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Wetland Function Evaluation and Expert Assessment of Organic Rice-Fish Mixed Farming System

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유기농 벼-담수어 복합영농의 습지기능평가 및 전문가 조사

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Abstract

A mixed farming system that includes organic rice production and freshwater fish farming is being called into attention in Korean agricultural industry and rural areas in order to improve farm management and environmental conservation. This study was conducted to evaluate the environmental and ecological value of such mixed farming practices. Expert assessment and rapid assessment method (RAM) of wetland evaluation were employed for this study. Experts have responded that biodiversity conservation including amphibian and reptile habitat (2.39), aquatic insect habitat (2.36), Fishery habitat (2.34), vegetation diversity (2.13), avian habitat (2.05), and experience and education were the most important function of mixed farming. The wetland function evaluation conducted using modified RAM indicated that rice-fish mixed system showed improvements in most of the evaluated functions, compared to the conventional rice paddies. The overall wetland function of rice paddies in rice-fish mixed system was greatly improved as compared with the conventional rice paddies. Rice paddies are known to play an important role in biodiversity maintenance, and provide ecosystem services such as climate modulation and carbon reduction. Rice-fish mixed system of farming may not only improve various ecosystem services of rice paddies, but may increase farm income through value added fish farming, as well as promotion of social services such as education and maintenance of tradition. Additional research is needed for quantitative analysis of the values gained from the most improved wetland function when mixed farming system is actually put into practice, and to utilize the results in advertising of the organic rice, and in various sectors such as food, education and direct payment policy.

Key words : Mixed Ecological Agriculture, Freshwater Fish, Wetland Function Evaluation

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요 약

우리나라 농업·농촌은 경영 개선을 위해 유기농 쌀 생산과 더불어 담수어를 생산하는 복합영농이 시작되었다. 본 연구는 복합영농이 환경, 생태적 기능에 얼마나 가치가 있는지 알아보았다. 연구방법은 전문가 평가와 습지평가체계(RAM)를 분석하였다. 전문가 조사 결과 양서파충류 서식처(2.39), 수서곤충 서식처(2.36), 어류 서식처(2.34), 식생다양성(2.13), 조류 서식처(2.05) 등 생물다양성 분야와 체험/생태교육(2.29) 기능이 1순위로 구분되었다. Modified RAM를 통해 관행논과 복합논의 습지기능평가를 실시한 결과 복합논이 대부분의 평가기능 항목에서 기능이 향상 되는 것으로 평가되었다. 보전가치 판단기준은 관행논 향상에서 복합논 보전으로 가치가 향상 되었다. 연구결과 복합영농은 관행논에 비해 습지기능이 탁월하게 개선되는 것을 평가를 통해 알 수 있었다. 논은 국가 생물다양성 유지에 지대한 역할을 수행하며, 기후조절, 탄소저감 등 다양한 생태계서비스를 제공하는 공간으로 평가받는다. 복합영농 실현은 논의 다양한 생태계서비스 기능을 증진시켜 줄 뿐 아니라 물고기 생산이라는 부가가치를 통한 농가의 소득증대와 그로 인한 체험, 전통계승 등의 사회적 기능 증진에도 유용 할 수 있다. 본 연구결과를 바탕으로 습지기능평가가 높게 개선된 항목과 전문가들로부터 높은 개선이 예상된 항목을 실제 운영 시 정량 평가 및 조사하여 생산되는 물고기과 쌀의 친환경 이미지를 제고시키고 브랜드, 음식, 체험, 논농업 직불제 등 다양한 분야로 활용하도록 연구를 추가적으로 추진해야 할 것으로 판단된다.

핵심용어 : 복합생태농업, 담수어, 복합영농, 습지기능평가

1. Introduction

Agricultural industry and rural areas in Korea are experiencing difficulties in farm management due to aging rural population, polarization of farmland scale, and the decrease of full-time farmers. To overcome such threats and difficulties, many efforts are being in rural communities, including training new farmers(Woo et al., 2018), increasing farm income(Park et al., 2016), reviving rural economy(You, 2001), expanding welfare in rural areas (Choi and Hwang, 2013), developing alternative crops(Han et al., 2017), and building horticulture facilities(Shin, 2016). In the case of rice, the greater decrease in demand than the decrease in production since 2000's, which has led to an oversupply of rice(Kim et al., 2018).

