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TECHNICAL CHANGE AND POLICY IMPLICATIONS FOR DEVELOPING ENVIRONMENTALLY-FRIENDLY AGRICULTURE IN KOREA

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ABSTRACT

Environmentally sustainable technologies may be broadly categorized as end-of-pipe technology and clean technology. Progress towards sustainable technologies in agriculture must call on farmers, agricultural economists, scientists, and government to act as partners in a process of technical change. Within this partnership approach, the government's role has a vital role to play in promoting the integration of both technologies and disseminating those technologies. As an integrated approach to establish sustainable technologies, Korean-type precision farming such as the integrated pest and nutrient management (IPNM) has the potential to make a major contribution towards improving agricultural practice and then increasing efficiency and reducing the impacts on the environment from agro-chemical wastage.

I. Introduction

Increasing population, higher incomes, and increasing consumption of animal proteins intensify pressure on land and require more

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intensive cultivation in Korea. The pressure on land is accentuated by the relative scarcity of other resources, such as water, energy, and so forth. During the past several decades, there has been a significant increase of agricultural production due to technological advances (e.g., green revolution). While the new technologies have led to an increase in input factors, such as fertilizers, pesticides, and water, they have also triggered environmental degradation. The environmental consequences vary from region to region and include soil erosion, contamination of surface and ground water, and loss of soil fertility. The environmental impact of technology-intensive agricultural practices is one of the more critical issues in the sustainable production of agriculture. However, farming systems based on a sustainable technology can help maintain traditional landscape, preserve habitats and biodiversity, and contribute to the sustainable management of water and soil resources, including flood and landslide prevention, as well as contribute to sustainable national and regional development.

The effects of agricultural production activities on the environment are of growing concern in Korea. There is a general recognition of the need to improve environmental performance in agriculture through sustainable technologies for enhancing the beneficial and reducing harmful environmental effects, and ensure the sustainability of resource use. In responses to the growing awareness of environmental problems arising from agriculture, the Ministry of Agriculture and Forestry (MAF) launched its sustainable agricultural policy for the 21st century initiative in July 1996 and made the *Environmentally-Friendly Agriculture Promotion Act* in 1997.[1] The new policy framework addresses the

[1] The *Environmentally-Friendly Agriculture Promotion Act* established in December 1997 has been serving as a basic guideline for formulating sustainable agricultural policies in Korea. Its objective is to support sustainable and environmentally-friendly agriculture through increasing the roles of environmental preservation in agriculture and reducing an environmental pollution from agriculture, and fostering farmers who activate sustainable farming.

reduction of pollution and other environmentally harmful effects from agriculture, the conservation and improvement of the agricultural environments and the encouragement of environmentally friendly farming system. Specific targets have been set for developing sustainable technologies such as reducing pesticide use by 40 percent and chemical fertilizer use by 30 percent by 2004. In order to achieve the targets, the MAF and the Rural Development Administration (RDA) initiated the precision farming system based on modern sustainable technologies. New policy programs including an integrated pest management (IPM) and an integrated nutrient management (INM) are therefore introduced.

The main objectives of this paper are to review current status of agricultural environments in Korea, to access technical changes for developing sustainable agriculture, and to suggest policy directions for developing sustainable technologies in agriculture.

II. Current Status of Agricultural Environments

The land area in South Korea is about 9.9 million hectares. Of this area, mountains occupy 64.7 percent while cultivated land covers only 1.9 million hectares or 19.1 percent of the total land area. Cultivated land per farm household is as small as 1.37 hectares in 1999 (MAF 2000b). Korean agriculture is characterized by small farmlands. It belongs to the Asian monsoon region, so its climatic condition is suitable for rice production. Rice is the dominant crop, accounting for about 30 percent of the total farm production value, while rising income growth has created increased demand for livestock products, fruits, and vegetables.

