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Reducing Agricultural Water Use While Conserving Ecosystems

Tai-cheol Kim

Agricultural Engineering, Chungnam National University, Daejeon 305-764, Korea

The aim of water managers in Korea is to assess the degree to which agricultural water use can be reduced while maintaining rural societies and conserving sound ecosystems. Toward this aim, a new irrigation management system for the Korea Rural Community and Agricultural Corporation (KRC) has been implemented in Korea to resolve the issues and to reduce wastage of agricultural water. The Organization for Economic Cooperation and Development (OECD) has recommended that farmers should be charged for irrigation water and that they participate in the operation and maintenance of irrigation systems. In addition, the Vitalization of Rural Improvement Act was enacted to develop water resources for rural communities and amenities. However, there are still questions as to how much of the country's rural water supply should be devoted to irrigation and ecosystem conservation. A practical strategy has been devised in which farmers receive incentives for voluntarily reducing agricultural water use. In addition, new eco-farming tourist programs could be developed to utilize the year-round circulation of water through reservoirs, irrigation canals, paddy fields, fish-ways, regulating ponds, drainage canals, and pumping stations; this would provide a boom to rural tourism in Korea.

Key words: Ecosystem, Globalization, Irrigation management, Rural tourism, Water saving

Introduction

Water is vital for all life on earth. For millennia members of traditional agricultural societies have irrigated their crops, providing the food necessary for their existence. Unfortunately, today people are not as aware of the role that irrigation and drainage systems play in securing adequate food supplies as before. Because of increased demand for water from other sectors, severe limitations are being placed on agricultural water resources. Each year 15 billion m^3 of water is consumed for agricultural purposes in Korea, but other sectors want to enforce a 10% reduction in this amount. Unlike modern agricultural practices, traditional agriculture was based on the circulation of materials across the environment—so-called eco-friendly agriculture—and using such practices may help to solve the water-shortage problems faced by Korea. Thus, from the perspective of water conservation, it is important to preserve the traditional, sustainable paddy farming practices passed down for generations. In addition, it is also important to preserve the unique cultures of these rural communities before they disappear—the population in rural areas is aging with 59% of farmers over the age of sixty. The issue is to determine the degree to which agricultural water use can be reduced while maintaining these traditional rural societies and conserving sound ecosystems.

Paddy Farming Irrigation in Korea

Present Status of Irrigation Water

Irrigation systems for rice farming require supplementary water supplies for cropping during dry spells. Most of the irrigation systems are for paddy farming and consist of a reservoir, pumping station, and weir, with a tube well used for the irrigation of upland crops. The Korean government has made great efforts to develop irrigation water for rice production, and 859,000 ha—79% of the total 1.086 million ha available for paddy farming—was being irrigated as of 2006. The pattern of irrigation has changed from seasonal rice irrigation to year-

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Corresponding author's current address: Agricultural Engineering, Chungnam National University, Daejeon 305-764, Korea.
Tel: 82-42-821-5797, Fax: 82-42-821-8877, E-mail: dawast@cnu.ac.kr

round irrigation for the vegetables, fruits, and dry crops grown on the upland fields. Although the nation's goal of self-sufficiency in rice production was achieved, the self-sufficiency ratio for other grains was only 27% in 2006.

Irrigation Water Management System

A dual system of irrigation management by national and local governments has been in place since 2000. An irrigated paddy area of 532,000 ha is managed by the KRC, which is an enterprise run by the national government. Most of the KRC's irrigation and drainage works are devoted to paddy farming and are relatively well managed by nationwide branch offices. The KRC's annual operation and maintenance cost was US $520 ha^{-1} in 2003; 48% of this cost is paid by government subsidies and the remaining 52% is the responsibility of the KRC. In addition, an irrigated paddy area of 327,000 ha is managed by *Surigye*—water-users' associations (WUAs) under the supervision of individual local governments. The annual operation and maintenance cost for *Surigye* was only US $50 ha^{-1} in 2003, with local government subsides paying for most of it (Kim, 2004). Although each *Surigye* is organized to manage autonomously the tertiary canals of its own paddy, there is no financial contribution to, or membership participation in, canal maintenance, such as dredging and weed control. Most of the non-*surigye* facilities (i.e., those with less than 5 ha and five head of livestock) use tube wells for groundwater extraction.

