WATER, AGRICULTURE, AND FOOD INTERACTIONS

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Summary

Most food produced worldwide depends on agriculture; “wild” ecosystems could produce not more than food for 10 percent of the global population. A main input to agricultural production is water, either in the form of rainfall or of irrigation water applied to crops. However, a large number of people (13 percent of global population, about 800 million) do not have access to sufficient and adequate food for their nutritional requirements. In particular, the impact of food insecurity on children, in terms of stunted bodies, minds and hopes, is devastating. The cause of food insecurity is poverty, an expression of lack of monetary income, social protection networks, or access to the land and water necessary for self-sustenance. A majority of poor and food-insecure people are rural people who can hardly get jobs in the industry and services sectors. Overall agricultural production constraints, including water scarcity, are not as yet a cause of food insecurity: more food could be produced on the globe if the poor could exercise demand for it. Various national policy measures addressing removal of the causes of poverty can contribute to improvement of the food security of disadvantaged groups. Such policies need to be pro-poor and redress existing entrenched inequity in terms of trade, government-provided services and gender. Large-scale irrigation projects funded through public debt have often been hijacked through corruption, graft and rent-seeking. Small-scale irrigation offers better opportunities for empowering the poor when these obtain secure rights to land and water, and consequent access to credit and extension services. Groundwater, allowing control of the resource at the farm and reduced vulnerability to natural hazards, provides food security benefits to individual farmers who can access it. Man-made agricultural systems claim sizeable amounts of water and other environmental resources and much larger efforts by society

will be required to ensure that agriculture finds a sustainable place in the environment in which it is embedded.

1. Introduction

Life as we know it is not possible without the many biophysical and chemical services provided by water. All the organic and mineral substances in living organisms contain water, are surrounded by water, and are transported by it within the organic body. Thus, 80 percent or more of a typical plant or animal is composed of water. Besides the water it contains and by which it is surrounded, water as well as its individual constituents of hydrogen and oxygen are major components of biomass. Availability of water is basic in the generation of all biomass, including food for humans. No ecosystem can exist without water and this is also true for the artificial, managed, or manipulated ecosystems used by man for the production of food and other benefits and commodities, called "agro-ecosystems".

The vegetal world basically takes its water from the soil through the root system. Soil moisture in the root zone—the water accessible to plants—is replenished by rainfall. Soil moisture can also be replenished and preserved through management actions by man. Agricultural water management aims at obtaining good crop yields, income, and food security, while limiting damage to the environment and problems with water-related diseases. It also aims at understanding the patterns of water use at different scales, so that water savings can be made and new resources identified. There are globally 270 million hectares, close to 20 percent of all agricultural land, where water is managed for its application to crops. Somewhat loosely, this article uses the word "irrigation" and the more cumbersome term "agricultural water management" interchangeably.

For most readers, the word "hunger" as related to missing food may recall incidental experiences. To be chronically hungry means something different: undernourishment, resulting in stunted bodies, minds, and hopes. The word "food security" is used according to the definition given in 1992 by the Food and Agriculture Organization of the United Nations (FAO) and the World Health Organization (WHO) as "the access of all people to the food needed for a healthy life at all times" Its converse "food insecurity" is a situation into which the poor may slide and which implies chronic hunger and malnutrition. Food insecurity correlates with "poverty."

"Poverty," the state of being poor, is a condition of deprivation and lack of means to attain adequate subsistence. Income is used as a monetary yardstick to measure poverty. "Absolute poverty" has been defined as having an income of less than one dollar per day, and 1.3 billion people on the globe live in this condition. This does not mean that people having say, two dollars per day are not poor. In fact, close to 3 billion people, half the population of the globe, have less than two dollars per day, but "only" 800 million qualify as stricken by food insecurity and chronically malnourished or, in more emotional terms, as "going to bed hungry."