Of demand due to the global increase in environmentally friendly and safe agricultural products, organic agriculture has increasing annually. Organic farms have generated higher income compared to conventional farms, and diverse farming practices has been used for organic food production in Korea(Lee, 2010; Jung, 2007; Lee et al., 2010; Ahn et al., 2012). In addition organic agricultural practices have improved the competitiveness of rice production industry, and have brought various benefits including safe food product, environment conservation, generation of habitat for aquatic life, improvement of soil physical properties, and increase of soil microbes(Wright et al.,1999; Park et al., 2010; Lee et al., 2011a; Park et al., 2012). Despite the aforementioned benefits, however, problems regarding pests, soil management, cropping system, and rice crop varieties resulted in the decrease of rice consumption and competitiveness in the market(Kim et al., 2018; Lee et al., 2011b; Lee et al., 2017; Son and Han, 2010). Therefore, mixed farming system that produce freshwater fish such as catfish, pond loach, and giant river prawn along with rice has been well recognized.

The history and tradition of rice-fish mixed farming system can be seen in ancient (206 BC) pottery with rice and fish symbols, and in stone tablets from Sukhothai era in thailand(Halwart and Gupta, 2004). The combination of rice and provides carbohydrate, calcium, essential amino acids, vitamin A, various minerals, and proteins(Kim, 1997). The combination also symbolizes richness and stability as well as ecological connection through reservoir, rivers, waterway, ponds and rice paddies.

To practice rice-fish mixed farming system, organically managed rice paddies are more suitable rather conventional rice paddies where chemical fertilizers and pesticides are used. Organically managed rice paddies embrace greater varieties and individuals of aquatic life including benthic invertebrates than conventionally managed paddies, add citations. Organic rice production provides a more stable environment for rice and freshwater fish production in terms of ecological food chain, role of freshwater fish as a natural food source, water purification for nitrogen, phosphorus, and suspended solids.

Nationally, pond loach production technology was developed in the early 2000s by Jinhae Inland Waters Institute, which was then extended to Nawon in 2006, and Sanchung in 2009. Currently, the rice-fish mixed farming system mainly used in Gyeongnam, Jeonbuk, and Chungnam provinces. Preceeding studies in mixed-farming include pond loach farming in rice paddies by Lee et al.(2013) and Lee et al.(2014), biological control of disease-transmitting mosquitoes using Chinese minnow and pond loach(Kim et al., 1994), and analysis of factors affecting changes in Chinese weatherfish community by different agricultural practices(Han et al., 2013b). Recently, many edible freshwater life(including catfish, Chinese weatherfish, pond loach, crucian carp, leather carp, Chinese mitten crab) and inedible freshwater life(including fancy carp and goldfish) are being considered by the Inland Water Institutes as the potential freshwater life to be produced in mixed farming, e.g., giant river prawn, freshwater shrimp, slender bitterling, and Chinese ninespine stickeback. However, research in freshwater fish other than pond loach and Chinese weatherfish is still lacking.

Rice paddies have been recognized as wetlands in 2008 Ramsar convention in Changwon, and are known to provide various ecosystem services(Maltby, 2009; Ramsar, 2008; Ramsar, 2014). Therefore, this study seeks to evaluate structural changes in paddies, and environment conservation effects through organic practices in rice-fish mixed farming, using rapid assessment method(RAM) from Tilton et al.(2001) which was used in Kong et al.(2014). Expert assessment was employed to analyze and prioritize positive and negative aspects of the rice-fish mixed farming system in order to determine improvements in ecosystem services and the environment.

2. Materials and methods

2.1 Structure and study site of rice-fish mixed farming system.

Due to the structural limitations of rice paddies, a relatively deep water channel was constructed around the edge of the paddies to allow freshwater fish to inhabit in the mixed farming rice paddies. A waterway was constructed so that rice plant growth and machinery operation would not be affected(Fig. 1).

Mundang-ri Hongdong-myun Hongsung-gun in Chungnam province was selected for this study, because the grower community aimed to practice rice-fish mixed farming, and organic rice production was already practiced in some areas.

2.2 Ecosystem service and function selection for expert survey

A total of ecosystem functions of rural area listed in Son et al.(2015) were used for the expert survey in this study(Table 1).

Son et al.(2015) analyzed 11 studies related to ecosystem services, and selected 17, ecosystem functions that should

Table 1. The expert survey items on the ecosystem functions.

