CARIBBEAN FOOD CROPS SOCIETY

30

THIRTIETH ANNUAL MEETING 1994

ST. THOMAS, U.S.V.I.

Vol. XXX

AGRICULTURE AND THE ENVIRONMENT

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ABSTRACT

This paper examines the evolution of agriculture and its relationship with the environment, through the various phases of its development. It traces man's food- gathering and food-producing activities through various phases of cultural advancement, up to the present time, identifying their impacts on the environment. In each phase of advancement the paper examines the influence of population growth, and science and technology on the evolution of agricultural practice. With the aid of science agriculture has become quite efficient, but still is not without some negative repercussions to the environment (Carson, 1962). For the future, agriculture has to become even more efficient, given projected increases in population.

This expository paper notes, though, that growth in agriculture cannot be expected to increase without limits, in view of environmental constraints. Growth therefore has to mean more than just a quantitative increase. The challenge then, is to fashion a meaning of growth consistent with the limits of the natural system and, for food production systems to meet the needs of burgeoning populations in a manner which will not excessively degrade the ecology which supports them. To meet this challenge, the paper identifies changes we need to make: in the way we apply science to solve problems in agriculture, in our approach to policy formulation and, in the way we organize institutional response to meet future challenges.

INTRODUCTION

Social scientists have long been intrigued by man's engagement with nature. Indeed, continuing research has shown that modern man is as much driven now by his need to triumph over the elements as was his historic counterpart centuries ago. Today, even while man waits at the equinox of a new millennium, his struggle for survival is still dependent on that aged relationship between himself and nature.

This paper discusses how man's agricultural practices throughout history have caused or precipitated certain negative environmental changes. Further, this paper suggests that these negative results of man's use of nature may be short-circuited and minimized through a process of cultural adaptation.

Through such a process, the careful and beneficial use of science and technology may be encouraged toward extracting the resources our natural systems provide, without harming the systems themselves.

The environment is a matrix of ecosystems supporting life. Each ecosystem is a self-regulating, self-sustaining community of plants and animals locked into relationships with each other and the surrounding elements. This set of interconnected and interacting units of living and non-living things produce the goods and services on which man depends.

From the earliest of times man depended on the environment for food and shelter. This relationship between man and nature evolved through a number of distinct stages. Each stage of the relationships had a feature which distinguished its impact on the environment.

Miller (1975) identifies five phases of cultural evolution and their repercussions on the environment. The five stages are:

- early hunter-gatherer;

- advanced hunter-gatherer;
- shepherd and farmer;
- industrial man;
- earthmanship man.

Conceptually, his impact on the environment at each stage may be summarized as follows:

Early hunter-gatherers and advanced hunter-gatherers are viewed as man in nature. Their relationship with nature was non-manipulative, any negative impact on the environment was relatively benign and the rate of recovery of the environment was quite swift.

Shepherd, farmer, and industrial man are viewed as man versus nature. Rudimentary attempts at manipulation by people in these groups can impact on nature quite severely. The damage can persist over a long period of time and the rate of recovery is often slow.

Man is said to be in a state of earthmanship when he is living within the limits of natural systems. Earthmanship allows man to develop an awareness of the limitations he has in respect to controlling nature. Earthmanship allows man to cooperate intelligently with nature. In this phase, Darwin's proposition - "survival of the fittest" - takes on added meaning. In this advanced relationship with nature man interprets Darwin's maxim to mean the "survival of those species most capable of adapting to variations in nature." In its original context, "survival of the fittest" meant survival of the strongest.

The relationships between man and nature described above can be looked at in terms of a gradient - from passive dependency, through aggressive manipulation, to intelligent cooperation. Man in nature, as early hunter-gatherer, took from nature whatever was available in the ecosystem in which he existed at the time. In this relationship with nature, man reaped from the bountiful harvest of nature. He did not produce any of the food he consumed: His role was one of passive dependency. Notably, most of mankind who have inhabited the earth have been hunter-gatherers; only a very small number have lived by agriculture (Lee and DeVore, 1968).

