Agriculture: Re-adaptation to the Environment

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Agricultural Impact on Natural Ecosystems

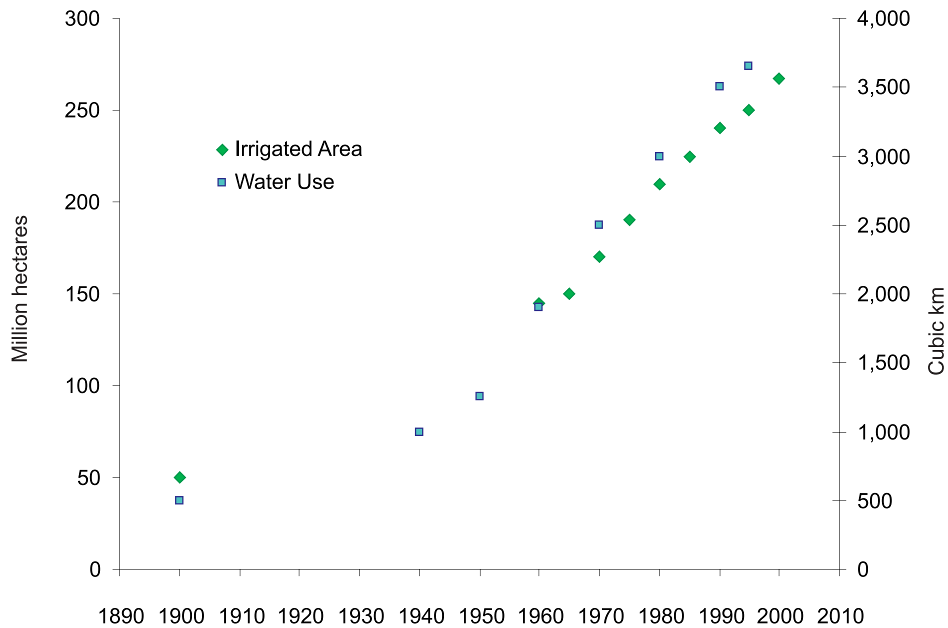
Agriculture—since its beginnings approximately 10,000 years ago—has significantly modified natural ecosystems in order to yield adequate and permanent staple food supplies for human populations. In creating artificial ecosystems, agriculture inherently interacts closely with pre-existing environmental conditions. Hydrology, soils, climate, topography and biology all have a major influence over the productivity and profitability of agriculture. Traditional agriculture has worked with these inter-relationships with the environment by adapting in ways that coordinate with local ecology. As early as 200 BC, Roman farmers were aware of methods to manage soil fertility. For example, Cato the Censor advised that land should be allowed to lie fallow for a year, as well as planting various legumes "not so much for the immediate return as with a view to the year later".[1] The Romans were not alone in the observation of lost soil fertility. In the same period, Chinese were using "green manure," a legume crop plowed into the ground before the next planting.[2]

While the recognition of the relationship between agriculture and the environment is longstanding, concern continues to heighten over increasing agricultural pressures on the environment. This is particularly true for aquatic and riparian habitats, as well as wetland ecosystems. Irrigated agriculture underwent exponential growth over the past half century—from 50 million hectares globally in 1900 to 267 million hectares in 2000.[3] As seen in figure 1, water use—dominated by irrigation—saw a parallel rate of growth. The marked increase in irrigated area from the 1960's through the 1980's can be largely attributed to the massive efforts of the Green Revolution, which rested on the modernist assumption that technological innovation alone could solve the problem of adequate food supply. By breeding better varieties of staple cereals, combined with improved access to fertilizers, pesticides and irrigation, annual increases in food production more than kept pace with increases in population.[4] For example, the average annual growth in rice production for Asia increased from 2.1 percent per annum during the period 1955-65 to 2.9 percent per annum during 1965-1980, surpassing the annual population growth rate of 2.3 percent.[5] As a consequence, hunger as a percentage of the population fell dramatically, from 35 percent of the developing world in 1970 to 20 percent in 1991, despite an almost 60 percent increase in population. [6] The increases also allowed many countries to become self-sufficient in production of food staples. Nevertheless, self-sufficiency as measured by trade only reflects the needs of those with the wherewithal to buy food. Hunger is still widespread, with over 800 million people suffering from chronic undernutrition today. [7]

