WORKING PAPER 43

Accounting of Agricultural and Nonagricultural Impacts of Irrigation and Drainage Systems

A Study of Multifunctionality in Rice

Y. Matsuno, H.S. Ko, C.H. Tan, R. Barker and G. Levine

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Introduction

Forty thousand square kilometers of the earth's freshwater are estimated to be a renewable resource, of which humans divert 3,800 km^3 from its natural course. Of this diverted water, 2,500 km^3 or 66 percent is used for irrigation (Molden et al. 2000). Since irrigation remains the largest water user in a scenario of increasing demands by industries and domestic water users, it is often claimed that irrigation is not an efficient water user—creating and contributing to the scarcity of water resources. It is also often assumed that despite its contribution towards food security, irrigation activity has a negative impact on the environment and human health. While this may be true in some cases, in recent years, there has been more specific recognition of the "non-commodity" functions associated with agriculture. These, especially those with non-market outputs, may have significant impacts (positive or negative) on the sustainability of agricultural activity.

In Asia, rice is the most important irrigated crop, accounting for close to 50 percent of the net irrigated area. Irrigation facilities targeted to deliver water to rice fields serve a multitude of other beneficial purposes, including, among others, provision of water for domestic use, bathing, livestock, trees and other natural vegetation, groundwater recharge and flood control. In industrialized countries such as Taiwan and Japan, rice fields are seen as providing environmental services and opportunities for recreational activities. We can easily see that in different settings the non-economic value that society places on rice culture will vary greatly, but can be significantly large.

Coupled with specific issues related to irrigation, there is a broad and increasing concern about the over-exploitation of our natural resources in the global community, which includes concern over water. The present rate of exploitation in many parts of the world is seen as unsustainable. Sustainability is a goal and refers to the use of resources—human, natural and man made—in ways that allow the current generation to satisfy its needs without jeopardizing the capacity of future generations to meet theirs (OECD 2001). The economic activities influencing sustainability, are increasingly being recognized as multifunctional, that is, they often have multiple outputs, and by virtue of this, may contribute to several social objectives at once. Multifunctionality is not a goal but a characterization of the production process. Taking this concept one step further, a number of countries have made an effort to expand their national economic accounts to take this into consideration, particularly the environmental effects of economic activities. This so-called green gross domestic product (green GDP) approach accounts for changes over time in the quantity and quality of natural resources, environmental assets and more recently, associated non-market service flows.

The concepts of multifunctionality and green GDP were designed to improve our understanding of the magnitude of both the positive and negative impacts of economic activities, particularly on the environment and natural resources and to quantify the trends. While the initial incentive was to evaluate the sustainability implications of various types of economic activities, it was quickly realized that these concepts had relevance for trade policy. This led to efforts by the World Trade Organization (WTO) to reduce trade distortions that occurred through domestic subsidies. The issues associated with these subsidies have not been resolved, and are likely to become an increasingly important in subsequent rounds of WTO negotiations (Blandford 2001). The reduction in domestic subsidies would presumably open up markets for exporters. By contrast support prices (and associated tariffs) pursued for environmental and social objectives (such as subsidies to rice farmers) are perceived to be trade distorting. What constitutes a subsidy, and what is a legitimate governmental payment for important outputs for public interest is in debate, as are the implications of other "non-subsidy" payments to the agricultural sector. Since Taiwan has just joined the WTO, these questions are of growing importance to the Council of Agriculture (COA) and Taiwanese irrigation association sponsors. The policy context for the work on multifunctionality rests in the commitment of WTO countries to further progressive reductions in domestic agricultural support and border protection. At the same time governments are increasingly looking for ways to ensure that the non-commodity outputs of agriculture correspond in quantity, composition and quality to those demanded by society (OECD 2001). Herein lies the dilemma.

In pursuing the immediate objectives of this study, assessing the methodologies for measuring and quantifying the multiple outputs of rice irrigation in Taiwan, we have not pursued the broader policy implications indicated above. However, we argue that these issues must be addressed in future work.

Collaborative Agreement

In view of the increasing concern for the externalities associated with agriculture, the collaborative program between the Agricultural Engineering Research Center (AERC) and the International Water Management Institute (IWMI) for 2001, with support from the Taoyan Irrigation Research Foundation, the Tsao-Jiin Memorial Foundation for Research and Development for Agriculture and Irrigation, the Environmental Greening Foundation, the Chi-Seng Water Management and Development Foundation and the COA , was designed to examine these non-commodity functions, particularly as they relate to society, human health, and the environment and to whatever extent possible, given the availability of data, quantify them for some situations in Taiwan.

This report summarizes the results to date. After presenting the objectives and methodology used, it presents a brief review of the literature related to the determination of the non-commodity outputs, then provides preliminary estimates of the values of selected non-commodity outputs for various regions in Taiwan. The report closes with a summary and projection of continuing work.

Objectives

Three objectives guided the work of the collaborative agreement:

1. to derive as much understanding as possible from a review of the literature
2. to determine, quantitatively, the non-commodity positive contributions of rice irrigation to the economy of Taiwan
3. to explore the implications of these contributions for the future of rice culture in Taiwan

Methodology

To achieve the foregoing objectives, comprehensive literature reviews were carried out in Japan (a leader in this area) and in the United States. The review in the US was carried out by a reference librarian,[1] and subsequently reviewed by the authors. This is presented in annex 1.

Meetings among the authors and other knowledgeable colleagues were held in Taiwan, to study materials developed in the course of the reviews, and to obtain the benefits of local experience. An initial paper reflecting on the Japanese experience was prepared by the senior author, and is included as annex 2.

Subsequent to those meetings, quantitative estimates of rice culture contributions to groundwater recharge, flood prevention and land subsidence reduction were determined. The estimates were made following the methodology used by the Mitsubishi Research Institute (1991). Prior to these evaluations, an earlier study (Chen et al. 2001) estimated values for relatively broad environmental categories of water preservation and land protection—this study utilized a Contingent Valuation Method (CVM). In view of the specific relevance of this earlier study, the results are also presented, along with those relating to groundwater recharge, flood prevention and land subsidence reduction. The full paper describing the methodology and results is given in annex 3.

Literature Review

Literature dealing with the multi-functionality of agriculture was reviewed from three perspectives. First, a general view of externalities related to irrigated agriculture; second, the identification of methodologies for valuing these externalities; and third, actual values that have been determined in various settings. Japanese, Taiwanese and English language sources were reviewed. There was an emphasis on the positive contributions of agriculture in these reviews. The references are presented in annex 1, starting with the exploration of methodology and then organized by potential functions.

The review of literature suggests that relatively comprehensive assessments of agricultural externalities are very recent. Prior attention was focused on negative externalities, such as salinization, and more recently, non-point pollution. Recognition of the more positive functions of agriculture, and particularly of irrigation, is new.

With the advent of major concern for protection of the environment, there has been an attempt to evaluate the status of national development incorporating environmental impacts—green GDP estimates. Generally, these attempts took a static view of natural resources, with estimates of the stock of soil, forests, water, etc. (Rylander 1996). Depreciation of the stock resulted in a reduction in the calculated GDP, and appreciation was seen as an increase. This static approach to viewing the use of natural resources is now being complemented by a more dynamic one that perceives natural resources in functional roles (Alexander et al. 1998). The functional aspect of resource use is somewhat reflected in the United Nations (UN) System for Integrated Environmental and Economic Accounting.