Miller (1975) observes that for most of man's sojourn on earth he was a hunter gatherer. Because of recent cultural shifts, today, less than one percent of mankind is involved in hunting and gathering food. In this phase of the cultural evolution man was entirely dependent on nature. He survived by learning to live within the limits prescribed by nature. During this phase the supply of food determined the size of the population, any increase in population size beyond the tolerance limits is swiftly adjusted by nature. In this situation man learned to respond to nature rather than attempt to control it. Any impacts from this human manipulation were therefore quite mild and within the capacity of nature to remedy.

As advanced hunter-gatherer, man developed more sophisticated tools. He learned to use fire, and through language he was able to pass on his experience to his offspring. Man learned to use fire to clear land and hunt large numbers of animals. Through specialization, he was able to increase his food supply significantly. All this led to him exerting much more pressure on the environment. Martin and Wright (1967) believed that the extinction of some of the larger game animals during the ice age could be attributed to the actions of advanced hunter-gatherers. Man, the advanced hunter-gatherer, altered the vegetative cover of the land by his use of fire.

His experience with the use of fire probably taught him that the vegetative cover that sprang up after burning land provided rather palatable grazing for the animals he hunted. Saurer (1952) and Stewart (1956) believed that repeated burning created the world's savannahs and grasslands. Man had begun to alter the environment in perceptible ways but because of his small numbers, the impact of his actions remained insignificant. Even at this stage man did not develop the capacity to manipulate the environment; he was not a food producer.

As man evolved from advanced hunter-gatherer to shepherd and farmer, his negative impact on the environment peaked. This period of cultural evolution began about ten thousand to twelve thousand years ago (Miller, 1975). The significant development during this period is that man became a food producer by domesticating plants and animals. That is, he was engaged in the deliberate cultivation of selected plants and the rearing of selected animals. In this phase, man became innovative in his use of existing tools. He became adept at using fire to clear land, using the digging stick as a hoe. Clearing by fire converted forests to savannahs and grasslands. Man used his domesticated animals to graze these grasslands. Grazing, in its turn, resulted in erosion. This pattern of overgrazing was repeated again and again and resulted in the destruction of vast areas of the Mediterranean and Middle East.

It was during this phase of animal rearing and grazing that horticulture (hoe-culture) developed. Man started growing some of his favorite plants as food by digging a hole with his digging stick, and inserting roots and tubers into the ground.

Other innovations during this period included slash and burn horticulture. The ash produced from the burnt vegetation enriched the soil, but the fertility was temporary as torrential rains would leach the soil and wash away the nutrients during rainy seasons. The cycle of burning and leaching would eventually render the cleared plot infertile. To produce food to support the population a new plot of land must be cleared; the cycle is therefore repeated. This method of production persists up to today in many developing countries and is one of the chief means by which the environment is degraded. In many countries there is significant loss of forest cover from slash and burn agriculture. This land degradation has devastating effects on the environment. In Jamaica, for example, it is estimated that loss of natural forest cover is occurring at a rate of five percent per year.

Soon after learning vegeculture, that is the growing of tubers and other plant parts (National Research Council, 1982), man began to plant seed crops, such as barley and wheat. It is believed that cultivation of seed crops began in the Middle East in the area of Mesopotamia (Miller, 1975). Most of the crops like wheat, barley, corn, peas, lentils and potatoes that we cultivate today were being cultivated by man in his role of shepherd and farmer three thousand years ago.

True agriculture began when man invented the plough. Initially, power was supplied by draught animals and then by the tractor. It is here that man became an advanced food producer. With his growing knowledge of food production, he was able to provide a constant supply of food. More importantly, he was able to provide a surplus on a regular basis. This surplus production had three effects:

1. The population increased dramatically;

2. Man cleared vast areas of land and started to grow single crops over large acreage. This marked the advent of monoculture which is characteris of modern agriculture

3. The pattern of dwelling in villages, towns and eventually cities which we refer to as urbanization, became a characteristic of agricultural society. Another distinctive feature was the advent of specialties other than farming. The surplus of food enabled the movement of people out of food production into other areas of endeavor. Urbanization and specialization, ushered in what is now referred to as modern civilization. Man's impact on the environment became severe.