In order to meet domestic demand for food given limited land area, the agricultural sector had to adopt large quantities of chemical fertilizers and pesticides. Table 1 shows trends in the use of fertilizers and agro-chemicals. The use of chemical fertilizers per hectare was 162 kilograms in 1970, but it jumped to 398 kilograms in 1999, showing an annual average growth of

3.4 percent. Although the consumption of chemical fertilizers has decreased since 1990, Korea is one of the most fertilizer-intensive users in the world (OECD 1999, p. 65). Two major factors contributed to the rapid growth in the use of chemical inputs: the rapid migration of rural labor force(s) to other sectors in the process of rapid industrialization, and subsidies for supplying cheap fertilizers. Due to the overuse of chemical fertilizers, farmland contains plenty of fertilizer components. When chemical fertilizers are overused, organic substances of the soil are reduced, and the soil quality is downgraded. The remaining fertilizer components after being absorbed by plants flow into streams or lakes, causing enrichment of nutritive substances, such as nitrogen and phosphorus. They also contaminate underground water. The input of fertilizers should be reduced, but farmers do not easily throw away their conventional fertilizing methods. Korean farmers generally prefer complex fertilizers to simple fertilizers due to application convenience, and accelerating accumulation of salts in soil.

The warm climate and intensified cropping system practiced in Korea provide a favorable environment for pest, disease and weeds that cause serious damages every year. Pesticides have been widely used to control pests and diseases of various crops. In particular, in order to increase rice productivity, farmers had been using high doses of pesticides, which in their view could reduce and minimize the risks of attacks of pests. The

TABLE 1. Trends of Chemical Input Use

	1970	1975	1980	1985	1990	1995	1999
Consumption of fertilizer (kg/ha)[1)]	162	282	285	311	458	434	398
Use of agricultural chemicals (kg/ha)[2)]	-	3.8	5.8	7.0	10.4	11.8	12.2

Note : 1) Based on fertilizer components.
2) Based on the agricultural chemical shipment from manufacturers with an active ingredient quantity.

Source : MAF(2000b).

use of agricultural chemicals per hectare grew from 3.8 kilograms in 1975 to 12.2 kilograms in 1999, as shown in Table1.

About half of the pesticides were used on rice and the rest on various horticultural crops and fruit trees. Since 1992, there has been a gradual decline in the use of pesticides for rice production.[2] However, there has been a continuous increase of pesticides for more profitable crops like fruits and vegetables. This trend is considered to reflect the farmers' increasing interest in profitability.

The fertility of farmland in Korea is low because it is mostly made up of sandy and acid soil. Since Korea's weather is mild and humid, organic substances in soil are decomposed rapidly. Heavy rains in the summer erode soil. In general, farmland is characterized by containing low organic contents and much acid soil (Ha and Kim 1998). Yearly changes in chemical properties of cultivated soils are given in Table 2. The content of exchangeable potassium and available phosphorus gradually have increased in both paddy and upland soils during the three decades. This is mainly due to the application of a large amount of chemical fertilizers and soil amendments. All the figures surveyed in the plastic film houses are much higher than those of open field soils.

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[2] Since the early 1990s, the pest control program for rice has been modified to cope with the rapid changes in agricultural conditions. With a decreasing farm population and an increasing concern for safe food and a sound environment, the pest control program was focused more on deducing the number of spraying with low toxic pesticides. It was also concerned with the safe use of pesticides in order to meet the minimum residue limits for crops.

TABLE 2. Changes in the Chemical Properties of Cultivated Soils

Year	pH (kg)	OM (mg/kg)	P2O5	K	Ca	Mg	Number of Sample
			---------(cmol/kg)--------				
Paddy Soils							
1964～68	5.5	26	60	0.23	4.5	1.8	5,130
1976～79	5.9	24	88	0.31	4.2	1.3	19,737
1980～87	5.7	23	107	0.27	3.8	1.4	612,942
1990	5.7	27	101	0.32	4.3	1.5	1,192
1995	5.6	25	128	0.32	4.0	1.2	1,168
Upland Soils							
1964～68	5.7	20	114	0.32	4.2	1.2	3,661
1976～80	5.9	20	195	0.47	5.0	1.9	18,324
1985～88	5.8	19	231	0.59	4.6	1.4	65,565
1992	5.5	24	538	0.64	4.2	1.3	854
1997	5.6	24	577	0.80	4.5	1.4	854
Plastic Film House Soils							
1964～1968	5.8	22	811	1.08	6.0	2.5	215
1976～1979	5.8	26	945	1.01	6.4	2.3	391
1990～95	6.1	30	876	1.11	6.5	2.7	216
1996	6.0	35	1,092	1.27	6.0	2.9	513

Source: NIAST (1998).

