Estimating Environmental Impact Caused to the Isahaya Bay Wetland by Applying Remote Sensing and CVM

K. S. Sarwar Uddin Ahmed
Graduate School of Science and Technology, Nagasaki University
1-14, Bunkyo-machi, Nagasaki 852-8521, Japan
ahmed@stu.civil.nagasaki-u.ac.jp

Keinosuke Gotoh
ditto
gotoh@civil.nagasaki-u.ac.jp

Kaoru Tachiiri
Department of Civil Eng., Faculty of Eng., Nagasaki University
1-14, Bunkyo-machi, Nagasaki 852-8521, Japan
tachiiri@net.nagasaki-u.ac.jp

Abstract: This study aims at integrating economic tools and remote sensing for environmental impact valuation of the Isahaya Bay Wetland (IBW). In doing so, we have used potential behavioral economic valuation technique: contingent valuation method and satellite remote sensing technique: land cover mapping. From the results of the study, we are able to bracket a range of values from (22 to 200 billion yen) for arriving at the true economic value lost due to the initiation of reclamation project on the IBW and would provide a new dimension to get nearer to the more accurate environmental impact assessment.

Keywords: Environmental Impact Valuation, Contingent Valuation Method, Remote Sensing, Isahaya Bay Wetland.

1. Introduction

The Isahaya Bay Wetland (IBW), located on the Isahaya Bay, Ariake Sea Nagasaki Prefecture, western Japan, is one of the largest tidal flat wetland in Japan comprising about 6% of the national total (see **Fig. 1** showing the location). Its 3,000 ha of muddy tidal flats are composed of fine silt with a high proportion of organic matter. However this wetland, with immense environmental and economic importance, is facing the fear of serious imbalances due to the construction of sea dikes on it in April 1997, under the project named 'The Isahaya Bay reclamation project (IBRP)'. This project is planned to cut one third of Isahaya Bay from the sea by a huge sea dike to reclaim 3,550 ha of tidal flat and shallow sea, with the objective of land reclamation and flood prevention and is expected to be completed in the year 2006 with a cost of $2 billion.

In the wake of these ecological imbalances it is of great interest to quantify the environmental impact caused to the Isahaya Bay Wetland in monetary figures. In doing so, we wish to apply both economic potential behavioral techniques CVM on the one hand and land cover mapping by remote sensing on the other. And to compare the value derived under these two methods to see how impact valuation differs under the two.

2. Objectives

The objectives of the study are to estimate the impact caused to the Isahaya Bay Wetland by the initiation of IBRP through the integration of remote sensing and CVM; and to see the difference in valuation of environmental impact by behavioral economic tools based survey and thematic mapping of land cover derived from satellite remote sensing images.

3. Methods

The research methodology followed in this study is outlined below:

1) Contingent Valuation Method

Under Contingent valuation method, mail survey technique and double bounded dichotomous choice (DC) elicitation method have been used for estimating the willingness to pay (WTP) for restoring the Isahaya Bay Wetland (IBW) as it was before the initiation of IBRP. Households were selected randomly from the telephone directory in the three cities of Kyushu Island, Japan: Isahaya, Nagasaki and Kitakyushu. In deriving the

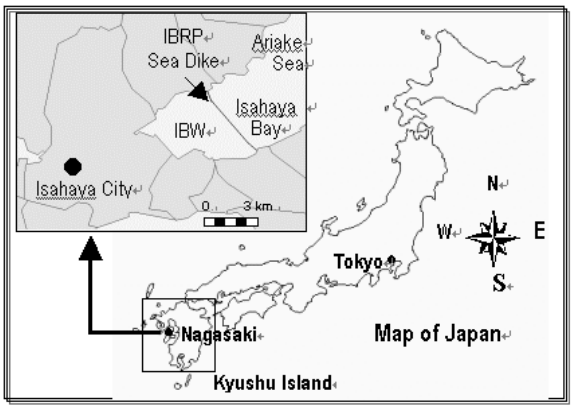


Fig. 1 Location of the IBW and IBRP.

average WTP, non-parametric estimation Turnbull method[1] is followed. Pre-testing studies are conducted before finalizing the questionnaire and the type of the elicitation method to be used in the study [1].

2) Land Cover Mapping

Land cover mapping by satellite remote sensing images of LANDSAT/TM 5 are used to determine the land cover changes in the reclamation site before and after the IBRP project and estimated the area of wetland destroyed after the closing of the sea dikes. Then, we have multiplied this area of wetland destroyed by the per ha value of the wetland to get the monetary estimate of wetland lost.