Number	Ecosystem Service Function*
1	Groundwater recharge
2	Water storage
3	Water purification
4	Flood control
5	Aquatic insect habitat
6	Amphibian & Reptile habitat
7	Vegetation diversity
8	Creating landscape
9	Experience, Education
10	Avian habitat
11	Climate regulation
12	Air quality regulation
13	Fishery habitat
14	Rest area
15	Biological control
16	Maintenance of genetic diversity
17	Mammal habitat

* Survey items listed in Son et al.(2015)

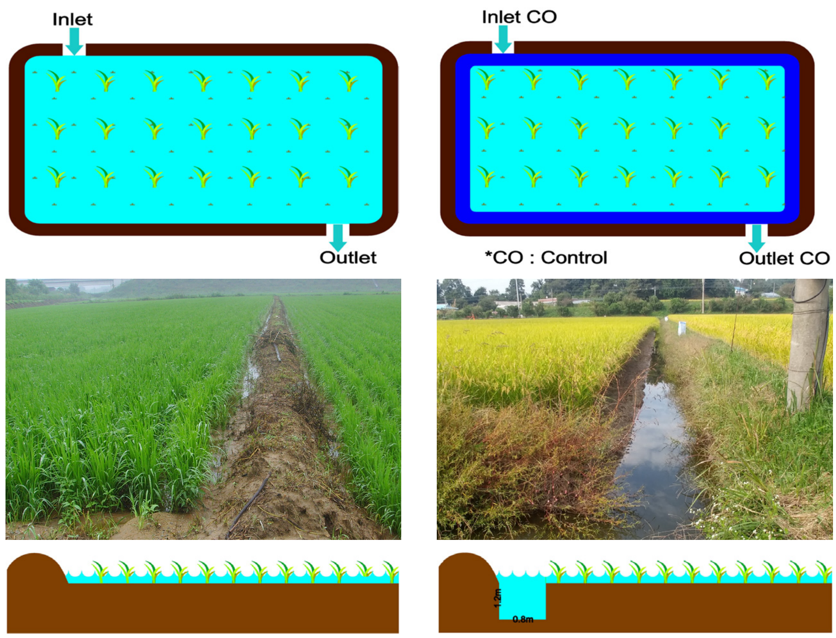

Fig. 1. Two-dimensional cross section of conventional(left) and mixed farming system of rice paddies(right).

be considered during, development projects such as the land-use conversion of the ecosystem, etc.. The important ecological functions selected include groundwater recharge, water storage, water purification, flood control, aquatic insect habitat, amphibian and reptile habitat, vegetation diversity, creating landscape, experience and education, avian habitat, climate regulation, air quality regulation, fishery habitat, rest area, biological control, maintenance of genetic diversity, and mammal habitat.

2.3 Expert survey and responses

The survey was conducted to seek expert opinion on the effect of rice-fish mixed farming on the ecosystem and rural environment, without considering the farm income. The ecological and social functions of paddies which may be positively or negatively affected by the mixed farming practice were evaluated using a Likert scale(-3, -2, -1, 0, +1, +2, +3). The collected data were analyzed using SPSS software (WIN 18.0). A total of 56 professionals responded to the survey, including 13 people from business corporations(23.6%), 18 from research institutes(32.7%), and 19 from universities(34.5%)(Table 2). Respondents with the highest degree of education included 43 respondents who had doctorate degrees(78.2%), and 3 ph.D candidates (5.4%). The fields of expertise of respondents were environment(20 respondents, 35.7%), biology(16 respondents, 28.6%), engineering(14 respondents, 25.0%), and agriculture(6 respondents, 10.7%).

Table 2. The general information of survey respondents.

Classification		Respondents (N=56)	
		Numbers	%
Work	University	19	33.9
	Institute	18	32.1
	Business	13	23.2
	Public Official	4	7.1
	Graduate course	2	3.6
Education	Doctor	43	76.8
	Doctor Course	3	5.4
	Master	6	10.7
	University	4	7.1
Major	Environment	20	35.7
	Biology	16	28.6
	Engineering	14	25.0
	Agriculture	6	10.7

2.4 Wetland evaluation and determination of conservation values

In this study, the modified RAM from Koo(2009) was used for wetland evaluation and analysis.

The modified RAM identified eight wetland functions, and each function was evaluated through 4 to 9 evaluation factors to give an average grade to a given wetland, which was then categorized into a grade of high value(>2.4), moderate value(1.7 to 2.3), or low value(<1.7)(Appendix 1, Table 3). Furthermore, wetlands could be categorized into different priority groups according to their function and criteria as given in Table 3. If a wetland is found to be high value, both domestically and internationally, the wetland is designated as protected area with absolute conservation goals.

3. Results and Discussion

3.1 Expert assessment of the ecosystem functions

The expert survey was sent to the experts on the member list of academic society related to wetlands via e-mail. A

Table 3. Conservation value criteria.