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[1] The authors are indebted to Ms. Evelyne Ferretti for her efforts in developing the literature presented in annex 1.

At present there is broad agreement that positive functions are often associated with agriculture. Among these are: erosion protection, soil purification, air purification, flood mitigation, groundwater recharge, global climate impacts, biodiversity maintenance, landscape improvement and subsidence reduction (Tsai 1993; Wen 1994). One or more of these are significant in many cases. It also is recognized that many of these values are not easily expressed in monetary terms (Yoshida and Nishizawa 1998). There also is increasing agreement that the contribution of these functions should be considered as decisions are made about the role of agriculture in the economy of individual countries. However, there is considerable uncertainty about the most appropriate methods to place values on those functions.

Methodology

The methods illustrated in the literature include traditional benefit/cost analyses, usually in the form of substitution benefits (Mitsubishi Research Institute 1991; Intizar et al. 2001; Gutman 2002) and CVM (Whitehead 1995; Chen et al. 2001).

These methods usually address each of the potential functions individually. However, there is some recognition that because of the inter-relatedness of some of the functions it is necessary to consider them jointly. A methodology for doing this is described in a recent Organization for Economic Cooperation and Development (OECD) report (OECD 2001).

Biodiversity

The literature shows substantial benefits to biodiversity as a result of irrigation, with specific reference to rice irrigation (Borad et al. 2000; Cai 1996; Edwards et al. 1999; Iguchi et al. 1999; Kimura and Nakagoshi 2000; Schoenly 1996; Steele et al. 1997; Upawansa 1999; Yamaguchi et al. 1998).

Among these benefits are increased numbers of avian species, increased plant species associated with rice levees and maintenance of rice-dwelling fish.

Environmental Protection

There were a relatively small number of references specifically identified with environmental protection, and these focused primarily on the purifying aspects of the wetland ecology (Scarth 1986; Tongdeelert and Lohmann 1991). These were relatively early papers addressing ecological issues. Later ones tend to address more specific functions.

Erosion Control

Irrigation has both direct and indirect effects leading to reductions in soil erosion. The direct effects result from the prevention of soil movement due to ponded topography. The indirect effects relate to the ability to produce agricultural products intensively on non-erosion susceptible land (Pereira and Gowing 1998)

Flood Protection

The ponding characteristic of rice irrigation provides significant opportunities for flood mitigation (Mitsubishi Integrated Research Institute 1992; Shimura and Hiroyasu 1982).

Landscape and Landscape Protection

The visual components of the agricultural landscape take on added value as countries become more industrialized and developed (Crook and James 1999). In addition, landscape protection has implications for overall productivity of the environment (Stefano 1997.)

Recharge

Recharge of groundwater aquifers by irrigation is recognized in many part of the world—Taiwan (Kuo et al. 1998; Ting-Cheh Shyh et al. 1998; Yeh et al. 1998), China (Lin 1991), Mexico (Scott et al. 2000), Japan (Goto and Saawata 1999), India (Hira 1998), Pakistan (Haigh et al. 1993) Bangladesh (Saleh et al. 1989), United States (Dokoozlian et al. 1987). While in some situations this recharge results in waterlogging, in many others it represents an important positive function.

Subsidence

Much of the literature dealing with irrigation and subsidence addresses the problem of managing organic soils (e.g., Barrington et al. 1992). However, three studies address various aspects of the problem and proposed solutions (Hsu et al. 1998a; Hsu et al. 1998b; Shih 1997).

Waste Management

In many areas the increasing competition for water is fostering the use of wastewater for irrigation. The research magnitude is evident in the 1968 annotated bibliography Agricultural utilization of sewage effluent and sludge (Law 1968). Research has continued, addressing environmental changes (Hinsley et al. 1978; Stehlik et al. 1984), health implications (Klinkenberg 2001), methods of application (Sourell 1987), guidelines on use (Monte et al. 1996). Of particular relevance may be the potential use of irrigated areas to serve as relatively low cost waste treatment sites (Scott et al. 2000).

Quantitative Estimates of Irrigation Functions

The externalities of rice fields in Taiwan were evaluated by three functions—groundwater recharge, flood attenuation, and land subsidence reduction functions.

Groundwater Recharge

The recharge of groundwater is due to the infiltration from soil top to the Vadose water zone and further to the aquifer in the rice field during the rice-growing season. The estimation of the amount of recharged water was based on three factors: area of rice, soil infiltration rate, and number of irrigation days. The equation for estimating groundwater recharge is as follows:

$$GW = 0.1 \ A \times I \ \times T$$

where:

GW = volume of groundwater recharge (m^3)
A = rice growth area (ha)
I = soil infiltration rate (mm/day)
T = number of irrigation days (day)

Table 1 shows the percentage of soil types and their infiltration rate in each of the irrigation associations in Taiwan. The numbers in the table indicate the percentage of each soil type in the corresponding irrigation association. The mean infiltration rate was computed by an area-weighted method.

Table 1. Soil content and mean infiltration rate for each of the irrigation associations.

	Soil content (%)							
Irrigation associations	Clay (3.2)*	Loam (3.5) *	Sandy Loam (3.7) *	Sand (4.1) *	Gravel Sand (4.4) *	Silty Loam (3.6) *	Clay Loam (3.3) *	Mean infiltration (mm/day)
I-lan	10.02	41.46	48.52					3.56
Pei-Chi		22.7	72.62		4.68			3.68
Tao-Yuan	19.78	41.41	16.36	22.45				3.60
Shi-Men	57.71	14.57	24.21				3.51	3.25
Shin-Chu		13.06	77.52	8.95	0.48			3.71
Miao-Li		35.52	58.55	5.92				3.65
Tai-Chung	3.87	18.02	68.14		0.09	9.88		3.60
Nan-Tou	0.08	16.68	71.07	0.46	11.71			3.75
Chang-Hwa		10.84	62.71			26.45		3.57
Yun-Lin	0.02	29.07	68.82	0.14	0.06	1.88		3.63
Chia-Nan	9.73	47.20	38.24	3.24	0.02	1.56		3.56
Kao-Hsiung	5.95	41.29	50.26			2.49		3.57
Pin-Tung		12.86	84.11	3.03				3.68
Tai-Tung		18.71	66.69	7.90	6.70			3.74
Hua-Lian	1.62	36.22	40.28	21.89				3.70

Note: *Soil infiltration rate (mm/day)

The rice growth area was obtained from the *Survey of the Rice in 2000* by the COA, in which the growth of rice was divided into two periods, the first and second crop—the computation of groundwater recharge was carried out for each period. The number of irrigation days was counted from the middle of transplanting to 10 days before harvesting. Once the rice fields in a county reached 50 percent of the transplanted area, it was assumed to be the starting date of irrigation for the county. The irrigation days were accumulated until 10 days before 50 percent of the harvested area in the county. It was assumed that water was ponded in the rice fields and considered infiltratable during the irrigation days. Since there is no irrigation on rainy days, the number of irrigation days were reduced by the number of rainy days in order to provide the actual number of irrigation days.

The groundwater recharges of rice fields during the first and second crop seasons in Taiwan in 2000 are listed in tables 2 and 3, respectively.

Table 2. Groundwater recharge of paddy fields in the first crop season in 2000.