Impressive as the Green Revolution gains in agricultural productivity were, they nevertheless came with a high environmental price in the form of increased pollution and depletion of water resources, primarily due to the effects of the package of inputs required by the green revolution plants: pesticide and synthetic fertilizers, as well as consistent watering, achieved in nearly all cases through large irrigation projects.[8] The resulting cascade of impacts includes compromised human health, declines in wildlife populations and biodiversity, dislocation of human populations, inundation of cultural sites, and loss of productive land. [9] Many of these impacts were not immediately evident, but have developed as widespread "slow-motion" crises.

Intensive agriculture has often been enabled by major public support for the overexploitation of water resources, and its consequences have been severe. In the United States, the State of California constructed the largest irrigation project in the western hemisphere. While giving the state one of the richest agricultural areas in the world, California's aquatic ecosystems and wildlife populations have been decimated,[10] and flows that had supported a rich estuarine delta system in the state of Baja California in Mexico only reach the system now in infrequent flood events.

Figure 1. Global irrigated area and annual water use.

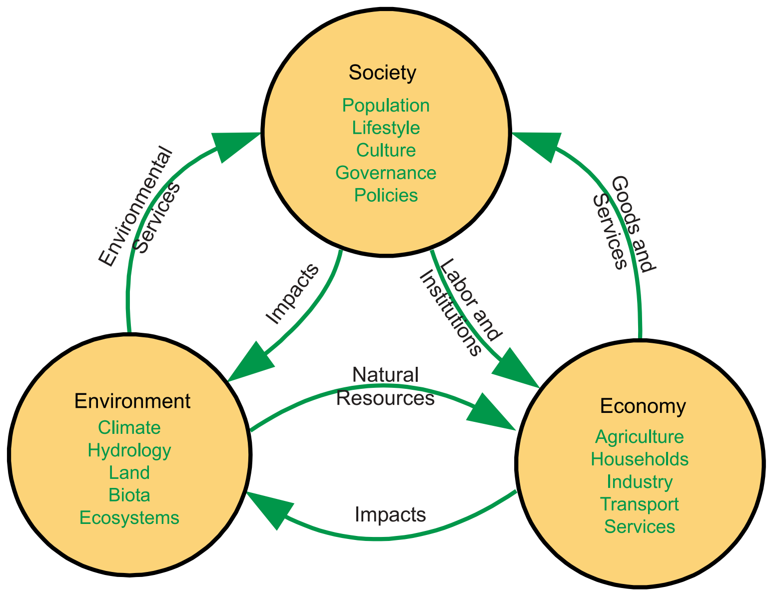


As a result, over 90 percent of the delta has disappeared.[11] Between 1980 and 1995, Saudi Arabia consumed 75 percent of the proven reserves of fossil groundwater in its major aquifers to irrigate wheat crops,[12] which will take hundreds if not thousands of years to restore. Groundwater overdraft in India, encouraged by energy subsidies for pumping water, now threatens the ability of India to be self-sufficient in food.[13] Perhaps most dramatically, irrigated cotton production in Central Asia has diverted so much water from the Amu Darya and Syr Darya rivers that they no longer reach the Aral Sea. With the sinking of the sea and extinction of endemic species of fish, a 44,000 ton fishing industry that supported 60,000 jobs in the 1950's has completely ceased.[14] Entire fishing villages have been abandoned due to contamination by salt and pesticide residues of the dry, windswept bed of the former Aral Sea, and as their source of livelihood vanished. The consequences of these vast projects are likely irreversible—certainly the extinction of species cannot be reversed and the public health damages cannot be undone. The link between human lack of awareness of natural systems, political short-sightedness and adverse environmental, social and economic impacts could not be more apparent.

How might these kinds of large scale errors and failures have been avoided? Although the history of the Green Revolution was well known by the time Gordon Conway documented it in 1997, Conway, now President of the Ford Foundation, chose to do so "…as a reminder of the power and limitations of innovative technology, and the crucial importance to its success of the economic, social and institutional environment within which it has to operate." To the economic, social and institutional environments, Conway also adds the natural environment in his book *The Doubly Green Revolution* (1997).

