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The Importance and Multifunctions of Korean Paddy Fields

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ABSTRACT: The Ministry of Agriculture and Forestry announced in 2001 that the overall amount of paddy land set aside for rice will be cut down by 12% by 2005, decreasing from 1.08 million to 953,000 hectares. When evaluating the value of paddy rice systems, the multi-function of paddy systems in the monsoon climate is vital importance. The main functions of paddy rice systems are to conserve biodiversity and maintain sustainability. Some crucial environmental benefits of the paddy rice systems include: flood prevention, recharge of water resources, water purification, soil erosion and landslide prevention, soil purification, landscape preservation and air purification. The paddy rice systems in Korea, which are more diverse than upland crop systems, are known to be composed of 14 orders, 36 families and 134 species. The sustainability of paddy rice production systems can never be overestimated. Rice is part of the culture and even the heart of spiritual life in the area under the monsoon climate. Therefore paddy rice systems should be preserved with the highest priority being the enhancement of the systems' multi-function. As an outlook to future research, the need of joint and interdisciplinary research projects between economists and natural scientists at inland as well as international levels were emphasized in establishing the development of counter-measure logic through actual proofed analysis.

***Keywords*:** biodiversity, flood prevention, multifunctionality, paddy field, purification

Korea faced a turning point in food production policy. Since domestic rice price became less competitive with international market and the overstocked rice cause troubles for rice processing centers by increasing storage cost, the Korean government has declared to cut off paddy rice area. There has been up-roar and increased arguments among the farmers against the policy. However, this cut off policy can be supported by ecological concerns. The conservation of the paddy field encourages the multi-functionalities of the systems in the monsoon climate condition. It is estimated the paddy rice systems in south Korea is worth 87 to 112 trillion Won (6.3 billion US$; Eum *et al.*, 1993; Oh *et al.*, 2001) and the estimates are directed to the following environmental beneficiaries: flood prevention, recharge of water resources, water purification, soil erosion and landslide prevention, soil purification, landscape preservation and air purification. Nevertheless, little attention was given to the economic value of the conservation of biodiversity (Kim, 2000; Lankoski, 2000; Romstad *et al.*, 2000). The Korean paddy rice systems, centered somewhere in the southeastern part of Asia, dated back to 7,000 years ago, has 4,300 years of history in the Korean peninsula (Greenland, 1997). Since the land systems have been regularly flooded, there has been rocognized any hazardous effects in such a long succesive cropping systems, while succesive upland horticultural cropping systems caused various soil sickness and disorders. The Korea paddy rice systems are known to be composed 14 orders, 36 families and 134 species (NARI, 2001), and it is more diverse than upland crop systems.

In this paper categories of multifunctionality of Korean paddy rice systems were extensively discussed (Kwon, 2001; MRI, 1997) and some details were given to the specification of multidisciplinary agricultural technology, characteristics and farming practices and areas and condition of occurrence. Items listed in Table 1 are presently agreed upon among the Asian countries in the monsoon climate from technical and agricultural economic viewpoints.

Flood prevention

Copious rainfall in Korea (1,000-1,300 mm/year) erodes the surface soils (Table 2). It is well known that depositing reservoir of paddy fields after intensive rainfall even if for a very short period, decreases flood occurrence, particularly downstream of flat land. This is proved by repeated use of irrigation canals within the rice area.

Two scenarios can be drawn for non-agricultural flood prevention function. One is to construct dams or reservoirs in place of a paddy field. Second is not to use paddy fields for farming, but instead to maintain them for static flooding. Several studies on the option of using dams as substitutes for paddy fields have been carried out by Korea Office of Rural Development (Eom *et al.*, 1993) (Table 3), Korea Rural

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Table 1. Hierarchical structure of the multi-functionality derived by rice farming.

Group of functions with economic externality - positive multi-functionality				
Rural vitalization	Encouragement of local rice related industries and job creation			
Social security Function	Food security and safety			
	Safety management of local community			
	Natural disaster prevention			
Preservation of nature and environment	Biological preservation	Preservation of biological diversity		
		Preservation of wildlife		
		Preservation of ecosystem		
	Preservation of land and environment	Land Preservation	Preservation of disaster due to sediment	
			Soil erosion prevention	
			Landslide prevention	
			Soil purification	
		Water Preservation	Water control	Flood control Water retention
			Stabilization of stream and river flow	
			Water resources Recharge	Surface water recharge Ground water recharge
		Air purification and cooling	Decreasing of CO_2 Increasing of O_2	
			Decreasing air temperature in summer season	
Social and cultural function	Preservation of amenity	Dwelling environment preservation		
		Recreation and relaxation		
		Disaster relief		
		Landscape preservation		
	Community viability	Support of local community		
	Culture preservation	Preservation of local traditional cultures		

Remarks: Existence of functions is largely depended on conditions of farming practices.