Preservation priority	Criteria	Conservation, Restoration strategy
First, Consider conservation	• International or domestic protection value if found in the protected Species of Korea or habitat. • A typical, rare case of high conservation value.	Absolute Conservation
High	• Individual function evaluation value is "high" as table the total function of 1/2 or more. • If the total value of the average is 2.4 or higher. • Evaluation elements of "High" to the table element is overall assessment elements of 1/2 or more.	Conservation
Moderate	• Individual function evaluation value "high" feature one or more, full function of 1/2 is less than. • If the total value of the average is 1.7, less than 2.4. • Evaluation elements of "High" to the whole element of the element table 1/2 is less than. • Evaluation elements of "high", but the elements of a "Middle" all the elements of more than 1/2.	Improvement
Low	• In the case of all other cases.	Restoration or Improvement

Table 4. Expert assessment of potential ecological functions expected from rice-fish mixed farming.

Functions	Field				Mean (n=56)	F-test[1)]
	Agriculture (n=6)	Engineering (n=14)	Biology (n=16)	Environment (n=20)		
Amphibian & reptile habitat	2.67^{bC}	2.00^{aEF}	2.50^{abF}	2.50^{abD}	2.39^{F}	N.S
Aquatic insect habitat	2.67^{bC}	1.93^{aDEF}	2.56^{bF}	2.40^{abD}	2.36^{F}	3.184*
Fishery habitat	2.67^{aC}	2.21^{aF}	2.31^{aDEF}	2.35^{aCD}	2.34^{F}	N.S
Experience and education	2.50^{aBC}	2.21^{aF}	2.38^{aEF}	2.20^{aCD}	2.29^{F}	N.S
Vegetation diversity	2.50^{bBC}	1.71^{aBCDEF}	2.31^{abDEF}	2.15^{abCD}	2.13^{F}	N.S
Avian habitat	2.00^{aABC}	1.79^{aCDEF}	2.25^{aCDEF}	2.10^{aCD}	2.05^{EF}	N.S
Groundwater recharge	2.50^{aBC}	1.64^{aBCDEF}	1.50^{aABCD}	1.70^{aBC}	1.71^{DE}	N.S
Water storage	2.67^{bC}	1.50^{aBCDEF}	1.44^{aABC}	1.70^{aBC}	1.68^{DE}	N.S
Maintenance of genetic diversity	2.50^{aBC}	$1.57^{abBCDEF}$	$1.81^{abBCDEF}$	1.35^{bAB}	1.66^{DE}	N.S
Biological control	1.83^{aABC}	1.50^{aBCDEF}	1.75^{aBCDEF}	1.45^{aAB}	1.59^{D}	N.S
Water purification	1.83^{aABC}	1.64^{aBCDEF}	1.38^{aAB}	1.30^{aAB}	1.46^{CD}	N.S
Mammal habitat	1.67^{aABC}	$1.21^{aABCDEF}$	1.63^{aBCDE}	1.25^{aAB}	$1.39B^{CD}$	N.S
Creating landscape	1.50^{aAB}	1.14^{aABCDE}	1.25^{aAB}	1.45^{aAB}	$1.32B^{CD}$	N.S
Climate regulation	1.17^{aA}	0.86^{aABC}	1.25^{aAB}	1.10^{aAB}	1.09^{ABC}	N.S
Rest area	1.33^{aA}	0.93^{aABCD}	1.00^{aAB}	1.00^{aA}	1.02^{AB}	N.S
Air quality regulation	1.33^{aA}	0.71^{aAB}	0.75^{aA}	1.25^{aAB}	0.98^{AB}	N.S
Flood control	1.83^{bABC}	0.29^{aA}	0.69^{aA}	1.20^{abAB}	0.89^{A}	3.305^{*}
F-test[2)]	2.590^{**}	3.053^{***}	5.519^{***}	5.916^{***}	14.503^{***}	-

* Test result is statistically significant at the P = 0.5 level(*),P = 0.01 level(**), 0.001 level(***); NS = Not significant result., Duncan : width a〈b〈c…, length A〈B〈C…,
1) The result is according field types, Lower case letters.,
2) The result is according ecosystem function, Capital letters.

total of 56 experts in the fields of agriculture, engineering, biology and environment were invited to respond on the 7 point(-3 to +3) Likert scale, about the potential improvements in function of rice-fish mixed farming system as wetlands.

