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Impact of Agricultural Practices on Environmental Sustainability in Korea

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Summary

Over the last 30 years, agricultural practices in Korea have changed from the traditional (manual labor-dependent) to modern system that depends on high levels of chemicals and energy use, in the pursuit of increased productivity. Agricultural modernization has produced benefits in food production and some improvement in resource conservation, though having driven out people engaged in agriculture. External inputs of machines, fossil fuels, pesticides and fertilizers have displaced farm workers and, as a consequence, more and more people have migrated to cities in search of jobs.

Environmental and health impacts are growing despite all efforts to reduce them. A largely hidden cost of modern agriculture is the fossil fuel that is used to keep outputs high. Modern agriculture has substituted external energy sources for locally available ones. A shift to high input farming systems could have an impact on the process of global warming (3-10 MJ/kg cereal produced under high input system vs 0.5-1 MJ under low input system), air pollution and depletion of world fossil fuel resources.

Pesticides have caused problems by inducing resistance in pests and damaging

the health of farmers, farm workers and consumers. According to the latest estimates from the WHO, a minimum of 3 million and perhaps as many as 25 million agricultural workers are poisoned each year, with perhaps 20,000 deaths, worldwide.

Despite the fact that indigenous systems of soil and water conservation are widespread, well adapted to local conditions, persist for long periods and are capable of supporting dense populations, soil erosion continues and the biological productivity of soils diminishes. Although it is difficult to calculate the precise costs resulting from agriculture, agriculture is widely considered to play a significant role in environmental degradation, particularly water contamination and soil erosion, mainly due to excessive or improper application of chemicals to crop lands, and also due improper animal waste treatments and overgrazing. It is important to set up comprehensive soil conservation programs in order to maintain or enhance the fertility, water-holding capacity and aeration of soil through alternative or sustainable agricultural practices. These practices may include crop rotation, conservation tillage, substitution of more organic fertilizer for chemicals, and use of integrated pest management.

Biodiversity has been reduced under modern agriculture. Farmers of traditional and low input agricultural systems have long favored diversity on the farm, but, recently, field monocropped to single species and varieties have become common. Scientists have developed new high yielding or high quality varieties, which has almost always displaced traditional varieties and breeds. According to the literature, during the 20th century, some 75% of genetic diversity of agricultural crops has been lost all the world over. Only about 150 plant species are now cultivated, of which just 3 supply almost 60% of calories derived from plants.

Sustainability of both agriculture and environment is to be a determining factor in choosing an agriculture practice and long-term effects of the practice on the balance between economic profitability and environmental impact must be considered. Agricultural policies should include the flexibility to adopt alternative production systems. Also more information and specific policies adaptable to local environmental and social conditions are needed to encourage farmers and local people to choose appropriate practices that create economic incentives and warrant sustainable environments.

Introduction

During the preparation of this manuscript, I realized there is so much to learn and to do to improve the quality of environments as well as lives of humankind. We, farmers, agriculture-related workers and researchers, and policy makers are concerned about the future directions of agriculture and supply of enough foods for increasing world population. Without balancing these two, conservation of environments may look sumptuous and environmental hazards may become beyond control. We see many conflicting environmental issues between the wealthy and the poor, and between developed and developing countries. Also competitions in the price of agricultural products among farmers and among countries add problems to easing environmental constraints under the present World Trade Organization systems.

Pretty well described the impact of agriculture on environments and suggested solutions to the problems in his enlightening book "Sustaining Agriculture" (Pretty, 1995), which many ideas and views on the sustainable agriculture and environments appearing in this paper have also been derived from.

Possible imppacts:

1. Contamination of water by pesticides, nitrates, soil and livestock wastes, causing harm to wildlife, disruption of ecosystems and possible health problems in drinking water.
2. Contamination of food and feed by residues of pesticides, nitrates and antibiotics.
3. Damage to farm and natural resources by pesticides, causing harm to farm workers and public, disruption of ecosystem and harm to wildlife.
4. Contamination of the atmosphere by ammonia, nitrous oxide, methane and products of burning, which play a role in ozone depletion, global warming and atmospheric pollution.
5. Overuse of natural resources, causing depletion of ground water and loss of wild foods and habitats, and of their capacity to absorb wastes, causing waterlogging and increased salinity.
6. The tendency in agriculture to standardize and specialize by focussing on modern varieties, causing the displacement of traditional varieties and breeds.
7. New health hazards for workers on the agrochemical and food processing industries.

