A Discussion on Development of Sustainable Agriculture in Korea

Young-Il Chung

Although the economic growth in Korea has increased national income drastically, environmental costs associated with it has skyrocketed as well. Water has been seriously contaminated by the industrial and mine wastes as well as by the sewage water. Water contamination directly affects not only human health but also ecological system and agriculture.

Environmental degradation is also caused by agricultural practices. Extensive tillage and improper cultivation of sloping lands cause soil erosion, which leads to surface water contamination, depletion of soil fertility and siltation in lower reaches.

Heavy dependence on chemical fertilizer and pesticide in agricultural production is another source of environmental degradation. In the short-run, the use of chemicals increases crop yields, but in the long-run, it decreases crop yields due to depletion of soil fertility. Furthermore, toxic chemicals and nitrates pollute water, which eventually threaten human health. Animal wastes also contaminate water.

Sustainable agriculture is a potential solution to reverse environmental degradation and to maintain agricultural productivity and food safety. Followings are the suggestions to develop environmentally sound sustainable agriculture.

— Investigation of current pollution level and setting environmental quality and food safety standards
— Proper management of sloping lands to control soil erosion
— Efficient use of chemical fertilizer and increase in manure application
— Introduction of integrated pest management (IPM) to reduce use of pesticides and to protect the ecological system
— Development of environmentally-sound fertilizers and pesticides
— Introduction of efficient rotation system to increase soil fertility
— Development of efficient treatment and recycling system for animal wastes
— Introduction of quality certification and marketing systems for agricultural products produced by organic or low input farming
— Development of policy measures for pollution control and improvement of environmental quality

A cooperation between decision makers, researchers and farmers are necessary to implement these suggestions and eventually to develop sustainable agriculture successfully.

It was the UN Conference on Human and Environment held at Stockholm, Sweden in 1972 that discussed the global issues on environment and natural resource for the first time. It declared that all development activities should harmonize with natural environment.

Twenty years later, in 1992, this issue was discussed in detail at the UN Conference on Environment and Development held in Rio de Janeiro, Brazil. Nations of the world gathered to discuss and debate global environment and development. Climate change, depletion of ozone, loss of bio-diversity, deforestation are major issues of the talk. Sustainable agriculture and food safety were also widely discussed for sound relationship between food production and environment.

This paper will concentrate on food safety and sustainable agriculture. In the first section, the relationship between economic growth and environment, highlighting unfavorable side of industrial development on environmental quality will be reviewed. In Section 2, external benefits of agriculture on environment will be discussed briefly. In the third section, the relationship between agricultural development and environmental problems, highlighting negative impacts of agriculture on environment and major factors of the problems, are discussed. In Section 4, a detail discussion on institutional measures for development of sustainable agriculture will be presented focusing on the case of Korea. The last section will summarize the paper.

1. ECONOMIC GROWTH AND ENVIRONMENTAL PROBLEMS

Korean economy has grown dramatically over the last three decades. The successful economic growth has been achieved primarily by the extensive development in heavy and chemical industries.

Although the economic growth has increased national income drastically, environmental costs associated with it has skyrocketed as well. Water has been seriously polluted by the industrial and mine wastes as well as by sewage. Heavy metals (such as cadmium, lead, zinc, copper, manganese, etc.), harmful chemicals and organic matters are the major contaminants of water. The contaminated water threatens human health directly and/or indirectly through polluting drinking water source and food. It also lowers water quality and destroys ecological

system.

Air pollution is another threat created in the process of industrialization. Carbon dioxides, methane and nitro oxides cause global warming, CFCs deplete ozone, and various harmful gases cause serious human diseases and environmental degradation.

Economic development is essential to increase welfare of mankind. Equally important is environmental quality. In general, the demand for environmental quality tends to vary directly with increases in per capita income, that is, environmental quality is a normal good. Indeed, considerable empirical evidence in the developed countries suggests more than this; in particular, environmental quality as a commodity tends to be income elastic, meaning that increases in per capita income induce more than proportionate increase in the demand for environmental quality. While the paucity of the data on the demand for environmental quality does not permit us to support an extension of this claim to developing countries, should this empirical observation be universally true then one conclusion is abundantly clear. Namely, there will be continuing, grass-roots pressure on the governments in the developing countries to effect higher levels of environmental quality and food safety as economic development proceeds.