Our results showed that the average rating of the 17 potentially improved functions from the practice of rice-fish mixed farming ranged from 0.89 to 2.39, and the highest rating function was amphibian and reptile habitat(Table 4). The construction of a channel around the rice paddies would provide habitat for amphibians and reptiles, contributing to an increase in the species varieties and population. Similarly, functions related to biodiversity such as aquatic insect habitat(2.36), fishery habitat(2.34), and vegetation diversity(2.13) were expected to greatly improve. Furthermore, experience and educational value was highly rated(2.29) due to the potential fishing and ecological field experience opportunities. Depending on the field of expertise, the expert assessment of the 17 ecological functions of rice-fish mixed farming differed. For example, experts from the field of engineering gave lower ratings to the potential aquatic insect habitat and flood control functions of the mixed farming system compared to the experts from other fields, which was statistically significant. Experts from the field of engineering tended to give lower ratings to the potential improvements in the other 15 functions, but was not statistically significant.

Table 5. Rating of wetland functions of rice-fish mixed farming based on expert assessment.

Consider rankings	Function
First	Amphibian & reptile habitat Aquatic insect habitat Fishery habitat Experience and education Vegetation diversity Avian habitat
Second	Groundwater recharge Water storage Maintenance of genetic diversity Biological control
Third	Water purification Mammal habitat Creating landscape
Exception	Climate regulation (carbon fixation) Rest area Air quality regulation (heat island effect mitigation) Flood control

Survey responses were statistically analyzed to classify the 17 functions into first, second, and third rating categories based on their potential for improvement through rice-fish mixed farming(Table 5). According to the standard error and statistical analysis result, four functions that were not deemed not likely to significantly improve (climate regulation, rest area, air quality regulation, and flood control) were excluded and classified as exceptions.

3.2 Expert opinions on ecosystem functions

Expert assessment indicated that all of the 17 studied ecosystem functions will be improve from the practice of rice-fish mixed farming. List citations have concluded that rice paddies has been evaluated as a space providing public service for diverse environments. However, other studies have also expressed concerns on the negative effect on the environment and ecosystem resulting from drying paddies during winter and fertilizer and organic matter application. Therefore, experts subjective opinions along with the evaluation through surveys were sought for consideration in the future research(Table 6).

In regards to habitat creation for amphibians and reptiles, the depth and area of open water would increase in rice-fish mixed farming, which providing breeding and hiding places for amphibians and reptiles such as frogs and toads. On the other hand, concerns that fencing and wall structures installed for fish farming, restricting the movement of amphibians and reptiles, have been raised. Similarly, as aquatic insect habitat, it was suggested that paddies during midsummer drainage or winter periods may serve as a shelter, but introduced fish may feed on aquatic insects, leading to a disturbance and decrease in the aquatic insect population. As fish habitat, a deeper channel of water constructed for fishery may accommodate a higher diversity of fish population, but introduction of new species apart from the artificially selected species would be not likely to occur due to the isolated nature of the system. The rice-fish mixed farming system would provide opportunity for experiential education not only in the rice paddies looking at rice plant growth, but also in fishing and collecting aquatic organisms to understand the ecosystem. Such activities may enhance the perceived value of organically grown rice, and fishing activity may be developed into a community fair, which may diversify the source of rural income. However, some experts commented that fishing activities would have little influence on rural income, but if field trips and activities are carried out early in the season not long after the release of young fish into the system, fish growth may be negatively affected, and would compromise the original goal of freshwater fish farming. Although many experts anticipated vegetation diversity would greatly improve as water channels provide habitat for different submerged, floating and emerged plants commonly found in wetlands, they worried that human management would introduce invasive or naturalized species, leading to lower vegetation diversity. An increase in avian population that feed on freshwater fish was deemed as an expected result, but since the purpose of rice-fish mixed farming is to produce fish stock, to avoid threatened by birds, bird prevention measures such as fencing, nets, and scarecrows are required. Therefore, the increase in bird species diversity may ironically be detrimental to the management of fishery in the system. In rice-fish mixed farming water infiltration constantly occurs due to the presence of water channels. Therefore, groundwater recharge function of the mixed farming system is expected to be improved compared to the conventional rice paddies. However, if the water depth required for fish farming is not fully supplied by rainwater or surface water, groundwater would be utilized, making the system not appropriate for groundwater recharge. Water channels in the mixed farming system is constantly filled with water, so water storage capability is expected to be higher than that of conventional paddies, during the winter period. However, evaporation is also expected to be increased and it was suggested that surface water in the channel would not provide any value as a water resource since any surface water inflow to the channel is used for the purpose of fish farming. There were expectations that rice-fish mixed farming system would contribute to the conservation of regionally or nationally protected species and to the maintenance of genetic diversity. However, it was also suggested that the created which environment is limited to local scale for fish farming, and human interference may be more favourable to naturalized Presence of fish may biologically control pests through preying. However the water channel may provide breeding ground and habitat for mosquitoes and flies, leading to an increased pest population.