County	Growth area (ha)	Infiltration rate (mm/day)	Irrigation days (day)	Groundwater recharge (10^6 m^3)
Taipei city	302	3.68736	62	0.69
Taipei	609	3.68736	68	1.53
Kee-Long		3.68736		
I-Lan	11,942	3.56698	57	24.28
Tao-Yuan	15,981	3.43026	59	32.34
Hsin-Chu	7050	3.71341	75	19.63
Hsin-Chu city	1513	3.71341	75	4.21
Miao-Li	9520	3.65227	68	23.64
Tai-Chung	16,277	3.60572	68	39.91
Tai-Chung city	1374	3.60572	76	3.77
Nan-Tou	1895	3.75005	56	3.98
Chang-Hwa	29,374	3.57252	68	71.36
Yun-Lin	30,834	3.63485	78	87.42
Chia-Yi	19,989	3.56344	78	55.56
Chia-Yi city	886	3.56344	87	2.75
Tai-Nan	21,194	3.56344	90	67.97
Tai-Nan city	144	3.56344	90	0.46
Kao-Hsiung	6,024	3.57734	78	16.81
Kao-Hsiung city	153	3.57734	86	0.47
Pin-Tung	5,736	3.6864	104	21.99
Hua-Lian	7,361	3.70739	62	16.92
Tai-Tung	6,901	3.74108	99	25.56
Total				521.25

Table 3. Groundwater recharge of paddy fields in the second crop season in 2000.

County	Growth area (ha)	Infiltration rate (mm/day)	Irrigation days (day)	Groundwater recharge (10^6 m^3)
Taipei city	577	3.68736	52	1.11
Taipei	688	3.68736	52	1.32
Kee-Long		3.68736		
I-Lan	12,013	3.56698	37	15.85
Tao-Yuan	28,452	3.43026	52	50.75
Hsin-Chu	13,226	3.71341	70	34.38
Hsin-Chu city	2926	3.71341	70	7.61
Miao-Li	17,512	3.65227	70	44.77
Tai-Chung	32,451	3.60572	76	88.93
Tai-Chung city	2,728	3.60572	76	7.48
Nan-Tou	4,209	3.75005	72	11.36
Chang-Hwa	55,166	3.57252	76	149.78
Yun-Lin	48,667	3.63485	79	139.75
Chia-Yi	36,834	3.56344	78	102.38
Chia-Yi city	1,738	3.56344	79	4.89
Tai-Nan	33,490	3.56344	66	78.76
Tai-Nan city	1,158	3.56344	61	2.52
Kao-Hsiung	9,706	3.57734	52	18.06
Kao-Hsiung city	246	3.57734	65	0.57
Pin-Tung	9,946	3.6864	63	23.10
Hua-Lian	14,370	3.70739	46	24.51
Tai-Tung	13,743	3.74108	66	33.93
Total				841.80

The value of groundwater recharge was estimated as the volume of recharged water times the unit price of water.

$$E_{GWR} = Vol_{GWR} \times P$$

where:

E_{GWR} = external value from groundwater recharge (NT$)
Vol_{GWR} = volume of water recharged to groundwater (m^3)
P = unit price of water (NT$/$m^3$)

The total value of groundwater recharged from rice fields in 2000 was estimated at new Taiwan dollars (NT$) 78.1 million as listed in table 4.

Table 4. Value of groundwater recharge in 2000.

Period	Groundwater recharge (10^6 m^3)	Price of water NT\$/m^3	Value of groundwater recharge (10^6 NT\$)
First crop	521.25	5.73	29.87
Second crop	841.80		48.24
Total	1362.05		78.11

Flood Prevention

Rice fields serve the function of holding flood water during heavy rainfall, so that the peak of flood is reduced and the time of concentration is delayed. There are embankments surrounding each rice field and there is an opening below the top of the embankment to allow excess water to drain. Therefore, the effective storage capacity is the volume between the embankment opening to the depth of ponding water in the rice field.

Storage = (Embankment height – Average ponding depth) × Total rice area.

The rainy season is in the second crop period in Taiwan, so that the flood prevention function is applicable only in the second crop season (Tsai 1993). The growth area of rice was adopted from the second crop growing area of the Survey of the Rice in 2000 by the COA. The average depth of ponding water was estimated to be 6 cm, and the embankment height was the average of field measurements in the Taoyuan area, given in table 5 (Shih 1977). The effective storage capacity of rice fields in 2000 was estimated as presented in table 6.

Table 5. Field measurements of average height of embankment opening in the Taoyuan area.

Width of embankment opening	Average length (cm)	Average height (cm)	Number of measurements
<20 cm	36.39	13.47	292
20 cm to 30 cm	41.85	16.76	814
>30 cm	47.67	19.38	150

Table 6. Effective storage capacity of paddy fields in 2000.

Cropping	Growing area (ha)	Height of embankment opening (cm)	Average depth of ponding water (cm)	Effective storage capacity (10^6 m^3)
Second crop	144,892	13	6	101.42
		16		144.89
		19		188.36

The external value of flood prevention can be estimated by the effective storage capacity multiplied by the raw water price of developing dams to hold the same amount of floodwater (table 7). The unit price of raw water (11.15 NT$/m^3) was from the average of the 6 recently designed dams. (AERC 2001). The average value of flood prevention by rice fields was estimated to be NT$1131, 1616 and 2100 million for embankment opening height at 13, 16, and 19 cm respectively, in Taiwan.

Table 7. External value of flood prevention in 2000.

Raw water price (NT$/m^3)	Storage capacity (10^6 m^3)	External value (10^6 NT$)
11.15	101.42	1,131
	144.89	1,616
	188.36	2,100

Land Subsidence Reduction

Land subsidence due to over pumping of groundwater in Taiwan's coastal areas has resulted in a variety of negative impacts, for example the increase of public expense, reduction of land price and reduced tax income. Rice fields can recharge the groundwater to reduce the degree of land subsidence.

There are eight major land subsidence areas in Taiwan based on the survey of the Research, Development and Evaluation Commission, Executive Yuan. They are Ping-Tung, Chang-Hwa, Yun-Lin, Chia-Yi, Tai-Nan, Kao-Hsiung, Taipei basin and Yi-Lan plain subsidence areas. In the Pin-Tung area, the social cost due to land subsidence was estimated to have an upper bound of NT$101.9 billion and a lower bound of NT$27 billion. The quantification of the land subsidence reduction function of rice fields was based on the value of Pin-Tung as a standard, computing the value for other areas by the degree and affected area of subsidence. The equation is as follows:

Cost in other area = 0.5×[(Maximum subsidence) / (Maximum subsidence in Pin-Tung) 2 × Cost in Ping-Tung]+ 0.5×(Area of subsidence / Area of subsidence in Pin-Tung × Cost in Pin-Tung)

The result of the computation is presented in table 8.

Table 8. Cost of land subsidence in Taiwan.

Area	Maximum subsidence (cm)	Area of subsidence (km^2)	Upper bound of cost (10^9 NT$)	Lower bound of cost (10^9 NT$)
Pin-Tung	294	175	101.90	27.00
Chan-Hwa	138	100	40.34	10.68
Yun-Lin	186	300	107.73	28.54
Chia-Yi	101	250	78.79	20.87
Tai-Nan	19	30	8.94	2.37
Kao-Hsiung	23	10	3.22	0.85
Taipei Basin	224	252	102.94	27.27
I-Lan Plain	19	50	14.77	3.91
Total			458.66	121.53

The upper and lower bound of cost can be further divided into five sectors of water consumption: agriculture, aquaculture, living, industry and family use. The cost of various consumptions of groundwater in Taiwan is computed in table 9.