Table 2. Annual rainfall in different monthwise. (Unit : mm)

Year \ Month	3	4	5	6	7	8	9	10	Total
'95	-	-	68	149	193	140	43	27	618
'96	109	30	40	366	39	64	0	17	663
'97	17	49	103	239	218	242	33	1	900
'98	62	119	109	215	195	453	235	55	1442
'99	31	82	162	221	339	429	88	93	1445
Mean	54.75	70.00	96.40	238.00	196.80	265.60	79.80	38.60	1,013.60

Economic Institute (Oh *et al.*, 2001) (Table 3), Mitsubishi Research Institute (MRI, 1997) (Table 3) and the Japanese Agricultural Research Institute (NARI, 1998) (Table 3). Construction cost of a dam with the same water-storing capacity as paddy field was determined by using an estimate of the economic value.

The second scenario involves self-maintenance and management of paddy fields implemented as measures to control rice production. The paddy fields are abandoned without rice and used as fallow ground to store water during the monsoon period. Certain flood resistant crops can be introduced as a substitute for rice. Few studies have been made to estimate the cost of managing these paddy fields as reservoir.

Soil erosion and landslide prevention

Terraced paddy fields in hilly lands have the most ideal

Table 3. Estimated flood prevention of paddy field by the different levee height.

Levee height (cm)	Submerging (%) 25	50	75	Flooding prevention (%) at 50% submerging
0	0.00	0.00	0.00	0.00
15	3.75	7.50	11.25	0.75
20	5.00	10.00	15.00	1.00
30	7.50	15.00	22.50	1.50
40	10.00	20.00	30.00	2.00

R.O.K. total land area: 9,800,00ha; low-land rice cropping: 1,000,000ha

topography for preventing soil erosion and landslide. Numerous agricultural engineering studies have pointed out that, where soil erosions is prone to occur, farmlands should be terraced for other crop farming under similar geographical conditions.

It has been frequently noticed that, on the technological basis, soil degradation is severe when slope-sided paddy fields are abandoned. For instance, daily-managed farmlands were effective for preventing landslides when heavy rains from typhoons caused damage and water was discharged from the paddy. Assuming that there is no runoff and that water flow in the root zone is one dimensional, the water balance equation can be expressed as:

$$\int_0^L \frac{\partial\theta}{\partial t}dz = P + I - ET_a - D + R,$$

where P is the precipitation rate, I is the irrigation rate, ET_a is the actual evapotranspiration rate, D is the root zone drainage rate to groundwater, R is the root zone recharge rate from groundwater, θ is the volumetric water content, t is time, z is depth, and L is the depth of the root zone (Wu *et al.*, 2001).

What is important about groundwater recharged from paddy fields is that the groundwater replenishes areas, where natural rainfall cannot reach, and natural flow is not possible.

It is well known that water percolation into soil is promoted through root holes and micro/macrop channels, when rice roots of the previous crop year decompose. Undoubtedly, this formation, which is a biological/biochemical process, cannot occur without rice farming. Percolation helps raise the groundwater level by plowing and irrigation. No-till, direct-seeded rice cropping is more effective than till and transplanted rice cropping in terms of retaining water in the root systems, however, all these exert an unfavorable effect when cultivation is abandoned.

Importance of levee for soil erosion and landslide prevention

The levees of paddy fields are an essential structure for paddy fields to contain water, prevent of soil and landslide erosion, and others. Levee length of paddy fields is related to the adoption of environmentally friendly farming practices. In Korea, the levee height is estimated 27 cm (Lim, 2002).

Table 4. Estimated multifunctional value of paddy fields according to substitutive cost method as an example (100 Million US\$[2)).

Multiunctionality	Korea ORD[3)] (1993)	Korea KREI[3)] (2001)	Korea R.D.A.[4)] (2001)	Japan MRI[3)] (1997)	Japan ARI[3)] (1998)
Flood prevention	13.19	11.09	12.08	162.72	239.91
Water resources recharge	NA	9.52	12.24	61.65	107.39
Water purification	49.68	9.96	16.51	NA	NA
Soil erosion and landslide prevention	0.61.7	3.78	7.13	3.93	35.66
Soil purification	NA	0.74	-	0.38	0.53
Landscape preservation[1)]	NA	9.35	-	142.63	NA
Air purification	2347	18.43	16.13	14.31	0.83
Disposal of organic wasters	-	-	55.8		
Climate mitigation	-	-	11.75		
Landscape (minimum value)			10.23 (7.45)		
Recreation/relaxation (Max.)			5.86 (25.72)		
Total externalities	86.75 111.98	62.87	97.51 (114.85)	385.62	384.32

1) evaluated only by the CVM method, 2) 1 US\$=1,200 Won=120 Yen, 3) ORD=Office of Rural Development, KERI=Korea Rural Economic Institute, MRI= Mitsubishi Research Institute, ARI= Agricultural Research Institute, 4) R.D.A.=Rural Development of Agriculture, Korea.