Localization and Globalization

Because of rice overproduction and the free trade system instated by the World Trade Organization (WTO), the Korean public is now less concerned about domestic paddy farming, and the Korean government no longer allots a large financial budget to irrigation and drainage projects. No one can assure the stability and continuity of the global trade system, however, so it is important to maintain a sound system of paddy fields in Korea. The OECD has recommended farmer participation in irrigation, basing farming practices on efficient economic principles, charging an irrigation water fee, minimizing market distortion, reducing irrigation water use, and diverting agricultural water to other sectors.

WTO System

The WTO system is unfavorable to the trade of agricultural products because of Korea's inability to compete effectively in the world market, and placing rice cultivation in a serious crisis. If the value of agricultural products is reduced, the agricultural infrastructure, which serves multiple functions in society, may collapse. Unless the multifunctionality of agriculture is properly recognized, there is a possibility that much of the rice cultivation in rural regions would be abandoned. Many Korean farmers are vigorously against the globalization of trade, because they are afraid of losing their jobs to foreign markets. They believe globalization cannot be successful without providing for the needs of local producers.

Irrigation Management by Government

Most irrigation projects have been initiated, invested, planned, constructed, and managed by governments, but many experts now believe irrigation systems should be turned over to local farmers. Many national governments and international organizations are attempting to implement such Participatory Irrigation Management (PIM). Judging from the OECD guidelines, the management system for paddy irrigation has several problems, including inequity of the cost burden and service level between the KRC and WUAs (*Surigye* districts), no charge for irrigation water, a lack of farmer participation in operation and maintenance, unstable financing of national projects, poor management of WUAs under the supervision of local governments, and a lack of integrated management at the watershed level.

Customary Water Rights for Irrigation

The provision of free water for irrigation in 2000 arose due to political reasons, not economic ones. The historic argument that water for irrigation should take precedence is being greatly weakened by the increasing needs of other sectors of water consumers. In 2006, the Ministry of Construction and Transportation (MOCT) revised the river law in order to convert the customary water rights for irrigation to registered and permitted ones. The ministry also intends to legislate the basic laws necessary for water management.

Irrigation Water Fee

In its 2005 report, the OECD strongly recommended that a demand-control policy should be reinforced and a water (especially irrigation water) fee should be charged under the beneficiary-burden rule. The concept of water pricing under discussion at the OECD, which involves assigning a price to water so that it can be freely bought and sold between possessors and users, hardly seems conducive to improving water-use efficiency in the Asian monsoon region. Moreover, to promote the stable production of food, agricultural water is usually subject to some sort of subsidy or low price determined by the government. In discussions of the appropriateness of irrigation water prices, due consideration should be given to differences in the characteristics of humid and arid regions.

Reducing Irrigation Water Use

The 21st Century has been called the century of water and ecology. Thus, reducing irrigation water use and conserving ecosystems associated with paddy fields is becoming a hot issue in Asian monsoon regions.

Necessity of Reducing Irrigation Water Use

Since the 2nd World Water Forum (WWF) in 2000, reducing the use of water for agriculture has become a much-discussed issue all over the world. Refining the definition of water rights, especially with regard to irrigation water, and water price evaluation are the greatest concerns of advanced countries and the OECD. A debate was held on the basis of the ministerial recommendations at the 3rd WWF in 2003 and this resulted in a strong message: "The water crisis is an agricultural crisis, and there will be no solution without a change in agriculture." According to the ministry statement at the 4th WWF in 2006, new good governance, capacity building, and stable financing are necessary for better water management. Because irrigation is most responsible for the overconsumption of water resources, integrated water management was recommended, with the operation and maintenance costs covered by the private sector rather than the public sector.