Assuming average flood retention, the total value of the three functions is approximately NT$110,000/ha (US$3304/ha).[2]

This estimate is approximately one-tenth the value determined for rice irrigation in Japan (MAAF 2000), though the Japanese study included a wider range of functions. Of particular interest is the value accorded to landscape preservation—approximately NT$430,000 (US$12,600)/ha—not included in the Taiwan study. For the comparable functions of water supply enhancement, flood prevention and erosion and subsidence reduction, the Japanese estimate is approximately NT$612,000 (US$18,000)/ha.

The study by Chen et al (2001), evaluated the public's willingness to pay for the environmental services of rice irrigation, which was estimated to be NT$4.66 trillion. This represents a value of approximately NT$13.7 million (US$400,000)/ha. This probably represents an upper value, since the willingness to pay represented only a shift in the allocation of taxes already paid. It is likely that if the value represented additional taxes, it would have been substantially lower.

The large discrepancy between these two methods illustrates some of the problems encountered in attempting to estimate the contributions of the multiple functions associated with rice irrigation.

Summary and Conclusions

Estimates of the non-commodity functions of rice irrigation in Taiwan varied from approximately NT$110,000/ha to NT$13.7 million. Comparable estimates in Japan were between NT$600,000 and 3,600,000/ha. While the wide range in estimates suggests that more work needs to be done to refine the "green GDP" methodology, it is clear that the monetary value of the multiple functions of rice irrigation is very substantial—on the order of its commodity value. Therefore, decisions about the future of rice agriculture should factor in both types of outputs.

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[2] Exchange rate NT$34 = US$1.

Table 9. Cost of various consumptions of groundwater in Taiwan.

Area	Over pumping of groundwater (10^6 m^3)						Upper bound of Cost (10^8 NT$)						Lower bound of Cost (10^8 NT$)					
	Total	Agri-	Aqua-	Living culture	Industry culture	Family	Total	Agri-culture	Aqua-culture	Living	Industry	Family	Total	Agri-culture	Aqua-culture	Living	Industry	Family
Pin-Tung	2191	868	1143	129	51	0	1019.00	403.69	531.59	60.00	23.72	0.00	270.00	106.96	140.85	15.90	6.28	0.00
Chan-Hwa	1285	665	500	20	100	0	403.40	208.76	156.96	6.28	31.39	0.00	106.89	55.31	41.59	1.66	8.32	0.00
Yun-Lin	817	677	103	20	17	0	1077.36	892.74	135.82	26.37	22.42	0.00	285.46	236.55	35.99	6.99	5.94	0.00
Chia-Yi	562	329	184	22	27	0	787.99	461.30	257.99	30.85	37.86	0.00	208.79	122.23	68.36	8.17	10.03	0.00
Tai-Nan	351	172	27	9	143	0	89.47	43.84	6.88	2.29	36.45	0.00	23.71	11.62	1.82	0.61	9.66	0.00
Kao-Hsiung	703	301	109	116	177	0	32.23	13.80	5.00	5.32	8.12	0.00	8.54	3.66	1.32	1.41	2.15	0.00
Taipei Basin	86	0	3	5	64	14	1029.44	0.00	35.91	59.85	766.10	167.58	272.77	0.00	9.52	15.86	202.99	44.40
I-Lan Plain	93	11	6	17	43	16	147.70	17.47	9.53	27.00	68.29	25.41	39.14	4.63	2.52	7.15	18.09	6.73
Total	6088	3023	2075	338	622	30	4586.59	2041.61	1139.69	217.96	994.34	192.99	1215.29	540.96	301.98	57.75	263.47	51.14

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Annex 2

Accounting Non-agricultural Impacts of Irrigation and Drainage Systems

Yutaka Matsuno

Introduction

Forty thousand square kilometers of the Earth's freshwater are estimated to be renewable resources, of which humans divert 3,800 km3 from its natural course. Of this diverted water, 2,500 km3 or 66 percent is used for irrigation (Molden et al. 2000). Since irrigation remains the largest water user in a scenario of increasing demands by industries and domestic water uses, it is often claimed that irrigation is not an efficient water user, creating and contributing to the scarcity of water resources. It is also often perceived that despite its contribution towards food security, irrigation activity has a negative impact on the environment and human health. While this may be true in some cases, the positive impacts of irrigation are not fully taken into account when viewing the contribution of irrigation to non-agricultural activities.

As such, the collaborative program for 2001 between the Agricultural Engineering Research Center (AERC) and the International Water Management Institute (IWMI) with support from the Taoyan Irrigation Research Foundation, the Tsao-Jiin Memorial Foundation for R&D for Agriculture and Irrigation, the Environmental Greening Foundation, the Chi-Seng Water Management and Development Foundation and Council of Agriculture (COA) will take a look at the impacts of irrigation systems, especially emphasizing on the impacts on society, human health, and the environment. This project is aimed at filling the gap in arguments on the impact of irrigation and drainage by describing and, where possible, quantifying various cases. As an initial step, this paper presents a review of past discussions on irrigation impacts in Asian countries.

Non-agricultural Benefit of Irrigation

Irrigation has other positive values besides food production: flood control, increasing biodiversity in irrigated areas, esthetic and social values (Tsutsui 2000) but it also has an environmental cost: depleted wetlands, salinization and other effects (UNDP/Wetlands International-Asia Pacific 1997). The non-agricultural impacts of irrigation vary in regions depending on their climate, social, cultural and economic conditions, in addition to settings of the irrigation infrastructure and management system. Perceptions about the contribution of irrigation often differ among people because members of society place widely different values on uses of water (Molden et al. 2000). Irrigation alters the natural water course and thus changes the hydraulic cycle and affects the natural vegetation and aquatic environment of its surroundings. Some, however, argue that irrigation has created a new environment which adds a positive value. This may be true, especially in traditional irrigation systems that were developed a long time ago and have adapted well to the society and the environment. However, the difficulty is how we evaluate and account for the non-agricultural contribution of irrigation under the pressure of water scarcity and increasing food supply that we are now facing.

Externality of Paddy Rice Irrigation

The difficulty for accounting for non-agricultural contributions of irrigation is that these services are neither priced nor traded in the market (Yoshida and Nishizawa 1998), and therefore this externality has often been neglected by policy makers and planners in the water sector. The amount of water required to optimize this externality has not been fully quantified because it is often informal and not recognized, since many irrigation infrastructures and their management systems were not ordinarily developed for such purposes or at least considered as a secondary function.

Paddy rice, a staple crop in many regions, especially in monsoon Asia owing to its unique nature, has been extensively cultivated in relatively water abundant areas. In industrialized countries such as Taiwan and Japan, paddy fields are seen as providing environmental services and opportunities for recreational activities. For example, individuals living in the urban sector can go sightseeing to these areas. As the country is located in the monsoon region with a relatively steep land gradient, the Japanese government recognizes that, besides food production, paddy field plays a significant role in mitigating Japan's geographical and climatic conditions and preserving the environment throughout the country (MAFF 2001).