Table 5.1. Areas of paddy fields by slopes.

Areas (%) of slope	0-2	2-7	7-15	15-30	30-60	60-100	Total
Total area	550,332	477,677	215,479	44,761	34	1	1,28,240
(%)	43	37	17	3	0	0	100

Source: RDA (1992)

Table 5.2. Estimated length of the levees of paddy fields.

	Area of paddy fields under environment-friendly farming (ha)	Number of plots	Estimated length of the levees (km)
1999	1,714	11,647	1,417
2000	2,171	15,821	1,856
2001	4,782	34,124	4,035
2002	11,077	62,213	8,280

Source: Data for area of paddy fields under environment-friendly farming and number of plots are obtained from the Ministry of Agriculture and Forestry (MAFF, http://www.maf. go.kr) and the land information centre (http://lic.mogaha.go.kr/main.html), respectively.

Table 5.3. Nutrient contents different soil conservation methods (mean of 5 years).

Treatment	pH (1:5)	O.M ($g{\cdot}kg^{-1}$)	Av. P_2O_5 ($mg{\cdot}kg^{-1}$)	Ex. Cations ($cmol{+}kg^{-1}$)	
				Ca	K
Normal	6.13	46.6	477	5.67	1.57
Grass belt	6.14	41.7	415	5.25	1.35
Gravel belt	6.04	41.8	385	5.77	1.30
Mean	6.10	43.4	426	5.56	1.40
Normal Upland soil	5.94	34.6	407	4.21	1.23

Their scenic value is comparable with those of hedgerows. In addition, the levees offer habitats for various species and become access route for people. The levees are a symbol of rural life to the people.

In 1992, the area of terraced paddy field was estimated of 260,240 hectares or about 20% of the total area covered by paddy fields (Table 5.2). The fact that about 70% of Korean territory is mountainous leads to relatively large areas of terraced paddy field. Its costly management and lack of farm labor has forced a large proportion of terraced paddy fields to be transformed into other uses or abandoned. Of 879,000 ha of upland area in Korea, over 7% (541,000 ha) are sloping. With regard to Yeongnam area, more than 75% of area is sloping upland (Table 5.1). Continuous soil erosion is the main hurdle for development of soils which cause poor organic content of these soils. In order to find out a method to reduce soil erosion and to increase the soil productivity of the upland area, different control measures were constructed such as grass-belt, gravel belt, terraced field and stone ditch during 1997-1998. It was observed that the grass belt method decreased the soil erosion by 34.4%. Among the 3 plant species, weeping love grass (*Eragrostis curvula*), many kinds of lawn grasses and clovers have reduced the soil erosion to the tune of 45.5, 38.6 and 19.2% respectively (Table 5.2). However, these kinds of cover crops could be applied in the upland or mountainous area or hill side, but are very hard to conserve.

Numerous agricultural engineering studies have pointed out that, should such farmland be used for other types of farming under similar geographical conditions, soil erosion would be prone to occur.

Even in terraced paddy fields without proper water control, probabilities of soil erosion and landslide occurrence are high. Technological studies have revealed that probability of farmland degradation is higher in paddy fields and erosion develops when cultivation is abandoned on slopes. When damages brought on by heavy rains, for example, from typhoons, and water is discharged from tillage areas into cultivated and non-cultivated paddy fields were comparatively analyzed, results showed that daily management of farmlands was effective for preventing landslides.

Flooding cost can not be estimated exactly, however, if we utilize the paddy field as a dam in the summer season, we can reduce the flooding damage (Table 3). However, Korean and Japanese farmers do not use the paddy field as small dams because most of levees are made of compacted soil. Farmers dislike levee submergence during heavy rains, therefore most farmers open the drainage cannel during heavy rains and it becomes the main source of flooding in the low-land. The estimated length of the levees expanded from 1,417 km in 1999 to 8,280 km in 2002, resulting in an increase of almost 500% (Table 5.2). This increase is attributed to a drastic increase in the areas of paddy fields under environmentally friendly farming practices. However, in structure, Japanese paddies could not used as environmentally friendly small dams because most levee are made by Cement concrete. In replacing dams with levees, the height and structure of the levee need to be considered heavy rains result in land-sliding and soil erosion which brings about nutrients depletion, especially severe erosion on top soil layer (Table 5.3). By managing the paddy field with terraces, the soil erosion and sliding can be reduced.

