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Article

Economic feasibility of environment-friendly farmland use policy for water quality improvement

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Abstract: This study examines the economic feasibility of the environment-friendly farmland use policy to improve water quality. Conventional highland farming, polluting the Han River basin in South Korea, can be converted into environment-friendly farming through land acquisition or application of pesticide-free or organic farming practices. We estimate the welfare measures of improvement in water quality and the costs of policy implementation for economic analysis. To estimate the economic benefit of improvement in water quality experienced by the residents residing in mid-and-downstream areas of the Han River, the choice experiment was employed with a pivot-style experimental design approach. In the empirical analysis, we converted the household perception for water quality grades into scientific water quality measures using Water Quality Standard to estimate the value of changes in water quality. To analyze the costs required to convert conventional highland farmlands into environment-friendly farmlands, we estimated the relevant cost of land acquisition and the subsidy necessary for farm income loss for organic agricultural practice. We find that the agri-environmental policy is economically viable, which suggests that converting conventional highland farming into environment-friendly farming would make the improvement in water quality visible.

Keywords: benefit-cost analysis; choice experiment; environment-friendly farmland; pivot-style experiment design; water quality

1. Introduction

The hydrological cycle of a river basin—for water purification, water storage, and climate regulation—is closely related to the services that humans benefit from the ecosystem (Grizzetti et al., 2016). Highly intense agricultural activities have a significant impact on river water quality through land use, and land cover (Larned et al., 2016). Thus, there is a concern that agricultural activities may erode the benefits of the ecosystem. Some countries including the United States, Europe, and Japan have already been engaged in non-point pollutant reduction projects and implemented subsidy policies in order to prevent agricultural non-point source pollutants from deteriorating water quality.

The Korean government also has been working on effective and systematic prevention of aquatic pollution in the agricultural region and in response to this, the Act on The Improvement of Water Quality and Support for Residents of The Han River Basin was enacted in February 1999. The water use charges which was imposed to the end users (in mid-and-downstream) who receive raw or filtered water collected from water source management areas in proportion to their water use based on the "Beneficiary Pays Principle" was proposed to finance fund for improvement in water quality of Paldang lake, the main water source for mid and downstream areas of the

Han River basin. The River Management Funds (RMFs) has been established since 1999 and amounted to approximately KRW 6170.8 billion (about US $5.6 billion), which had been spent for installation and operation of basic environment facilities (46%), land acquisition and water side management (21%), and community support in upstream areas (19%). Nevertheless, water contamination and highly concentrated turbid water caused by farming practice in the highland agricultural areas kept bringing up the issues of water management and efficient management of the RMFs.

Highland agriculture in Gangwon-do has been blamed for causing water quality degradation of the Doam lake (Hong et al., 2020). Radishes and Korean cabbages, the major product of highland agriculture in Gangwon-do, dominate radishes and Korean cabbage market in summer (early July to early October). In the highland agricultural lands located in upstream of the Han River basin, a great amount of chemicals and pesticides containing nitrogen, phosphoric acid, and alkali are used. Due to highland agricultural land use, two types of pesticides, endosulfan sulfate and oxadiazon, were detected in the Han River basin and endosulfan sulfate is forbidden to use in South Korea (Kim et al., 2019). In addition, the highland agriculture is very vulnerable to even low precipitation, discharging the soil and sand. A great portion of them is flowed into streams to become a known cause of contamination in the aquatic ecosystem (Cho, 2018; Lim et al., 2019).