We believe all of these elements are required if we are to realize sustainable agriculture, with special emphasis on the importance on the underlying natural resource base and ecological systems. These elements of sustainable development – social, economic, and ecological—are depicted in figure 2. [15] Sustainable societies rest on the strength of these three pillars, each dependent on the others. Neglect of these interdependencies leads to development failures, including continued hunger, lost livelihoods and ecosystem destruction.

Figure 2. Elements of sustainability (adapted from Gallopín and Raskin 2002).



Re-adaptation

Since the early 1990's, agriculturalists and development specialists increasingly recognize the importance of a tri-partite, integrated approach to agricultural development, with important efforts to design new policies and programs with long-term sustainability in mind. The 1980's saw increasing recognition of the interrelated nature of a number of different issues in both industrialized and developing countries. These were given a coherent voice in the report of the Brundtland commission, *Our Common Future*,[16] the report that introduced to the policy world the notion of *sustainable development*. In 1992, the international understanding was codified in Agenda 21 (1992). That same year, responding to increasingly obvious problems with water—for both ecosystems and people—the Dublin Principles were set forth by the Dublin International Conference on Water and the Environment (1992). Consistent with these changes, agricultural policy and research institutions began to change. In one notable shift, at the turn of the 1990s, the CGIAR changed its mission statement to include "sustainable improvements in the productivity of agriculture, forestry and fisheries," in order to "enhance nutrition and well-being, especially of low-income people." Organizations such as the FAO, the EU, the United States Department of Agriculture and the World Bank now promote sustainable agriculture in their publications. The idea of learning to re-adapt to better accommodate ecosystems is in the air, and methodologies are being developed on the ground. A key statement of the new approach is found in Conway's *The Doubly Green Revolution*. The "doubly green" revolution is "green" in two senses, the original sense of the Green Revolution as the green of plants in the field, and the word "green" as interpreted to mean having an environmentally-sensitive focus.

It would be easy to despair of a policy of re-adaptation, given the current degraded state of many agricultural and natural lands. However, we have learned that some ecosystems are resilient and may be restored if sufficient resources and knowledge are applied. For example, the new sustainable management regimes for agriculture, forests and wildlife on arid or semi-arid lands are resulting in rapid recovery of these systems in Africa. Globally, coastal resource systems also respond to management for sustainability, involving cooperation among tourism, fishing and community interests.

A recent trend in North America and elsewhere is to decommission dams that caused serious ecological damage in the past. In North America, nearly 500 dams have been removed to restore natural river flows.[17] Fish population recovery on some of these rivers has been dramatic. For example, within a few months of removing a dam in the state of Maine in the US, salmon, striped bass, alewives and other affected fish returned to waters above the old dam site in a matter of months—water they had been absent from for 162 years.[18] In Europe, the International Commission for the Protection of the Rhine (ICPR) adopted a 40-year action plan in 2000 that includes measures on flood management and habitat protection and restoration in the alluvial zone around the river's banks. The flood management goal is to restore as far as possible the natural course of the river. The emphasis is on planning around the water system itself, rather than trying to control the water. This is a major shift, particularly for the Dutch, who have been building dikes for the past 1000 years.

We are also learning that as open space is lost to urban development, agriculture can be an essential habitat for displaced wildlife. For example, a recent literature review revealed that while irrigation or activities associated with irrigation *can* cause adverse impacts to wetland ecological resources—ranging from localized and subtle, to large-scale and severe—they can also result in the creation or enhancement of important wetland ecological resources. Further, depending on the irrigation activity and scale, irrigated agriculture and ecological resources can coexist in a potentially sustainable fashion.[19]

One example of re-adaptation to a degraded environment is the change taking place in a series of villages located in the Indian state of Mahrashtra, which experiences recurrent droughts. An NGO established in 1993, Watershed Organization Trust (WOTR) brought about significant improvements in the quality of life and the ecosystems in 20 villages, over an area of 20,000 hectares. Their work is based on a simple premise: "the nature and incidence of poverty in a rural agrarian economy is closely linked to the robustness of the local ecology and environment…as well as the socio-economic relationship…".[20] WOTR works closely with villagers, building their capacity to restore and manage their natural resources, both land and water.