III. Technological Assessment for Developing Environmentally-Friendly Agriculture

A working definition of sustainable technology is necessary in order to assess technical changes in sustainable agriculture.[3] Environmentally sustainable technologies (or called environmentally desirable and environment-saving or -friendly technologies) may be broadly categorized as end-of-pipe technology and clean technology. The end-of-pipe technology means pollution control technology that prevents the direct release of environmentally hazardous emissions into soils, water or air. It is also called an add-on technology because it is typically added to the production. The clean technology means a process-integrated change in production that reduces the amount of pollutants and waste materials that are generated during production. The clean technology is preventive whereas the end-of-pipe technology is curative. The clean technology in agriculture includes new biotechnologies, since these technologies have been perceived as being potentially "cleaner" with respect to the environment than existing technologies as they require fewer chemical inputs and rely more on biopesticides which do not pollute. The ability of biotechnology to displace chemical inputs could potentially be important in developing production process that are environmentally sustainable. However, most of the current sustainable technologies practiced in agriculture are included in the category of the end-of-pipe technology.

The technology selected for agricultural production, characterized by levels of inputs and cultivation practices, not

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[3] There are conceptual distinctions between technical and technological changes or between technique and technology. A technique is a tangible method of production. The term of technology is defined as the body of knowledge about techniques, but it frequently used to encompass both the knowledge itself and the tangible embodiment of that knowledge. For more detailed exposition about the concepts of technologies, see Kemp (1997, pp.7-11).

only determines agricultural outputs, but also affects the quality of soil and water. Sustainable technologies in agriculture can form and conserve resources of natural environment and allow for a sustainable cyclical usage of resources. It is characterized by providing high yields without destroying the environment or undermining current productivity. For farmers, an appropriate system of sustainable approach must be technically feasible, economically viable, socially acceptable, and environment-friendly, consistent with their endowments. For example, soil enrichment produces healthy plants that resist diseases, cover crops retard erosion and control weeds, and natural predators help control pests. The result is that farmers are able to minimize their use of pesticides and fertilizers, thereby saving costs and protecting the environment.

As an integrated sustainable technology in agriculture, precision farming (also known as prescription farming or site-specific farming) which aims at reducing environmental impacts while increasing productivity has been rapidly developed in the world during the 1990s.[4] It is developing technology that modifies existing techniques and incorporates new ones to produce a new set of tools for farmer to precisely monitor and assess the farming conditions at local and farm level uses. Inevitably, it integrates a significant amount of computing and electronics but higher levels of control require a more sophisticated system approach.

Korean-type precision farming is characterized as the Integrated Pest Nutrient Management (IPNM) system which resulted from the combination of the Integrated Nutrient Management (INM) and the Integrated Pest Management (IPM). In 1999, 16 pilot areas were designated as the IPNM system to

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[4] In the United States, National Research Council (NRC 1997) proposed to the federal government to encourage the research and development on precision farming as a national strategy. European countries are also pushing the development on precision farming. In Japan, the Ministry of Agriculture has started an R&D project on Japanese precision farming in 1998.

implement precision farming programs over a three-year period (1999-2002). The program is supported by local governments to finance facilities and equipments in six environmentally-friendly farming areas, bringing the total number of designated areas to eleven. Over the period 1999-2004, the government plans to designate 189 areas, backed up with a total investment of 378 billion won (about US $ 328 million).[5]