Groundwater recharge

The amount of water filtration mostly depends on the soil texture and ground water height. Filtrated water in soil that causes damages to slopes replenishes groundwater in low flatlands. Groundwater recharge from paddy fields is important because it replenishes areas that natural rainfall cannot reach. By using canals to transfer water in large quantities to areas where natural flow is not possible.

Preservation of biological diversity

Up to date, 536 species of freshwater arthropods, belonging to 112 families, 18 orders, and three classes and including 494 species of aquatic insects in 96 families, have been documented in Korea (Bae and Lee, 2001). Paddy fields provide a niche to entomofauna, which comprises some hundreds species including the terrestrial insects and aquatic insects, both resident and migratory. Characteristics of such habitat depend on the attributes of rice farming, and cannot be observed in other farmlands. Paddy fields and irrigation canals are dwelling places for insects, including both species that reside or lay eggs there. Many types of fish and amphibians also live in paddy fields and irrigation canals, with something rare species. This diversity is possible because rivers and paddy fields are linked. If rice is not grown in these paddy fields, however, the waterways linking rivers and paddy fields which fish travel will disappear.

Sometimes conservation of biodiversity is attacked by grain damage. For water birds, including migratory birds, paddy fields serve as both feeding and dwelling places. The loss of feeding ground due to decreasing paddy field areas, along with indiscriminate hunting, has been pointed out as factors leading to the extinction of rare birds. Today, many animals are endangered and recorded on the red list of extinction. One of the most endangered birds, under the risk of extinction worldwide is cranes. In Korea, their major habitats are found in mid and southern Korean peninsular. Preservation of cranes not only requires safe habitat but also abundant food (Http, 2002). Urbanization of great magnitude has been occurring in East Asian countries, which constitute the largest habitat of cranes globally, making it extremely difficult for birds to find foods during the winter season in these areas. Lee and Rhim (1999) found that the remaining grains in paddy fields after harvest are essential food source for cranes. They also revealed a close correlation between the number of the two different types of cranes (Table 6). Protection of valuable cranes is only one example of the contributions of paddy rice production to biological diversity.

Table 6. Relationship between cranes and rice grains left over after harvest in paddy fields.

	Region1	Region2	Region3
Number of grains (mean ± s.e)	28±4.98	5±3.78	37±7.25
No. of red -crowned crane	84	21	173
No. of white-nape crane	197	57	239

Rice farm practices such as plowing and irrigating of fields and the subsequent transplanting of rice seedlings also promote habitat segregation of species living in paddy fields, further enhancing the biological diversity.

Landscape preservation

Since landscape of rice cultivation fields requires the actual growth of rice, it is practically impossible to detach it from agricultural production. Rice is an annual crop which does not continually vegetate in the soil. Therefore, landscapes are different notably between summer and winter. Typical landscapes of paddy fields are green in summer and golden-colored before harvest in fall. Moreover, a study through a contingent valuation method (CVM) has shown that even winter fields, if they contain leftover hays, whether they may be piled high or bound and hung for drying, are highly valued by local people as part of the landscape.

Climate mitigation

About 6 mm of the water in paddy fields evaporates every day (Suh, 2001). This causes reduction in air temperature during hot summer in Korea. The value of the energy which would be otherwise needed for cooling amounts to about 346 million kl of crude oil and the value of this function is about US$1,175 million.

Air purification

Rice production cleans the atmosphere by absorbing 14 million mt of CO_2, and emitting 10 million tons of O_2 annually and the value of rice crops in purifying is about US$ 1,613 million (Suh, 2001).

Food security

Food security for the people is the most important function of rice farming. Since most of Asian monsoon paddy fields have a solid history of continued production, some that stretches over a thousand years, and their sustainability has been proven by cultivation and soil sciences, paddy rice framing is a dependable means of future food security. Continued rice production not only supplies present foods, but also enhances the future food supply. General activities of rice cultivation and production have been playing roles in accumulating human resources, as well as proper maintenance and improvement of the land foundation for paddy fields. As described in the previous chapter, due to the uniqueness of paddy rice culture in the Asian monsoon areas, most governments in the Asian monsoon countries have declared or tempted to declare that food security is to be improved by raising the self-sufficiency rate of rice. Although, national consensus on this should have been reached prior to implementing the policy.