In Korea, a draft of a basic law for water management and a committee for water management were set up at the Prime minister's meeting in 2005. Discussions included the creation of an organization to manage water use (including agricultural water use), and the organization of a new ministry for the integrated management of national land and water resources. In 2005, the Board of Auditing and Inspection delivered a policy notice regarding the unification of bodies that manage water use. The government's Sustainable Development Committee contributed to the policy by explaining the best way to control water demand to solve the water shortage problem while avoiding the construction of massive dams. The policy calls for farming patterns to be changed to stop the overconsumption of water for agriculture, with a target set at a 10% reduction in irrigation water use (Kim, 2004).

Water Balance in the Rice Paddy

Kim *et al.* (2007) analyzed the water balance of paddy fields on the basis of 30 years of data gathered at Yedang irrigation reservoir (Fig. 1). With regard to the annual amount of irrigation water supplied from the reservoir, the minimum amount was 540 mm, the maximum was 1,775 mm, and the average was 935 mm. The 10-year frequency intake was 1,565 mm. During a representative irrigation period of 120 days, rainfall was 956 mm and the irrigation water supplied from the reservoir was 1,565 mm; thus the total amount of water supplied to the paddies was 2,511 mm for a 10-year frequency. Of this total, 1,487 mm was lost to percolation, 659 mm was lost to evapotranspiration, and 365 mm was direct runoff to the river. Of the percolated water, 492 mm recharged the groundwater system. In managed irrigation systems, 995 mm of the total 2,146 mm is returned flow, which some see as wasted, but it helps to conserve ecosystems.

Means of Saving Water

It has been reported (KICT, 1999) that irrigated rice can be cultivated with 800 to 1,000 mm of water—approximately 50% of the current use—without affecting yield. The main obstacle to saving water is that the water is not priced properly. Especially in schemes where the user is charged on the basis of irrigated area and not the volume of water used, there is no economic incentive to reduce water use.

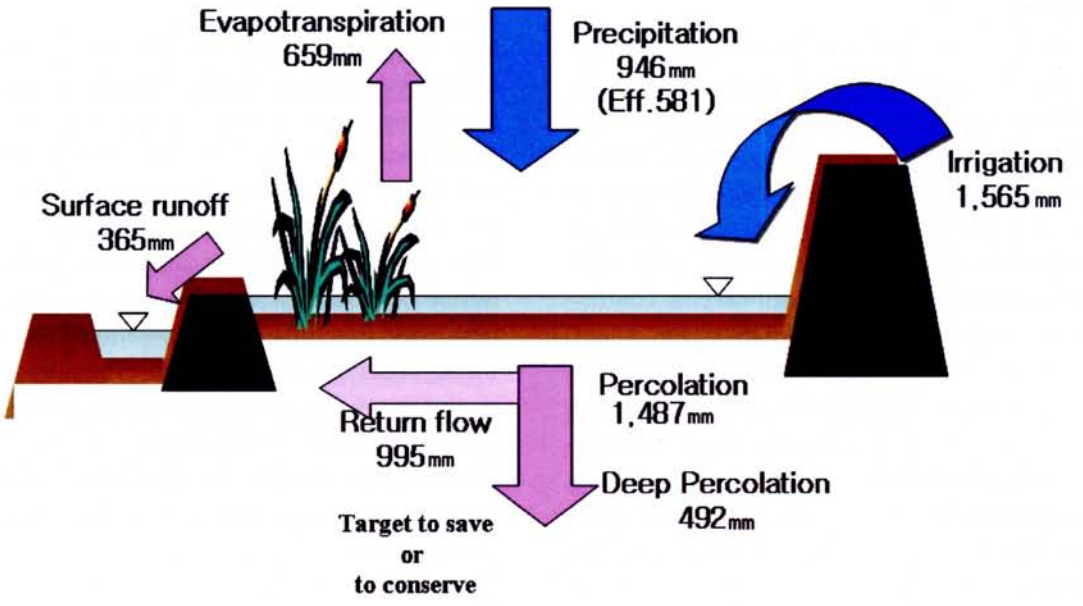

Fig. 1. Schematic of the water balance in a rice paddy in Yedang district (10-year frequency)