Figure 1 shows the estimated external values of paddy fields in Japan by applying the substitutive cost method (MAFF 2001). Paddy fields play the function of temporal storage of water before it reaches rivers (preventing flood), recharging groundwater and maintaining river flow (fostering water resources), preventing soil erosion and landslides and absorbing nutrients and other materials from water and air (soil and air purification). The beauty of the paddy landscape and its contribution to wildlife, ecosystem, and thus to society, is also seen as a considerable benefit. In figure 1, the soil purification function shows no value, but it is actually estimated as ¥ 4.5 billion. The total estimated value of externality is ¥ 4,600 billion, which is more than 30 percent of total agricultural outputs (¥ 11,300 billion) and exceeds the total national rice production of ¥ 3,800 billion in 1994. Similarly, figure 2 shows the external values of the upland fields in Japan. It again shows no values for the soil purification and prevention of soil erosion and landslide functions, but these are estimated as ¥ 3.7 and 5.5 billion, respectively.

When compared with paddy fields, upland fields have less value in terms of fostering water resources and flood prevention, which is due to the paddy field's capacity to hold much more water. For purposes of preserving landscapes and recreational amenities, the values of paddy and upland fields is the same. This is probably due to the similar areas between paddy and upland fields in Japan, which is 54 percent or 2,200,000 ha of agricultural land being paddy fields.

There are several reasons for people in Japan seeing paddy fields as valuable to their society. First, water is not a severe limiting factor for rice production as Japan enjoys monsoon weather patterns. There have been occasional droughts resulting in conflicts for water use among farmers in the past when irrigation development was taking place. But controlling plentiful water has been

Figure 1. External value of paddy fields in Japan (MAFF 2001).

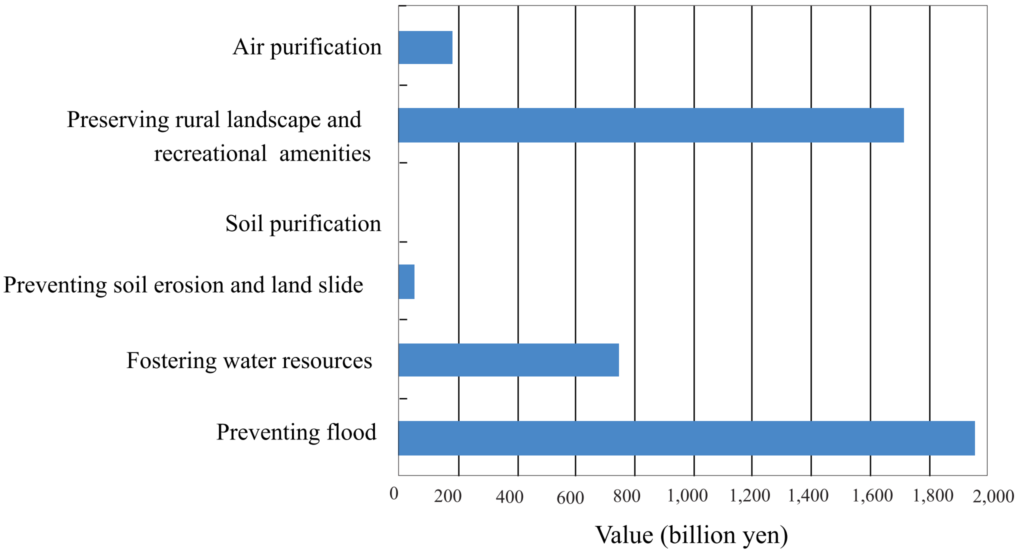
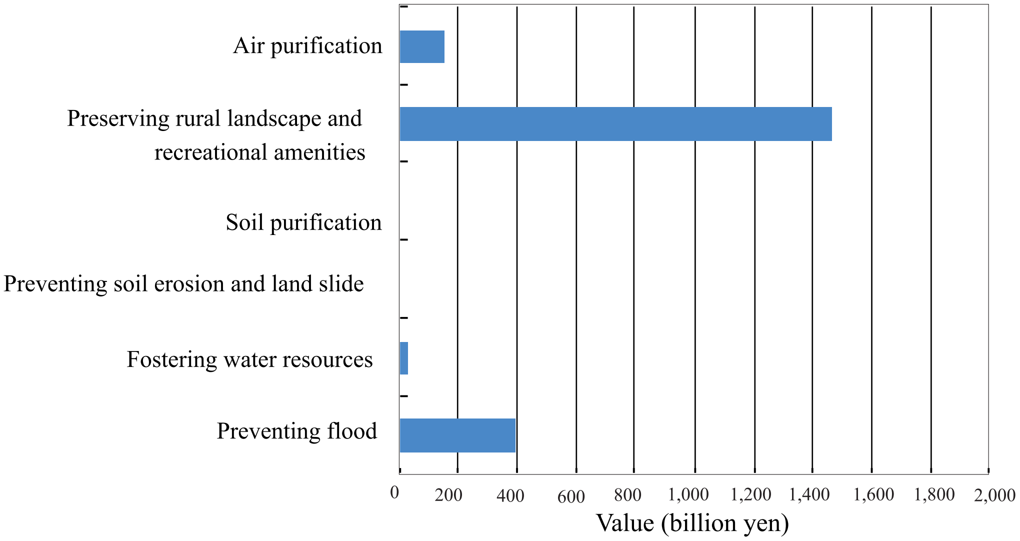


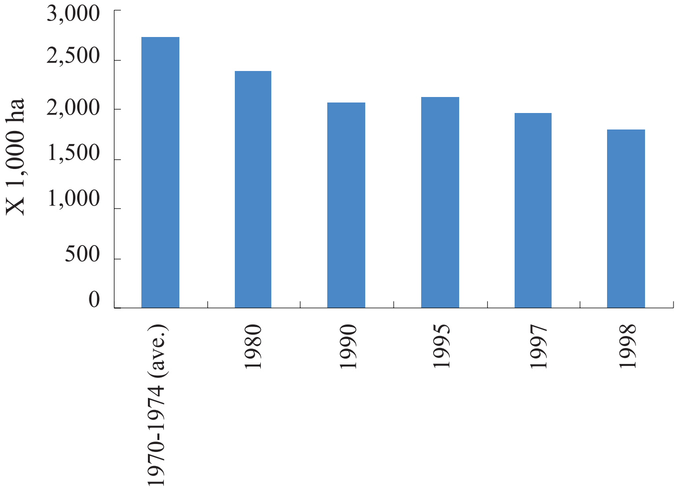
Figure 2. External value of upland field in Japan (MAFF 2001).



a bigger issue, and thus it led to a recognition for the role of flood control and the other hydrologic advantages of paddy fields. There is a general belief that under the projection of severe water scarcity in the world, monsoon Asia would be the only region that may survive and even develop in the future (Ishi et al. 2001) because of the quantity of water available to it. This may or may not happen, but it is true that water is not a limiting factor in monsoon Asia if it is properly managed with appropriate infrastructure and paddy rice is a sustainable crop (but may not be so in an economic sense) for the region.