In Mahrashtra, the impact on water resources relates directly to the increase in biomass vegetative cover, which enhances the ability of soils to absorb and hold water. This is particularly important in a country like India, which receives 80 percent of its rainfall in three to four months, most of that coming in the form of intense monsoon storms. The soil's ability to absorb water in these events can make the difference between devastating floods and droughts and a stable year-round supply. With WOTR's work, combining institutional capacity building and technical training, the villagers made landscape modifications. These included the use of gully plugs and bunds combined with afforestation to improve soil moisture, reduce erosion and control drainage. As a result, groundwater tables have actually *risen* in parallel with a rise in biomass. The increased biomass translated into increased incomes for the villagers. This in turn brought sufficient security for farmers to send more of their children to school, from a pre-intervention rate of 50 percent to nearly 100 percent. Problems of migration in the villages WOTR operated in for the last 5 years were virtually eliminated. All three elements of sustainability—social, economic and ecological—are being addressed successfully. Water and agriculture are linked in this project as a joint positive force across each dimension of sustainability.

Future Directions—Sustainability

Ultimately, agricultural professionals, governments and farmers must approach the creation of socially and environmentally sustainable agricultural systems with a long-term perspective. With regard to water resources, one definition of sustainability is, "the use of water that supports the ability of human society to endure and flourish into the indefinite future without undermining the integrity of the hydrological cycle or the ecological systems that depend on it."[21] Other definitions, such as those of American Society of Civil Engineers and the Global Water Partnership, are similar. What prevents us from achieving sustainability? This is a question that people have been attempting to answer with increasing urgency since the publication of the Brundtland report.[22] In the case of agricultural water use, the broad and practical outlines of an answer have been emerging from literature since the early 1990s.

The central issue is illustrated in figure 2, namely, that agricultural water use is determined by and affected by a combination of social, economic and environmental factors. Although these can sometimes be ignored in the short term, they will all play a role in the long run. Moreover, they interact with one another. When farmers have secure access to land, or hold secure tenure to the land they work, they take a more environmentally sustainable approach to land management.[23] Thus the application of policy and law to promote sustainable management can be critically important.

Pricing incentives and disincentives can also be major management instruments. A rise in the price of a land-intensive export crop can lead to rapid expansion of production for short-term gain. Alternatively, the removal of subsidies and the provision of other alternative incentives can help restore degraded agricultural and ecological systems. In this case, the economic environment (pricing) affects both the natural environment and social structures.

In the case of agriculture, the difficulties of integrating the three elements of sustainability are acute. The aggregate figures for total national crop production that are reported in national yearbooks are the result of thousands of micro-level decisions, made under uncertain and risky conditions. Adoption of new techniques requires not only knowledge of the technique, but also a reasonable certainty of a substantial short-term payoff, to make the investment of time worthwhile.[24] To reduce the risk, governments may choose to take some of the burden when the weather is poor or commodity prices fall. They may also try to encourage production of highly-valued cash crops. But these strategies can lead to distorted outcomes. In the case of water, this may take the form of subsidies for water or agricultural energy consumption, or high levels of production of water-intensive crops, such as cotton or rice.

Ensuring *real* sustainability, beyond rhetoric, requires that existing economic, political and institutional frameworks be restructured using approaches that cause minimal disruption to human well-being and natural systems. National decisions have global implications. The inability to take steps toward true sustainability is still painfully obvious, even in highly developed countries. For example, the United States' recent decision to offer large export subsidies to domestic farmers is contrary to long-term, wise management of resources. Even under an administration that is strongly aligned with a free-market stance, subsidies were adopted that are both potentially environmentally damaging within in the U.S., and economically devastating to farmers in low-income countries. [25]

The work being undertaken to examine agricultural production decisions to sustain both agriculture and the environment—from the field level, to watersheds, to river basins—must be continued and given increasing priority. In other words, agricultural management on all scales must be linked directly to economic, social and ecosystem function, with integrated attention to each of these pillars. Critical institutional barriers to planning exist at each of these levels. To overcome them, we must work together to achieve real sustainability, real coordination between agriculture and the environment, and real security for those people living in poverty.

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