Irrigation measures

There are several irrigation techniques that would allow reduction of water consumption when irrigating rice. Water use could be reduced without affecting yields by intermittent flooding using an alternating drying and wetting method. Supplementary irrigation could be provided only for crop establishment or at critical growth stages. Water recycling and conjunctive use would enable farmers to reuse seepage, percolation losses from canals, and groundwater. Newly developed aerobic rice cultivars which are grown in nonpuddled fields with no standing water or soil saturation (Zeigler, 2005) would provide an alternative to flooding and water suppliers could initiate rotational irrigation systems to save water (Kim *et al.*, 2006a).

Legal and systematic measures

New river law and Basic water management law

Farmers have had rights to irrigation water for centuries, and Korean law recognizes those rights as customary water rights based on judicial precedents. Irrigated rice production, however, is particularly known for its excessive use of water. Thus, the river law was revised to minimize water waste by decreasing the amount of water allowed for agricultural use. When customary water rights for irrigation are converted to registered and permitted ones, the amount of water used for agriculture is expected to be greatly reduced.

Water supplier's initiative system

In this system, water suppliers manage the allotment of irrigation water. This concept is quite different from the PIM, in which the farmers are directly involved in water management. The management of water by the suppliers in districts managed by the KRC is being considered. The application of this technique allows suppliers to play a direct role in water delivery, with high flexibility and automated Telemetering/Telecontrol systems. This kind of water supplier initiative system should result in great savings of irrigation water.

Participatory Irrigation Management

Efficient water use during abnormally dry spells should be improved through promoting PIM in paddy fields in the WUA areas. In the PIM system, farmers participate in the management of the irrigation system not merely at the tertiary level but across the entire system. Management by the irrigation users, rather than by a government agency, is often the best solution to inefficient water use. The sustainable transfer of management from government to users, however, requires the participation of all farmers. It is widely recognized that the establishment of a water users' group—an essential

element of PIM—and its stable management to save irrigation water and reduce costs are very difficult (Satoh, 2007).

Modernization and repair of irrigation facilities

As of 2005, 227,000 ha—21% of the total paddy fields in Korea—remains rain-fed without irrigation systems. Because of their poor irrigation facilities, approximately 50% of the irrigated paddy fields are subject to possible damage from droughts that recur about every 10 years. Sixty-one percent of the reservoirs are older than 50 years, and 48% of the pumping stations are older than 20 years. These facilities do not function well owing to their deterioration. However, it is difficult to develop new water resources and supply systems because of the environmental issues and financial constraints. Therefore, repair, reinforcement, and modernization of existing irrigation systems and automation of water distribution are generally considered to be the best alternatives for saving water and meeting the water demand.

Environmental Impacts of Rice Irrigation Patterns

Rice irrigation patterns affect not only the paddy fields, but also the surrounding environments and ecosystems. Several scenarios of the affects of irrigation patterns on the environment can be discussed.

First, irrigation water could be supplied in amounts sufficient only to cover losses to evapotranspiration (659 mm), which is the irrigation pattern for dry crops grown in arid regions. Although this would save 1,852 mm of water, the paddy fields would turn into dry uplands, and the yield of rice would be greatly reduced. Also, changing a humid farming ecosystem to a dry ecosystem would undoubtedly have great impacts on the traditional cultures in the rural communities of Korea.