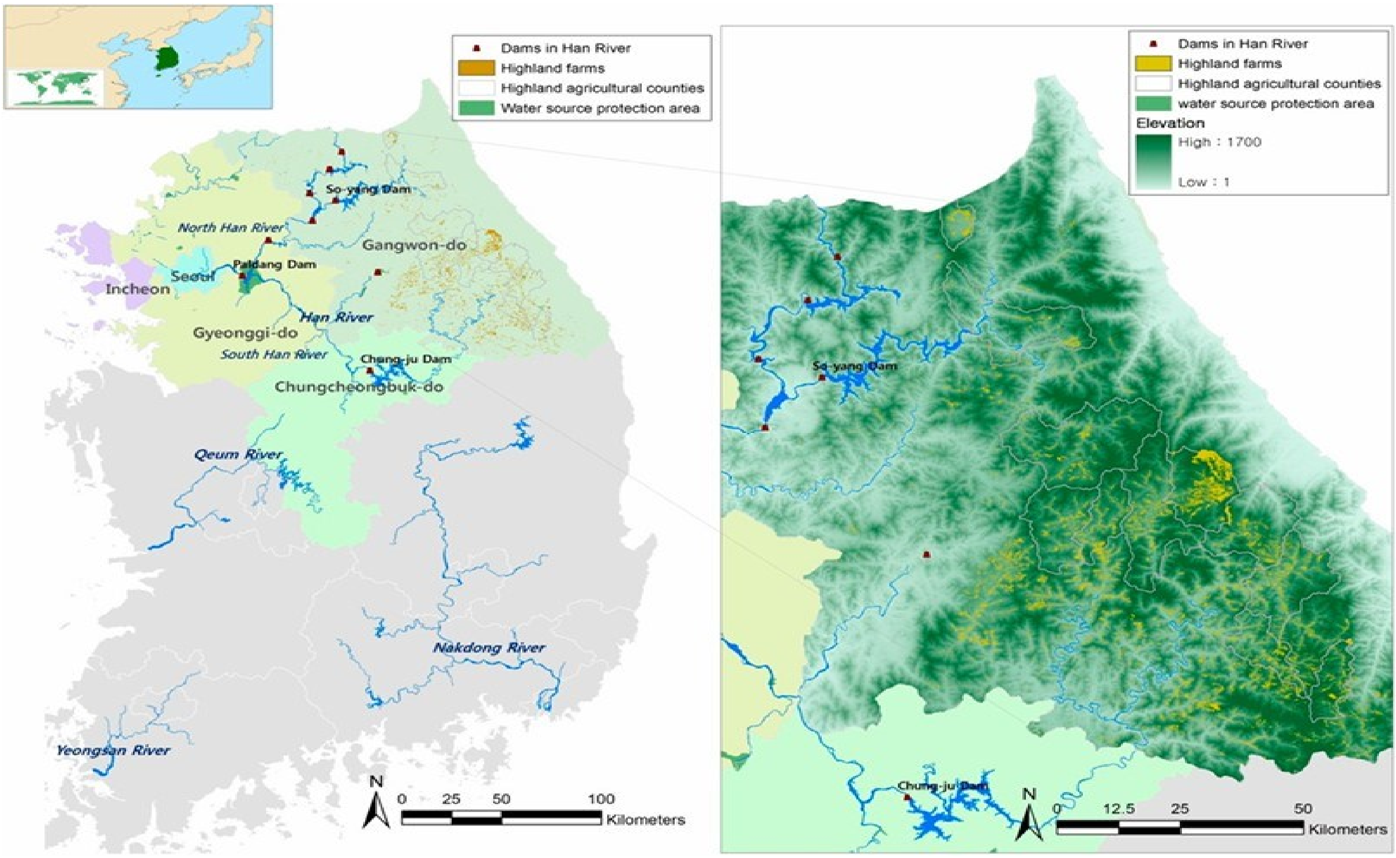


Figure 1. Study area: Paldang Lake in the Han River basin.

This study examines the economic feasibility of the policy turning the highland farmlands into the environment-friendly lands for the purpose of effective conservation of water quality in Paldang lake in the Han River basin (study area in **Figure 1**) and efficient planning for the operation of the RMFs. For the environment-friendly farmland use policy, we choose two policy scenarios; land purchase and application of environment-friendly farming practice (pesticide-free or organic agricultural practice) in the highland farming areas. To estimate economic benefits of water quality improvement caused by the policy we used linkage between the respondents' perception of water quality and scientific water quality measures. Among various water quality indexes, we choose the Total Phosphorus (T-P) which would be the most suitable water quality measures affected by highland agriculture. For each policy scenario, the benefit and cost are estimated.

We apply choice experiment (attribute-based stated choice method) for valuing economic benefits from improvement of water quality in the Paldang lake. Hypothetically the level of T-P would be reduced as a result of highland agriculture areas being replaced by the environment-friendly land use. However, the beneficiary households are hardly able to perceive the actual TP level and the extent of T-P improvement in response to the policy. Therefore, this study links the household perception for water quality with the official water quality grades (7 grades), projecting the welfare measures based on scientific water quality measures. Furthermore, in developing the choice experiment, we used a pivot-style experimental design approach. This pivot-style experimental design prevents the respondents from systemically treating proposed hypothetical alternatives differently by including reference alternative that a respondent evaluates based on her knowledge or experience in designing a questionnaire (Hess and Rose, 2009). To estimate cost of the policy implementation, we calculate the costs necessary to purchase highland farmlands under non-point source pollution management and the subsidies required to compensate the loss of farm household income applying pesticide-free or organic farming practices. Finally, we apply the benefit-cost analysis to assess the economic feasibility of the policy.

This study makes three contributions to the relevant literatures. First this paper links the scientific water quality changes caused by highland agriculture to the perceived benefits of households with respect to the empirical contribution. Second, the advanced econometric model is presented to solve the issue of independent and identical distributed (IID) assumption of error components caused by the pivot design and heteroscedasticity across alternatives in choice models. Lastly, not only the benefits from the policy but the costs required for its execution are estimated to validate actual policy applicability.

