The research context:

Water Supply and Demand, 1995 to 2025

David Seckler and Upali Amarasinghe

Prophecy is a good line of business, but it is full of risks.

Mark Twain, *Following the Equator*

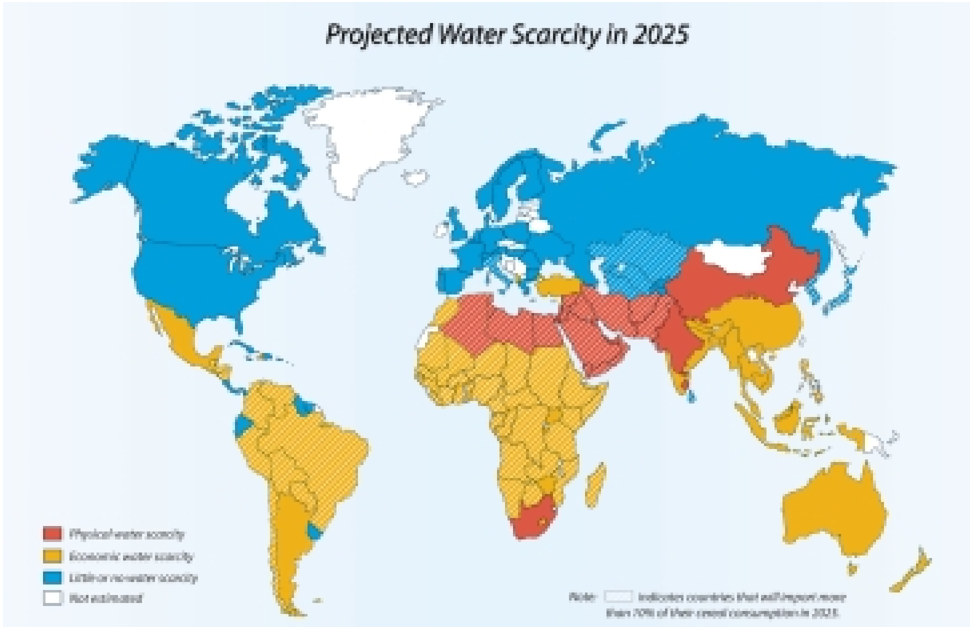
Water scarcity is determined by a variety of factors. In this paper we summarize some key issues for water management that will influence the degree of scarcity that different countries and regions will face in the coming 25 years. These questions are covered in detail in the IWMI monograph that was published as the Institute's contribution to the World Water Vision's component on Water for Food and Rural Development. The following is extracted from the monograph, which can be read at www.iwmi.org *(IWMI's contribution to the World Water Vision).*

Water scarcity and major issues

Over the past four years, the International Water Management Institute (IWMI) has been developing scenarios of water supply and demand for 2025. Since the first report on this subject, the analysis and data have been refined through the development of PODIUM, the *Policy Interactive Dialogue Model*. The PODIUM is designed to simulate alternative scenarios of the future. The results presented here are based on what we call the *basic scenario.*

The basic scenario is rather optimistic. Within an overall framework of social, technical and economic feasibility, it relies on substantial investments and changes in policies, institutions and management systems intended to achieve four major objectives:

- Achieve an adequate level of per capita food consumption, partly through increased irrigation, to substantially reduce malnutrition and the most extreme forms of poverty.
- Provide sufficient water to the domestic and industrial sectors to meet basic needs and economic demands for water in 2025.
- Increase food security and rural income in countries where a large percentage of poor people depend on agriculture for their livelihoods through agricultural development and protection from excessive (and often highly subsidized) agricultural imports.



- Introduce and enforce strong policies and programs to increase water quality and support environmental uses of water.

Realizing these objectives requires three major actions in the field of water resources and irrigation management in water-scarce countries:

- Greatly increase the productivity of water resources use.
- After productivity is increased, there generally remains a need for substantial increases in the amount of developed water supplies.
- Water resources must be developed with substantially reduced social and environmental costs than in the past—and people must be willing to pay the increased financial costs this policy necessarily entails.

Water Scarcity

As our water scarcity map shows, we have grouped the forty-five countries into three basic categories of water scarcity.

Group I represents countries that face *physical water scarcity* in 2025. This means that, even with the highest feasible efficiency and productivity of water use, these countries do *not have sufficient water resources* to meet their agricultural, domestic, industrial and environmental needs in 2025. Indeed, many of these countries cannot even meet their present needs. Their only options are to invest in expensive desalinization plants and/or reduce the amount of water used in agriculture, transfer it to the other sectors and import more food.