Second, irrigation water could be supplied in amounts sufficient only to cover losses to evapotranspiration (659 mm) and deep percolation (492 mm), which would save 1,360 mm of water. Although this would increase of water use efficiency by 54%, the crop yield would not be reduced. In this case, however, there would be no return flow of 995 mm to downstream, and thus no water would be available for downstream ecosystems. This outcome would be detrimental to maintaining sound ecosystems and the scenic values they provide. A third option is to simply retain the present continuous flooding irrigation, which has been adapted to Korean environments over a long history.

How Much Water Needs to be Saved to Maintain Sound Ecosystems?

Recently, there is growing interest in water reuse. The apparent consumption in a unit block is influenced by the deep percolation and the evapotranspiration in the paddy field plots. However, at the river basin level, system management water should be added to the net water requirement as estimated by the Critical Block method. A reasonable ratio between the net water requirement and the system management water at the project level should be established by more case studies (JSIDRE, 1999).

Sound and sustainable circulation of irrigation water

Paddy field irrigation using ample water has multifunctional roles: recharging groundwater, mitigating floods, providing domestic water supplies and water for fish farming, protecting biodiversity, forming aquatic landscapes, purifying water quality, inducing positive socioeconomic effects, and passing on traditional cultures. Water serves as a network of wetlands and waterways, creating an excellent natural environment with enriched flora and fauna. Water drained from paddies and returned to rivers reinforces the ecosystems of the downstream rivers and swamps. Most of the river stretches covered under the River Act in 1971 are required to release the minimum amount of river flow needed for maintaining ecosystems.

Target amount of irrigation water to be saved

The target amount of water to be saved from irrigation systems can be assumed as 995 mm, which is returned to the river, or 492 mm, which is recharged to the groundwater. As noted above, supplying irrigation water only to cover the loss to evapotranspiration (659 mm) would save 1,852 mm of water, and supplying irrigation water only to cover evapotranspiration and deep percolation

(1,151 mm) would save 1,360 mm of water. However, these measures would have negative ecological, environmental, social, and cultural impacts in rural communities. Thus, the target amount to save assumes to be from a maximum of 995 mm to a certain optimal amount to be properly determined. Management systems must strike a balance between not wasting water while maintaining the multiple functions of irrigated rice paddy systems.

Conceiving Agricultural Water as Rural Water

Rural water sources should supply water not only for the irrigation of paddy and upland fields, but also for households, industrial complexes, livestock and ecosystems. It was suggested to the Ministry of Agriculture and Forestry (MAF) in 2005 to include the regional water in snow melting, extinguishing fires, cleaning machinery, recreation and maintaining ecosystems for green tourism as well as the agricultural water into the rural water as shown in Fig. 2. This means that rural water = agricultural water + regional water, and regional water = domestic + industrial complex + environmental + recreational water (in the rural areas). But, in reality, only agricultural water for paddy, upland, and livestock was taken into account in the national long-term plan for water resources by the MOCT in 2005.

There is a general misconception that dams destroy nature and ruin ecosystems. Although some dams may cause environmental damage, this is not true of all dams. The building of eco-friendly dams would allow water resources to be used effectively during the dry season (October to July) and would help to conserve sound ecosystems and environments in the watershed. Such dams would capture valuable water that would otherwise be flushed out to sea in the flood season without any chance for it to be utilized. New water resources could be developed by building eco-friendly cascade dams in the tributaries of major river basins.

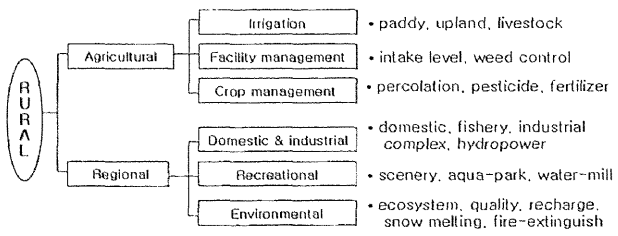

Fig. 2. Rural water use plans proposed to the MAF

Conserving Ecosystems and Rural Amenities

The MAF introduced a direct payment system for sustainable agriculture in 1999, and various programs to promote sustainable agriculture were initiated under a 5-year (2001–2005) plan.

