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An action framework for agriculture and food security

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About this report

The report aims to provide a conceptual framework to address food security under conditions of water scarcity in agriculture. It has been prepared by a team of FAO staff and consultants in the framework of the project "Coping with water scarcity – the role of agriculture", and has been discussed at an Expert Consultation meeting organized in FAO, Rome, during the period 14–16 December 2009 on the same subject. It was subsequently edited and revised, taking account of discussions in the Expert Consultation and materials presented to the meeting.

The purpose of the Expert Consultation was to assist FAO to better design its water scarcity programme. In particular, the experts were requested to provide recommendations on the range of technical and policy options and associated principles that FAO should promote as part of an agricultural response to water scarcity in member countries.

The document offers views on the conceptual framework on which FAO's water scarcity programme should be based, proposes a set of definitions associated with the concept of water scarcity, and indicates the main principles on which FAO should base its action in support to its member countries. At the meeting, experts were requested to review the draft document and provide feedback and recommendations for its finalization. Issues that were addressed in discussions included:

- Water scarcity: agreement on key definitions.
- The conceptualization of water scarcity in ways that are meaningful for policy development and decision-making.
- The quantification of water scarcity.
- Policy and technical response options available to ensure food security in conditions of water scarcity.
- Criteria and principles that should be used to establish priorities for action in response to water scarcity in agriculture and ensure effective and efficient water scarcity coping strategies.

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FAO recently embarked on a long-term partnership with the Government of Italy, which has agreed to fund a modular programme on the theme "Coping with water scarcity – the role of agriculture". The development of a conceptual framework to address food security under conditions of water scarcity is part of this programme.

This report was prepared by a team from the Land and Water Division of FAO with assistance from several experts. Pasquale Steduto, as leader of the Italian Trust Fund "Coping with Water Scarcity", lead the initiative and coordinated the preparation of the report. The report was written by Jean-Marc Faurès, Jippe Hoogeveen and Jim Winpenny, in collaboration with Pasquale Steduto and Jacob Burke. Charles Batchelor prepared a background document focusing on water accounting and water audit, which was extensively used in the preparation of this report.

Participants in the Expert Consultation, who contributed to reviewing and validating the report, were: Mary Harwood (Australia), François Molle (France), Humberto Peña Torrealba (Chile), Mei Xurong and Gan Hong (China), Walter Huppert and Elisabeth Van Den Akker (Germany), Nicola Lamaddalena and Stefano Burchi (Italy), Wim Bastiaanssen (The Netherlands), Amadou Allahoury Diallo (Niger), Rivka Kfir (South Africa), Consuelo Varela-Ortega and Elias Fereres-Castiel (Spain), Netij Ben Mechlia (Tunisia), Chris Perry and Charles Batchelor (United Kingdom), Mark Svendsen and Donald A. Wilhite (United States of America), Chandra A. Madramootoo (International Commission on Irrigation and Drainage, ICID), Rudolph Cleveringa (International Fund for Agricultural Development, IFAD) and David Molden (International Water Management Institute, IWMI).

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Executive summary

Simply stated, water scarcity occurs when demand for freshwater exceeds supply in a specified domain.

Water scarcity = an excess of water demand over available supply

This condition arises as consequence of a high rate of aggregate demand from all water-using sectors compared with available supply, under the prevailing institutional arrangements and infrastructural conditions. It is manifested by partial or no satisfaction of expressed demand, economic competition for water quantity or quality, disputes between users, irreversible depletion of groundwater, and negative impacts on the environment.

Water scarcity is both a relative and dynamic concept, and can occur at any level of supply or demand, but it is also a social construct: its causes are all related to human interference with the water cycle. It varies over time as a result of natural hydrological variability, but varies even more so as a function of prevailing economic policy, planning and management approaches. Scarcity can be expected to intensify with most forms of economic development, but, if correctly identified, many of its causes can be predicted, avoided or mitigated.

The three main dimensions that characterize water scarcity are: a physical lack of water availability to satisfy demand; the level of infrastructure development that controls storage, distribution and access; and the institutional capacity to provide the necessary water services.