As more and more land was taken up for growing food and rearing animals, deforestation and its resulting erosion caused the silting up of rivers and irrigation canals. This caused a lowering of the water table and the loss of agricultural productivity. It is reported that deforestation accounted for the silting up of the Tigris and Euphrates rivers and the elaborate Babylonian irrigation canals. Saggs (1962) attributes the downfall of the Babylonian empire to the canals' damage and the concomitant losses in agricultural production. Other degrading effects caused by the rising popularity of agriculture include desertification and the extinction of plant and animal species due to the destruction of habitats.

Irrigation without proper drainage and over-pumping led to the build up of salts in topsoil. The build-up later caused a lowering of productivity levels. As the population grew, the clearing of more forests to free up land for food production became necessary. The land clearing resulted in erosion, as well as the pollution of streams, rivers and lakes. Clearing these forests also increased the insect and pest population.

The advent of agriculture marked a radical shift in man's relationship with nature. He began to manipulate the environment to satisfy his needs. This is in contrast to man as hunter-gatherer who chose to live in harmony with the environment. Through progressive cultural adaptations man became increasingly adept at manipulating the environment. He learned to use tools for hunting and gathering food, learned to live in a hostile environment by developing means of efficient social organization and cooperation, and he used language to convey the knowledge he was acquiring from his experiences (Miller 1975). As the cultural evolution progressed, man became even more adept at manipulating the environment as he learned to apply scientific principles to his food producing activities. From studying this phenomenon of cultural evolution, one can say that modern agriculture is the product of progressive cultural adaptation, with particular strong influence from science and technology.

The development of modern agriculture can be traced through three phases:

1. The Industrial Mechanical Phase:
   Here the application of mechanical power enabled man to transform large acres of forest and grass land into cultivated land. This led to massive conversion of forests and natural grasslands into monocultured fields of crops which in turn resin habitat loss, soil erosion and the emergence of insect and plant disease as important threats to crop culture.

2. Chemical Industrial Phase:
   Here, man through the application of science developed fertilizers, weedicides, insecti cides and growth regulating substances was able to produce more per unit of input. The insecticides and weedicides were required to protect the expansive fields of monocultured crops from fierce competition from insects and weeds. When there is innovation in the application of fertilizer, insecticide, weedicides, plant breeding and irrigation technologies--which result in increased production over large areas--it is referred to as "green revolution" (Miller, 1975). There have been four major green revolutions:

i. During AD 1500 to AD 1800 when the major crops - wheat, rice, maize and potato - were spread throughout the world.
ii. 1850 to 1950 - the period saw intensive application of scientific principles to crop and animal production. This occurred in North America and Europe.
iii. Post World War II innovations in plant and animal breeding which produced varieties which were more resistant to disease and insects.
iv. This particular episode of the green revolution, which occurred in developing countries in recent times, was widely heralded. Really, it only entailed the adoption of the scientific principles of the second and third green revolutions by developing coun tries. The main effect was to introduce high yielding varieties of rice, maize and wheat into developing countries. In this phase of agricultural evolution. man's manipulation of the environment rose to new levels. Even though agricultural production was significantly increased and Malthusian's starvation long predicted was averted, there were serious environmental impacts.

The seminal work of Carson, (1962) awakened us to the dangers of man's excessive manipulation of the environment through the application of science to agricultural production. There are many arguments that the gains made were probably neutralized by the adverse impacts produced by the use of the technologies developed in this era. Some of the significant impacts include the magnification of insecticides in the food chain, and alteration of the structure of ecosystems as a result of insecticide use, which killed targeted insect pests as well as others of the non-target insect population. Another important impact was the pollution of rivers and lakes and underground water systems from leached insecticides and fertilizers. This situation posed a serious health threat as food was often contaminated by chemical residues. Another impact was the loss of bio-diversity which was the basis for improvement in animal and crop production through breeding, and the threat of monoculture to genetic diversity among cultivated plants.