The remaining sections are organized as follows. In the second section, the relevant literature is reviewed. The third section deals with an empirical analysis and experimental designs. The data used in this study are described in the fourth section followed by a discussion on model specifications for quantitative analysis. The empirical results are then presented and discussed in the sixth section. The seventh section presents a conclusion.

2. Review of related literature

In this section, we summarize studies which examined household preference for improvement in water quality in a specific region based on stated choice method.

Hampson et al. (2022) examine respondents' preferences on the quality of water service, combining a choice experiment with a Q-methodological analysis. This integrated approach allows researchers to capture respondents' subjective preferences for river management since the Q methodology can divide respondents into five groups in which each respondent has comparable socio-characteristics, an environmental viewpoint, and a frequency of visits to the recreational area. They used the Conditional Logit Model (CLM) and found that all attributes are statistically significant and only the price attribute shows a negative sign. Respondents are willing to pay for a higher level of ecological quality compared to a medium level. However, each group showed a different preference for ecological quality and recreational quality.

Khan and Zhao (2019) estimated households' preference and willingness-to-pay of the benefit of ecosystem services a river provides in China. They used a choice experiment with a mixed logit model and multinomial logit model. Five attributes were chosen in this designed survey: water quality, upper/middle/lower basin ecological water distribution, and payment. The result from the random paramer logit (RPL) model, which has higher explanatory power, showed that all attributes are statistically significant except for the attribute named upper basin ecological water distribution. Households significantly prefer water quality to other attributes and they are willing to pay more to improve water quality, 113.05 RMB. The alternative-specific constant (ASC) shows a positive sign, which means households prefer alternatives to the status quo of the river attributes.

Choi et al. (2016) estimated the economic benefits of the highland agriculture regulation policy, which was designed to tackle the persistent issue of contaminated water by the agricultural activities in the highland agriculture located in the Han River upstream area. This study identified that intensive use of highly-concentrated agrochemicals in the upstream had threatened the ecosystem of the Han River and made the turbid water. Using the contingent valuation method (CVM) they estimated the economic benefits of the mid-and downstream areas from regulation policy for water quality improvement of the highland agriculture. As a result, they found that the total benefits for midstream and downstream residents from the policy were around KRW 297.7 billion (about $270.6million) a year.

In this study we differentiate our study from the previous ones by estimating the benefits of improving the water quality of Han River using choice experiment. This allows us to conduct cost-benefit analysis to measure the feasibility of the policy, environment-friendly conversion of highland agriculture. In addition, we link the respondents' perception of water quality to scientific water quality measures using pivot-style approach. This approach can improve the accuracy of estimating households' preference on water quality improvement at each level since this survey design helps respondents understand intuitively difficult scientific terms of water quality.

3. Methods and experimental design

We use stated preference method (SPM) to assess the value of a change in the level of water quality improvement. The Revealed Preference Method (RPM) data have a limitation in measuring new attributes and features of the products, services and options. We choose the choice experiment (CE) method that offers to consumers a market-like environment in which they can choose one between several goods. The CVM can be also employed to measure the economic welfare in response to the changes in an environmental quality. However, the choice experiment is preferred for reasons as follows (Kim et al., 2015). First, the CVM is focused on the monetary attributes (price or tax changes), whereas the CE considers several attributes of a good in addition to a monetary attribute. Second, respondents are presented with one situation to choose in CVM while in the CE design they are presented with more than one choice situation. This enables researchers to elicit consumer's preference in a more effective and efficient manner, obtaining more information from the same number of respondents (Kim et al., 2016).

In generating choice experiments, this paper utilized the pivot-style design approach. The distinct feature of this design is to base respondent's specific experience or knowledge on deriving attribute levels for hypothetical alternatives. In other words, the choice alternatives given to the respondents comprise of one alternative in which attribute levels are customized by their evaluations and other alternatives where attribute levels are hypothetically formulated depending on their evaluation levels. This has the merit of making respondents reveal their preferences more effectively, which is why pivot-style design approach has recently gained popularity in the choice experiment literatures.

In developing household choice experiments, four major services provided by the Han River are chosen—accessibility, eco-friendliness, water level, water quality, and water use charge (cost) as a trade-off. The selection of attributes and their levels was based on research from similar studies and professional advice obtained from the focus group meetings. The set of attributes and their levels used to create choice alternatives are presented in **Table 1**. The conjoint analysis used in this study is a structured approach to have a data generation process (Grafton et al., 2008), and leads to the choice sets, where alternatives consisting of the attributes and levels as above should affect the respondents' choices. In this study, we used the main-effects orthogonal fractional factorial design to ensure orthogonality among individual attributes.