DRIVING FORCES BEHIND WATER SCARCITY AND THE ROLE OF AGRICULTURE

Unconstrained water use has grown at global level to a rate more than twice the rate of population increase in the 20th century, to the point where reliable water services can no longer be delivered in many regions. Demographic pressures, the rate of economic development, urbanization and pollution are all putting unprecedented pressure on a renewable but finite resource, particularly in semi-arid and arid regions.

Of all economic sectors, agriculture is the sector where water scarcity has the greatest relevance. Currently, agriculture accounts for 70 percent of global freshwater withdrawals, and more than 90 percent of its consumptive use. Under the joint pressure of population growth and changes in dietary habits, food consumption is increasing in most regions of the world. It is expected that by 2050 an additional billion tonne of cereals and 200 million tonnes of meat will need to be produced annually to satisfy growing food demand.

But to what extent is this steady growth in water demand 'negotiable'? There is a general agreement that water to satisfy basic needs is not – human health requires a minimum level of access to good quality water. Similarly, with the right to food being increasingly recognized, since water as a critical factor in food production, a minimum quantum for subsistence production could be considered non-negotiable. However, domestic water withdrawal represents globally only about 10 percent of all water uses, but has a very low consumption rate – most domestic use is returned to the environment with little evaporative loss even if quality is degraded. By contrast, agricultural use has direct downstream (or down-gradient) consequences since the production of biomass requires huge quantities of water to be transpired. If the water is sourced for irrigation and transpired, this represents a local hydrological loss that reduces availability in the downstream domain. The purpose of this report is to assess the options and scope for adjustment in agricultural water use as a response to water scarcity.

MEASURING WATER SCARCITY: THE HYDROLOGICAL CYCLE

A correct understanding of water scarcity hinges on an understanding of the laws of physics that govern hydrological processes, and the means to allocate and measure use.

1. **Water is a renewable resource**, but patterns vary in space and time.
2. **Water exists in a continuous state flux** in all its phases (solid, liquid, gas) that is driven by energy gradients applying to the physical processes of evaporation, transpiration, condensation, precipitation, infiltration, runoff, subsurface flow, freezing and melting. It is these flows and fluxes, rather than stocks, that should be the focus of planning and management.
3. **A water balance is governed by conservation of mass**, and the rate of water entering a specified domain is equal to the rate of water leaving the same domain with any differences resulting in changes in storage. The linkages between surface water, groundwater, soil moisture content and the process of evapotranspiration are of critical importance, and still inadequately reflected in many water management plans.
4. **All land areas in a river basin are interlinked through water.** Therefore actions in one part of a hydrological system will have impacts on other parts of the system, and for most intents and purposes water is best managed on the basis of hydrographic units.
5. As water use intensifies, **the diluting and cleaning functions of aquatic ecosystems are stretched to their limit, resulting in accumulation of pollutants.**
6. Any desire to maintain a set of **aquatic ecosystem goods and services implies a limitation** in the availability of water for human use in a given domain.
7. **Water accounting,** i.e. the systematic organization and presentation of information relating to the physical volumes and quality of flows (from source to sink) of water in the environment as well as the economic aspects of water supply and use, should therefore be the starting point of any strategy for coping with water scarcity. Water accounting involves a comprehensive view of the water resources and supply systems and how they are related to societal demands and actual use.
8. **Water audits** go one step further, and place water supply and demand in the broader context of governance, institutions, finance, accessibility and uncertainty These are all elements needed to design effective water scarcity coping strategies.

POLICY AND MANAGEMENT OPTIONS

Options to cope with water scarcity can be divided between *supply enhancement* and *demand management*. Supply enhancement includes increased access to conventional water resources, re-use of drainage water and wastewater, inter-basin transfers, desalination, and pollution control. Demand management is defined as a set of actions controlling water demand, either by raising the overall economic efficiency of its use as a natural resource, or by operating intra- and intersectoral re-allocation of water resources. Options to cope with water scarcity in agriculture can be seen as a continuum from the source of water to the end user (the farmer), and beyond, to the consumer of agricultural goods. These options are discussed below. However, it should be stressed that at the level of agricultural water demand commonly observed in food producing countries, supply enhancement and demand management measures are often linked through the hydrological cycle.

SUPPLY ENHANCEMENT

During the twentieth century, large multipurpose dams have served the needs of agriculture, energy and growing cities, and helped protect populations from flood hazards. While potential for further dam development still exists in some regions, most of the suitable dam sites are already in use, and the development of new dams is increasingly questioned in terms of economic, social and environmental considerations.