Group II represents countries that face *economic water scarcity* in 2025. They have sufficient water resources to meet the 2025 needs but they will have to increase water supplies through additional storage, conveyance and regulation systems by 25 percent or more over the 1995 levels to meet their 2025 needs. Many of these countries face severe *financial and development capacity* problems in meeting their water needs.

Group III consists of countries that have no physical water scarcity and that will need to develop less than 25 percent more water supplies to meet their 2025 needs. In most cases, this will not pose a substantial problem for them. In fact, several countries in this group could actually decrease their 2025 water supplies from the 1995 levels because of increased water productivity.

The crosshatched countries on this map are those that are projected to import over 10 percent of their total cereal consumption in 2025. The correlation between this set of countries and Group I is clear.

The data in PODIUM are currently being updated by IWMI, with local partners in several locations, to provide a more accurate perspective of the water/food picture at the country and regional level.

Food Demand and Supply

Food and water are two of the basic human needs—and the latter, in the form of irrigation, is necessary to produce much of the former.

The single most important component of nutrition is calorie consumption per capita. The average for developing countries is around 2,200 kcal/person/day. With reasonably varied diets, if people satisfy their calorie requirements, they will also satisfy their requirements for protein, minerals and vitamins. A major exception to this rule is when a very high percentage of total calories is from rice, which is low in protein. Other exceptions occur with low vegetable consumption, which may cause vitamin and mineral deficiencies. But, on the whole, the principal target is adequate calorie consumption.

But even if the average calorie intake of a country is 2,200 kcal/capita/day, this is not enough to assure that everyone in the country is actually obtaining enough. People with relatively high incomes tend to overconsume calories, mainly from animal products. Therefore, it is necessary to get a substantially higher average calorie consumption in a country to attempt to achieve the minimum for poor people. How much higher this amount must be is largely a function of the distribution of income in a country. As a rule of thumb, something in the range of 2,700–3,200 kcal/day is adequate for most countries to satisfy basic food needs, depending on the distribution of income and other factors in individual countries.

One of the most difficult issues in projecting the demand for food and related agricultural products in 2025 is consumption of animal products—meats, milk, cheese, etc. In most countries, the total calories consumed and the percentage of calories from animal products increase with income, even at high-income levels.

However, because of a variety of causes including urbanization, health concerns and costs, it is likely that there will be:

- A reduction in excessive per capita calorie consumption by higher-income groups.
- A rapid growth in consumption per capita of meat products in developing countries, such as China and India, as incomes increase, combined with a tendency to plateau at lower levels of consumption than in the traditionally meat-consuming countries of the west.
- A shift toward more vegetarian, or "Mediterranean" diets, away from meats.
- A shift from red meats, notably beef, to white meats, notably chicken.

Agricultural Policies, Food Production and Rural Livelihoods

The issues to be discussed in this section may be introduced by the following statement from the World Bank 1997:

Irrigated farmland provides 60 percent of the world's grain production. Of the near doubling of world grain production that took place between 1966 and 1990, irrigated land (working synergistically with high-yielding seed varieties and fertilizer) was responsible for 92 percent of the total. Irrigation is the key to developing high-value cash crops. By helping guarantee consistent production, irrigation spawns agro-industry. Finally, irrigation *creates significant rural employment. The Bank has been a major actor in the expansion of irrigation systems.… More than 46 million farming families have benefited directly from the Bank's irrigation activities.*[1]

While the exact values cited here may be debated,[2] the importance of the central issues is beyond question. These are:

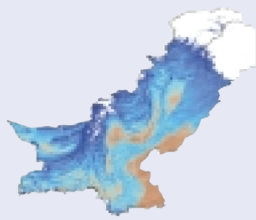
- The near doubling of cereal production, which kept food prices low for poor people in face of rapid population growth.
- The crucial role of irrigation, working synergistically with the other factors, in achieving this result.
- The importance of sustaining and improving rural livelihoods.

As this report also notes, the policies under which these accomplishments were achieved have been substantially changed by the World Bank and other donors—and, to a lesser extent, by developing countries. Since agricultural policies are major variables in projections to 2025, these changes present an especially difficult problem because the policies under which past results were created are changing in a way that is difficult to predict.

Irrigated and Rain-fed Agriculture

A popular idea is to concentrate food production in rain-fed, rather than in irrigated areas. The total cultivated area of the world

How satellite technology improves rural livelihoods



Low cost, high-tech tools help poor countries better manage their water resources

IWMI researchers have developed satellite remote sensing tools that interpret low-cost public domain satellite images to have a more precise view of water resources and water/crop interactions.