1. Integrated Nutrients Management (INM)

Intensive use of chemical fertilizers has been widely practiced for a long time, resulting in accumulation of available nutrients in the soil. Thus, it was necessary to develop the method to adjust the amount of fertilizers based on the soil characteristics of each cultivated land. An excessive plant nutrient in crop field soils has caused environmental problems associated with the quality of surface water (i.e., rivers and lakes) and underground water because of run-off and leaching of plant nutrients from field soils. INM approach to control water pollution comprehensively deals with sustainable farming technologies of nutrients and soil. First of all, in order to establish an INM, the database of cultivated soil information readily accessible to various users have to be set up in digitalized (in) image form. Based on the analytical results of the Detailed Soil Survey (1995-1999), the Korean government set up the Integrated Soil Improvement Project in 1996 (Kim 1998). The information on soil characteristics such as soil texture, drainage, soil depth, and clay contents of the soil with different mapping units were computerized using the geographical information system (GIS).[6]

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[5] According to the *Environmentally-Friendly Farming Promotion Act*, the pilot precision farming villages in applying INM and IPM for rice production were established. The village is financially supported by central and local governments and technically supported by *Regional Agricultural Technology Center*.

[6] The GIS is a compuer-based system for the input, storage, retrieval, analysis and display of geographic data. The GIS database is usually composed of map-like spatial representation on a number of attributes including land evaluation, land use, land ownership, crop yield, and soil nutrient levels (National Research Council 1997).

In practice, matching the amount and timing of nutrient applications to the needs of crops is the most cost-effective and efficient way to control nutrient contamination of surface and ground water. The best way to minimize environmental damage caused by accumulation of crop nutrients in soil is to adopt new recommendation models for 50 kinds of crops, as shown in Figure 1. It has been found that if such recommendation guidelines based on soil testing are used by farmers throughout the country, large quantities of chemical fertilizers could be saved without affecting crop yields. Fertilizing methods are prescribed based on the results of soil examination to reduce the use of chemical fertilizers and to protect soil. Rural extension offices are operating soil testing laboratories for soil samples for farm fields. The extension offices manage soil information for a specific site, chooses appropriate technologies, and disseminate them to farmers for soil management. Based on the results of soil examination and diagnosis of each crop's nutrition, bulk-blending (BB) fertilizers are supplied by fertilizer manufacturers for optimum fertilization for each lot. The prescription slips for soil management are prepared by computerized system. Farmers are given information on fertilizer informations with the reports on soil information. In this note, the INM system is an outcome of complex interactions involving farmers, agricultural scientists, extension workers, and fertilizer manufacturers. In order to establish more advanced INM system as a clean technology, new fertilizers and rational fertilizing methods are also being developed. If slow releasing fertilizers are used, the use of fertilizers can be reduced by 30 percent through less fertilizer loss. Wider application of advanced INM techniques, which make use of technologies that administer fertilizers only at the times and in the amounts needed, can be expected to increase crop yields further while reducing leaching and runoff of nutrients.

FIGURE1. Fertiliger Recommendation Process for Farmers

<Recommendation Database>

- Cereal, oils, vegetables, etc (50 kinds of crops)
- Lowering the optimum rate in accumulated nutrition of soil
- Regression equation: Y = a - bX,
  (where Y: opt. rate, X: soil value)

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<Development of Computer Program>

- Coding of soil value
- Coding of recommendation equation
- Calculation of optimum rates

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<Fertilizer Guideline for Farmer>

- Adjustment of plant nutrition
- Integrated soil management

Source: Rural Development Administration (2000).