On-farm water conservation, particularly the adoption of agricultural practices that reduce runoff, to increase the infiltration and storage of water in the soil in rainfed agriculture, is the most relevant local supply enhancement option that farmers have to increase production. On a slightly larger scale, small, decentralized water harvesting and storage systems contribute to increasing water availability and agricultural production at the household and community levels. However, large programmes of small-scale water harvesting, like the watershed management programmes developed in Andhra Pradesh and other parts of India, have shown significant impacts on the catchment's hydrology and downstream water availability.

Groundwater exploitation has grown exponentially in scale and intensity over recent decades. Groundwater's capacity to provide flexible, on-demand water in support of irrigation has been seen as a major advantage by farmers. While intensification of groundwater use has contributed to improved livelihoods of millions of rural people, it has also resulted in long-term aquifer depletion, groundwater pollution and saline intrusion into important coastal aquifers.

The adoption of re-cycling of drainage water and wastewater use in agriculture tends to be positively correlated with water scarcity. Re-use of drainage water is a reality in most large irrigation schemes, in particular in the large rice-based systems of Asia. Of lesser global significance, but locally important, is the re-use of urban wastewater (it is estimated that world-wide some 20 million hectares of agricultural land is irrigated with wastewater). Efforts are needed to better assess re-use and its potential, and promote safe recycling of wastewater in agriculture, in particular in water-scarce areas.

DEMAND MANAGEMENT IN AGRICULTURE

In broad terms, agriculture has three options for managing overall water demand *within* the water domain:

- reduce water losses;
- increase water productivity; and
- water re-allocation.

The first most commonly perceived option is that of increasing the efficiency of water use by reducing water losses in the process of production. Technically, 'water use efficiency' is a dimensionless ratio that can be calculated at any scale, from irrigation system to the point of consumption in the field. It is generally applied to any management that reduces the non-beneficial use of water (i.e. reducing leakage or evaporative losses in water conveyance and application). The second option is increasing crop productivity with respect to water. This involves producing more crop or value per volume of water applied. The third option is to re-allocate water toward higher value uses through intersectoral transfers (transfers to municipal supply, for instance) or intrasectoral transfers by limiting the irrigated harvested area under a particular crop to reduce evapotranspiration or diverting water towards higher value crops.

Clearly there is scope for managing the demand for water in agriculture in time and in space. But excessive emphasis is often placed on the first option, with efforts aimed at reducing water 'losses' within irrigation distribution systems. Two factors limit the scope for and impact of water loss reduction. First, only part of the water 'lost', while withdrawn for *beneficial use* (defined as water that is diverted for purposes that have clear and tangible benefits, such as for household purposes, irrigation, industrial processing and cooling), can be recovered effectively at a reasonable cost. Second, part of the water 'lost' between the source and final user returns to the hydrologic system, either through percolation into the aquifers or as return flow into the river systems. The share of water lost through *non-beneficial consumption*, either through evaporation or through drainage into low quality water bodies or to the sea, varies according to local conditions. A clear understanding of the real potential for reducing water losses is needed to avoid designing costly and ineffective demand management strategies.

In most cases, the single most important avenue for managing water demand in agriculture is through increasing agricultural productivity with respect to water. Increase in crop yields (production per unit of land) is the most important source of crop water productivity increase. Yield increases are made possible through a combination of improved water control, improved land management and agronomic practices. This includes the choice of genetic material, and improved soil fertility management and plant protection. It is important to note that plant breeding and biotechnology can help by increasing the harvestable parts of the biomass, reducing biomass losses through increased resistance to pests and diseases, reducing soil evaporation through vigorous early growth for fast ground cover, and reduced susceptibility to drought. Therefore managing overall demand through a focus on water productivity rather than concentrating on the technical efficiency of water use alone is an important consideration.

