Harris, Jonathan M. "Overview Essay: Agriculture and Renewable Resources," Part V, Frontier Issues in Economic Thought, Volume 6: A Survey of Sustainable Development. Island Press: Washington, D.C. 2001. pp.155-164.

Social Science Library: Frontier Thinking in Sustainable Development and Human Well-being

"Agriculture and Renewable Resources" by Jonathan M. Harris

The earth's renewable resource systems have suffered major damage during the last century, with the severity and scale of ecosystem impacts increasing significantly between about 1950 and the present. Examples of civilizations undermining their resource base are common in history (Box 1), but the present global scale of the damage to soils, water, forests, atmospheric and ocean ecosystems is unprecedented. The United Nations Environmental Programme report *Global Environmental Outlook 2000* finds that "environmental gains from new technology and policies are being overtaken by the pace and scale of population growth and economic development" (UNEP 2000 p. xx-xxii). Among the major environmental problems cited by UNEP are: climate change caused by fossil fuel emissions and other greenhouse gases; pollution and soil damage from intensive agriculture; degradation and loss of forests, woodlands, and grasslands; biodiversity loss; water contamination and overdraft; degradation of coastal areas by agricultural and industrial runoff; and overexploitation of major ocean fisheries.

The World Resources Institute documents these and similar impacts, but also notes that a shift to sustainable management can significantly alter these trends: "Already, the transition to more environmentally benign ways of growing food, producing goods and services, managing watersheds, and accommodating urban growth has begun in many far-sighted communities and companies. How fast this transition to more 'sustainable' forms of production and environmental management will proceed, and whether it can effectively mitigate the effects of large-scale environmental change, is the real question." (WRI 1998, p. 140.)

In this section we explore some of the issues involved in a large-scale shift to sustainable management of natural resource systems. To use the terminology introduced in Part I of this volume, we will discuss the conditions for the conservation of natural capital rather than its depletion. In the areas of agriculture, biodiversity, fisheries, forests, and water, we review the nature and scale of current problems. The questions which concern us are: What sustainable management techniques are available? What economic incentives and political institutions are needed to promote sustainable techniques? And what are the economic and political barriers to their implementation?

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Box V.1. Exceeding the Limits: The Collapse of a Civilization

The first literate civilization in the world collapsed because of its failure to recognize ecological limits. Around 3000 B.C. the Sumerians of southern Mesopotamia, between the Tigris and Euphrates rivers, built a complex society based on irrigated agriculture, and invented wheeled vehicles, yokes, plows, and sailboats, as well as accounting and legal systems.

But their growing population placed too heavy of a demand on the natural resources of the region. Deforestation and overgrazing led to heavy soil erosion. Irrigation caused the underground water table to rise, depositing salts that poisoned cropland. Eroded soils loaded the rivers with silt, leading to catastrophic flooding.

"The limited amount of land that could be irrigated, rising population, the need to feed more bureaucrats and soldiers, and the mounting competition between the city states all increased the pressure to intensify the agricultural system. The overwhelming requirement to grow more food meant that it was impossible to leave land fallow for long periods.

"Short-term demands outweighed any considerations of the need for long-term stability and the maintenance of a sustainable agricultural system. . . . Until about 2400 B.C. crop yields remained high, in some areas as high as in medieval Europe and possibly even higher. Then, as the limit of cultivable land was reached and salinization took an increasing toll, the food surplus began to fall rapidly . . . by 1800 B.C., when yields were only about a third of the level obtained during the Early Dynastic period, the agricultural base of Sumer had effectively collapsed." (Ponting 1993)

The process of irrigation, salinization of soils, and agricultural collapse was repeated twice more as later societies attempted to rebuild in the same region. Finally, the land was exhausted. "Once a thriving land of lush fields, it is now largely desolate, its great cities now barren mounds of clay rising out of the desert in mute testimony to the bygone glory of a spent civilization" (Hillel 1991).

AGRICULTURE: CONSUMPTION, PRODUCTION, AND ENVIRONMENT

The discussion on world agriculture has shifted from a debate between optimists and pessimists about overall adequacy of food supplies to a focus on distributional and environmental issues. Technological productivity and yield increase outran population growth in the second half of the twentieth century, but at the cost of significant environmental degradation and without solving the problem of hunger. The number of seriously malnourished people remains stubbornly high -- over 800 million worldwide (FAO 1996) -- while soils, water supplies, and ecosystems have suffered widespread damage.