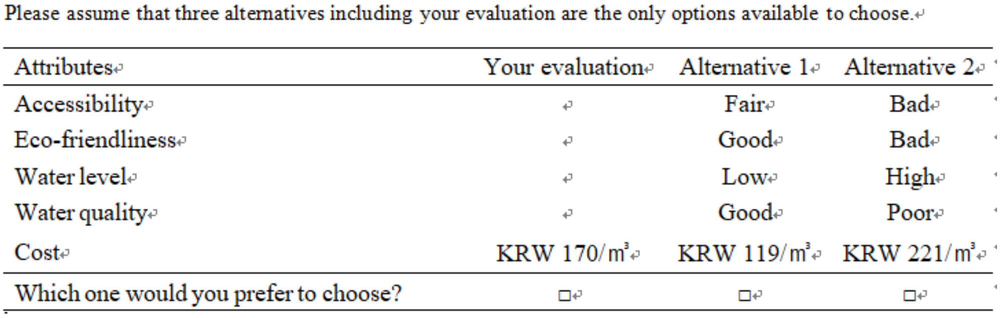
Table 1. Definition of the attributes and levels used in CE.

Attribute	Definition	Attribute levels	Change
Accessibility	• The level of accessibility to the water body	Very bad Bad Fair Good Excellent	One level down No Change One level up
Eco-friendliness	• The level of eco-friendliness such as biodiversity and ecological habitat	Very bad Bad Fair Good Excellent	One level down No Change One level up

Table 1. (*Continued*).

Attribute	Definition	Attribute levels	Change
Water level	• Water level perceived from May to September	Very low Low Mid High Very high	One level down No Change One level up
Water quality	• Water quality level perceived from May to September	Very good Good Fairly good Fair Fairly poor Poor Very poor	Two levels down One level down No change One level up Two levels up
Cost	• Water use charge that the household pays to protect water quality in water supply source	KRW 170 / m^3	30% down 15% down No change 15% up 30% up

Figure 2 shows one of the choice scenarios given to the survey respondents. The respondents were asked to evaluate the levels of each attribute based on their perception/knowledge. Pivoted on respondents' evaluation for each attribute which is served as the reference alternative (Your evaluation in **Figure 2**), the attributes' levels in hypothetical alternatives (Alternative 1, Alternative 2 in **Figure 2**) are presented as absolute changes (accessibility, eco-friendliness, water level, and water quality) or percentage changes (cost). Therefore, the choice set includes three alternatives and the respondents were asked to choose one alternative which render them the greatest utility among three alternatives. This choice task was repeated six times per respondent and in each choice task the levels of attributes in hypothetical alternative consisted of different levels of each attribute.



Please assume that three alternatives including your evaluation are the only options available to choose.

Attributes	Your evaluation	Alternative 1	Alternative 2
Accessibility		Fair	Bad
Eco-friendliness		Good	Bad
Water level		Low	High
Water quality		Good	Poor
Cost	KRW 170/m^3	KRW 119/m^3	KRW 221/m^3
Which one would you prefer to choose?	☐	☐	☐

Figure 2. An example of a choice scenario used in the CE.

In this study, the water quality criteria set by the Ministry of Environment is also used to assess how respondents evaluate water quality. Clear definitions of each level of water quality criteria are also given to help the respondents understand difference between each level of water quality (**Table 2**). Respondents' perceived evaluation on water quality is linked to scientific water quality measures. We think this approach may have the advantage of estimating welfare measures in association with changes in physical measures of water quality, overcoming the limitation of most of previous studies that only investigated the conceptual value changes for estimation of environmental goods and services.

Table 2. Definition of water quality level and linkage between water quality level and scientific water quality measures in lake water.

Level		**Definition**	**COD (mg/L)**	**T-P (mg/L)**
Very good	Ia	A residential use after a simple purification process	<2	<0.01
Good	Ib	A residential use after a general purification process	<3	<0.02
Fairly Good	II	A residential/ swimming pool use after a general purification process	<4	<0.03
Fair	III	A residential use after an advanced purification process or an industrial use after general purification process	<5	<0.05
Fairly Poor	IV	An agricultural use or an industrial use after an advanced purification process	<8	<0.10
Poor	V	An industrial use after exceptional purification process	<10	<0.15
Very poor	VI	Polluted water; few fish to survive	>10	>0.01