If productivity is considered in terms of added value and not production, re-allocating supply from lower value to higher value crops is an obvious choice for farmers seeking to improve income levels. For this to happen, changes are required in both the management and technology associated with irrigation to provide farmers with a much higher level of control of water supply. In addition, shifts to higher value crops also require access to inputs, including seeds, fertilizers and credit, as well as technology and know-how, and reasonable conditions to operate in much more competitive market conditions. However, in practice, very few farmers are able to make this choice since the market for higher value crops is limited compared with the market for staples. Beyond productivity concerns, agricultural water demand can simply be limited or capped. This is a commonly applied measure where the volume of evapotranspiration used in the production of a unit of agricultural output is limited by reducing the area under irrigation.

Understanding the roles, attitudes and strategies of various stakeholders, including relevant institutions, is a key aspect of demand management strategies. Ultimately, it is at the farmer level that most water will be consumed. Their behaviour and their capacity to adapt will be driven by a carefully selected set of incentives that include both structural and institutional changes, improved reliability and increased flexibility of water supply. Farmers' strategies will be driven by water saving only when water availability becomes their main limiting factor. Policies based on systems of water tariffs aiming to reduce agricultural water demand have proved successful in some cases, but require very constraining conditions and are often difficult to enforce. Approaches based on water quotas and water use (or withdrawal) rights have, in most cases, a higher probability of success.

ACTIONS BEYOND THE WATER DOMAIN

The agricultural response to water scarcity lies, at least partially, *outside* of the water domain. To this extent it is possible to recognize other measures that can help manage water demand:

- reduction of losses in the post-harvest value chain;
- reduction in demand for irrigated production through substitution by imports of rainfed staples; and
- reduction of per capita agricultural water demand.

Reduction of losses in the post-harvest value chain

Beyond agricultural production, substantial savings of water can also be obtained by addressing the issues of waste in the food chain, diets, and the role of agricultural trade. Losses and wastages occur all along the food chain, and have been estimated at up to 50 percent of production in developed countries. While part of these losses may be irretrievable, it makes sense to carefully identify the major sources of losses and assess the scope for their reduction.

Reduction of demand for irrigated production through substitution

Options include enhanced production in rainfed agriculture, and imports of food product through international trade.

There are several reasons to consider investing in rainfed agriculture as part of a water scarcity coping strategy, but the opportunities vary greatly from one place to another. In places where climate is conducive to rainfed agriculture, there is high potential to improve productivity where yields are still low, as is the case in many regions of sub-Saharan Africa. Here, a combination of good agricultural practices, upward and downward linkages (access to finance, inputs and markets), and weather insurance schemes can improve agricultural productivity with little impact on water resources.

The issue of trade is particularly relevant in countries where water scarcity limits the capacity of agriculture to satisfy all the needs for other agricultural commodities. The concept of 'virtual water' was developed in the 1990s to indicate that in a reasonably safe and interdependent world, gains in water productivity can be achieved by growing crops in places where climate enables high water productivity at lower cost and trading them to places with lower water productivity. Although rarely expressed in water terms, virtual water trade is already a reality for many water-scarce countries, and is expected to increase in the future.

Reduction of per capita water demand

Finally, increasing consumption of meat and, to a lesser extent, also dairy products translates into increased water consumption, as their production requires large volumes of water. The extent to which societies are willing to modify their diets as part of a larger effort to reduce their environmental *footprint* reaches far beyond water scarcity concerns. Yet, it has implications in terms of national food security and associated water-scarcity coping strategies.

ASSESSING AND COMBINING FOOD SUPPLY OPTIONS THROUGH A COST CURVE APPROACH

In order to guide decision-makers' choices among the range of available options, these options need to be assessed in terms of their effectiveness, cost, and technical, social and environmental feasibility. The political dimension of their choice will also be carefully scrutinized.

The "food supply cost curve" can help to provide insight in the way a country can bridge its food supply gaps in a cost-effective way. The curve ranks food supply options in terms of their cost and provides an easy way of assessing cost-effectiveness in the achievement of food supply objectives. When used at national level, each country will have its own curve, based on current level of intensification, availability of land and water, and level of losses in the food chain. The cost curve provides a simple but powerful method for identifying and ranking options for food production in conditions of water scarcity. Much of the complexity lies in the establishment of the individual cost curves for the different options, which requires a good understanding of the agronomic, hydrological and socio-economic conditions under which improvements will take place.