Second, through the long history of paddy irrigation management, irrigation water has been perceived as important for the rural community (Shimura 1989). Unlike in the urban water sector, Japan's rural water system, particularly the irrigation system, has the following characteristics (Ikegami 1989): 1) farmers manage operation and maintenance of irrigation systems by themselves, 2) water is recycled within the system 3) besides being used for irrigation, the same source of water is used for multiple purposes such as cooking, washing, fire prevention, snow melting, and recreational activities such as fishing and swimming and 4) irrigation infrastructure is considered a part of the local ecosystem and rural scene. After irrigation was modernized, when many irrigation canals were lined, covered, and even pipelined, these functions deteriorated. This led to losing the incentive for protecting water. However, the people started realizing the importance of multi-functions in irrigation systems from around 1980 (Ikegami 1989). This may have come from a trend in declining agricultural fields over the past years (figure 3) which may have motivated the conservation and protection of agricultural land. Now, the Japanese authorities are fully aware of these functions.

Figure 3. Change in rice cultivated area in Japan.



Non-agricultural Uses of Irrigation Water in Developing Countries

In developing countries, increasing food production is usually the first priority for rural development, and thus the mutifunctionality of irrigation has not been given enough attention or at times has been ignored by the authorities (Bakker et al. 1999). In those countries, the role of irrigated land for providing recreational activities could be minimal, but use of irrigation water for nonagricultural purposes is directly related to their every day life, especially in arid and semi-arid regions where irrigation water is the only water source available. In the dry zone of Sri Lanka, where annual evapotranspiration is much higher than rainfall, irrigation water is directly or indirectly used for domestic (bathing, drinking, cooking, home industry and home garden), livestock and fishing (Bakker et al. 1999). This is in addition to its impact on the environment. In Sri Lanka's case, recharge of shallow groundwater by percolation from irrigated fields, canals, and small reservoirs (tanks) provides a continuous supply for natural vegetation and home gardens (Renault et al. 2001). On the other hand, drainage water from paddy fields has a negative impact on the downstream aquatic ecosystem (Matsuno and van der Hoek 2000).

Water availability for these non-agricultural purposes is dependant on irrigation water management. For domestic water supply, the people use shallow wells which are constructed near the irrigation canal to capture the seepage water so that the water is readily available at shallow depths and is relatively clean by natural filtration through the soil. The southern Punjab of Pakistan is a similar case. Groundwater is often brackish, so it cannot be used for any purpose, and the seepage water from irrigation canals is used extensively for domestic purposes (van der Hoek et al. 1999). Tables 1 and 2 show the main sources of water used for domestic purposes in the southern area of Sri Lanka and southern Punjab, Pakistan, respectively (van der Hoek et al. 1999). In these countries, the availability of irrigation water has a significant implication for the health of the local population because the quantity of water is of crucial importance for hygienic behavior (van der Hoek et al. 2001). Of course, building the water supply system would improve the situation, but these countries do not have enough funding, and even if the water supply infrastructure is provided, available resources and institutional settings often do not allow to carry the proper operation and maintenance of water supply systems. Under these circumstances, irrigation infrastructure and its management presently have an important role for many parts of the world, and this situation does not seem to have improved drastically.

Many developing countries also lack sanitation and sewage systems. Wastewater is often untreated and, either intentionally or unintentionally, enters irrigation systems. This may cause a risk to the environment and human health as excessive application of wastewater results in the pollution of groundwater, and farmers and consumers may have higher risk of being exposed to transmitted pathogenic diseases. On the other hand, wastewater irrigation may be considered, if properly managed, as a means of waste disposal (Matsuno et al. 2001) in places lacking a treatment system. The positive impacts of wastewater irrigation can be seen in many cities around the world. However, industrial effluent that includes heavy metals is not suitable for wastewater irrigation. However, more research is necessary to assess the full impact of wastewater irrigation and to identify the best options for managing this practice.

Table 1. Main sources of water for different domestic uses of households (n=156) in the Kirindi Oya Irrigation and Settlement Project, Sri Lanka (van der Hoek et al. 1999).

	Standpipe		Well		Canal		River		(tank)		Other		Total
Uses	n	(%)	n	(%)	n	(%)	n	(%)	n	(%)	N	(%)	(%)
Drinking, cooking	109	(70)	46	(29)	0	(0)	1	(1)	0	(0)	0	(0)	(100)
Washing utensils	100	(64)	47	(30)	3	(2)	4	(2)	1	(1)	1	(1)	(100)
Laundering	48	(31)	23	(15)	57	(36)	12	(8)	16	(10)	0	(0)	(100)
Bathing	49	(31)	22	(14)	55	(35)	13	(8)	16	(10)	1	(1)	(100)
House cleaning	43	(28)	19	(12)	4	(2)	3	(2)	3	(2)	3	(2)	(48)
Sanitation	92	(59)	44	(28)	9	(6)	5	(3)	6	(4)	0	(0)	(100)

Note: Only 75 (48%) of the 156 households reported using water for house cleaning.

Table 2. Main sources of water for different domestic uses of households (n=364) in Hakra 6R, Pakistan (van der Hoek et. al 1999).

	Village tank		Seepage from canals, fields		Water supply scheme		Canal (direct)		Total
Uses	n	(%)	n	(%)	n	(%)	n	(%)	(%)
Drinking	64	(18)	265	(72)	28	(8)	7	(2)	(100)
Cooking	87	(24)	233	(64)	35	(10)	9	(2)	(100)
Washing utensils	178	(49)	125	(34)	43	(12)	18	(5)	(100)
Laundering	166	(46)	82	(22)	42	(12)	74	(20)	(100)
Bathing	174	(48)	120	(33)	43	(12)	27	(7)	(100)
House cleaning	78	(21)	39	(11)	28	(8)	3	(1)	(41)
Sanitation	181	(49)	141	(39)	42	(12)	0	(0)	(100)

Note: Only 148 (41%) of the 364 households reported using water for house cleaning.

Towards the future

In summary, the potential positive impacts of paddy irrigation are:

- irrigation water is an important water source for non-agricultural activities, especially in developing countries where a proper domestic water supply system is lacking
- percolating water from irrigated areas recharges groundwater, which could be extracted downstream for beneficial uses
- increased water availability in irrigation schemes contributes towards improved hygiene behavior of users.
- through seepage from canals and reservoirs, irrigation provides water for natural vegetation.
- by flood control, purification of water, and prevention of soil erosion and landslides, it conserves land and water.
- if properly managed, paddy fields could play a role in the treatment of polluted water.
- it increases bio-diversity in urban and peri-urban areas which is beneficial to society

If we take the non-agricultural benefit of irrigation and drainage into account, an exclusive focus on water use efficiency, for example, increasing the agricultural production per unit of water used—would possibly eliminate the side-benefits of irrigation. There is a need for many countries to realize all the possible contributions, both positive and negative of irrigation, which could reflect on national policies and development planning.

However, the extent of these contributions has not been fully explored, especially from an economic point of view. A difficulty is that interaction between water uses is often complex, and a lot of work requires to be done for quantification of water requirements, especially quantifying the water required to sustain and conserve the natural environment. Of the several techniques available for valuing environmental and social services, very few have been applied for the valuation of irrigation and drainage water.

Moreover, a question still remains on how to manage when sufficient water is unavailable to satisfy all needs or in areas where water is severely scarce. The bottom line is to understand all the possible costs and benefits of irrigation and drainage and have a clear picture of the cause-effect relationship between the uses. Then it would be up to policy makers and the stakeholders to arrive at a consensus as to which use has higher priority and which use needs to be compensated in such a situation.