Where is the potential for increasing the productivity of water in agriculture? Where can water be reallocated from one area—or use—to another to best fulfill the needs of all users? Where is water in an irrigation system reaching crops or not reaching them? These questions can be answered using IWMI's satellite remote sensing tools.

IWMI is currently working with partners in Sri Lanka, Iran, Turkey and Pakistan to help these countries put in place satellite imaging services to strengthen their water and food security policies. Sri Lanka has been used as a test case. Using these new techniques, its meteorology office will soon be reprocessing satellite images that it receives for weather forecasting, to answer water resources and crop planning questions for colleagues in the agricultural and irrigation departments.

For more information visit our website www.iwmi.org

[1]Rural Development: *From Vision to Action*. 1997. Environmentally and Socially Sustainable Development Studies and Monographs Series 12.

[2]We estimate that in 1995 irrigated area produced 43 percent of world cereals, with this value increasing to 57 percent in 2025. However, the World Bank values are correct for the developing countries.

is about one billion hectares, of which only about one-third is irrigated. Thus, a 10-percent increase in the productivity of rain-fed agriculture would have twice the impact as the same increase in irrigated agriculture. As the beneficial impact would be largely on poor farmers in marginal areas, this is an enormously attractive idea.

It should be recognized from the start, however, that this is by no means a new idea. The goal of increasing productivity of marginal rain-fed areas has been energetically pursued, using all the tools of agronomic science, for at least a century, with highly disappointing results. We believe that the sciences and technologies of agronomy and water management have now advanced to the point where there are grounds for optimism in this field—and, indeed, there are notable cases of success on the ground. But before solutions can be found, the depth and extent of the problems must be thoroughly understood.

There are three central problems of agriculture in marginal rain-fed areas.

- Most of a farmer's costs are the fixed costs of cultivating land, independent of yield. Thus as yields decrease, net returns to farmers decrease even faster. For example, if costs represent 2 metric tons per hectare (MT/ha), the farmer earns a net of 3 MT/ha at an economic maximum yield of 5 MT/ha, with optimal water supply. But the farmer makes only 1 MT/ha if yield is reduced to 3 MT/ha due to deficient water supply.
- In most cases, rainfall is highly unreliable. Farmers rationally minimize their investments in labor, improved seeds, fertilizers, soil and water management and the like to minimize losses due to drought. But this lack of investment in productive inputs means that even when good rainfall occurs, the yield is not as large as it should be.
- Since rainfall affects large areas, prices rise dramatically in times of drought, when there is nothing to sell and collapse in periods of good rainfall, when harvests exceed subsistence needs and there is alot to sell.

It is hoped that advances in biotechnology will result in drought-resistant and more water-efficient crops. One problem with this idea is that, hitherto, drought-resistant crops and varieties have been, for that very reason, low-yielding. Such a crop may produce a more stable yield over varying climatic conditions but at such a low-yield potential that it is uneconomical or unable to respond to favorable conditions. As with yield, there is no single gene, or any known set of genes, that determines drought resistance. While there are likely to be advances in this field, largely through classical selective breeding, there is little likelihood of a substantial breakthrough.

Last, it is important to guard against the common assumption that rain-fed agriculture somehow uses less water in food production than irrigated agriculture. Several effects of rain-fed agriculture should be understood:

- Rain-fed crops are almost always planted on lands that previously supported low-valued grasses or trees. These plants consume all the water that enters the soil, through evapotranspiration, just as do the crops. Thus there may be a gain in the value per unit of water consumed, or "crop per drop"—if the crops are more valuable than the previous plants. In terms of environmental values, they may not be.
- Rain-fed crops are usually planted using various kinds of soil-moisture conservation techniques, such as tillage, mulching, bunding, terracing, etc., to reduce non-beneficial evaporation from the land and runoff from the fields. When non-beneficial evaporation is reduced, there is a real gain in water productivity; but utilizing runoff may simply represent water that does not flow into other surface and subsurface areas where it may have a higher-valued use—such as domestic water supplies or, indeed, downstream irrigated areas.
- The productivity of water used in agriculture, the "crop per drop," is highest when the relative water supply is low, at around 0.35. But this finding must be treated cautiously, because it only optimizes returns to water—not to all the other factors of production that affect farmers' income. Also, the degree of water-management precision required to attain this optimum is available only in the most sophisticated irrigation technologies and management systems.
- Another problem in rain-fed agriculture without inorganic fertilizers is that plant density is typically low in order to extract nutrients from the soil. Consequently, the crop canopy is open and non-beneficial evaporation from the soil surface increases. A study in Africa, for example, showed that only 5 percent of the water entering a field was

A new research focal point for sub-Saharan Africa

By the end of 2000, IWMI will have established its sub-Saharan regional office in South Africa. This office will coordinate research being done in East and West Africa. This work links into IWMI's research programs—especially on groundwater, smallholder water management and water management policies and institutions.