In this study we select the five highland crop areas (Pyongchang, Jungsun, Gangreung, Samchuk, Hongchun) which are designated as the non-point pollution management areas in Gangwon-do and produce radish and Korean cabbage mostly. We set a scenario that those highland agricultural lands are converted into environment-friendly lands, resulting in water quality (T-P) improvement in the Paldang Lake. There is a reason for choosing T-P for standard of water quality improvement. It has been known that highland farming practice affects mainly three (T-P, TN, SS) water quality measures. TN of the river and stream water quality measure is not available, and SS of lake is given the identical figures (under 25) for its four levels. That means, the TN value and change of perception cannot be used and SS does not have a distinguishable analysis power for different levels. There are two specific scenarios for conversion into environment-friendly lands. Assuming that the highland farming areas under the non-point pollution management in Gangwon-do are 1) purchased and, 2) adopting pesticide-free or organic farming practice, we estimate changes in the level of TP of the water inflow to the water system nearby. In addition, we considered the extent of contribution of rivers from Gangwon-do to the T-P value improvement in Paldang Lake, estimating their impact of the improved upstream water quality to Paldang Lake. First, for estimation of water quality impact, we assume that the land acquisition would lead the average T-P level in the water near the highland farmland to decline by as much as the level of T-P generated during the farming period, and that the land conversion into pesticide-free or organic farming would reduce the level of T-P during the farming period by around 20%. For the estimation of the latter, we refer to the research that all the rivers flowing from Gangwon-do contribute to 46.5% of T-P improvement of Paldang Lake (Han, 2009). **Table 3** shows changes in the T-P levels at Gangwon-do highland and Paldang Lake as a result of two policy scenarios.

Table 3. T-P changes in the Gangwon-do highland and Paldang Lake as affected by land acquisition and environment-friendly farmland conversion.

Scenario	TP at Gangwon-do highland (mg/L)	TP at Paldang Lake (mg/L)
Land acquisition	0.0382	0.0178
Environment-friendly conversion	0.0450	0.029

4. Data

This study uses the survey data of 1500 house owners who live near mid-and-downstream areas along the Han River and pay water use charges (KRW 170/m^3) based on the beneficiary pays principle. The respondents of this survey were selectively limited rather than taking the whole Han River basin, because the water users in the mid-and-downstream areas stand to benefit more from improvement in water quality than those in the upstream. The survey was conducted for 14 days. To ensure accuracy and optimization of the outcome, pre-survey test was carried out for three days from September 27 to 29 in 2017. After refining the questionnaires with its outcome, final survey was conducted for the 11-days from October 10 to 20 in 2017. This survey was administered as an online survey by a survey expert organization in South Korea. The sampling was done based on proportional quota sampling with the census data as of August 2017.

5. Empirical analysis

5.1. Benefit analysis cost analysis

Random utility theory assumes a respondent is a utility maximizer choosing one alternative which renders her the greatest utility among a finite set of alternatives (Bockstael and McConnell, 2007). The CLM presents econometric structure to explain how a respondent's probability of choice would be affected by individual attributes of alternatives. The conditional indirect utility obtained in the case, where decision-maker (i) chooses alternative (j) among given alternatives, is represented as Equation (1). Equation (1) has V_j^i as the deterministic term and ε_j^i as a random component.

$$\begin{gathered} U_j^i = V_j^i + \varepsilon_j^i \\ V_j^i = \sum_k \beta_k X_{jk}^i \end{gathered} \tag{1}$$

where X_{jk}^i are a set of the attributes of alternatives. β_k are parameters to be estimated including alternative specific constants (ASCs).

In Equation (1), when respondent i is given three alternatives ($j = 1, 2, 3$), where one of which is her evaluation (reference alternative) and the others are hypothetical, in choice occasions ($n = 1, \ldots, 6$), the utility function can be expressed as Equation (2). Note that the deterministic term for current alternative is denoted as V_1^i rather than $V_{1,n}^i$ because the attribute levels are held constant across n times of replications for each respondent (Kim et al., 2016).

$$\begin{aligned} U_{1,n}^{i} &= V_{1}^{i} + \varepsilon_{1,n}^{i} \\ U_{2,n}^{i} &= V_{2,n}^{i} + \varepsilon_{2,n}^{i} \\ U_{3,n}^{i} &= V_{3,n}^{i} + \varepsilon_{3,n}^{i} \end{aligned} \tag{2}$$

Noting that econometric issues may arise through use of the pivot-style design, we used error component logit (ECL) formulation of the mixed multinomial logit approach. According to Hess and Rose (2009), in a pivot style dataset, the attributes of the reference alternatives are invariant across choice occasions for the same respondent so that the IID (independent and identical distributed) assumptions can be violated. Another issue in relation to error terms is the possible existence of heteroscedasticity across alternatives, which stem from the different levels of variations in attributes between alternatives (Hess and Rose, 2009). This issue can be accommodated through an ECL model which introduces error components associated with the alternative specific variance in Equation (3).