Possible solutions:

1. More thorough incorporation of natural processes such as nutrient cycling, nitrogen fixation and pest-predator relationships into agricultural production processes.
2. Reduction in the use of those off-farm, external and non-renewable inputs with the greatest potential to damage the environment or harm the health of farmers and consumers, and a more targeted use of the remaining inputs used with a view to minimize variable costs.
3. More equitable access to productive resources and opportunities, and progress towards more socially just forms of agriculture.
4. Greater use of the biological and genetic potential of plant and animal species.
5. Greater use of local knowledge and practices, including innovative approaches not yet fully understood by scientists or widely adopted by farmers.
6. Increase in self-reliance among farmers and rural people.
7. Improvement in the match between cropping patterns and the productive potential and environmental constraints of climate and landscape to ensure long-term sustainability of current production levels.
8. Profitable and efficient production with an emphasis on integrated farm management, and the conservation of soil, water, energy and other biological resources.

Until the 1970's, most farms in Korea were mixed crop-livestock operations. Farmers produced grains (mainly rice) and used by-products and some forages to feed their farm animals. Soil productivity was maintained by crop rotations including nitrogen-fixing legumes, return of crop residues and animal manure to the land. Few pesticides were used. Weeds, insects and plant diseases were controlled mainly through crop rotations, mechanical cultivation and biological means, such as natural predators.

Over the last 30 years, with the economical growth (from $252 /capita in 1970 to about $10,000 in 1997), agriculture in Korea has changed gradually from traditional (manual labor-dependent) to modern practices that depend on high levels of chemicals and energy use, and its production levels has increased accordingly (Table 1). For example, chemical fertilizer use increased from about 70,000 tons in 1951 to almost 1,000,000 tons in 1990 and pesticide use from 770 tons to 25,000 tons during the same period.

Modern practices may be defined as "capital-intensive, large scale, highly mechanized agriculture with extensive use of chemical fertilizers, herbicides and pesticides, and also with intensive animal husbandry (Knorr and Watkins, 1984). The improvements through modern agricultural practices look so remarkable that it is easy to be tempted to forget: "What is the cost of this improvement?" "Who benefits and who loses out?" Many would argue that the ends surely justify any reasonable means (Pretty, 1995).

The agriculture production enhanced by high input packages has brought

Table 1. Trend in agricultural production since 1951 in Korea

Item	1951	1960	1970	1982	1990	1998
Farm households	2,183,930	2,349,506	2,487,646	1,995,769	1,767,034	1,413,017
Farm population	12,778,550	14,559,271	14,431,914	9,688,222	6,660,891	4,399,643
Cultivated Land area (ha)						
- Total	1,958,236	2,041,668	2,131,527	2,180,084	2,108,812	1,910,081
- Paddy	1,159,224	1,216,298	1,205,023	1,311,512	1,345,280	1,157,306
- Upland	779,011	825,370	926,504	868,572	763,532	752,775
Consumption of chemical fertilizer (M/T)						
- Total	69,927	136,827	562,902	617,205	997,912	860,327
- Nitrogen	50,404	87,653	355,550	311,568	523,469	447,286
- Phosphorus	19,523	42,784	124,354	148,941	222,880	187,064
- Potassium	-	6,390	82,998	156,696	251,563	225,977
Consumption of pesticides (M/T)						
- Total	770	5,845	25,023	116,640	25,082	22,103
- Fungicides		3,452	11,057	19,844	7,778	6,543
- Insecticides		2,372	8,863	50,944	9,332	8,765
- Herbicides		9	4,957	43,133	5,509	5,116
- Others		11	144	2,719	2,463	1,679
Rice production (milled, M/T)						
- Total	1,815,880	2,551,915	3,939,260	5,175,073	5,605,979	5,096,879
- Per 10a	156	209	325	394	416	440
No. of livestock (head)						
- Cattle	572,642	1,011,757	1,027,348	1,753,892	2,093,014	2,922,046
- Pigs	335,286	1,397,139	990,973	2,183,159	4,395,094	7,543,777
- Chickens	1,394,668	12,030,411	1,199,378	46,591,640	76,636,557	85,847,387
- Horses	17,979	19,917	10,278	3,092	4,937	8,470