Based in Pretoria, the office is home to a core of scientists from several countries and disciplines, including hydrology, economics, agronomy and sociology. Much of the work done here is being done in collaboration with universities, including the University of the North and the University of Pretoria. Current African research projects include: Catchement management (national and regional/international level), small-scale community-based irrigation, water harvesting, groundwater and smallholder precision irrigation, environmental sustainability of water systems and multiple uses of water, agro-ecology and human health.

An important goal for this research office is to identify and promote the exchange of research findings between Africa and Asia. As the only CGIAR center in the region, this IWMI office provides a useful link for other CG centers to further their research in the region.

beneficially used for crop production; the balance was runoff and non-beneficial evaporation; this study also shows the potential for improving the situation because of this high water loss.

For these and related reasons, contrary to what is commonly thought, a large shift to rain-fed agriculture in many marginal areas could *result in reduced productivity per unit of water consumed in agriculture*.

However, *under specific agroclimatic conditions*, small-scale farming can be productive in marginal rain-fed areas through *supplemental irrigation*. Of course, all irrigation is supplemental irrigation because it is designed only to "top up" effective precipitation on the crops. But supplemental irrigation is a technique specifically designed for water-scarce regions, where scarce water is stored and used only in limited quantities at the critical growth stages of crops.

In many areas, for example, there is sufficient *average* rainfall over the crop season to obtain good yields, but yields are greatly reduced by short-term, 15- to 30-day, droughts at critical growth stages of the plant. Water stress at the flowering stage of maize, for example, will reduce yields by 60 percent, even if water is adequate throughout the rest of the crop season. If there is a way to store *surplus water* and apply it if the rain fails in these stages, crop production would increase dramatically.

There are many ideas for water conservation and supplemental irrigation for smallholders. This is a long and complex subject that cannot be gone into here other than to say that most of these ideas have failed in practice because of two important factors:

- They do not adequately consider the need to actually *have and store surplus water* before the drought episode.
- They fail to consider the economic costs, relative to benefits—which is all the farmer cares about.

One of the single most promising technologies in this field that has gained wide adoption in India, is "percolation tanks." These are small reservoirs that capture runoff and hold the water for percolation into shallow water tables. The water is then pumped up onto fields when and only when, it is most needed. Groundwater storage avoids the high evaporation losses of surface storage; with pumps, the water table provides a cost-free water distribution system to farms; and percolation losses from irrigation are automatically captured by the water table for reuse. These percolation tanks can be combined with highly efficient sprinkler and drip irrigation conveyance systems to provide just the right amount of water when it is needed most.

In order to evaluate the agricultural potential for marginal rain-fed areas it is necessary to have rather detailed climatic maps of countries. IWMI's Climatic and Agriculture Atlas of the World (on IWMI's website: http://www.iwmi.org), the final version of which will be available for Asia and Africa within the next 6 months, will be of enormous help in addressing this issue.

In sum, for all these reasons, it is likely that an *increasing proportion* of the world's food supply will have to be from irrigation. An important need is supplemental irrigation, in marginal rain-fed areas such as in sub-Saharan Africa, using advanced irrigation technologies. In fact, this absolutely has to happen if sub-Saharan Africa is to produce enough food to feed its rapidly growing population without an unacceptably high level of food dependence and provide remunerative rural employment.

Research to support water-sector reforms

IWMI researchers in Pakistan have become trusted advisers of national and regional irrigation authorities. The most recent impact of IMWI's research here is lending support to the Punjab Province in its efforts to reform the irrigation management structure and the legal basis that allows cost sharing and devolution of irrigation management to local Farmer Organizations.

From its Lahore office, IWMI helped facilitate the dialogue that created the farmer/irrigation department cost-sharing and joint-management structure.

From its field station in Haroonabad, IWMI researchers worked with farmers and authorities to create a pilot Farmer Organization. Now the key research activity for IWMI is to measure the progress and problems that this ambitious experiment will encounter.

Dr. David Seckler, an agricultural economist, was Director General of IWMI from 1995 to 2000. Dr. Upali Amarasinghe is a researcher in the Institute's Irrigation and Water Resource Program.

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