$$\begin{aligned} U_{1,n}^{i} &= V_{1}^{i} + \sigma_1 \varphi_{1,n}^{i} + \varepsilon_{1,n}^{i} \\ U_{2,n}^{i} &= V_{2,n}^{i} + \sigma_2 \varphi_{2,n}^{i} + \varepsilon_{2,n}^{i} \\ U_{3,n}^{i} &= V_{3,n}^{i} + \sigma_3 \varphi_{3,n}^{i} + \varepsilon_{3,n}^{i} \end{aligned} \tag{3}$$

In Equation (3), σ_j $(j = 1, 2, 3)$ is the standard deviation and parameter to be estimated associated with the variance for each alternative and $\varphi_{j,n}^{i}$ is the error component which has a standard normal distribution ($\varphi_{j,n}^{i}$~N [0,1]). As discussed by Walker (2001), one of the three σ_j's should be normalized, which would have the smallest variance between them which can be identified from preliminary estimation (Ben-Aviva and Moshe, 2001)

This study examines water quality changes enabled by T-P improvement and users' preference. For the analysis above, the deterministic term of the indirect utility function can be generalized from Equation (1) and re-specified as Equation (4).

$$V_j = sq + \beta_{access} Access_j + \beta_{eco} Eco_j + \beta_{wl} Wl_j + \beta_{tp} TP_j + \beta_{cost} Cost_j \tag{4}$$

The definition of the variables used for household preference analysis towards water quality improvement in highland farming is provided in **Table 4**. The sq variable is a dummy variable which served as an ASC equal to 1 for a reference alternative and 0 for the other two hypothetical alternatives. The Access variable represents accessibility, Eco variable is eco-friendless, *Wl* variable represents water level, TP variable indicates T-P concentration, and Cost variable represents water use charges (170 won/m^3). For TP variable, a respondent's choice out of 7 levels of water quality in the survey is converted into the corresponding T-P levels.

Table 4. Definition of the variables used in the econometric analysis.

Variable	Definition
sq	1: reference alternative, 0: otherwise
Access	Accessibility (5: Excellent...1: Very bad)
Eco	Eco-friendless (5: Excellent...1: Very bad)
Wl	Water level (5: Excellent...1: Very bad)
TP	TP level (mg/ℓ)
Cost	Water use charges (KRW 170/ m^3)

5.2. Cost analysis

For cost estimation associated with land acquisition and rent, we targeted the area concerned in the highland agricultural lands of the non-point pollution management load. For practical cost analysis, costs are estimated for each scenario—1) Entire land acquisition, 2) Partial land acquisition and rent. The former indicates acquisition of the concerned land as a whole, whereas the latter does partial land acquisition (43.3%) plus rent for the rest (56.7%). This is because according to our survey conducted on highland farming households, 43.3% of respondents answered they are willing to sell the land to the government. In the study, actual farmland transaction prices and posted market prices disclosed by the farmland bank and actual rent prices for the concerned area provided by the Korea Rural Community Corporation are adopted.

The cost for environment-friendly farmland conversion is estimated as follows. First 3940 ha (as of 2016) of highland crop land in Gangwon-do for radish and Korean cabbage is defined as the convertible land for environment-friendly farming. Most of the highland farming lands for radish and Korean cabbage in Gangwon-do belong to non-point pollution management load. Moreover, we assumed that the reduced portion in net profit, when the land is environment-friendly converted, would be 100% compensated or 47.8% supported in direct payment. The change in ratio of output volume and production cost resulted from the environment-friendly farming (pesticide-free, organic farming) is considered, and average output volume and average production cost of each farming practice are accommodated.

6. Estimation results

Econometric model parameters of CLM and ECL were estimated using maximum likelihood and simulated maximum likelihood estimation procedures using the NLOGIT and STATA. The results are summarized in **Table 5**. CLM and ECL models were all found statistically significant at the 1% or the 5% and followed expected signs. The sq variable is positive and statistically significant at the 1% in both models implying that all else being equal, respondents prefer their current evaluation to hypothetical options. Other important variables of access, bio, and wl are positive, proving each variable's positive impact on alternative choice-making. On the other hand, the cost and T-P variables are negative, making a negative influence on choice-making as a level goes up.

Looking at the estimates for ECL model, the estimated coefficient of σ is positive and statistically significant. The statistically significant parameter for σ indicates that while the variance for the reference alternative is fixed to $\frac{\pi^2}{6}$, the variance for the rest two hypothetical alternatives is $\frac{\pi^2}{6} + 1.91998^2$. Besides, based on the likelihood ratio test, the ECL model is preferred over the basic CNL, because the former allows for potential heteroscedasticity between alternatives (LR test result: $\chi^2(1)$ = 1826.98, Prob. > χ^2 = 0.000)). Pseudo R^2 is estimated higher in the ECL (0.18) than the CLM (0.08). The estimated coefficients on most of the variables are slightly higher than those in CLM except for sq. The comparison between CLM and ECL models shows when specifying the empirical models with pivot-style data it is necessary to apply more flexible structures in error terms of the indirect utility function.