The world is producing enough food to provide every person with 2700 calories per day, a level that would be sufficient for normal nutrition if food were equally distributed—which it is not. Although the world population doubled between 1960 and 2000, the noted concern of Thomas Malthus—that while population grows geometrically, food supplies can only grow linearly—was not fulfilled: food production increased faster than population, and world per capita supplies of food for direct human consumption in the 1990s was some 20 percent higher than in the 1960s. The agricultural production gains were based on the application of the "green revolution" technology package, based on high-yielding crop varieties developed at agricultural research centers, supported by the use of irrigation, fertilizer, and pesticides. During the green revolution great strides were made to improve the nutritional situation, in particular in Asia, while the situation in Sub-Saharan Africa actually worsened. There were also negative social and environmental impacts needing to be corrected.

With the green revolution, agriculture claimed a very large share, about 70 percent globally, of all water taken from rivers, lakes, and aquifers, with some developing countries dedicating to the agricultural sector 90 percent of all the water they use. In the late twentieth century, water scarcity, driven by competing claims for the resource stemming not only from agriculture but increasingly from the urban, industrial, and services sectors, was striking a growing number of countries and regions. The magnitudes involved in the hydrological cycle remain substantially unchanged and the world is not "drying up"—indeed, the total amount of water supplied annually through the hydrological cycle as rainfall on the continents varies within narrow brackets—but the number of people claiming a share of water has greatly increased and therefore there is a decreasing share of freshwater per person and year. Satisfying the competing claims within the physical and economic limitations of the resource requires higher levels of technology, management and finance, and usually results in increased stress on the environment. The water scarcity crisis impinges also on the social resources scarcity—the limited ability to cope with change and stress-prevalent in developing countries.

Water is unevenly distributed in space and in time. Droughts continue to alternate with floods and in parts of the world water is not scarce; and indeed can be very abundant. Natural water distribution is a given fact and not a case of man-made inequity which is caused by any human, as is, for example, the denial of basic rights. Water scarcity throws light on the fact that the resource available is being mishandled and mismanaged. This article examines some of the numerous interactions between water, agriculture, and food, and between all these and people. In so doing, one must keep in mind the Universal Declaration of Human Rights, where it states that, "everyone has the right to a standard of living adequate for the health and well-being of himself and of his family, including food, clothing, housing and medical care, and necessary social services". For most of humanity, these rights remain inaccessible. Access to food is scandalously uneven, but adjusting the allocation and use of water to the needs of people and to the constraints of the environment, can greatly contribute to a more balanced world closer to the human rights goal.

2. The forces that shape agriculture

For people that make a life hunting, fishing, and gathering fruits, seeds, and roots over an extended territory, the thought to sow, under favorable conditions, seeds of preferred food plants, for example in the humid silt left behind by receding river floods, and to return for harvest, is quite obvious. Similarly, our ancestors probably kept young animals of favorite hunting prey for convenience and future consumption, as pets or as religious tokens. Did anybody invent agriculture? Even 200 million years ago, long before the appearance of man, ants applied the principles of agriculture to the survival and success of their species. For the human race, agriculture emerged as a major economic activity in various parts of the world some 10 000 years ago. Ever since then, natural ecosystems have been converted by man into artificial, agricultural ecosystems, in the process changing the face of the world. Under various given biological and physical environments and constraints, people in diverse ecological regions domesticated different sets of plants and animals, thus evolving different agricultural systems to provide for their needs of food and fiber. Some traditional agro-ecosystems are quite complex, involving various interacting plants and animals to reap food and fiber benefits. Such systems have undergone the test of time and proved sustainable for man and for the environment.

Through its more intensive use of the soil than gathering and hunting, agriculture made higher population densities possible. Surplus production gave room for specialization in society, with the emergence of non-farming classes of people. Successful societies evolved ethical perceptions and religious systems that protected crops, seeds, and domestic animals as well as trade in food and other products derived from agriculture. Some 7000 years ago, development of irrigation in river valleys that flow through arid land, such as the Tigris-Euphrates, the Indus, and the Nile, resulted in another leap in agricultural productivity and population density. In the lapse of a few thousand years, the population that could be sustained per unit of land increased radically: a slash-and-burn system, as practiced in the humid tropics could sustain 30 people per square kilometer, while irrigated valleys under a sunny climate could sustain 300 people per square kilometer. Cities emerged, from whence the word “civilization” derives. During history, and as far back as archaeology can show, societies and civilizations that were unable to look beyond immediate profit proved unsustainable and collapsed.