2. IMPACTS OF AGRICULTURE ON ENVIRONMENT

Agriculture is influenced by environmental conditions seriously. Unfavorable climatic conditions such as drought, cold weather and typhoon significantly reduce crop yields. Agricultural production is also affected by contaminated air, water and soil. For example, substantial crop injuries occur at concentrations of sulfur dioxides and nitro oxide in air, and that various pollutants in irrigation water lead to soil acidification, yield reduction and food safety problems [Park (1995)].

Contrarily, agriculture affects environment, both positively and negatively. Let us start by exploring favorable effects of agriculture on environmental quality.

Agriculture controls flood. Surrounded by ridges with 20-25 cm height, as an example, paddy fields temporarily keep run-off when raining, and thus, reduce flood damages. Without paddy fields, a number of flood control dams should be constructed to get the same effect.

Thus, the flood control effect of paddy field can be evaluated from the depreciation and maintenance cost of the dams. The values, paddy field alone, are estimated to be 133-1,080 million dollars per year in Korea and 12-20 billion dollars per year in Japan [Oh (1995)].

Agriculture also has favorable effect of recharging groundwater. By keeping water on a wide area for relatively long hours, paddy fields recharge aquifers. The aquifers are primary sources of safe drinking water and gradually supplies water into rivers to stabilize streamflow. The estimated values of recharged water from agriculture are 700-1,200 million dollars per year in Korea, and 60-70 billion dollars per year in Japan [Oh (1995)].

Besides the impacts mentioned above, agriculture gives several other external benefits. Agriculture purifies air in the process of photosynthesis, i.e., absorbing carbon dioxides and emitting oxygen. Crops also absorb some harmful gases (such as sulfur dioxides and nitro oxide) too. Paddy fields purify water by infiltrating water into aquifers and by absorbing chemical contaminants in irrigation water. In addition, terrace farming on sloping lands prevents soil erosion and land sliding, and thus, reduces water pollution and siltation in lower reaches.

Total values of the favorable effects mentioned above are evaluated to be 4-10 billion dollars per year in Korea and 47 billion dollars per year in Japan [Oh (1995)].

3. AGRICULTURAL DEVELOPMENT AND ENVIRONMENTAL PROBLEMS

Traditional farms in most Asian countries, even in some developed countries, were mixed crop-livestock operations. Crop residues were used for animal feed, and animal wastes were used as organic fertilizer for the crop. Soil fertility was maintained by crop rotations (including nitrogen-fixing legumes) and the return of crop residues and animal wastes to the land. Pest and disease control was done mainly through crop rotations, natural pesticides, and biological means such as natural predators. This system was ecologically sound and did not degrade environment.

Recently, as agriculture became commercialized and modernized, farmers began to shift from the mixed farming to highly specialized monoculture system. Instead of natural inputs,

this system uses large amount of chemical inputs such as fertilizers, pesticides, animal health products, and plant growth regulators. The use of these chemicals not only enhanced crop yield and quality but also permitted intensive cultivation of farm lands.

While the adaption of new technologies has kept food cost relatively low, there is a growing concern about its viability in the long-term. Major problems of the input-based modern agriculture are human health risk, food safety problems, pollution of surface and ground water, soil erosion, soil acidification and loss of soil fertility, damage to ecosystem, and air pollution due to disposal of animal wastes. Several factors which induce these problems and their consequences on health and environment will be discussed below.

3.1. Excessive Use of Chemical Fertilizers

The use of chemical fertilizers in Asian countries has increased significantly for the last two decades. Between 1970 and 1990, total consumption of fertilizers doubled in Korea, Iran, and the Rep. of China. Fertilizer use per hectare of cropland has increased even faster. During the same period, application rate of fertilizer doubled in India, Malaysia and Thailand, and tripled in Korea. In 1990, total use of chemical fertilizers was 1.1 million tons in Korea, 1.4 million tons in the Rep. of China, and 2.1 million tons in Iran. The amount of fertilizers applied to one hectare of land was 400-450 kilogram in Korea, Japan and the Rep. of China, which is 4-5 times higher than the United States [Kada (1994)].