Adapted from Korean Ministry of Agriculture, Forestry and (Fisheries).

great benefits to many people. But in order to assess the true net benefits of high input packages, it is important also to understand some of the external costs: soil erosion, water contamination, loss of genetic diversity, cost-price squeeze and decay of rural communities (Schaller, 1991). Although public awareness of environmental problems has increased in Korea in recent years, we do not have many data on long-term effects of agricultural practices on environments. However, the problems of Korea are not expected to be much different from those experienced by other countries. Therefore, I will discuss the problems in general and also specific to Korea in this paper on the basis of published literature.

Social and environmental costs

The social and environmental costs of agricultural modernization have been increasingly recognized. Modernization in rural environment has been characterized by alienation and conflict increased individualism and a breakdown of communities. Jobs have been lost, environments polluted, communities broken up and people's health damaged (Pretty 1995). External inputs of machines, fossil fuels, pesticides and fertilizers have displaced farm and, as a consequence, more people have migrated to cities in search of work. Farm population (per total) has drastically decreased from 37.5% in 1971 to 9% in 1998 (Table 1).

Farms have become simplified and some resources, once valued on the farm, have become wastes to be disposed off the farm. Some external inputs are lost to the environment, so contaminating water, soil and atmosphere. Agriculture has become more fossil-fuel intensive, so contributing to global warming. Overuse or continued use of some pesticides causes pest resistance, and leads to pest resurgence, encouraging farmers to apply yet more pesticides.

The environmental problems caused by farming are a direct result of an increasingly intensive and specialized agriculture. The mixed farm can be an almost closed system, generating few external impacts. Crop residues are fed to livestock or incorporated in the soil; manure is returned to the farmland in amounts that can be tolerated; legumes fix nitrogen; trees and hedges bind the soil, and provide valuable feeds, fuel wood and habitats for predators of pests. In this way the components of the farm are complementary in their functions. There is little distinction between products and by-products in the traditional farming. Both flow from one component to another, only passing off the farm when the household decides that their produces should be marketed.

Increased use of chemicals in agriculture has caused consumers to worry about food safety. As a result, support is growing among both farmers and consumers for alternative agriculture or organic farming systems. Systems of agriculture that will continue indefinitely to be productive and profitable, conserve resources, protect the environment, and enhance the health and safety of the people, are desirable. An ideal system that accomplishes these goals is widely referred to as "Sustainable Agriculture (SA)" (Schaller, 1991), although the term SA is not a simple model or package, but more of a process of learning.

With modernization, many highly integrated farms have disappeared. Farms have become more specialized with crop and livestock enterprises separated. Intensification of agriculture has meant greater use of inputs of pesticides, fertilizers and water, and a tendency to specialize operations. The inputs are not entirely efficiently used by the receiving crops or livestock and, as a result, some are lost to the environment. Some 30-80% of applied nitrogen and significant but smaller amounts of applied pesticides are lost to the environment (Table 3) to contaminate water, foods and feeds and atmosphere (Conway and Pretty, 1991). Eroded soil also disrupts water flow, and runoff from eroded land causes flooding and damage to housing, irrigation systems and natural resources (Conway and Pretty, 1991).

Table 2. Heavy metal contents in the soil (mg/kg)

Metal	Cd	Cu	Pb	Zn
Paddy field				
Average	0.133	4.52	4.62	3.90
Range	ND-0.90	ND-60.8	ND-18.27	ND-43.03
Dry land				
Average	0.135	2.77	3.47	10.7
Range	ND-0.660	0.07-78.24	ND-43.0	0.3-65.1
Green house (use high level of pig and chicken manure)				
Average	0.298	3.69	2.49	23.4
Range	0.027-0.605	0.18-31.4	0.02-33.5	2.1-113.2

Contents in 0.1 N HCl-soluble form adapted from RDA (Rural Development Administration) of Korea.