In parts of the world, the industrialization process of the nineteenth and twentieth century attracted rural people into urban jobs while providing agricultural machinery that hugely increased agricultural work productivity. The process was decisively accelerated when convenient high-density sources of energy, such coal and oil, became available in abundance at a low price. In the last three decades of the twentieth century, whilst the world population doubled from 3 to 6 billion, land in agricultural use increased only 11 percent, meaning a decline in land per capita of 42 percent. This was possible because, where agro-ecological conditions permitted and demand for food made it necessary, yields per hectare of cropped land increased, as did the cropping intensity (reduced fallows and more crops per year). World average grain yields doubled from 1.4 tons per hectare in 1962 to 2.8 tons per hectare in 1996, while cropping intensity—the number of crops carried by the same unit of land—increased by some 10 percent on average. This means that, on average, the same amount of grain that was produced on one hectare in 1962 was produced on 0.55 of a hectare in 1996. Yields can be further increased—the present goal for rice is to achieve 15 tons per hectare or 1.5 kg per square meter—but these achievements are increasingly fragile and dependent on dwindling biodiversity.

The green revolution agricultural productivity leap of the 1970s and 1980s were supported by irrigated agriculture: high-yield seeds developed by agricultural research centers were brought to fruition through the managed application of water, fertilizers, and pesticides. The green revolution did only touch the parts of the world where development of irrigation was possible, while in other parts of the world agriculture changed little from traditional ways. The pillars of the twentieth century green revolution each faced its own crisis: Indiscriminate application of large quantities of fertilizers and chemical pest control resulted in contamination of water and land and in conflict with the environment, while the past rates of irrigation expansion could not be continued into the future because the amounts of low-cost freshwater that would be required simply are not available. New technological and societal challenges have emerged: to keep increasing crop yields safely while protecting biological sustainability; to provide the nutrients needed by crops without letting the excess fertilizer pollute the water and the soil; to control pests while preserving the integrity of the agricultural and natural ecosystems; and to provide adequate and timely water for crop production within the limits of regulated freshwater resources available to humans. The need to review and change policies related to agriculture in general and water in particular emerged strongly in the late twentieth century.

At the dawn of the twenty-first century, there are large differences in the way agriculture is carried out in various parts of the world, sometimes captured in the plural term “agricultures” applied to what farmers do under different physical and socio-economic environments. There is no single agricultural model universally applicable. In the industrialized countries, less than 5 percent of the population produces the food required for the 95 percent engaged in manufacturing and services activities, and agricultural work productivity is closing in on the point where one farmer produces food for 100 non-farmers. Certain less industrialized countries have reached very high levels of agricultural productivity per unit of land while keeping a relatively high level of agricultural employment and national food security. In some other non-industrialized countries, up to 90 percent of people are engaged in agricultural activities and, with demographic growth and environmental degradation, hard pressed to feed themselves while sustaining a minimum acceptable level of infrastructure and services.

The globalization agenda is being pursued with insufficient regard for the agricultural productivity gap between the industrialized and the non-industrialized world is enormous. The difficulty of the situation in some developing countries is compounded by a natural resource base used to its limits, scarcity of the capital and labor resources needed to intensify production and generate employment, and high demographic growth rates. In other developing countries, however, there are still untapped resources of land and water.

While enough food for all can be produced, malnutrition continues to be a major problem. The global capacity to produce food is not exhausted but, out of a global population of 6 billion, 800 million people are counted as being malnourished. The number of those that suffer micronutrient deficiencies is much larger. Particularly worrisome is the carrying over of the present situation into the future through the large numbers of stunted and wasted children, and the burden of learning disabilities and of weak mothers giving birth to disadvantaged children. The number of children denied normal nutrition and development of the body and the mind is close to 200 million.