When applied to ground, some proportion of fertilizers are lost to environment through leaching and run off. The lost fertilizers contaminate groundwater (and also surface water). The rate of the loss depends upon quantity of fertilizer applied, timing of application, climate, soil characteristics, irrigation technique, depth of vadose zone, and so forth.

Although phosphorus and potassium also pollute aquifers, nitrogen, in the form of water-soluble nitrates (NO_3), is the most common and problematic contaminant comes from chemical fertilizers. Nitrate is chemically unreactive in dilute aqueous solutions, and since nitrates and soil solids are both negatively charged, nitrates are not attracted to colloid surface and move freely through soil strata along with the flow of soil water.

Ingestion of nitrates may cause methemoglobinemia, so called blue baby disease. Once ingested, nitrates are reduced to nitrites (NO_2), then interact with hemoglobin to produce methemoglobin in human blood system. Since methemoglobin can not carry oxygen to body

tissue, death may result when 60 percent or more of the hemoglobin is converted to methemoglobin. High concentration of nitrates in drinking water can be fatal to infants, especially within the first six months of life. Some adults such as pregnant women are also susceptible to methemoglobinemia. The fatality rate is reported to be eight percent [NRC (1981)]. Nitrates may also cause gastric cancer.

No research data are available for actual leaching rate of nitrogen in Korea. One study, conducted in the United States, reports that approximately 33-50 percent of the nitrogen applied is lost to surface water and groundwater sinks. If this result is applicable to Korea, 150-250 thousand tons of elemental nitrogen is to be emitted to drinking water source annually. In fact, a number of scientists agree that large proportion of aquifers in Korea are already contaminated by nitrogen.

Besides the human health risk, fertilizers also degrade environmental quality. Excessive use of chemical fertilizers may decrease soil productivity in the long-run. Chemical fertilizers lead to soil acidification, under which condition crops are impeded to uptake specific nutrients. Fertilizers also deplete soil organic matter. Under this condition, soil pore volume and beneficial soil micro-organisms are reduced, and thus, soil compaction, reduction in water holding capacity, and soil erosion are resulted.

3.2. Excessive Use of Chemical Pesticides

The use of pesticides has increased rapidly in most Asian countries. Total consumption of pesticides in 1990 was 28 thousand tons in Korea, 42 thousand tons in the Rep. of China, 50 thousand tons in Iran, and 82 thousand tons in India. The use of pesticides in these countries nearly doubled between 1970 and 1990. In Korea, the consumption has shown a 7-fold increase in the last two decades. Application rate per hectare was 13 kilograms in 1994 in Korea comprising 38 percent of insecticides, 31 percent of fungicides, 21 percent of herbicides, and 10 percent of plant growth regulators and others [MAFF (1995)].

Like fertilizers, leaching rate of pesticide is not known. Many scientists, however, believe that 30-60 percent of pesticides applied would be lost to the environment.

The consequences of lost pesticides to human health and environment are significant. Pesticides contaminate surface and ground water through run-off and leaching of toxic materials. Although regulations are promulgated to use only low toxic pesticides which

decompose within several weeks of application in Korea and many other countries, considerable amount of pesticides are detected in swallow wells. Pesticide residues are also found frequently in agricultural products, decreasing food safety and quality. Many Asian countries, including Korea, Hong Kong, the Rep. of China, Thailand, Malaysia and Japan, have reported that thousands of people are poisoned by pesticide residues in food [Kada (1994)].

In addition to the human health risks, pesticides also deteriorates environment. Sometimes, run-off of high-toxic pesticides kills fishes and living creatures in down stream. Application of pesticides often lead to development of pesticide-resistance species of insects and diseases, and kills natural predators.

3.3. Disposal of Animal Wastes

Animal wastes pollute water with nitrogen, phosphates, virus, and bacteria, and emit ammonia and methane which contribute global warming. Animal wastes also contaminate environment through attracting harmful insects and emitting bad smell. Total manure produced from animal husbandry in 1994 was 18 million tons in Korea. It is believed that 20-40 percent of the wastes are disposed to the environment without proper treatment [Ministry of Environment (1995)].