Table 5. Parameter estimates for CLM and ECL models.

Variable	**Choice Model**			
	CLM model		**ECL model**	
	Coefficient	**Std. Err.**	**Coefficient**	**Std. Err.**
Sq	0.621515***	0.022051	0.54952***	0.05868
Access	0.242688***	0.017154	0.24970***	0.01769
Eco	0.163575***	0.01634	0.16854***	0.01687
Wl	0.034058***	0.015819	0.03752**	0.01632
TP	−1.63383***	0.067883	−1.63368***	0.06900
Cost	−0.00083***	0.000344	−0.00087**	0.00036
σ			1.91998***	0.02868
LL	−9062.81		−8149.32	
Pseudo R^2	0.08		0.18	

Note: ***, ** indicate statistical significance at the 0.01 and 0.05 levels respectively.

7. Benefit-cost analysis

Since the ECL model was more suitable than the CLM model we used the estimation results of the ECL model to analyze the benefit of T-P value decrease through the land acquisition and the environment-friendly land conversion. The benefit from a change in T-P value was estimated through the compensating variation (CV) as below;

$$CV = -\frac{V^1 - V^0}{\beta_{cost}} = -\frac{\beta_{tp} * (TP^{improve} - TP^{current})}{\beta_{cost}} \tag{5}$$

In Equation (5), $TP^{improve}$ and $TP^{current}$ indicate an improved TP (mg/L) and a current T-P(mg/L), respectively while β_{tp} indicates the estimated coefficient of TP (mg/L). The results are summarized in **Table 6.** The WTP for a TP decrease occurring during the farming season after land acquisition was estimated KRW 32.298/m^3. And the annual water usage volume (2594 million m^3) of households who pays water use charges in the metropolitan area was applied to the estimated WTP of each model. As a result, the WTP for a change in TP value resulted from the entire land acquisition/rent was found to be and KRW 83.8 billion. The benefit of the environment-friendly farmland conversion reducing the T-P level by 20% was analyzed to estimate the WTP at KRW 11.267. The total benefits from the environment-friendly farmland conversion as a whole was around KRW 29.2 billion.

Table 6. Compensating variation (CV) for water quality improvement (T-P) by scenario and total annual benefit.

Scenario	**Model**	**CV (KRW/ m^3)**	**Annual Benefits (KRW billion / year)[1]**
Land acquisition	ECL	32.298	83.8
Environment-friendly conversion	ECL	11.267	29.2

[1] Annual benefits = CV × water usage volume of the metropolitan area (2594 million m^3).

In the meantime, as a result of the highland farmland conversion (restriction on farming or eco-friendly conversion), Korean cabbage and radish may suffer short supply and price increase, which would create welfare loss of consumers living in mid-and downstream areas along the Han River. We applied the following equation to calculate welfare loss.

$$\text{Welfare loss} = -\sum \int_{p^1}^{p^2} x_{cabbage}(p,y)dp_i + -\sum \int_{p^1}^{p^2} x_{radish}(p,y)dp_i \tag{6}$$

where p^1 is current price, p^2changed price, $x_{cabbage}(p,y)$ the demand function for highland cabbages, and $x_{radish}(p,y)$, the demand function for highland radish. The first term indicates the sum of consumer surplus from the cabbage price change (difference between current price and changed price) and the second term shows the sum of consumer surplus from the radish price change. To estimate the welfare loss in each scenario (land acquisition and environment-friendly farmland conversion), we used the consumer prices and per capital consumption of highland radish and cabbages, and disposable income data of the 24 years (1993 to 2016). First, we estimated the inverse-demand function for each item and calculated the increased prices after output decrease, and then Equation (6) was applied to calculate the welfare loss.

As for the final benefit estimate, which was calculated taking welfare loss from reduced production of radish and Korean cabbage as a result of both scenarios into account, it was around KRW 67.7 billion for land acquisition scenario (**Table 7)**. The final benefit was estimated regarding the environment-friendly land conversion at around KRW 27.6 billion (**Table 7)**.

Table 7. Final benefit estimation considering welfare loss due to radish and Korean cabbage price increase by scenario.

Scenario	Annual Benefits (KRW billion/year)	Welfare loss from reduced production of radish/cabbage (KRW billion/year)	Final benefit (KRW billion/year)
Land acquisition	83.8	−16.1	67.7
Environment-friendly conversion	29.2	−1.7	27.6

Table 8 shows cost estimation results for the land acquisition scenario. The actual transaction price for the entire land acquisition was about KRW 1410.9 billion, and the public disclosure value KRW 1104.7billion. In the partial land acquisition and rent, the actual price and public disclosure value were estimated at around KRW 619.7 billion and KRW 487.1 billion respectively.