2. Integrated Pest Management (IPM)

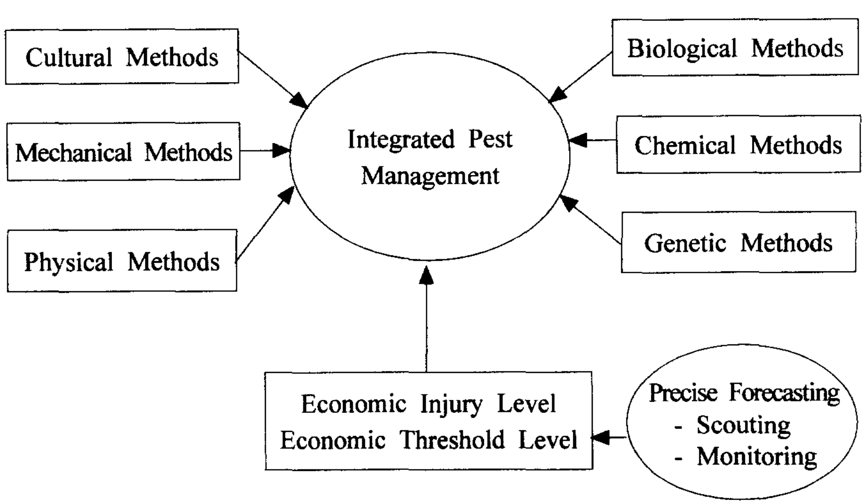
To reduce environmental pollution caused by agricultural chemicals, the amount of agro-chemicals used should be curtailed by using them effectively and safely. One of the most promising sustainable technologies on the control of pests is the integrated pest management (IPM) which is socially acceptable, environmentally responsible and economically practical methods of controlling pest populations. As shown in Figure 2, IPM incorporates a variety of cultural, biological, and chemical methods to efficiently pest populations while lowering dependence on chemical means of control.[7] The alternative

[7] IPM, through its multi-tactical approach 1) lessens the potential for pesticide resistance, 2) reduce chemical costs, 3) limits human exposure to pesticides and 4) lowers the environmental impacts of pest management. For more detailed description of an integrated pesticide management, see Gallagher and Lee (1995) and Kwon (1998).

methods most commonly cited are cultural (i.e., using good farming methods and pest-resistant crop varieties) and biological (i.e., using pests' natural enemies, parasites or pathogens). IPM approach relies heavily on field scouting combined with economic thresholds to reach management decisions. IPM seeks to balance environmental and economic concerns, taking into account crop yields, farm profits, health and environmental safety, and resource sustainability. Depending on in-field information allows farmers to react to changes in pest population levels and plant damage only when it is necessary. The economic injury level is the lowest populations density of pests that will cause crop loss, so using this level provides a safeguard against over-treatment with insecticides. Being able to use the economic injury level on a practical basis in production on another pest density and damage level indicator is called the economic threshold level.

The national IPM program in Korea was initiated in 1993 by the joint project of Rural Development Adminstration and the United Nations Development Program (UNDP), with technical assistance of Food and Agriculture Organization (FAO) Inter-Country

FIGURE 2. Methods and Procedures of IPM



Program on rice. In the beginning stage, the pilot IPM program was designed primarily to develop the model of training of IPM extension staff and farmers in rice fields. Then, a core group of IPM for apples has also been developing a training program in apple orchards. Biological control of insect pests in vegetables is also being undertaken.