4. INSTITUTIONAL MEASURES FOR DEVELOPMENT OF SUSTAINABLE AGRICULTURE

Agricultural pollution has several characteristics different from those of other contamination sources. First, it is normally non-point-source pollution. Since, pollution can not be readily traced to particular sites or individuals, and the area vulnerable to pollution is extensive, agriculture may represent the most serious long-term environmental problems. Second, agricultural contaminants are influenced by weather conditions (especially rainfall) which are stochastic and uncontrollable factors, making it difficult to completely avoid pollution. Third, environmental degradation caused by agriculture have been traditionally addressed with voluntary programs, so that any other forms of regulation may meet with considerable political resistance from the agricultural community. Finally, agricultural

pollutants can accumulate slowly for a long time period, and thus, monitoring the pollutants is difficult and costly. Moreover, the health and safety issues of chronic exposure to the low doses of contaminants have not been resolved [Oh (1991)].

Therefore, agricultural pollution should be dealt carefully together with profound research and investigation. Many Asian countries have taken institutional measures to deal with problems confronting sustainable agriculture (SA). The Rep. of China has set a zero growth for the agricultural sector in order to address issues concerned with SA. In Iran a committee has been appointed for SA in the Ministry of Agriculture to catalyze policy changes to adopt SA practices. Nepal has given policy priority to the protection of the environment in the current Five-Year Plan. Indonesia has taken several steps to adopt integrated pest management to reduce the large use of chemicals [Country papers in Sustainable Agriculture Development in Asia (1994)].

In Korea, measures for SA are not actively implemented yet, because the government had placed emphasis on increasing quantity of agricultural products rather than quality. Recently, however, increasing awareness of pollution and food safety has created pressure for government action to reduce emissions to the environment. The followings are suggestions to develop environmentally sound sustainable agriculture in Korea.

4.1. Investigation of Pollution Level and Setting Environmental Standards

The most important and urgent task to establish SA is investigating current pollution level of environment. Agricultural products, surface and ground water, and soils must be sampled and analyzed for pesticides, nitrates, phosphates, heavy metals, and other toxic materials. The monitoring work should be continued periodically to check speed of contamination.

Setting environment quality standards is the next. Maximum contaminant level allowable for the standards should be set for each pollutant. For example, the United States has established the maximum level of nitrogen to be 10 mg per liter (10 ppm). This is equivalent to 45 mg/l as NO_3. In addition, the States has defined 5 mg N/l as the threshold for continuous monitoring. European standards of maximum nitrate level is 50 mg/l for groundwater and 11 mg/l for surface water. The level is 0.15 mg/l for phosphate [MANMF (1991)].

4.2. Introduction of Low Input Agricultural System

Farmers usually apply too much inputs to reduce risk and maximize physical yields. This

management practices were influenced by government policy which aimed to increase food production in the '60s-'80s. Since emissions of agricultural pollutants are directly affected by quantity of input applied, reduction of emission requires some modification of farm management practices.

Farmer's objective of farming is to maximize profit rather than physical yields. To maximize profit, in economic principle, marginal value product (MVP) of an input should equal marginal factor cost, i.e., unit cost of the input. Since marginal factor cost is not zero for commercial inputs, such as fertilizer and pesticide, profit maximizing input level is lower than yield maximizing one at which MVP is zero. Therefore, it is necessary for government to find the efficient level of input use through experiment and research, and then, educate farmers.

Another way of implementing the low input agriculture is best management practice (BMP). The idea behind BMPs is that if a proper amount of input is applied with appropriate timing, there will be little loss of the input in any condition. As an example, a research showed that fertilizer use can be reduced by 22 percent without a decrease in farm income, and more importantly, nitrate leaching can be reduced by 40 percent by adopting improved irrigation and fertilization practices [Oh (1991)]. To introduce BMPs, government's active programs for developing this technique and educating farmers are necessary.

Organic farming is the extreme case of the low input agriculture. Since no chemical fertilizers and synthetic crop protection agents are used, this farming practice significantly reduces environmental loadings.

Although organic farming is the best farming practice from standpoints of environment and food safety, there are several managerial problems. It requires large amount of labor and compost, resulting in high production costs. Risks are high and productivities are usually low. Consequently, government should play an active role to settle down organic farming successfully. The followings are suggestions for development of organic farming:

— Development of certification system for agricultural products grown by organic farming.
— Price discrimination of organic products from conventional products.
— Acceleration of farm mechanization and development of labor saving compost production system.
— Development of crop rotation system which maintains soil productivity and controls

weeds, insects, and diseases.