Table 8. Cost estimation for the land acquisition scenario.

	Entire land acquisition scenario		Land acquisition and rent scenario	
	Actual transaction price (KRW billion)	Public disclosure value (KRW billion)	Actual transaction price (KRW billion)	Actual transaction price (KRW billion)
Total	1410.9	1104.7	619.7	487.1

Table 9 shows the results of net profit reduction of farm households for the environment-friendly conversion scenario. Net profit reduction of farm households for highland cabbage (KRW 16.1 billion) and radish (KRW 10.2 billion) was estimated by KRW 26.3 billion.

Table 9. Estimation of net profit reduction of farm households in the environment-friendly conversion scenario.

Environment-friendly conversion	Cabbage (A) (KRW billion/year)	Radish(B) (KRW billion/year)	Total (A + B) (KRW billion/year)
Net profit reduction	16.1	10.2	26.3

Finally, based on the ECL model, we conducted economic feasibility analysis (benefit-cost ratio) by scenario using Net Present Value (NPV) of the benefit which used 4.5% of social discount rate up to 30 years and 3.5% thereafter. In the case of the entire land acquisition, while under 30-year benefit the scenario is not economically feasible the B/C ratio for 50-year benefits was 1.46 for actual transaction price and 1.87 for public disclosure value, having the economic feasibility of land acquisition proven. For partial land acquisition and rent, the ratio for 50-year benefits was 2.35 for actual transaction price and 2.77 for public disclosure value, showing higher economic feasibility (see **Table 10**).

Table 10. Economic feasibility analysis of the land acquisition scenario.

	Entire land acquisition		Partial land acquisition and rent	
	Actual transaction price (KRW billion)	Public disclosure value (KRW billion)	Actual transaction price (KRW billion)	Public disclosure value (KRW billion)
Cost	1410.9	1104.7	754.3	621.7
30-year benefits	1103.1			
30-year B/C	0.78	0.999	1.46	1.77
50-year benefits	2525.5			
50-year B/C	1.46	1.87	2.35	2.77

The environment-friendly conversion scenario has the two cases of compensation for net profit reduction; full compensation (100%) and partial support (47.8%). When net profit reduction is fully compensated, the ratio comes to 1.05, and when partially supported, it comes to 2.19, showing that the scenario is economically feasible (**Table 11**).

Table 11. Economic feasibility analysis of the environment-friendly farmland conversion scenario.

	Full compensation	Partial support (47.8%)
Final benefit (KRW billion)	27.6	27.6
Final cost (KRW billion)	26.3	12.6
B/C	1.05	2.19

8. Conclusion

This study focuses on economic feasibility of converting conventional highland farming into the environment-friendly farming (land acquisition or pesticide-free or organic farming practice) under non-point pollution source management in Gangwon-do. We identify the economic benefits of water quality change for the beneficiaries in the mid-and-downstream of the Han River who would enjoy the improved water quality of Paldang Lake. In addition, the cost required for environment-friendly farmland conversion is calculated. Examining the welfare measures, we linked the people's perception of water quality to the level of T-P concentration among other water quality measures. Net welfare measures were calculated taking account of consumer's welfare loss which results from reduced production and increased prices of radish and cabbage in highland farmlands in response to the policy implementation. We also estimate the cost of policy scenarios: the land acquisition and the land conversion into environment-friendly farming practices (pesticide-free and organic farming). For land acquisition, we estimated the land acquisition price based on the actual transaction price and the public disclosure value, whereas the land conversion, we estimated the direct compensation payment for net profit loss due to application of environment-friendly farming practice. The former was further segmented into 1) entire land acquisition, and 2) partial land acquisition and rent and the latter was specified into 1) full compensation payment for net income reduction and 2) partial compensation payment. Finally benefit-cost ratio was computed for economic analysis, which led to a conclusion that both measures and their sub-measures were all economically feasible.

Based on B/C analysis this study suggests the following policy implication. The improvement in water quality in consequence of environment-friendly highland would require more effective and efficient operation of the Han River Management Fund and revision of Water Environment Conservation Act. For better management of the fund, it is suggested to expand the coverage area of the land acquisition project, purchase highland farmlands within the non-point pollution management by priority, and adjust compensation price of land to reflect real land values. In addition, responsibility for recommending on environment-friendly agricultural practices in farmlands at high altitude, should be transferred to the Minister of Environment from local authority in order to lay legitimate foundation for consolidated management.

It is expected that an effective and practical measure for improvement in water quality of the Han River basin would establish the direction of the long-term water-related policy based on economic analysis and enhance the benefits enjoyed by the residents in the mid-and-downstream areas of the Han River.

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