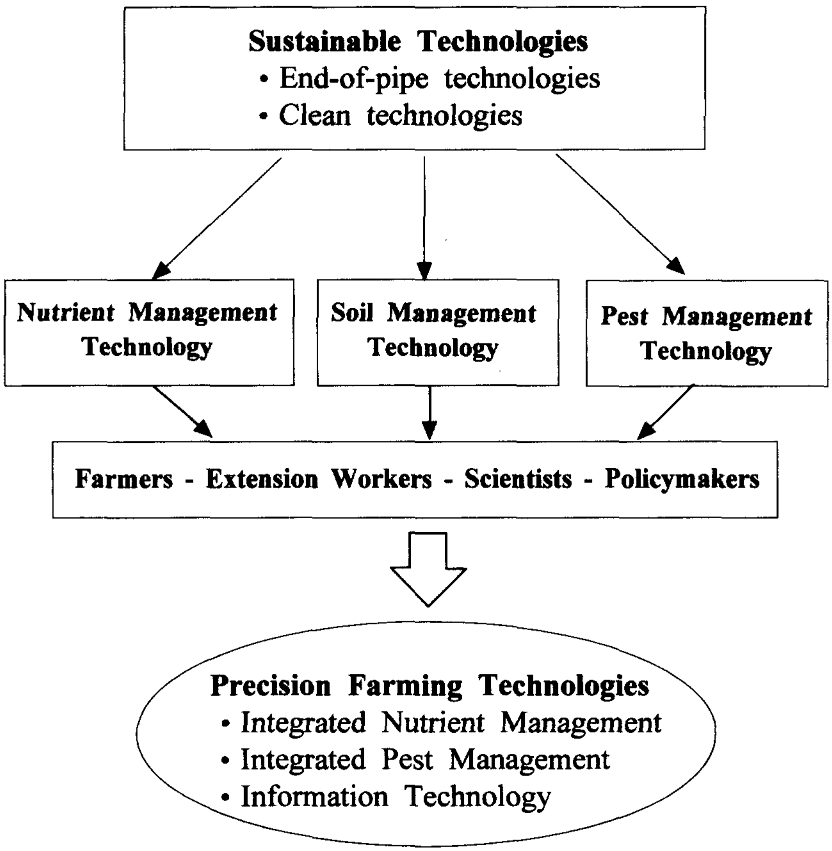
The validation studies of IPM at Provincial Rural Development Administrations showed that pesticide use could be reduced by 58.1 percent without significant changes in yields. When farmers have received basic education on IPM in their communities, the result also indicated that pesticide use could also be reduced by 62.4 percent without significant changes in yields (Gallagher and Lee 1995). The RDA has educated over 9,000 instructors and farmers to implement the IPM program since 1993. This program calls for reduction of the number of agricultural chemicals sprays and the amount used by half by 2004 through an economic control of diseases and pests based on precise scientific experiments and biological control using natural enemies.

IPM methods and systems from foreign countries could not be imported directly because circumstances and status of Korean agriculture can not be coincided with those of other countries. So, we have to develop and establish our own IPM system to work out most efficiently. In particular, as a clean technology in the context of pest control, several pesticides such as antibiotics, sex pheromones, semiochemicals, and microorganism seem to be developed.

III. Policy Implications for Developing Sustainable Agro-Technologies

In order to develop sustainable technologies in agriculture with growing public environmental awareness and consciousness of health and safety, it is necessary to identify current agricultural production technologies (i.e., end-of-pipe technologies or clean technologies) and to establish an integrated system in which all

FIGURE 3. Scheme for Developing Sustainable Technologies



parties concerned, such as farmers, agricultural economists, scientists, and policy makers, can work together, as shown in Figure 3. It is also necessary to spread technology extensively through close cooperation with production fields, so that sustainable technological levels in Korean agriculture can be raised as a whole.

Precision farming technologies based on an Integrated-Pest-Nutrient Management (IPNM) system has become feasible because of several advanced information technologies through fast computer and powerful graphical management softwares like a geographic information system (GIS). Adoption of technology of sufficient capability to provide fully supported precision farming is likely to be evolutionary process, with farms gradually improving their information technology capability. Consequently, precision farming will bring about some technological innovation or paradigm shift in agriculture towards information-oriented and sustainable farming. Thus, the research conducted by the public or the private sector should emphasize the fields of technologies in nutrient, soil, pest, and information management in line with administrative measures, particularly those supporting the technological capability of the whole nation. In addition, it is necessary to reorganize the research system along with these lines, strengthen cooperation with the educational-industrial complex, and enhance international research collaboration.

Regarding agricultural extension projects, it is necessary to review the role-sharing between the government and agricultural organizations, and specify the goals and objective fields in order to implement these projects efficiently and effectively.[8] In doing so, it is necessary to consider the farmer's expectations for modern sustainable technology and management guidance, and the growing importance of technological guidance regarding environmental preservation.

Based on lessons learned from past successes and failures in developing sustainable technologies, the following policy actions should be considered (Kang 1995; Kim 1998):

[8] The *Rural Development Administration* (RDA) is the centralized government organization responsible for agricultural research and extension services. It plays a key role in research on the improvement of sustainable farming technology and rural development, dissemination of technology to the farmers, and education of farmers. Technology transfer is essentially the responsibility of the *Regional Agricultural Technology Center* as a county extension office under supervision of the *Provincial Rural Development Administration*. In addition, the *National Agriculture Cooperative Federation* plays an essential role in technology transfer, covering such activities as banking and credit input supply, marketing, insurance, and other related support services.