3. Biotechnology Information Phase:
   In this phase the innovative application of genetic engineering and computer technology promises to revolutionize agricultural production. There are risks associated with the application of biotechnologies to agriculture. Their impact seems to be uncertain at this time.

Some writers though have been pointing out the positive effects of genetic engineering (Wagner 1986, Peterson and Swinton, 1992). It is felt that new plant and animal varieties will cut production cost, cut processing cost while adding desirable marketing qualities. A reduction in production costs will lead to the conservation of resources. Additionally, insect and disease-resistant plants may lead to less use of pesticides, thus reducing the environmental threat from these chemicals. It is also envisioned that new varieties will be more efficient in their use of fertilizers: another positive for the environment since using less fertilizer will reduce the threat of contamination to steams, lakes and underground water systems. On the other hand, the information age ushered in by advances in computer technology will promote ecosystem based farm management. Computer models will facilitate agro-ecosystem analysis and forecasting of changes within and among ecosystems. The obvious challenge in the application of genetic engineering technologies is to protect the environment from the ill effects of engineered genotypes. It is hard to imagine having technological advancement without risk, so the key to successful use of these technologies (with the minimum danger to the environment) is being able to assess the nature and degree of risk associated with them. In fact, systems to reduce and manage risk must be developed. The application of computer technologies should provide avenues to accomplish reasonable risk analysis and management.

It is clear that the evolution of agriculture or man's food gathering activity and food producing activity from the early phase of hunter gatherer up to modern agriculture has traced a path of increasing intervention by man with concomitant increase in the severity of negative impacts.

In spite of these negative impacts, man was able to increase agricultural productivity dramatically, thus making food available to an increasing number of people. In other words, food production has managed to keep apace with population increase. There are predictions for further population growth, especially in developing countries. Mann (1994) reports that the world's population is likely to increase between 10 and 12 billion by the year 2100. To meet the food needs of this projected increase in population, there has to be further increase in agricultural productivity globally.

Can improvements in agricultural productivity without negative environmental impacts be expected? Many believe the answer to this question is "No." Mann (1992) refers to an analysis by Ehrlich which points out that mankind has already used or destroyed fifty percent of the potential output from terrestrial photosynthesis and if the world's population doubles, this would put mankind in severe competition with insects over the last scraps of grass. But, there are others who think that technological improvements will lead to even more advancements that will ultimately meet the future needs of a growing population.

In support of the latter view, it is noted, however, that not only did farmers keep pace with food production, but per capita food production on a global scale rose more than ten percent over the period 1968 to 1990 and the number of chronically malnourished people fell by more than 16 percent (Mann, 1994). Still, there is need to assess the environmental impact of this growth in food production.

Thermodynamically, growth without limit is not possible (National Research Council, 1992; Miller, 1975; and National Round Table on the Environment and Economy, 1992). The ecosystems of the earth produce a finite amount of goods and services, that is these systems are in a steady state of equilibrium. This fact limits the quantity of goods and services which man can extract through manipulation of these natural systems.

Furthermore, the second law of thermodynamics tells us that as man attempts to create greater order by applying advanced technologies to increase agricultural production one result will be a net increase in disorder of the system and its environment taken as a whole. For example, breeding more productive plants and animals will require greater protection from disease and insects, as well as the more intensive use of insecticides and fertilizers which increases the potential for pollution: the entire process resulting in net disorder.

The first law of thermodynamics states that energy can neither be created nor destroyed. This implies that within the ecosphere there is a fixed amount of energy available to drive natural or manmade systems. It is clear then that these two laws taken together put a cap on the productivity of natural systems.

Development then, as used in the phrase "sustainable development," cannot mean unlimited quantitative increase in food production. In other words, development in this context cannot be synonymous with growth because nothing in nature grows limitlessly. Sustainable agricultural development means improving the capacity of mankind to convert a constant supply of resources to the increased satisfaction of human needs. Development as a concept, therefore, should be expanded to include differentiation, qualitative improvements and synergistic effects.