To project a successful future for world agriculture in 2000-2050 and beyond, several major issues must be addressed:

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- Is it possible to expand food production to accommodate the needs of 8-9 billion people at higher per capita consumption levels without worsening environmental damage?
- Can food consumption patterns become more equitable or will the needs of the affluent for meat and luxury foods squeeze out the world's poor?
- Can local and regional food production in the developing world come close to self-sufficiency or will import dependence continue to grow?

A comprehensive study by the International Food Policy Research Institute (IFPRI, 1995) projected that in the medium term (through 2010) "world food supply would probably meet global demand, but that regional problems could occur" with South Asia and Sub-Saharan Africa most likely to suffer shortfalls. While contributors to the IFPRI study generally leaned towards the optimistic side in projecting food availability (Mitchell and Ingco 1995; Agcaoli and Rosegrant 1995), they also acknowledged that environmental problems posed important future constraints .

According to Pierre Crosson, "maximum realization of potential land and water supplies at acceptable economic and environmental cost in the developing countries still would leave them well short of the production increases needed to meet the demand scenario over the next 20 years." (Crosson 1995). This picture is borne out in a more recent overview of global population-supporting capacity by researchers at the U.S. Department of Agriculture Office of World Soil Resources: "From a global land-productivity point of view, the specter of Malthusian scenarios seems unwarranted. Sadly, however, local and regional food shortages are likely to continue to occur unless mechanisms for adequate food distribution, effective technical assistance, and infusions of capital for infrastructure development are implemented in some developing countries." (Eswaran et al. 1999.)

Area in cereal crops, a fundamental mainstay of global nutrition, is no longer growing (Harris 1996), and grain area per person has been declining since the 1950s as a concomitant of population growth (Brown 1999). Maintaining yield growth is therefore critical to feeding a world population projected to grow by about 2 billion people in the next generation. But there is some evidence that yield increases, the key to maintaining and increasing per capita consumption in developing countries, are slowing (Harris and Kennedy 1999). While a Malthusian scenario is not likely, it is apparent that maintaining an adequate food supply while preventing further environmental damage presents a major challenge.

Per Pinstrup-Andersen and Rajul Pandya-Lorch argue that food security can be achieved, but that this will require significant reforms in the structures of production and distribution. Since major cropland expansion is not possible, yield increase is key, but the current high-input techniques of the Green Revolution which have worked in prime agricultural lands are not suited for many of the world's more marginal areas. In addition, they have caused unacceptable environmental damage. Thus a different paradigm of agricultural development is needed, more environmentally-friendly and oriented to the needs of small farmers and the rural poor.

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The dimensions of this new paradigm for sustainable agriculture are discussed by **Gordon Conway**. The essential issue is the perception of agro-ecosystems as modified versions of natural systems, rather than as rural production units converting inputs to marketable outputs. Within the agroecological perspective, there are many possibilities for multicropping, agroforestry, biological pest controls, and crop/livestock systems. Few of them fit well into the economic formula of monocrop output, as they have multiple and not always easily measurable products, including biodiversity conservation. All involve significant reduction of external inputs such as fertilizers and pesticides.

Issues of production techniques are interrelated with issues of equity and social relations, as local management is often key to successful agroecosystems, while large-scale production of monocrops is conducive to centralized and concentrated agribusiness. Local food systems can often provide both greater food security and greater equity (Campbell 1997; Anderson and Cook 2000; Barkin 2000).

There is an expanding literature on the principles and economics of sustainable agriculture. The 1989 National Research Council report *Alternative Agriculture* first gave authoritative support to the proposition that "Alternative farming methods are practical and economical ways to maintain yields, conserve soil, maintain water quality, and lower operating costs." (NRC 1989). A study by Lockeretz et al. (1981) indicated that yields in organic agriculture in the U.S. and Canada were comparable to those of farms using mainstream high-input techniques. The *American Journal of Alternative Agriculture* provides continuing detailed analysis of such issues as providing alternatives to pesticide use (den Hond et al. 1999) and the productivity of organic agriculture (Hanson et al. 1997). Comprehensive assessments of the economics and agronomics of sustainable agriculture in both developed and developing nations are provided by Edwards et al. (1990) and Lampkin and Patel (1994), and numerous articles address specific issues involved in implementing sustainable practices. (Brummer 1998; Lewandowski et al. 1999). Pretty et al. (1992) focus on the agroecology of low-input and community-based agriculture in developing nations.