Water purification is a typical function of a wetland, and water flow may temporarily be slowed resulting in deposition of suspended solids and organic matter if water channels are formed around rice paddies. Also, microbes and aquatic plants are expected to help organic matter decomposition and absorption of eutrophication-causing nutrients such as nitrogen and phosphorus. However, fish feeds input for fish farming has been identified as a possible source of water pollution. Freshwater fish population may attract mammals such as badgers, raccoons, and otter that feed on fish. However increased mammal population can impede fish farming which is main objective of this research. Creating landscape for rice-fish mixed farming would provide a view

Table 6. Expert opinion on construction of rice-fish mixed farming system.

Grade	Function	Ranking	Expert opinion	
			Positive	Negative
First	Amphibian and reptile habitat	1	Water channels provide habitat	Restricted movement due to nets and walls
	Aquatic insect habitat	2	Water channel provide habitat and hiding place during winter	Introduction of fish by humans may disrupt insect population
	Fishery habitat	3	Increased fish diversity in rice paddies	Isolated ecosystem limits fish movement and natural diversity
	Experience and education	4	Fishing and experiential learning	Disturbance to fish population and negative effect on fish production
	Vegetation diversity	5	Increased wetland plant diversity in water channel	Invasive or naturalized species introduction
	Avian habitat	6	Fish population provide food for birds	Threat to fish production for human use
Second	Groundwater recharge	7	Constantly filled water channel acts as source of groundwater recharge	Use of groundwater for water channel maintenance during drought
	Water storage	8	High water storing capacity due to constantly filled water channel	Water not valuable as water resource since it is for fish farming
	Maintenance of genetic diversity	9	Possible introduction of protected species	Naturalized species introduction due to human management
	Biological control	10	Fish feeding on harmful insects	Water channels may provide breeding ground for pests
Third	Water purification	11	Water purification effect of water channel by deposition and decomposition of organic matter	Fish feeds can be a source of water pollution
	Mammal habitat	12	Fish population provide food for mammals	Threat to fish production for human use
	Creating landscape	13	Scenery of rice paddies and water channels	Nets and walls can destroy scenery

of non-typical rice paddies, but it was pointed out that nets and blocking structures may destroy the scenery.

3.3 Wetland function evaluation using modified RAM

Along with expert assessment and comments on ecological functions as wetlands of rice-fish mixed farming, the modified RAM was used to evaluate conventional rice paddies and rice-fish mixed farming(Table 7). Evaluation categories consisted of eight wetland functions including floral diversity and wildlife habitat, fishery and herptile habitat, flood and storm water storage, runoff attenuation, water quality protection, shoreline and stream bank protection, aesthetics and recreation, and groundwater recharge. Each function was evaluated using 4 to 9 scales, and the point for each score given in appendix 1.

For fishery and herptile habitat function, the degree of interspersion of open water and cover, hydroperiod, and vegetation type elements were graded as 'high'(3 points), resulting the mixed farming gaining a higher average grade than the conventional paddies. The result showed that mixed farming was rated as 'high'(average 2.4) in every wetland function except for flood and storm water storage.

In detail, among the 52 evaluation elements, rice-fish mixed farming was rated higher than conventional rice paddies in 12 elements. In the floral diversity and wildlife habitat function category, the degree of community

Table 7. Wetland function evaluation of conventional rice paddy and rice-fish mixed farming paddy.

Evaluated function	Conventional rice paddy		Rice-fish mixed farming paddy	
	Average	Grade	Average	Grade
1. Floral Diversity and Wildlife Habitat	2.50	High	2.83	High
2. Fishery and Herpetile Habitat	2.20	Moderate	2.80	High
3. Flood/Storm Water Storage	2.33	Moderate	2.33	Moderate
4. Runoff Attenuation	2.13	Moderate	2.50	High
5. Water Quality Protection	2.22	Moderate	2.44	High
6.Shoreline /Stream Bank Protection	2.00	Moderate	2.40	High
7. Aesthetics and Recreation	2.56	High	2.67	High
8. Groundwater Recharge	2.50	High	2.50	High

interspersion was rated as low in conventional rice paddies, but high in rice-fish mixed farming. This was attributed to the potential increase in the wetland plants around the water channel.