Multifunctionality of Agriculture and Paddy Farming

Rural communities with unique histories, inherited cultures, and scenic ecosystems may be collapsing in the face of competition from the global free trade of agricultural products led by the WTO since the 1990s. However, the multiple functions of agriculture and paddy farming are gaining greater appreciation, and these functions were discussed at the 3rd WWF. Hopefully, the concepts of multifunctionality will be widely accepted all over the world. In Korea, the positive externalities of paddy farming were estimated to be in the range of US $3.4–16.7 billion as of 2005, depending on which multifunctional attributes were included (Kim *et al.*, 2006b)

The Effects of Eco-Friendly Farming on Ecosystems

At the 3rd WWF, discussions of the multiple uses of irrigation water for paddy fields focused on ecosystem conservation, recreation, and the amenities in the Asian monsoon region. For example, the Japanese Institute of Irrigation and Drainage (JIID, 2002) reported that about 1,600 species inhabited the paddy fields near the Omiya suburbs, whereas only about 100 species inhabited the dry fields in the same region. These findings imply that rice farming allows biodiversity that is 16 times greater than upland wheat farming. Paddy farming not only increases biodiversity, it also produces rich and beautiful scenic landscapes. Paddies provide open green spaces during the spring and summer, with golden waves of color during the autumn. In addition, the many weirs and reservoirs built for paddy farming are in harmony with the mountains and upland fields and create scenery unique to Korea. Paddy fields provide a valuable habitat for many creatures, as the combination of warm shal-

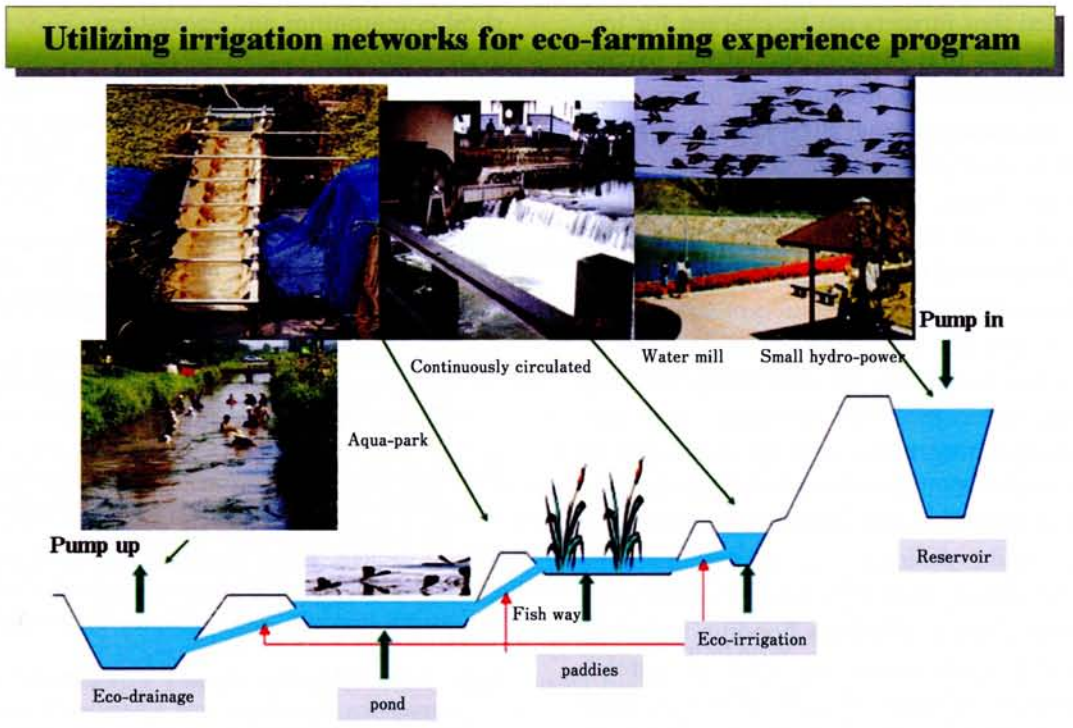

Fig. 3. Example of a sound irrigation network for an eco-farming experience program