A major economic barrier to the adoption of sustainable agricultural techniques is the existence of an extensive network of subsidies for agricultural inputs and energy, as well as for crop and livestock production (Panayotou 1998, pp. 68-71). Both in developed and developing countries, these subsides typically provide the greatest benefits to affluent farmers and agribusiness, who constitute a powerful political lobby for their continuation. At the same time, subsidy removal may create hardships for small farmers and low-income consumers. Thus it is important to integrate the process of subsidy removal, which is well justified on both economic and ecological grounds, with policies aimed at supporting small farmers and promoting equity. These could include agricultural extension and informational outreach on low-input techniques, to enable farmers to maintain or improve productivity while reducing fertilizer, pesticide, and water use. Targeted food subsidies and social investment strategies may help low-income consumers while reducing the budget costs of broad-based subsidies (see Donaldson 1991; Hopkins 1991; and summarized article by Heredia in Part 10 of this volume).

BIOTECHNOLOGY IN AGRICULTURE

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Among advocates of sustainable agriculture, there is a division of opinion on the acceptability of biotechnologies. Some, like Pinstrup-Andersen and Conway, see biotechnology as an essential complement to agroecological systems. Others warn of the potential of biotech to disrupt and destroy natural ecosystems (Rifkin 1998). Modern genetic technologies differ in nature and scope from traditional cross-breeding techniques, and raise novel issues concerning the social governance of technology (Krimsky 1991; Krimsky and Wrubel 1996).

In agriculture, genetic technologies involve a whole spectrum of issues such as pest, disease, and herbicide resistance, nitrogen fixation, and animal growth hormones. While the advocates of biotechnology see great promise for directly or indirectly increasing yields, **Jane Rissler and Margaret Mellen** argue that the potential for unintended negative consequences from genetically modified organisms is great. Once introduced into the environment, traits such as pest-resistance may "jump" from crops to weedy relatives, thereby creating super-weeds.[1] Pesticides genetically engineered into crops may hasten the development of resistant pests, already a major problem in "modernized" agriculture, or may kill beneficial species (already reported in the case of genetically modified corn and monarch butterflies).

Mae-Wan Ho (1998) emphasizes the importance of the interconnections of genetic patterns in natural ecosystems. While genetic engineers concentrate on the development of a single trait, they ignore the more complex effects on the organism as a whole and on the ecosystem. New and more powerful viruses may be unintentionally created, some of which may affect humans as well as plants.

Advocates of the rapid adoption of biotechnology argue that it will help solve urgent food supply problems in developing nations (Paarlberg 2000). However, the social impacts of genetic engineering imply an expropriation of genetic resource from the South and increased marginalization of small farmers (see article by Vandana Shiva in Part III of this volume). In Europe, resistance to corporate control of genetic material has grown, and together with health and environmental concerns has led to strong consumer resistance to the introduction of genetically modified foods (Lappé and Bailey 1998).

Perhaps the most far-reaching threat associated with genetic engineering in agriculture is the destruction of natural biodiversity. Rissler and Mellen point out that the introduction of non-transgenic cross-bred crops has already led to numerous cases of extinction of wild relatives. The greater power of transgenic techniques implies greater potential ecosystem impacts. While such impacts are unlikely to enter into the profit-oriented calculations of agribusiness corporations, they can create irreversible changes which would undermine the long-term sustainability of agro-ecosystems. To get a sense of the importance of this issue, we need to examine the concept of biodiversity and its implications for the future of human systems and of the natural world.