— Research on various aspects of organic farming and operation of demonstration farms.

4.3. Development of Clean Technologies

Development of fertilizers which does not (or little) degrade environment would be significantly helpful for pollution control. Three types of fertilizers are being studied: coated fertilizer, low-soluble fertilizer, and oxidization inhibited fertilizer. The first and the second types are designed to dissolve slowly in soil water, and hence, to increase fertilizer use efficiency. The third uses nitrification inhibitors so as to reduce transformation of ammonia to nitrates. Since ammonia is attracted to soil colloid surface, this type of fertilizers emits less pollutants than conventional fertilizers.

Development and use of low-toxic and/or bio-pesticides are another clean technology. These pesticides should not threaten ecological system and human health, and decompose quickly in natural conditions.

Development of animal waste treatment and purification facilities and installation of the facilities to cattle farms also reduce environmental degradation significantly. The best way of treating animal wastes developed so far is the waste-sawdust-fermentation method. This is to ferment sawdust that was spread in a feedlot, and hence mixed with animal wastes, with fermentation bacteria. Several types of bacteria have been developed for this purpose. The fermented wastes are used in organic farming and low-input farming as compost. Since, however, the costs of installing and maintaining the fermentation facilities are higher than price of the compost, financial aids of government and active extension are necessary to distribute this system.

4.4. Development of Policy Options for Controlling Pollution

There are several policy measures frequently suggested to control agricultural pollution. These include: imposing a tax on the effluent itself (Pigouvian tax); subsidizing pollution reduction activities (Pigouvian subsidy); imposing a pollution standard; establishing excise taxes on inputs which generate pollution (input tax); and regulating input uses (input standards).

The Pigouvian tax is the most preferred and economically efficient measure in theory. It requires less abatement and transaction costs than the others [Oh (1991)]. However, in

practice, it has critical problems in setting the tax rate and estimating the emission level.

The Pigouvian subsidy is as efficient as the effluent tax in controlling pollution. However, this measure also has difficulties in determining the subsidy for each farmer. In general, farmers are better off under this scheme than under the tax policy while the rest of society is worse off.

Pollution standards can also reach the optimum pollution level, but present difficulties in determining the limit, monitoring emission, and enforcement.

The input tax has appealing advantages in that it can be implemented relatively easily and measuring the emission is not necessary. However, its effectiveness is doubtful because of the inelastic nature of demand for fertilizer and pesticide. Setting the appropriate tax level is also a complex and difficult task.

Finally, an input standard can be as effective as the input tax, but setting a standard is difficult and enforcement requires much costs.

There is no perfect policy measure to control pollution caused by agriculture. All the policy alternatives discussed can, in theory, achieve efficient level of pollution. At the same time, all have problems in application. Therefore, the government must choose the most effective, least cost, and most workable policy (or combination of them) case by case.

4.5. Research, Education and Extension

Government effort on research and experiment is required to develop technologies for SA. For example, development of clean technologies and low input agricultural system can be accelerated with government aids. Research on what costs will be imposed on agriculture and its constituents to meet lower pollution standards should be conducted before regulations are promulgated to achieve such pollution level. Equally important, an active program for educating farmers and extension services are necessary to distribute the developed technologies. This requires government long-term plans since farmers are usually very slow in adapting new technologies.

5. SUMMARY

Over the last two decades, agricultural production in Asia has largely increased through

technological advances. Extensive use of agricultural chemicals, such as fertilizers, pesticides, herbicides, animal health products, and plant growth regulators, is a major cause of the advances. The use of these chemicals not only enhanced crop yield and quality but also permitted intensive cultivation of farm land.

While the adaption of new technologies has kept food cost relatively low, there are environmental and human health costs associated with the heavy dependence on chemicals. Concerns receiving increasing attention are food safety and environmental degradation caused by agricultural run-off such as fertilizers, pesticides, animal wastes, and so forth.

Nitrogen, in the form of water-soluble nitrates, is the most problematic pollutant comes from chemical fertilizers. It causes serious human diseases (such as methemoglobinemia) and environment degradation. It is believed 33-50 percent of nitrogen applied are lost to environment each year.