4. Environmental Impact Valuation by CVM

1) Contingent Valuation Survey Description

A total of 1,800 questionnaires were distributed in the three cities of Kyushu- Isahaya, Nagasaki and Kitakyushu (600 each). The response rate and sample characteristics are as shown in **Table 1**.

2) Monetary Impact Estimation by CVM

The WTP estimated by applying Turnbull method in all the three cities revealed that the mean (WTP) is approximately 6,500 yen per household for all the sample respondents of Isahaya, Nagasaki and Kitakyushu (See **Table 2**). We are going to use this amount as a representative sum, and extrapolate it to the households of Kyushu. In doing so, we are going to divide the household population of Kyushu Island into two categories on the basis of use[2] and non-use[3] values for IBW. In the first category of use value, the entire households of four prefectures of Kyushu located on the coast of Ariake Sea- Nagasaki, Saga, Kumamoto and Fukuoka (NSKF) are taken which are repotted to be having direct impact due to the commencement of reclamation project on the IBW (see row 6 in **Table 2**). On the other hand, in the second category of non-use value, the households of remaining prefectures of Kyushu, viz., Oita, Miyazaki and Kagoshima are also included as although they are not having any direct impact from IBW, but possess potential optional conservation value for it (see row 7 in **Table 2**).

Accordingly, after extrapolating the mean WTP of 6,500 yen to the respective category of households, we have found that, the residents of directly affected NSKF prefectures and residents of entire Kyushu are willing to pay approximately 22 and 32 billion yen, respectively, to restore the Isahaya Bay Wetland (See **Table 2**). This amount would be considered as the monetary value of the negative impact caused to IBW, as the respondent's are willing to pay this amount to restore the ecological condition of the region to the position it was before the initiation of IBRP.

Table 1. Response rate and sample characteristics

	Isahaya City	Nagasaki City	Kitakyushu City
Response Rate (%)	20.67	19.50	26.67
Percent Male	56.00	58.00	43.00
Average Annual Income (in ten thousand yen)	Between 400-499	Between 400-499	Between 500-599

Table 2. Total estimated WTP

1. Sample size (complete)	396
2. Mean WTP (¥/household)	6,500[a]
3. Median WTP (¥/household)	4,000
4. SD of the Mean	399
5. Range of 95% confidence interval (¥)	± 1,565.3
6. Total No. of Households in NSKF	3,372,400 [c]
7. Total No. of Households in Kyushu	4,976,000 [c]
8. Estimated Total WTP for NSKF (2X6)	21.92 [b]
9. Estimated Total WTP for Kyushu (2X7)	32.34 [b]

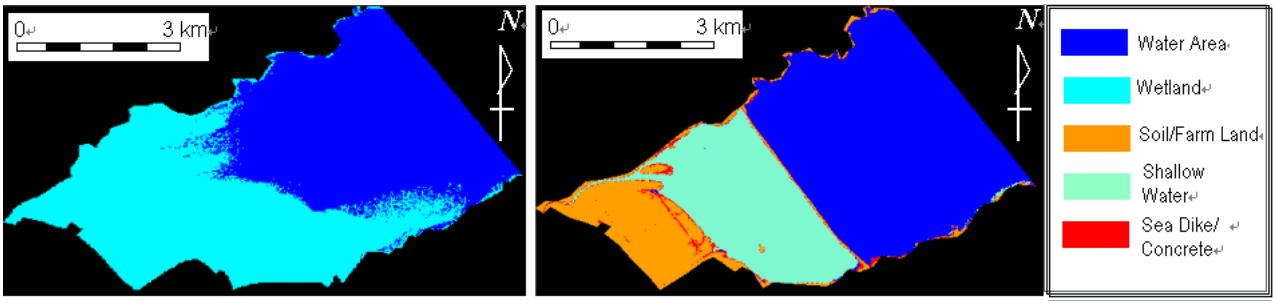
Note : [a] Rounded to nearest 100 yen.
[b] Billion yen.
Source: [c] MPHP, 2003 [3].

5. Environmental Impact Valuation by Land Cover Mapping

1) Estimating the Area of Wetland Destroyed

In order to estimate the portion of the wetland destroyed by the IBRP, we have examined the land cover changes by satellite images of LANDSAT/TM 5 before and after the initiation of the project. Although the sea dikes of the project are closed in April 1997, the construction work in the wetland area began long before. Hence in this study we have taken the images of April 1988 to see the extent of wetland before any sort of project work begun. Then we have compared it with that of April 1999 to see the extent of wetland destroyed since the initiation of the project work. **Fig.2** shows such land cover changes result by unsupervised classification. We have extracted only the water area to have more insight into the wetland area changes. From the results of the classification verified with ground truth, it has been reveled that in April 1988 there had been approximately 4,000 ha of wetland in the region. Conversely, in April 1999 it is not at all exaggerating to say that, the 3,550 ha (the area in the left side of the sea dikes as shown in the right image of **Fig. 2**) of wetland out of 4,000 ha cut off by the reclamation project have been totally destroyed. The cut out area, which was previously wetland, are now turned into shallow water or catch basin (62 %), farm

[1] Methodological details are not provided for lack of space. For details see Turnbull, 1976 [2].
[2] Value derived from actual use of a good or service. Uses may include indirect uses.
[3] Values those are not associated with actual use, or even the option to use a good or service.