BIODIVERSITY AND NATURAL GENETIC RESOURCES

Biodiversity is one of the most important elements of natural capital, as well as one of the most difficult to measure and value. Biodiversity refers both to the total number of species and also to the rich complexity of species' inter-relationships in natural settings. It can thus be degraded

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by simplification of the species patterns in ecosystems, as well as permanently diminished by species extinction.[2]

One way of understanding the value of biodiversity is to consider the tremendous complexity of genetic codes. The genetic code of each species is a store of information built up over millenia, adapted specifically to planetary ecosystems, and irreplaceable once lost through extinction. Biodiversity is one of the most valuable resources on the planet, “the key to the maintenance of the world as we know it” (Wilson 1992). Using the economic terminology introduced in Part I, an excellent case can be made for defining biodiversity as “critical natural capital”.

To some extent biodiversity can be conserved by preserving genetic specimens, for example in seed banks. However, in addition to the genetic code itself, the structure of complex ecosystems involving many types of symbiosis is an essential part of biodiversity. Further, most complex ecosystems have a minimum size below which species loss occurs due to ecosystem fragmentation. Thus in many cases the only effective method for preserving biodiversity is to maintain natural ecosystems in an unchanged or minimally modified form.

Achieving this goal presents major problems in a production-oriented economic system which values resources only insofar as they contribute directly to meeting human consumption demands. Many traditional agricultural and production systems have achieved coexistence with minimally disturbed ecosystems, but are threatened by competition with more “productive” but biologically simplified techniques (see article by Shiva summarized in Part III).

Estimates of species loss indicate a continued rapid decline in biodiversity, despite publicity and some efforts to address the problem by NGOs and multinational institutions. **Gretchen Daily and Paul Ehrlich** show that the scope of the problem is greater than implied by species extinction figures. Loss of local populations, even when members of the species survive elsewhere, have left huge areas of the world, including Europe and much of Asia “biologically depauperate”. Impoverished ecosystems possess diminished life-support capability and adaptability. The loss of ecosystem services such as water retention and detoxification, nutrient recycling, and carbon fixation have significant economic costs (Daily 1997). The esthetic and spiritual losses associated with a diminished natural world are more difficult to measure, but nonetheless real. More extreme consequences, such as the spread of plant blights and animal and human diseases, can lead to the kind of devastating ecological backlash discussed by C.S. Holling in Part IV of this volume.

Kamaljit Bawa and Mahdav Gadgil point out that the people most exposed to declines in ecosystem services are the rural poor. At the same time, local communities can be the most effective stewards of ecosystem diversity, given the right incentives (Bawa and Gadgil 1997). Like Barkin (2000), they point out the need to devise systems which provide economic incentives for the maintenance of biodiversity in agriculture, forestry, and fisheries as well as through ecotourism or other sources of income from conservation.

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In the area of biodiversity, the limitations of standard economic theory for resource conservation are brought into sharp relief. Theories and techniques which work well for mineral deposits are ill-adapted to the much greater complexity of biological systems. This is especially true on an international scale; the globalization of markets threatens existing ecosystems with degradation, species extinction, and the introduction of invasive species, whether natural or engineered. Attempts to value ecosystem services are relatively crude, but indicate that even in standard economic terms their value is very large (see Costanza et al. 1998, and discussion in Part I of this volume). Policies based on the "internalization of externalities" constitute a relatively weak response compared to the broader goal of ecosystem preservation.

WATER, FORESTS AND FISHERIES

Economic theory is a better guide to the over-exploitation of common property resources. The well-known economic principle of the "tragedy of the commons" is misnamed, however – it should be "the tragedy of open-access." While common property resources have often been well-managed through traditional rules and local government oversight, broadening markets and advancing technology has brought more powerful extractive techniques to bear on water, forests, and fisheries, with predictable results of overuse and depletion.

Where property rights are well-defined, exploitation is more rational and sometimes more restrained, but here too ecological values and future interests are poorly represented. The private owner of a forest has some incentive to replant after an economically optimal rotation period, but little incentive to conserve biodiverse forest systems as opposed to monocrop plantations. Proper pricing of water will help reduce wasteful use, but may actually increase incentives to deplete rivers and aquifers to meet consumption demands. For all these systems, principles of economic rationality must be matched with principles of ecological conservation.