Under the fishery and herptile habitat function category, the conventional rice paddy was rated as moderate in the degree of interspersion of open water and cover, and vegetation type elements, but rice-fish mixed farming was rated as high in the same elements. Thus, structural changes in rice paddies may improve wetland functions. In the flood and storm water storage function category, there was no difference in the ratings between conventional paddy and rice-fish mixed farming, similar to the result of expert assessment. As there would be no structural change in the water inflow or outflow, the two systems received the same rating in the runoff attenuation category, and rice-fish mixed farming was rated high. In the water quality protection category, the mixed farming system was rated high in the hydroperiod and channel or sheet flow elements mainly due to structural changes in the system. Son et al.(2010) reported that water quality protection and shoreline and stream bank protection functions can be enhanced through control of inflow and outflow. Among 9 evaluation elements in the aesthetics and recreation category, conventional rice paddy was rated as moderate for interspersion of vegetation, but rice-fish mixed farming was rated as high. These results are similar to those of Choi et al.(2017), where wetlands with diverse distribution of aquatic plants are rated as high, and the creation of water channel in the mixed farming system may potentially provide similar environment for vegetation diversity.

Kong et al.(2014) also reported that wetland functions that important in valuation and conservation of wetlands are degree of interspersion of open water and cover, and vegetation area width. Therefore, the structural changes from conventional rice paddies to rice-fish mixed farming and the practice of organic farming would enhance wetland functions and provide a stable environment for wetland ecosystem.

Conservation value of wetlands are determined with evaluation element, function evaluation, and average value. Among 52 evaluation elements, 19 elements were given 3 points(high) for conventional rice paddies, but due to structural changes in rice-freshwater fish farming, the mixed farming system received 3 points in 31 evaluation elements(Table 8). In the functions categories, conventional rice paddies received high ratings in 3 functions whereas the mixed farming system received high ratings in 7 functions. This enhancement in wetland functions was attributed to the increase in open water area, vegetation cover, and diversity through structural changes in the mixed farming system. As a result of comprehensive wetland conservation value assessment, conventional rice paddies were given conservation strategy rating of 'improvement' required in all of the three evaluation standards (evaluation element, function evaluation, and average value), whereas the whereas the rice-fish mixed farming were given conservation strategy rating of 'conservation', indicating that conservation value as wetlands was higher for the mixed farming system.

Table 8. Conservation valuation of conventional rice paddies and rice-freshwater mixed farming system.

Valuation standard		Valuation result	
		Conventional rice paddy	Rice-fish mixed farming paddy
Evaluation element	3 points	19	31
	2 points	30	19
	1 point	3	2
	valuation	Improvement	Conservation
Function	High	3	7
	Moderate	5	1
	Low	-	-
	Valuation	Improvement	Conservation
Average	Value average	2.31	2.56
	Conservation value	Improvement	Conservation

Therefore, based on the result from wetland conservation value assessment and expert opinions and survey results, mixed farming paddies were considered more suitable for mixed agriculture, compared to conventional paddies. Further studies on mixed and combined agriculture appropriate for the environment in Korea are required to enhance wetland functions, sustainable agriculture, and stable ecological environment.

4. Conclusion

Many efforts are being made by the Korean agricultural industry and rural communities to improve agriculture management. Organic production of agricultural products has created higher income relative to conventional agriculture, and diverse methods are practiced nationally to produce organic products. This study was conducted to investigate the value of rice-fish mixed farming on rural environment and ecosystem.

The degree of ecosystem service improvement expected from the practice of rice-fish mixed farming was evaluated through expert surveys on rural ecosystem services and functions identified in a preceding study. Rapid assessment method (RAM) was used to assess the functionality of mixed farming system as wetlands, and expert survey responses on the positive and negative aspects of the mixed farming on wetland functions were pooled to identify expected ecological improvement.

Survey responses from 56 experts on 17 potentially improved wetland functions resulted in average ratings in the range of 0.89 to 2.39, and amphibians and reptile habitat was the highest rating function. Functions related to biodiversity such as aquatic insect habitat(2.36), fishery habitat(2.34), vegetation diversity(2.13), avian habitat(2.05) were given high ratings, and experience and educational function also received a high rating(2.29) due to increased opportunity for ecological experience. Survey responses were statistically analyzed and the functions were classified into first, second, and third rating categories.