(1) Testing sustainable technologies developed by public or private sectors under farm condition and making a recommendation made only after consultation with the farmers concerned.

(2) Increasing investments of research projects on sustainable technologies (i.e., INM and IPM) in agriculture through new financing arrangements.

(3) Emphasizing a demand-driven precision farming technology development and timely delivery of developed technology to the sustainable farming community.

(4) Improving information and dissemination of INM and IPM, through widely linked, user-friendly information systems for farmers.

In particular, the following research for sustainable technologies should be given high priority by agricultural scientists and extension workers in Korea:

(1) Conducting research on sustainable farming systems with a holistic or an inter-disciplinary approach. A holistic approach may require the development of new methods and technologies related to chemical, physical, and biological interactions with soil fertility, crop productivity, and environmental quality.

(2) Estimating consequences of integrated pest and nutrient management systems including risk and profitability associated with existing technology. This should be done on a whole farm basis. Such data are absolutely essential to raise credibility for on-farm precision farming.

(3) Developing more effective methods for transferring best management practices of soil conservation and pest management. One of the best means to transfer technological information is through farmers organizations and networks.

(4) Identifying barriers and constraints that limit the development and adoption of end-of-pipe or clean technologies for precision farming practices.

V. Concluding Remarks

Technological change affects the environment and natural resources in a number of ways. Increasing productivity can have environmental benefits in that less inputs are required for the same level of outputs. Also, to the extent that productivity enhancement raises incomes, the demand for environmental quality may increase.

Modern sustainable technologies will change the agricultural environments and structure to a great extent in the future. Progress towards sustainable technologies in agriculture must call on farmers, agricultural economists, scientists, local and central governments to act as partners in a process of technical change. Within this partnership approach, the government's role has a vital role to play in promoting the integration of environmentally sustainable technologies both in end-of-pipe and clean technologies and disseminating the technologies. Currently, public concern on improving environmental performance is shifting from end-of-pipe technologies to the development of clean technologies. This has considerable implication for environmental innovation, since clean technology includes a wider range of technologies than those used in end-of-pipe processes. The Korean government should spend a large amount of financial resources to develop advanced clean technologies in agriculture through new financing arrangements.

The technology of precision farming has the potential to make a major contribution towards improving agricultural practice and then increasing efficiency and reducing the impacts on the environment from agro-chemical wastage. Adoption of technology of sufficient capability to provide fully supported precision farming is likely to be an evolutionary process, making farms gradually improve their information-technology capability. Most of the component parts needed for fully supported precision farming are sufficiently developed to be used in the near future by farmers. The area that is likely to need continuing development for the foreseeable future is the software to support farmers who makes decisions concerning appropriate treatments and levels of treatment to be spatially applied.

The Asian region has been on the forefront of generation and transfer of modern agricultural technologies, which is called "green revolution" through the developing high yield varieties of rice. green revolution made a notable contribution to raising the production of rice, particularly in Korea. The high yielding varieties are responsive to very high application of fertilizers and pesticides, and are efficient producers under intensive management conditions. In addition, advances in soil and water management, pest management, post-harvest handling and other technologies have synergistically contributed to enhancing productivity. However, the green revolution technology has not only raised environmental issues but also generally by-passed rainfed dryland areas and resource-poor farmers, thus exacerbating inequity in incomes.

There are encouraging prospects of reducing farmers' dependence on agro-chemicals and raising yields even in unfavorable production where the green revolution technology has largely by-passed. Given the complex multidisciplinary and inter-sectoral nature of sustainable technology development and transfer, effective linkages among concerned sectors should be strengthened and managed for attaining sustainable agriculture development. Although the types of links will depend on the types of technology, the most important linkages envisaged are farmers-extension workers-scientists-policymakers. To facilitate the establishment of joint partnerships in developing sustainable technology, it may be expedient to foster networking among Asian research and extension agencies.

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