The challenge then for agriculture is to identify opportunities where the principles of an amplified concept of development can be applied to provide adequate food at reasonable cost for the world's population without irreversibly degrading the natural systems on which it depends. No single strategy will enable mankind to meet this challenge. Technology by itself (as some believe) will not resolve the problem, neither will population control.

A more robust perspective of development must be applied across the board, and to a large number of strategies which include scientific and technological approaches, population control, institutional innovation, and cultural adaptation.

The problem of agricultural development in the context of finite resources is concerned with the reconciliation of primary issues:

(1) limits imposed by the natural system and/or the ecological ceiling, above which the ecosphere cannot support life, and

(2) the efforts of humans to satisfy their need for food and fibre from the resources and services provided by the system.

The first is quite rigid. We are unable to amend the laws of thermodynamics which prescribe the outer limits of its boundary. The ceiling imposed by the natural system is not subjected to alterations through manipulation by mankind. However, the second factor is quite malleable and is subjected to manipulation. Really, the best hope of achieving sustainable agricultural growth is to make a concerted effort to change the way in which man relates to the environment. It could be said that we need to undergo a cultural revolution.

Culture, here, refers to an accepted set of beliefs, values and particular ways of doing things which have evolved over several years and have proved to be useful in promoting the success of human endeavours. Such a revolution would entail adopting innovative approaches to creating and operating the institutions through which we respond to and interact with the environment. The fairly stable and integrated set of roles and streams of processes (institutions) which we employ to produce the wide variety of goods and services should be designed as flat, fluid and flexible, but, allowing the performance of job tasks. There should be adequate process capacity to handle large volumes of information, resolve conflict, conserve human resource, encourage enquiry and independent thought. The institutions through which we will act to respond to environmental imperatives should emphasize the importance of structure in determining the character of the institutional processes and behavior.

The second aspect of the cultural revolution should address changes in the way we apply the scientific method to solve problems in agriculture. Because of the large volume of information that science ordinarily deals with, knowledge is compartmentalized into disciplines.

Each discipline, develops its own traditional ground rules and approaches to problem-solving; thus producing a fragmented approach to the process of finding solutions. But problem-solving would likely be more effectively achieved if there was a way to integrate the disciplines with certain pervasive problems. Even within disciplines, there isn't a coherent approach to selecting the types of problems to be solved. This tradition of categorization and fragmentation deprives science of the benefits of synergy.

The artificial system set up to categorize knowledge may have influenced the actual application of the scientific method whereby a problem is reduced to its simplest form in search of a solution. After formulation of the solution, the complexity of the phenomenon is usually not reconstructed in order to restore linkages, this usually results in loss of fidelity and failure to identify significant interactions. If, in the application of science it was possible to apply problem solving techniques without over-simplifying the phenomenon under study, we might be able to formulate solutions which would have taken into account the external linkages originally characteristic of a complex phenomenon.

Ecosystems - with their interconnections and interactions - are truly complex phenomena. If these interactions and interconnections are broken to simplify the system (to make it amenable to analysis), then the system loses its fidelity, so what is studied or analyzed is not really the system. The situation is made even more unrealistic since no attempt is made to re-establish connections after a solution is proposed. So, knowledge gained is usually inadequate and not sufficiently general to hold over varied conditions and settings.

For agriculture to develop sustainably, a scientific method will have to be defined to take into account the complex nature of ecosystems and make adjustments to study them with their interconnections in place as much as is possible. This will require a re-orientation of our thinking. That is, we have to become system thinkers, applying what Peter Senge calls "the fifth discipline." (Senge, 1994).

This paper suggests that cultural adaptation, as here described, is a faster way to adapt. It is much quicker than the biological way of the double helix of genetic material. Palmer (Dialogue No. 4, 34, 1992) suggests that cultural adaptation is much quicker than genetic adaptation.

The challenge that man has today is to satisfy human needs from the resources that natural systems provide, and still put these life-supporting systems at minimum risk. Given this challenge, development in agriculture must look to exciting and innovative ways of using the instruments of our culture--namely science, technology, methods of cooperating and organizing--to communicate with nature.

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