Pesticides also threaten human health and ecological system. It is believed that 8-15 thousand tons (active ingredient) of pesticides contaminate drinking water sources every year in Korea. Animal wastes pollute water with nitrogen, phosphates, virus and bacteria. Among annual production of 18 million tons, 20-40 percent of the wastes are disposed to environment without proper treatment.

Agricultural pollution is very difficult to control since contaminants come from diffuse sources and locations. Therefore, government active roles are necessary to establish sustainable agricultural system. The most important and urgent task is knowing current level of pollution and its increasing speed. Setting environmental standards is the next. Maximum contaminant level allowable for the standards should be determined for each pollutant.

Introducing low-input agricultural system is also important. Farmers should understand economic principle of profit maximization and know how to increase input use efficiency. Organic farming is the best farming practice from environmental standpoint. However, since profitability of the farming practice is not higher than conventional farming, some incentives are necessary to induce organic farming.

Development of environmentally sound fertilizers, low-toxic pesticides, and animal waste treatment facilities is an important task for government to do. Equally important is to develop pollution control measures. Strengths and weaknesses of each measure should be studied

before the regulations are promulgated. Research, experiment, and extension services are also important to develop SA technologies and to distribute them to farm level.

Professor, School of Economics, Seoul National University
Kwanak-Ku, Shilim-dong, Seoul 151-742, Korea
Phone: 82-2-880-6371
Fax: 82-2-888-4454

REFERENCES

Dobbs, T.L. (1994): "Agricultural Systems in the Context of Sustainable Agriculture Development: The Case of Low-Input Sustainable Agriculture (SA)," *Sustainable Agriculture Development in Asia*, Asian Productivity Organization, Tokyo, Japan.

Hsiao, Ching-Kai (1994): Country paper of the Republic of China, *Sustainable Agriculture Development in Asia*, Asian Productivity Organization, Tokyo, Japan.

Kada, R. (1994): "Issues and Prospect of Sustainable Agriculture in Asia," *Sustainable Agriculture Development in Asia*, Asian Productivity Organization, Tokyo, Japan.

Lee, Ho-Jin, and Young-Sang Jung (1993): "Sustainable Management in Crop Production and Farmland," *International Symposium: Sustainable Agriculture & Environmental Conservation*, Agricultural Development Institute, Seoul National University.

Man Ling Kwong, Elvera (1994): Country paper of Hong Kong, *Sustainable Agriculture Development in Asia*, Asian Productivity Organization, Tokyo, Japan.

Ministry of Agriculture, Forestry and Fisheries (MAFF) (1995): *Major Agricultural Statistics.*

Ministry of Agriculture, Natural Management, and Fisheries (MANMF) (1991): *Agricultural Structure Memorandum*, The hague, Netherlands.

Ministry of Environment (1994, 1995): *White Paper on Environment* (in Korean).

Moghaddam, A. (1994): Country paper of Iran, *Sustainable Agriculture Development in Asia*, Asian Productivity Organization, Tokyo, Japan.

National Research Council (NRC) (1981): *The Health Effects of Nitrate, Nitrite, and Nitroso Compounds*, National Academy Press, Washington, D.C.

Notoatmojo, B. (1994): Country paper of Indonesia, *Sustainable Agriculture Development in Asia*, Asian Productivity Organization, Tokyo, Japan.

Oh, Se-Ik (1991): *Managing Nitrate Groundwater Pollution from Irrigated Agriculture: An Economic Analysis*, Ph.D. Dissertation, Washington State University.

_____ (1993): *A Study on Agricultural Development and Environmental Protection* (in Korean), Research No. 283, Korea Rural Economic Institute.

_____ (1995): *A Study on Valuation of External Benefits of Rice Farming* (in Korean), Research No. 321, Korea Rural Economic Institute.

Park, Moo-Eon (1995): "Environmental Policies in Agricultural Aspects (in Korea)," *Seminar on Policy Measures for Agricultural Environment Protection*, Agricultural Environment Research Forum.

Ramasamy, K. (1994): Country paper of India, *Sustainable Agriculture Development in Asia*, Asian Productivity Organization, Tokyo, Japan.