low water and fertile soil provides the resources needed for growth and survival. Furthermore, the irrigation ponds connected with paddy fields through canals and scattered coppices and groves provide aquatic habitat and refuge for creatures during the non-irrigation period. In the 14 areas in Japan surveyed by the JIID (2003), paddy fields accounted for only 7% of the area but more than 30% of all species of fish and dragonflies and more than 20% of all species of reptiles, amphibians, and plants inhabited paddy fields and canals.

Enhancing Off-Farm Income Through Rural Green Tourism

Recently, rural green tourism has been highlighted as a good alternative to provide off-farm income and thus improve farmers' quality of life. Programs that allow tourists to engage in the farming experience are well matched with rural tourism, and many such programs are being organized all around the Korean countryside. In the 1960s, rivers in rural areas were full of water where children swam, men enjoyed fishing, and women washed clothes. However, because of the over-withdrawal of ground water and the decrease of infiltration by the increase of impervious surface, water has been depleted and rivers have run dry. Because 3.7 billion m^3 of water is withdrawn from the groundwater each year, to restore dried rivers back to their normal condition water discharge sources must be secured.

Rural tourism programs involving farming and ecological experiences—especially those geared toward families with children—already utilize the paddy and irrigation networks. In villages where rural tourism is proposed or planned, new eco-farming experience programs could be developed to utilize the year-round circulation of water through reservoirs, irrigation canals, paddy fields, fish-ways, regulating ponds, drainage canals, and pumping stations (Fig. 3). Facilities for a farming and ecological experience program might include a small hydro-power facility, water mill, aqua park, water pool, and fishing pond.

Conclusions and Recommendations

A new irrigation management system has been implemented in Korea to resolve the issues between the KRC and the numerous WUAs and to reduce wastage of agricultural water. The OECD has

recommended that farmers not be charged for irrigation water and that farmers should not participate in the operation and maintenance of irrigation systems. In addition, the Vitalization of Rural Improvement Act was enacted to develop water resources for rural communities and amenities. However, there are still questions as to how much of the country's rural water supply should be devoted to irrigation and the conservation of ecosystems. A practical strategy has been devised in which farmers receive incentives for voluntarily reducing agricultural water use. In addition, new eco-farming tourist programs could be developed to utilize the year-round circulation of water through reservoirs, irrigation canals, paddy fields, fish-ways, regulating ponds, drainage canals, and pumping stations; this should provide a boom to rural tourism in Korea. The continuous flooding irrigation used in paddy fields consumes a lot of water—perhaps much more than is needed. However, these irrigation techniques have been fine-tuned by farmers to local conditions through a long history of trial and error. At present, continuous flooding irrigation is normally used in Korea. Saving agricultural water is an important issue all over the world. However, drastic reductions in the use of water for agriculture would disrupt both rural communities and the ecosystems connected to the paddy fields. The issue to debate, then, is how much agricultural water could be reduced while still conserving sound ecosystems. Without farmers' approval it is nearly impossible to save water in practice. Therefore, farmers must be provided with some incentives to save water. Further research is needed to fully understand the characteristics of irrigation water in the paddy fields, as well as the roles of irrigation water in ecosystems of the watershed. This information can then be shared with farmers, members of other economic sectors in Korea, and members of international development and trade organizations in order to achieve sound rural communities and ecosystems.

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