April 15, 1988 (Before) April 14, 1999 (After)

Fig.2 Land cover changes in the IBRP site from images of LANDSAT/TM 5

land or soil (34 %) and sea dike or concrete structures (4 %). Thus, both by land cover images and ground truth it has been confirmed that, around 3,500 ha of wetland area enclosed by IBRP by shutting down sea dikes has been destroyed.

2) Monetary Impact Estimation by Land Cover Mapping

In this section we have attempted to convert the 3,500 ha wetland destroyed into monetary figures. Costanza *et al.* (1997) in a study attempted to place a total value on the Earth's ecosystem and estimated the total area covered by 17 biomes classified by Bailey [4]. In valuing each biome, the services provided are identified and given a monetary value based on past research and original calculations. The value of wetland was estimated as 1.72 million yen ha^{-1} yr^{-1} ($14,785 ha^{-1}, converted by taking $1=¥116.20 as on 17 September 2003)[4]. Based on this, we have calculated the present value of wetland per ha in perpetuity by taking 3% and 8% as the discount rate range to see the variation, though a lower discount rate is preferred for wetland valuation [5]. The formula for calculating present value of a sum in perpetuity is as follows:

$$PV = \frac{C}{r} \qquad (1)$$

Where, PV is the present value, C is the annual cash value and r is the discount rate. The present values calculated are shown in **Table 3**, provides us present value of wetland lost ranging form 75 to 200 billion yen depending on the discount rate.

Table 3. Present value of wetland lost

	Discount rate	
	3%	8%
Wetland Area Destroyed (ha)	3,500	3,500
Wetland value ha^{-1} $year^{-1}$ (million yen)	1.72	1.72
Present value of wetland ha^{-1} (million yen)	57.33	21.50
Total estimated present value of wetland lost (billion yen)	200.66	75.25

Table 4. Summary of wetland impact value estimates

	Impact Valuation Method	
	CVM (Billion yen)	Land Cover Mapping (Billion yen)
Lowest Value	22	75
Largest Value	32	200

6. Conclusions

If we compile the two different impact valuation methods, then we can conclude that the environmental value lost due to the destruction of the Isahaya Bay Wetland by the reclamation project is worth 22 billion yen at the lowest value and 200 billion yen at the largest value (see **Table 4**). Some where in between these the true value lies.

Finally, the estimation of monetary value of wetland lost due to some human activities is a very difficult and complex task. But it is essential for safe guarding the invaluable environmental resources from being vanished. This study in his regard is a modest attempt to integrate CVM and satellite remote sensing and leaves the scope for further studies and discussion.

[4] There are various studies concerning the valuation of wetland providing value ranging from $6,200 ha^{-1} yr^{-1} to $72,000 ha^{-1} yr^{-1}. In this study we have taken the estimation made by Costanza et al. 1997, as it provides a more generalized and conservative value.

References

[1] Gotoh, K., Ahmed, S.U., and Kojima, H., 2002.Environmental evaluation of the Isahaya Bay Wetland: preliminary tests for designing appropriate CVM questionnaire, *J. of JSCE*, 87(8), pp. 71-74.

[2] Turnbull, B.W., 1976. The empirical distribution with arbitrarily grouped, censored and truncated data, *J. the Royal Statistical Society*, 3(38), pp. 290-295.

[3] Ministry of Public Management, Home Affairs, Posts and Telecommunication (MPHP), 2003. *Statistical Yearbook*. Statistical Survey Department, Statistics Bureau, Japan.

[4] Coatanza, R., d'Arge, R., deGroot, R., Farber, S., Grasso, M., Hannon, B., Limburg, K., Naeem, S., O'Neill, R.V., Paruelo, J., Raskin, R.G., Sutton, P.C., van den Belt, M., 1997. The value of the world's ecosystem services and natural capital. *Nature 387*, pp. 253-260.

[5] Coatanza, R., Farber, S.C., and Maxwell J., 1989. Valuation and management of wetland ecosystems, Ecological Economics, 1, pp. 335-361.