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The Measurement of Externalities of Paddy Field an Application of Contingent Valuation in Taiwan

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Abstract

After a certain degree of industrialization many countries find that agricultural production appears to result in negative economic profits due to the substantial opportunity cost of keeping land in use for agriculture. The value of land in nonagricultural uses rises considerably with industrialization. This process is especially acute in small, densely populated countries, such as Taiwan. However, the profitability of agricultural production may be underestimated if the positive externalities associated with farmland are not included. A proper accounting for these positive externalities casts agricultural production in a more favorable light. This paper focuses on paddy rice fields in Taiwan. A double-bounded dichotomous contingent valuation method (CVM) is combined with the selection-bias-correction procedure to estimate the extent of the positive externalities. The evidence suggests that the externalities of paddy rice fields are recognized by the majority of people in Taiwan. Each household is willing to pay on average about NT$6731 (US$170) annually to sustain the rice fields' water preservation and land protection functions, which is about 1.26 folds the intrinsic economic value of rice. Thus, the rising opportunity costs of retaining land in agricultural production is not yet sufficient to justify a reallocation of this resource from agriculture to other uses. The policy prescription favors retention of the land in agricultural production. In fact, if efficiency is the goal of policy makers, then more than half of the rice fields recently converted to other uses should have remained rice fields.

Introduction

Land and water are basic natural resources used in virtually all industries. When industries become the mainstream in a country's development, the land area allocated to agriculture declines. This decline is particularly dramatic in small, densely populated countries such as Taiwan, Singapore

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and Switzerland.[4] The move towards free trade in recent decades has facilitated the decline in the extent of agricultural lands in these countries by making low priced agricultural imports available. This further motivates efforts to convert farmland to industrial uses.

The reallocation of land from lower-valued use to a higher-valued use is apparently efficient. However, consideration of the role of farmlands in environmental protection and maintaining watersheds suggests that there is a significant positive externality associated with agricultural production. For purposes of environmental protection, farmland is irreplaceable by the high-valued industrial parks. Because there is no existing market for the external benefits gained from farmlands, attempts to estimate the value of the external benefits arising from farmland production directly, pose a significant challenge. This paper uses a contingent valuation method (CVM) to investigate to what extent farmland provides value other than agricultural production to members of the economy. A double-bounded dichotomous choice questionnaire was thus employed for the purposes of this study. The estimated value of the externality will then be added to the value of the agricultural products to calculate the final worth of paddy fields. This paper contributes to policy discussions by providing the first estimates of the value of agricultural production that include the externalities arising from farming activities in Taiwan.

This paper is organized as follows: the second section provides the theoretical foundations of the employed methodology for the externality estimation. The following section explains the data sources and collecting process for the empirical study. The empirical results are presented in the next section and the last section concludes the paper and makes some final remarks.

Research Theory

Over the past few decades, several methods have been developed in the field of environmental studies to evaluate environmental externalities (Davis 1963; Field 1994; Brookshire and Coursey 1987). This paper employs CVM due to its popularity for evaluating immeasurable economic benefit (Mitchell and Carson 1989). Similar studies applied to environmental and non-environmental issues, previously conducted, include air quality, preservation of wildlife, and the value of programs designed to reduce the risks of respiratory diseases.[5] In this study we used a double-bounded dichotomous CVM to investigate the external benefit of farmlands. Respondents were asked a series of questions with numerical values provided by the survey to induce the willingness-to-pay (WTP) without losing much information (Boyle and Bishop 1988). The formal theory is as follows.

The double-bounded model of CVM survey involves asking an individual if she/he would pay a specified amount to secure a given improvement in environmental quality with two bids. The level of the second bid is contingent upon the response to the first bid. If the individual responds "yes" to the first bid, the second bid (to be noted as B_i^H, some amount greater than the

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[4] According to the Food and Agricultural Organization of United Nations, the falls in agricultural land area for small open economies are evidential. For example, in the past three decades, the drop of agricultural land area is 27.3% in Switzerland, 7.08% in UK, 12.9% in Sweden, 7.3% in Netherlands, 14.4% in South Korea, 12.9% in Italy, 8.3% in Germany, 8.2% in France, 16.7% in Belgium, 12.1% in Austria, and 90% in Singapore.

[5] See Bowker and Stroll 1988; Carson and Mitchell 1993; Krupnick and Cropper 1992; Boyle and Bishop 1987; Greffle et al. 1998; Brookshire and Coursey 1987; Ready and Berger 1997; and Schulze et al. 1983, for details.

first bid), if the individual responds “no” to the first bid, the second bid B_i^L is some amount smaller than the first bid ($B_i^L \langle B_i \langle B_i^H$). Thus, there are four possible outcomes with the likelihoods as $\pi^{\mathrm{YY}}, \pi^{\mathrm{NN}}, \pi^{\mathrm{YN}}$ and π^{NY}. Under the assumption of a utility-maximizing respondent (Hanemann 1984), the formulas for these likelihoods are as follows (Hanemann, Loomis and Kanninen 1991).

$$\pi^{\mathrm{YY}}(B_i, B_i^H;\theta) = P_r\{B_i^H \le WTP\} = 1 - G(B_i^H;\theta) \qquad (1.1)$$

$$\pi^{\mathrm{NN}}(B_i, B_i^L;\theta) = G(B_i^L;\theta) \qquad (1.2)$$

$$\pi^{\mathrm{YN}}(B_i, B_i^H;\theta) = G(B_i^H;\theta) - G(B_i;\theta) \qquad (1.3)$$

$$\pi^{\mathrm{NY}}(B_i, B_i^L;\theta) = G(B_i;\theta) - G(B_i^L;\theta) \qquad (1.4)$$

where:

G(B; θ)is some statistical distribution function with parameter vector 0 and can be interpreted as a utility -maximization response within a random utility context where G(B; θ) is the cumulative density function of the individual’s true maximum WTP. It is also assumed that G is logistic distributed and

$G(B;\theta) = \dfrac{\exp(B - X\beta)}{1 + \exp(B - X\beta}$, where X is the explanatory variables,

and $\theta = \beta$ X, is the correspondent coefficients of X.

With N respondents, where B_i^L, B_i, B_i^H are the bids used for the ith respondent, the log-likelihood function takes the form:

$$\ell nL(\theta) = \sum_{i=1}^{N} \{ d_i^{YY} \ell n \pi^{YY}(B_i, B_i^H;\theta) + d_i^{NN} \ell n \pi^{NN}(N_i B_i^L;\theta)$$

$$+ d_i^{YN} \ell n \pi^{YN}(B_i, B_i^H;\theta) + d_i^{NY} \ell n \pi^{\mathrm{NY}}(B_i, B_i^L;\theta) \} \qquad (2)$$

where:

$d_i^{YY}, d_i^{NN}, d_i^{YN}, and\ d_i^{NY}$ are the binary-valued indicator variables and the formulas for the corresponding response probabilities are as mentioned above. Applying the maximum likelihood (ML) method, we obtain the aforementioned estimation parameters of the dichotomous model. That is, we estimate:

$\dfrac{\partial 1nL(\hat{\theta})}{\partial\theta} = 0$ to obtain θ the coefficients.

The estimating model is now $WTP_i = X_i\beta + \varepsilon_i$, where WTPi is the willingness to pay of the ith individual. Differing from B_i^L, B_i, B_i^H that are with observable discrete values, WTPi is an unobservable continuous series. We assume that ° is normally distributed with zero mean and $\sigma^2 I$ as the standard errors, ° ~ $N(0, \sigma^2 I)$.