The future is going to be what we—the present generation—will do to shape it within politically accepted guiding principles and the existing and emerging forces of change. As re-affirmed at a global conference on Water, Life and the Environment in The Hague in March 2000, it is widely accepted that all people have basic rights to sufficient food and water for drinking and sanitary purposes. This does not mean that people should not have to pay or work to satisfy these rights but that human society should be organized in such a way that water and food are accessible to all, and in particular to its weakest members, the children and the poor. It is also generally accepted that each generation has a moral obligation to preserve the global heritage for its successors, implying that today's food production should not reduce the capacity for future generations to produce food. In addition, few dispute that people should have a voice, shared by both women and men, in making decisions that affect them, including decisions related to water allocation and management.

In giving shape to a vision of a desirable and possible future, the main global driving forces that will account for change may be the following:

Population growth: the United Nations projects that there will be about 8.3 billion people living in 2030, and that 80% of these will be living in developing countries. Population growth is almost totally concentrated in developing countries. Food for 30% more people than are living at present will have to be produced, and jobs created for those that are not engaged in agriculture.

Urbanization: current strong trends point to a shift in population from rural to urban areas, and by 2030 a large majority of people, in developing countries also, will be resident in cities. Urban people acquire new dietary habits with a shift in preferred cereals and to higher meat consumption. These new and changing demands for food will be satisfied by those rural areas that have higher output per unit of labor.

Technology: technology is continuously changing rapidly, particularly in the fields of communications, information, and biotechnology. Depending on how they are used, these technologies can allow for the provision of more intensive agriculture and food services at a lower cost.

Energy prices: mechanized agriculture, with its high labor productivity, is dependent on the cost of energy. Energy prices have been at historically low levels and current projections tend to be sanguine about their future. Even so, many question the wisdom of increasing dependency on non-renewable energy sources, because known reserves are limited and the greenhouse gas carrying capacity of the atmosphere is already taxed.

Market economics: the continued drive towards market-based economies together with reduction in subsidies to, and taxation of, agriculture can provide new opportunities for low-cost producers. Trading in water and water rights are bound to expand and will raise ethical, legal, institutional, and management questions. One third of the global workforce may be left unemployed by the market, and large numbers of people find it increasingly difficult to find employment and thus ensure household food security.

Democratization: democratic forms of governance, when fully manifested, with mechanisms of accountability and transparency in place, have the power to improve the functioning of resource allocation and reduce the cost of water-related infrastructure. However, the increasing concentration of wealth and power in a few hands does not bode well for democracy.

Environmental awareness: as it becomes increasingly difficult for the environment to accommodate agriculture, growing awareness of the importance of natural ecosystems to planetary health will lead to increasing pressure, led by public opinion, to improve the quality of water and to protect wetlands.

Global warming: global warming caused by human actions is leading to increased variability in precipitation and river flow, calling for further efforts to control and regulate the flow of water—and to limit greenhouse gas emissions.

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Biographical Sketch

Wulf Klohn is a Senior Water Resources Officer in the Land and Water Development Division of the Food and Agricultural Organization (FAO) of the United Nations located in Rome, Italy. He received his B.S. degree in Civil Engineering in 1961 from the University of Chile, Santiago, Chile. He worked for the Irrigation Directorate in Chile as an irrigation engineer from 1962 to 1969. From 1969 to 1975, he worked for the World Meteorological Organization (WMO) on various water resource projects in Colombia, Burkina, Faso, Cameroon, Nigeria, and Guatemala. He was brought to Geneva, Switzerland, by WMO to work on hydrological forecasting where he worked as senior officer from 1975 to 1988. Since 1989, he is working as senior officer at the FAO office in Rome, Italy, on water availability, lake management, hydrologic monitoring and forecasting, information, and transboundary water policy problems