ECONOMIC VALUE OF MULTIFUNCTIONALITY

Many estimates are available on the value of multifunctionality as assessed by the benefits. These are related to environmental benefits, and have been conducted using a substitutive cost method (SCM) and CVM for evaluation of food security, landscape preservation, and rural revitalization.

A few studies have been conducted in Korea and Japan in estimating the multifunctionality of paddy rice fields at a national level though a nationwide SCM and CVM surveys. Mitsubishi Research Institute[10] estimated expanses by using alternative means that provide similar level of effects for each major function, rather than directly measuring demands for these multiple functions. The Japanese Agricultural Research Institute (1998), through the same method used by Mitsubishi Research Institute (1997), estimated the value at about 38.4 billion US$. In Korea, however, Office of Rural Development (Eom *et al.*, 1993) and Korea Rural Economic Institute (Oh *et al.*, 2001) have evaluated the multi-functionality for the paddy farming as, respectively, 8.7 to 11.2 billion and 6.3 billion US$, excluding the North Korea portion. Table 3 shows the economic value of multi-functionality from paddy farming in both Korea and Japan.

There are some difference in evaluation categories and values, however most of the evaluation methods and category were closely related to each other.

Comparison of economic value between two countries will have little significant differences due to their economic, social, and cultural similarities. However, its structure of multifunctionality of paddy rice farming can be understood through such comparison research. Nevertheless, paddy fields do provide various environmental and social non-commodity outputs, accounting for 70-150% of the total annual rice production cost.

AN OUTLOOK TO DIRECTION OF THE FUTURE

As pointed out, multifunctionality inevitably lead to controversy on how to measure optimal non-market outputs, such that they are not under- or over- estimated as a pretext for agricultural protectionism and the legitimate policy to be implemented. A universally acceptance and agreeable logic of count-measure requires verified analysis backing it. However, only limited information is available for rural vitalization and food security, which are difficult to be expressed in terms of monetary value. Joint and interdisciplinary research projects between economists and natural scientists at inland as well as international level should be developed, and the cooperative research system should be established for the development of counter-measure logic through actual proofed analysis. In addition, it should be further verified that not only are many benefits linked in the paddy rice production, but also, within the benefits, one beneficial function is linked to another function.

For the development of counter-measure logics, interdisciplinary and international researches should focus on the following points.

1. Differences between maintaining paddy fields without cultivation, and cultivating paddy rice for recharging of water resources, prevention of floods, and effects of landslide and soil erosion of paddy rice fields.
2. Assessing the net effect of environmental preservation of paddy fields by comparing the effects of environmental pollution and preservation achieved through paddy rice farming.
3. Differences in costs between those achieved through rice production and resulting in environmental preservation by paddy rice cultivation to those accrued by importing rice and achieving environmental preservation through means other than paddy rice cultivation.
4. Establishing the direction of future research, which contribute to understanding the multifunctionality of paddy rice cultivation by estimating demand and supply of water resource in an era of worldwide water shortage.
5. Estimating the capability of worldwide demands and supply of rice in standpoints of science and technology, taking into consideration the effects of economic variables.
6. Measurement of social loss due to declining living standards in rural areas caused by rural exodus phenomenon and development of concrete examples.
7. Analysis of consumer's propensity for food safety and their willingness to pay higher prices for safer foods.
8. Providing fundamental materials and data necessary for estimating various social costs due to the cityward preference.

CONCLUSIONS

1. Wet rice farming in the Asian monsoon region is unique compared to dry land farming of Western countries in terms of climate, farming practices, water use, self-sufficiency principle, and agricultural structures of small family farms. These characteristics are strong evidence, supporting the

multiple benefits from paddy rice farming, other than producing rice.

2. Multiple functions in the monsoon Asian countries, where the paddy rice farming predominates were identified as rural vitalization, social security, nature and environment preservations, and social and cultural functions. Paddy rice farming also contributes to flood prevention, groundwater recharge, landslide and soil erosion prevention, landscape preservation, biological diversity preservation, and food security.

Studies from Korea and Japan revealed that the nature and environmental functions of paddy fields provide the economic value of 6.3 billion US$ in Korea and 38.4 billion US$ in Japan, approximately 70-150% of the total price of annual rice production of each country.

The interdisciplinary and international researches within the monsoon Asian countries for the multifunctionality of paddy rice farming is necessary to develop counter-measures against the logistics of the Western dry land and commercial farming countries. Furthermore, efforts to disseminate the significance and recognition of the multifunctionality of paddy rice farming under the Asian monsoon climate to the local people as well as societies worldwide become more critical.

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