Table 3. Pesticide residues in paddy field soil

Name	Detected frequency (%)	Conc (mg/kg)
Bactericides		
Hexaconazole	11.8	0.008-0.637
Iprobenfos	17.1	0.004-0.698
Oxadixyl	1.0	0.044-0063
Pencycuron	1.0	0.013-0.023
Tricyclazole	1.0	0.053-0.068
Insecticides		
Chlorpyrifos	2.7	0.005-0.134
Chlorpyrifos-methyl	0.5	0.004
Carbosulfan	0.5	0.024
Diazinon	12.3	0.003-0.045
Fenitrothion	1.0	0.059-0.066
Isofenphos	3.7	0.003-0.051
Isoprocarb	2.7	0.011-0.184
Primiphos-methyl	2.1	0.006-0.251
Herbicides		
Butachlor	4.8	0.023-0.153
Chlometoxyfen	0.5	0.069
Dimepiperate	1.0	0.015-0.033
Dimethametryn	1.0	0.011-0.014
Molinate	3.2	0.023-0.070
Oxadiazone	11.8	0.026-0.325
Pendimethalin	2.1	0.057-0.637
Piperophos	1.0	0.009-0.019
Propanil	0.5	0.049
Simetryne	2.1	0.003-0.047
Thiobencarb	7.5	0.014-0.165

Adapted from RDA of Korea (determined in 1995)

Various pollutants also harm farm and local natural resources. Pesticides damage predator populations and other wildlife and induce resistance in target pests. Nitrates from fertilizers and ammonia from livestock wastes disrupt nutrient-poor wild plant communities. Minerals from livestock wastes raise mineral contents of soils, especially copper and zinc (Table 2), and pathogens in wastes can harm human and livestock health. The atmosphere is contaminated by ammonia originating from manure and soil and exhaustion from farm machinery, which play a role in acid rain production; by nitrous oxide derived from fertilizers, which plays a role in ozone layer depletion and global warming; and by methane from livestock and paddy fields, which also affects global warming.

A large hidden cost of modern agriculture is the fossil fuel. Modern agriculture has tended to substitute external energy sources for locally available ones. With the increasing use of nitrogen fertilizers, pumped irrigation and mechanical power, which are all particularly energy-extensive, agriculture has become progressively less energy efficient. These three account for more than 90% of the total direct and indirect energy inputs to farming in Third World countries (Leach, 1985). Mechanization reduces the labor required for agriculture and so cut variable costs if energy is cheap, as it is in most industrialized countries. But for poorer countries, mechanization forces increased foreign exchange expenditure on fuel, oil, engines and spare parts.

One consequence of this increased substitution of energy for labor in agriculture is a growing contribution to global warming. Agriculture is a major direct source of atmospheric pollution, emitting methane, nitrous oxide, ammonia and the various products of biomass burning (IPCC, 1990). The single main cause of global warming, however, is carbon dioxide, estimated to contribute about half of the projected warming over the next 50 years (Pretty, 1995). Agriculture contributes to carbon dioxide production directly through the burning of biomass and indirectly through its consumption of fossil fuel. For each kg of cereal from modernized high input conditions, 3-10 MJ of energy are consumed in its production; but for each kg of cereal from sustainable, low input farming, only 05-1 MJ are consumed. A shift to low input systems could, therefore, have an impact on process of global warming.

However, there is considerably more energy consumed between the farm and the consumer. In the USA, it is said that food travels on average 3000 km from farm to plate. In Britain, the production of 1 kg loaf of bread consumes about 20.7 MJ (equivalent of 0.48 kg of oil), of which 80% is consumed by milling, baking, transport and retailing (Leach, 1976). Making agriculture more energy-efficient, by transferring to low input sustainable processes, could only decrease the energy consumed in the remaining 20%. However, for cereals processed and consumed on the farm, or those passing through fewer processing or transport stages, significant improvements in energy efficiency could be possible following transition to a more sustainable agriculture.