World fisheries are a glaring example of the perverse incentives and institutional failures of the current economic system, as outlined by **Anne Platt McGinn**. Both national policies and international agreements have so far been ineffective in preventing the depletion of the world's major fisheries. Aquaculture can fill some of the gap between growing demand and limited supply, but many forms of aquaculture are also associated with major environmental problems. In part the problem of overfishing arises from growing population and per capita demand, in part from failures of national policy, and in part from globalization of fishery access without comparable global regulation. The principles for sustainable management of fisheries are not hard to define, but the institutional barriers to achieving effective conservation are great.

The problems of forest management are somewhat different. Wooded land is often privately owned, which should in theory promote efficient resource use. However, private owners usually "see" only a limited portion of the true values provided by forests. They may manage efficiently for timber and perhaps some non-wood products, but generally ignore the many environmental services provided by forests. Given the imperative to produce commercial returns, private owners will also have a bias towards plantation forestry -- monocultures of fast-growing species. Old-growth forest will be "mined" for one-time profit, then abandoned or turned to ecologically degraded uses.

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Norman Myers provides a broader perspective on forest ecology and forest decline. He sees an inadequate public presence in forestry management both at the national and international levels. Too often, government agencies serve essentially to promote the interests of timber producers, making forest tracts available for commercial exploitation at low cost, thereby squandering potential revenues as well as encouraging deforestation, siltation, and floods (Panayotou 1998, p. 69). Myers outlines the scope of the challenge confronting new global forestry institutions, as well as existing government agencies. Most important, these authorities must accept a definition of sustainable forestry that goes well beyond maintaining timber revenues, including broad ecological and social functions. Improved scientific inputs to forestry decision-making are essential to complement the economic perspective which has characterized management in the past. Perhaps the single most pressing issue is the removal of widespread subsidies which continue to promote rapid forest destruction.

Water systems are another area in which economic analysis can be a useful guide to policy only if it is combined with an understanding of the ecological function of water cycles. Postel (1999) offers an alarming overview of the worldwide decline in the capacity and function of water systems. Over-use and overdraft of water have led to escalating problems of soil salinization, declining water tables, and ecological damage. Dams, intended to increase water supply, have contributed to drying up rivers and in many cases have rapidly lost capacity to siltation. Worldwide, irrigation is the largest source of water demand, and this mainstay of world agriculture is threatened by its own excesses, combined with growing urban and industrial demand.[3]

Postel suggests a range of solutions to water problems which draw both on traditional systems and modern technology. Water harvesting and small-scale irrigation are low-tech solutions; efficient modern micro-irrigation is more expensive, but effective in water-short developed areas like Israel. Here also economics plays a crucial role: only with proper water pricing can incentives for efficient use be created. A range of vested interests militate against effective water policies -- large users insist on maintaining subsidies, government bureaucracies respond to public pressure for big new projects and cheap, or free, water. Local communities may be well placed to implement effective water management, but need both technical and institutional support. Much of the current institutional and economic infrastructure is oriented in the wrong direction, towards centralized control and supply augmentation. Technological and economic solutions are at hand, but are held back by political constraints.

CONCLUSION

While the scope of the problems associated with damage to natural resource systems is staggering, the possibilities for sustainability-oriented policies is also great. The first principle must be the recognition of ecological limits. As we saw in Part I, a shift is needed from viewing natural resources as inputs to economic production towards adapting economic production to ecological realities. In the analysis of the management of natural systems, a key issue is broadening the scope of analysis from demand, supply, and production to the management of ocean and forest ecosystems, watersheds, and other biomes.

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Many useful technological applications and economic incentive systems can be brought to bear within such a framework. Without appropriate institutional control and direction, however, the logic of the market tends to select destructive technologies and create incentives for more rapid exploitation. In all cases, the scope of the problems has grown steadily during the last fifty years. This implies that significant institutional and attitudinal changes will be required to reverse course in the twenty-first century toward reclamation of damaged resource systems.

Notes

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1. A case of triply-resistant weeds has already been reported in Canada as a result of the planting of genetically engineered weedkiller-resistant canola.
2. For an in-depth treatment of biodiversity and an assessment of current losses and future threats to biodiversity, see E.O. Wilson, 1988 and 1992.
3. For a comprehensive overview of the state of the world's water resources, see Gleick, 1998.

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