building, and gender equity approach. It is significant that 2,084 women farmer volunteers are engaged in data collection, and 837 of the 2,064 farmer facilitators are women.

- APFaMGS engages the farmers around a crucial element of information that is vital for planning the agricultural operations. In areas with limited-storage hard-rock aquifers, having an estimate of the water availability in the aquifer at the time of dry season planting gives the farmers extremely valuable information on the risk to their crops. The history of farmers’ familiarity with borewells spans barely three decades, and participation in the project promises to the people a reliable understanding of this critical resource. This is a powerful hook for enlivening the practice of groundwater management, as is borne out by the results of the farmer survey, which showed that for a large majority of surveyed APFaMGS farmers, factors pertaining to profitability of crops, availability of groundwater, and knowledge of improved agricultural techniques are the primary determinants of project participation.
It is evident that the reductions in groundwater draft in APFaMGS are not coming from an altruistic collective action, but from the individual risk management decisions of thousands of farmers. This makes the APFaMGS model robust and replicable, since no authoritative leadership is required for enforcement of compacts. With emphasis on improved farming and irrigation techniques, and with the use of innovative and radically effective communications on groundwater status, APFaMGS primarily taps the farmers’ incentive to save their dry season crops and to improve crop yields. Instead of coaxing farmers to adopt water-saving measures with the objective of reducing groundwater use, APFAMGS encourages farmers to select cropping patterns and irrigation interventions that minimize risk and maximize return.

Further Details: Mr Gavin Lindsey Wall (Gavin Wall@fao.org), FAO Representation in India, New Delhi.

4. Strategic Pilot on Adaptation to Climate Change (SPACC) - Awareness and capacity building

The strategic Pilot on Adaptation to Climate Change (SPACC) project being implemented in India is funded by Global Environment Facility (GEF). The goal of the initiative is “Reversing environmental degradation and rural poverty through adaptation to climate change in drought stricken areas in Southern India”. The Food and Agriculture Organization of the United Nations (FAO) is the GEF Agency for implementation of the project, while Bharathi Integrated Rural Development Agency (BIRDS) is the Executing Partner. The development objective of the project is to increase the knowledge and capacity of communities to adapt to climate variability and change in seven drought-prone districts of Andhra Pradesh. The project helps to build the skills and tools for communities to integrate climate adaptation into sustainable land and water management (SLWM) practices and their decision making.

The project has been structured into three main components: (i) information tools for decision making and local institutional capacity development; (ii) pilots on adaptation measures integrated into SLMW practices; and (iii) platform for scaling up climate change adaptation measures suitable for drought prone areas. Project outcomes will include: (i) farmers and community based organizations make informed decision on land and water management based on scientific and local knowledge taking into account impacts of climate variability and change; (ii) farmers have acquired skills in managing climate risks through participation in climate change schools; (iii) adequate adaptation technologies and practices piloted and best practices identified; (iv) package of best adaptation tools and practices documented and disseminated to support scaling-up.

Further details: Mr Gavin Lindsey Wall (Gavin Wall@fao.org), FAO Representation in India, New Delhi.