Health

The consumer is most likely to be directly affected by eating food contaminated mainly by residues of pesticides, but also by nitrates and antibiotics. In the industrialized countries, the level of pesticides in foods have been falling steadily since the 1950s (Conway and Pretty, 1991; WPPR, 1994; Gartrell et al., 1986a, b). None the less, there are occasional scares over particular products and rare incidents of severe poisoning arising from the spraying of illegal products. But in Third World countries, daily intakes are often very high. These may be in cereals, in fish, in lakes and rivers, and in milk from cows affected by spray or contaminated feeds. The major hazard lies in locally marketed food. Leafy vegetables are often sprayed twice a week and may come to market with a high degree of contamination, especially in the dry season. Farmers themselves are suffering declining incomes or health effects from these modern approaches to agriculture.

There is no doubt that pesticides are hazardous. At very high dosages many are lethal both laboratory animals and people, and can cause severe illness at sublethal levels. But just how serious is the hazard from medium to low dosages is open to question (Conway and Pretty, 1991). In the 1950s, 1960s and 1970s, organochlorine insecticides were in widespread use in the industrialized countries, and high levels of exposure were common in those engaged in their manufacture, in agriculture workers and among the general public (because of the presence of residues in foods). Nevertheless, there is little evidence of serious ill-health, other than as a result of accidental exposure to high dosages. The herbicides, 2,4,5-T and 2,4-D were also commonly used in that period, and were originally thought to be a cause of miscarriages. Subsequent, more thorough, studies suggest a link with increased incidence of a certain rare cancer, non-Hodgkin's lymphoma, but not with miscarriages or other reproductive effects (Conway and Pretty, 1991). There continues to be considerable public concern over the risks arising from exposure to pesticides and herbicides, in particular through accidental spraying and spray drift, or from residues in foodstuffs.

Many environmental and health impacts have increased in recent years; others have continued to persist despite all efforts to reduce them. Water systems have become increasingly contaminated (Table 4). Nitrate in water can give rise to the condition methemoglobinemia in infants and a

Table 4. Water quality measurements (national average)

	EC	COD	NH_4-N	NO_3-N	SO_4	Cl
	DS/m	---	---	mg/L	---	---
Surface*	0.24	16.7	2.45	2.00	34.1	29.3
Ground well+	0.36	14.2	-	14.2	35.3	37.8

*Values determined in 1997.
+Values determined in 1998.
Adapted from RDA of Korea

possible cause of cancers. Pesticides contaminating can harm wildlife and exceed drinking water standards. Nitrates and phosphates from fertilizers, and organic wastes from livestock manure and silage effluents all contribute to algae growing in surface waters, deoxygenation, fish and coral deaths, and general nuisance to leisure users.

Soil and water

Farmers may not be conserving soil and water for a variety of reasons. They may lack the locally appropriate knowledge or skills, particularly if they have been resettled or migrated to new areas. They may be unwilling to invest in conservation measures if the economic costs of conservation are greater than the expected benefits, particularly if the future is uncertain, such as if political instability or conflict threatens the future, or if security of tenure is uncertain. Farmers may be short of labor for construction or maintenance, such as following a decline in population, outmigration in the face of better opportunities for income earning, particularly in urban centers, or simply rising labor costs. They may not be conserving because of the misguided efforts of earlier soil and water programs. Finally, they may be so responsive to policies encouraging increased food production that they simply ignore the costs.

To farmers, erosion reduces the biological productivity of soils and the capacity to sustain productivity into the future. Although soil erosion is clearly costly to economies as well as to farmers, it is difficult to calculate reliably the precise costs (Eaton, 1993). Off-site costs are also important. Soils are less able to retain water, which runs off more readily into waterways carrying sediments. These block downstream irrigation canals, reservoirs and harbors. Reduced volume means both greater maximum flows and so more likely floods, and reduced minimum flows in dry seasons creating drought dammage. The functional lifetime of reservoirs has declined in many countries including Korea. And natural systems, particularly fisheries and coral reefs, are threatened by sediments and agricultural and aquacultural pollutants.

Genetic diversity

Farmers of traditional and low input agricultural systems have long favored diversity on the farm. Today, there is a huge variety of mixtures cultivated, including cereals, legumes, root crops, vegetables and tree crops. In Africa, more than 80% of all cereals are intercropped, producing in some cases highly complex patterns on the ground, with up to 20 species grown in close proximity (Vandermeer, 1989). Andean farmers grow some 3000 traditional varieties of potatoes with all shapes and sizes, and a variety of colors including black, red, blue, purple, yellow and white (Rhoades, 1990).