PRINCIPLES FOR ACTION

The selection of the right range of options will depend on local conditions, and it is unlikely that a single set of options can be designated as the 'optimal' solution. Nor is a particular option to be seen as desirable in all contexts. The choice of 'no action' is not an option under scarcity; it would translate into environmental degradation, sub-optimal use of scarce resources, inequity in access to these resources, and overall negative impacts on the economy and societal well-being. Therefore, rather than attempting to prescribe solutions to water scarcity, it is suggested that policy options and related strategies should be based on a set of generic principles that are valid across socio-economic settings. Six basic principles have been developed, and are presented below.

Knowledge: base strategies on a clear understanding of the causes and effects of water scarcity

Strategies should be based on the best available evidence, and not on hearsay or intuition, and detailed accounting of water supply and demand should be carried out from the onset. The inter-relationship between surface water and groundwater, between upstream and downstream catchments, between quality and volumes, and the importance of water recycling within river basins all have implications in terms of effectiveness of proposed actions. Well intentioned but ill-informed strategies for coping with water scarcity can have significant perverse impacts on the way water is distributed within the river basin, without achieving expected savings.

Impact: assess the full range of benefits and costs and use systematic and comprehensive decision criteria

It might seem obvious that cost-effectiveness should be considered along with equity and collective values when choosing between options. However, past experience shows that cost-benefit analyses have often overlooked or under-estimated the potential negative impact of water development interventions on people or the environment, while overestimating other benefits. In particular, supply enhancement options have often been selected beyond any reasonable analysis, leading to an over-equipped subsector and 'artificial' or 'constructed' water scarcity. Calculating cost-effectiveness needs to encompass several dimensions. It varies with time, as a result of change in knowledge of social and environmental processes and values, as well as relative changes in added value of different water use sectors. Only a careful analysis of the cost-effectiveness of each option allows for better identifying the most promising sources of gains in water demand management.

Realistic financing mechanisms are required for water initiatives to meet the full costs of water scarcity interventions and programmes. In many cases, this involves putting less emphasis on capital costs of construction and engineering and more emphasis on capacity building, stakeholder-based planning, operation and maintenance, and other long-term institutional support costs.

Capacity: ensure that the right level of water governance and institutional capacity is in place

Disputes between users increase with water scarcity, as does the likelihood of negative impacts on vulnerable social groups and on the environment. As demand management takes increasing importance, much stronger institutions are needed to guarantee equitable distribution of benefits and maintenance of environmental services. Better definition of roles and responsibilities, empowering of local institutions, review of policies, adaptation of laws, and the use of incentive mechanisms become increasingly important as water scarcity progressively builds up. Efforts for a new water management culture are needed, including public awareness campaigns, educational programmes, capacity building and training at all levels, including water users groups. Institutions also need to adapt to approaches where public, private and other operators can carry out management tasks jointly.

Context-specificity: adapt response to local conditions

The response of a country to water scarcity depends on a number of conditions, including local agro-climatic conditions, levels of water scarcity, the role agriculture plays in national economies, and societal values. It will also depend on external factors, including the global trade and cooperation environment, and the prospects for climate change. Further, in view of the rapid changes in the geo-political, societal and environmental fields, what could be considered well adapted today may no longer be so tomorrow, and strategies must be expected to change.

Coherence: ensure policy alignment between water, agriculture and food security

Decisions outside the water domain, such as those determining energy prices, trade agreements, agricultural subsidies and poverty reduction strategies, can all have a major impact on water supply and demand, and therefore on water scarcity. Alignment of the many policies, legislation and fiscal measures that influence water management, service delivery and level of demand is crucial. Agriculture and food security policies are strongly connected to water policies and that degree of connection needs to be appreciated to ensure overall coherence.

Preparedness: anticipate change through robust decision-making and adaptive management

Planning and management systems need to be flexible, adaptive and based on continuous social and institutional learning. Adaptive management recognizes the high level of uncertainty associated with future situations, and places emphasis on flexible planning that allows regular upgrading of plans and activities. Such a level of responsiveness is only possible if information and knowledge are updated, and if monitoring and information management systems continually provide decision-makers with reliable information. There is always the risk that coping strategies will be derailed by external factors, such as climate change, global financial and economic shocks, and shifting international cooperation agreements. Scenario building, as an integral part of strategy development, is one means of identifying and mitigating these risks, and developing robust responses to uncertainty of future situations.

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