Expert survey and analysis revealed that all ecological functions would increase from rice-fish mixed farming. It was suggested that relatively deeper water and increased open water surface in the mixed system would create habitat and breeding ground for amphibians and reptiles, but also, that artificial screens and walls used for fish farming may restrict movement of amphibians and reptiles. Aquatic insects and fish habitat creation function was also similarly evaluated. Avian and mammal habitat was expected to improve in the mixed system, but for the purpose of this research, it was suggested that birds and mammals might damage the farming system. Therefore, further research is required to construct a system that would harmonize with the surrounding environment. The mixed farming system was suggested as having potential to become an educational space for experiential learning of ecosystem, fishing and collecting insects and plants. Water channels would also allow introduction of diverse wetland plant species such as submerged, emerged, and floating plants, but careful management and control of naturalized species would be required. Water channel and ponds that can be constantly filled with water would have positive effect on surface water and groundwater recharge and water purification, but the effect is small, and if not properly managed, would have adverse effect on water quality therefore, careful management was suggested.

Wetland function assessment through the modified RAM revealed that most of the wetland functions improved in the mixed farming system. In detail, 12 out of 52 evaluation elements were rated higher in the mixed farming system compared to conventional rice paddies, especially in the degree of interspersion of open water and cover, and vegetation type were rated highly due to creation of water channel in the mixed farming system. Moreover, hydroperiod and channel or sheet flow were also improved by water channel. Based on the assessment results, the conservation value increased in the wetland function category, with conventional rice paddies receiving high ratings in 3 functions, whereas the mixed farming system received high ratings in 7 functions. Wetland conservation strategy rating improved from 'improvement' in conventional rice paddies to 'conservation' in mixed farming in all evaluation standards.

Rice paddies play an important role in national biodiversity maintenance, and also provide ecosystem services such as climate regulation and carbon sequestration. However, proper management of rice paddies is critical as pesticide and fertilizer application can cause non-point source pollution. From this perspective, practice of rice-fish mixed farming not only enhances ecosystem services provided by rice paddies, but also increases farm income through fish farming and provide social services such as ecological education and traditional activities. Additional research is needed for quantitative analysis of the values gained from the most improved wetland function when mixed farming system is actually put into practice, and to utilize the results in advertising of the organic rice, and in various sectors such as food, education and direct payment policy.

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Appendix 1. Wetland evaluation result.

Evaluation topics	Evaluation elements	Wetland Evaluation	
		Conventional	Mixed farming
1. Floral Diversity and Wildlife Habitat	Distance to Other Wetlands	3	3
	Number of Different Types of Vegetative Communities Present	3	3
	Degree of Community Interspersion	1	3
	Wetland Size	2	2
	Surrounding Land Use	3	3
	Wildlife Corridor	3	3
2. Fishery and Herpetile Habitat	Relationship to permanent waterbody	2	2
	Percentage of open water	3	3
	Degree of interspersion of open water and cover	2	3
	Hydroperiod	2	3
	Vegetation type	2	3
3. Flood/Storm Water Storage	Ability of immediate watershed to deliver runoff	3	3
	Relation to surface water connection	2	2
	Inlet type	2	2
	Outlet	2	2
	Wetland size	2	2
	Wetland to immediate watershed ratio	3	3
4. Runoff Attenuation	Ability of immediate watershed to deliver runoff	3	3
	Inlet type	2	2
	Outlet	2	2
	Interspersion of land and water	2	2
	Hydroperiod	2	3
	Channel or sheet flow	2	3
	Vegetative type	2	3
	Wetland size	2	2
5. Water Quality Protection	Ability of immediate watershed to deliver runoff	3	3
	Inlet type	1	1
	Outlet	2	2
	Percentage of open water	2	2
	Maximum water depth	3	3
	Hydroperiod	2	3
	Channel or sheet flow	2	3
	Wetland size	2	2
	Wetland to immediate watershed ratio	3	3
6.Shoreline /Stream Bank Protection	Channel or sheet flow	2	2
	Vegetation type	2	3
	Vegetation width	2	3
	Evidence of active erosion	3	3
	Land use	1	1
7. Aesthetics and Recreation	Vegetation classes present	3	3
	Interspersion of Vegetation	2	3
	Wetland size	2	2
	Surround landuse	3	3
	Accessibility	3	3
	Visibility	3	3
	Presence of debris	3	3
	Presence of wildlife habitat	2	2
	Presence of fishery habitat	2	2
8. Groundwater Recharge	Soil characteristics	2	2
	Ratio of wetland to immediate watershed	3	3
	Ability of immediate watershed to deliver runoff	3	3
	Outlet	2	2