In variable conditions, farmers rarely standardize their practices. They maintain diversity, develop a variety of strategies and so spread risk. Mixtures of crops and varieties clearly provide farmers with a range of outputs, and also represent logical approaches to coping with variable environments. Mixed crops can also be less variable in time and space, and combined yields are often greater, particularly if differences in root and shoot geometry allow the crops to use light, nutrients and water more efficiently(Vandermeer, 1989). Intercroping can reduce weed problems, so influence labor requirements; returns to labor can be increased; and erosion and run-off may be reduced by greater ground cover given by the mixture (OTA, 1988).

Recently, a field monocropped to a single species or varieties has become common. The introduction of modern varieties and breeds has almost always displaced traditional ones. During the twentieth century, some 75% of the genetic diversity of agricultural crops have been lost. Only about 150 plant species are now cultivated, of which just 3 supply almost 60% of calories derived from plants (FAO, 1993). The trend has been rapidly downwards in many countries including Korea. With these losses of genetic diversity could go future opportunities. Locally adapted crops or livestock can be critical for helping to deal with particular challenges brought by pests and diseases.

Perspectives and future directions

It is possible to manage all nutrient sources including fertilizers, organic manure, waste materials suitable for recycling, soil reserves and biological N-fixation such a way that yield is not knowingly jeopardized (a financial penalty to farmers), while every effort is made to minimize losses (a financial benefit to the farmer and to the environment). It requires the support of all those engaged in agriculture from policy makers through to farmers. It requires setting of appropriate limits for soil fertility, the ability to make good N recommendations, and to achieve both needs, additional resources for research and development. It requires a massive educational program for farmers. Not least if future food supplies are to be secured, it requires the fertilizer industry to be able to continue to supply the nutrients the farmer needs in the most appropriate and economical forms and to support the research needed to achieve these needs. However, agriculture must meet the challenges for the sake of human kind, food supplies and sustainable environments.

Despite all the problems involved in modern agricultural practices, many scientists and policy makers still argue vigorously that modern agriculture, characterized by externally developed packages of technologies that rely on externally produced inputs, is the best, and so only path for agricultural development (Pretty, 1995). Influential international institutions, such as the World Bank, the FAO, and some institutions of the Consultative Group on International Agricultural Research have long suggested that the most certain way to feed the world is by continuing the modernization of agriculture through the increased use of modern varieties of crops and breeds of livestock, fertilizer, pesticides and machinery. Remarkably, these international institutions often appear unaware at policy level of what can be achieved by a more sustainable agriculture. However, there are some signs of change, mostly limited to small groups of individuals, plus some small modifications in policy.

One of the major obstacles to widespread adoption of sustainable agriculture is the lack of readily available scientific information for farmers and how to disseminate this information about SA systems to farmers (Singh and Osawaru, 1990). Most studies have been done from the perspective of the researcher or professional conservationist rather than to looking at the decision making process from the farmer's perspective. To promote further spread of SA system for sustainable development, there is a need to better understand the farmers' viewpoint (Nowak, 1983).

It is also possible to graft new technologies to SA. Biotechnology and genetic engineering will open up new frontiers. Scientists hope that these will produce crops and animals that are more efficient converters of nutrients with better drought tolerance, and pest and disease resistance. The incorporation of nitrogen-fixing nodules into the roots of cereals has been attempted to make these crops self-sufficient in nitrogen. If such breakthroughs do occur, it will be important that ways are found to ensure their availability to poorer farmers. If they are still part of a package, or rely on hybrid seeds that must be repurchased after every replanting, then they are likely simply to encourage even greater dependency on external resources and systems, and open up gaps between and wealthy and poor farmers (Hobbelink et al., 1990). However, sustainable farming can be compatible with small and large farms and many different types of technology, especially resource-conserving technologies: 1) integrated farming (grain-livestock), 2) integrated pest management (balancing pray-predator) and 3) integrated nutrient conservation (crop rotation or mixed cultivation).

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