When a survey method is employed to collect the data the problem of non-responses is encountered. If the values of environmental amenities to the individuals who do not respond are different from the value of these amenities to those that do respond, the use of the survey data can result in biased estimates. To account for the potential selection problem, the Heckman two-stage selection bias correction procedure is used. Thus the estimated model becomes:

$$\mathrm{WTP}_i = X_{1i}\beta + \sigma_{12}/(\sigma_{22})^{0.5}\lambda_i + v_i \tag{3}$$

where:

$\sigma_{12}/(\sigma_{22})^{0.5}$ is the inverse Mill's ratio and v_i is the residual. With the Heckman two-step procedure, if the estimated coefficient of λ_i is a positive number, the unadjusted regression may give an overestimated result. If it is negative, the unadjusted regression then tends to underestimate the impacts of the variables.

Design and Enforcement of Survey

There are many different types of agricultural fields and the environmental benefits provided by them differ from one to the other. We selected Taiwan's paddy rice fields as our sample in this study since they are known for several environmental benefits: groundwater storage and recharge, green field landscaping, polluted water purification, prevention of soil erosion, microclimate regulation, habitats for wild animals, air purification, prevention of flood damage, transbasin water transfer stabilization and prevention of salt water intrusion into the groundwater system (Tsai 1993). The coverage of the involved river basins is shown in figure 1.

In this study, two functions were classified: water preservation and landscape protection. These were focused on and studied as the external benefits of paddy fields.

The survey was conducted from April to May in 1999 over the entire island of Taiwan (total 21 district areas). We used the computer-assisted telephone interviewing system (CATI) to conduct the interviews. The sampling method was random and uses computerized phone books provided by the local telephone company to select the base sample. The usual demographic questions were asked during the interview. To induce each individual's WTP, five groups of bids were designed, based on a pretest of a 900 sample-size open-ended question survey result. The WTP is divided into 5 categories by its standard deviation. The result is presented in table 1.

Each respondent was randomly assigned into one of the five groups. The result of the attempted telephone numbers is summarized in table 2.The success rate was 16 percent.

The questions to induce the respondent households' WTP are based on a tax reallocation scheme. It is considered to be a more common means for financing environmental commodities and changes neither a disposable income nor the price of the evaluated commodity. It does, however, reduce the amount of a household' tax money that has been spent on other public services. Thus, the following two questions were asked:

Figure 1. River basins studied.

Table 1. Alternative bids for paddy fields (NT$).

Water preservation function			Land erosion protection function		
First round bidding	Second round bidding		First round bidding	Second round bidding	
B	B^H	B^L	B	B^H	B^L
33	50	17	21	30	10
85	40	125	121	180	60
151	225	75	162	243	81
203	304	102	263	394	132
320	480	160	404	605	202

Table 2. Results from attempted telephone numbers.

Result	No. of observations	Percentage
1. Success	1,225	16.0
2. Refusal	1,318	17.3
3. No answer or busy tone	3,517	46.0
4. No adults around	159	2.1
5. Verbal communication problems	192	2.5
6. Out of service numbers	754	9.9
7. Business or fax numbers	473	6.2
Total	6.638	100%

1. Given the groundwater protection function of paddy fields, would you vote for the program if it reduced the amount of your household's tax money[6] spent on the other public services by $___Bw____ per year? Yes No

If the above answer is "Yes", the same question is asked again by changing $BL to $BwH. If the answer is "No", the amount $Bw will be changed to $BwL.[7]

2. Given the landscape preservation function of paddy fields, would you vote for the program if it reduced the amount of your household's tax money spent on the other public services by $___BL___ per year? Yes No

If the above answer is "Yes", then the same question is asked again by changing $BL to $BLH. If the answer is "No", the amount $BL will be changed to $BL.[8]

Empirical Result

The statistical summary of the interviewed sample is presented in table 3.

Table 3. Demographic summary.

Variables	No. of observations	Mean	Standard error	Min.	Max.
Age	1,013	39.71	12.03	20	89
Education	1,186	12.82	3.90	6	25
Family size	1,178	4.88	2.47	1	20
No. of working people in a family	1,157	2.54	1.67	0	18
Tenure	947	11.99	10.60	1	60
Average expense (x104)	555	68.37	36.12	36	170
Marriage status	1,225	0.72	0.44	0	1
Average income (x104)	695	82.07	42.67	36	170
Homeowner	1,225	.72	.44	0	1
Urban residents	1,225	0.46	0.49	0	1
Flood	1,209	0.14	0.35	0	1
Gender	1,225	0.51	0.50	0	1

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[6] Yabe, Bergstorm and Boyle (1999) compare the effects of two payment vehicles of a special tax and a tax reallocation method on willingness to pay. In this study, we use the tax reallocation method meaning that the residents do not need to pay out of their own pockets to finance the environmental protection program. Instead, the tax money allocated to other public services will decline along with an increase in the amount of money allocated to the environmental protection program.

[7] The amount of B,B H and BL are determined from the pretest. They are presented in table 4.

[8] The amount of B, B H and BL are determined from the pretest. They are presented in table 4.

Table 3.1. Demographic summary.

Occupation:		No. of Observations	Percentage
	Public worker	119	10.57
	Business	199	17.67
	Farmers	60	5.33
	Self-employed	139	12.34
	Blue collar	197	17.50
	Staff	145	12.88
	Other	206	18.29
Working position:			
	Owner of the business	62	9.66
	Manager	168	26.16
	Staff	412	65.18

The monetary values from the questionnaire are denominated in New Taiwan Dollars (NT$), which convert to US dollars at a ratio of NT$33 to US$1. Table 4 presents the summary of participants' responses to the initial and the second bids.

The results in table 4 show that more than 76.35 and 68.82 percent of households think that paddy rice fields require some degree of public subsidy due to their water preservation function and land protection function, respectively. The result of the maximum likelihood estimates of the respondents' double-bounded WTP is summarized in table 5.

The variable "flood" means respondents with experience of flood. Column 1 and 2 are the results of the WTP estimation without the selection bias correction and column 3 and 4 contain the

Table 4. Participants' responses to the initil and second bids.

For water preservation function			
Answer type		Second bid	
		Yes	No
First bid	Yes	539 (54.94%)	158 (16.11%)
	No	52 (5.30%)	232 (23.65%)
For land protection function			
Answer type		Second bid	
		Yes	No
First bid	Yes	408 (44.78%)	148(16.25%)
	No	71(7.79%)	284 (31.18%)

Table 5. Maximum likelihood estimates of the respondents' WTP.

Variables	Water preservation	Land protection	Water preservation	Land protection
Education	20.77	22.05	-702.89***	-389.87**
	(36.38)	(37.78)	(190.74)	(202.48)
Income	-27.75	-18.94	-239.84***	-142.89**
	(24.59)	(25.18)	(60.23)	(64.86)
Tenure	4.44	12.39	67.50***	28.29**
	(9.71)	(10.27)	(18.96)	(20.16)
Marital Status	14.74*	36.26	301.69***	202.86**
	(22.58)	(23.14)	(77.47)	(83.68)
Gender	20.54	15.32	89.08***	53.84**
	(19.06)	(19.85)	(25.99)	(27.21)
Urban	-.57	-14.75	-52.62**	-43.49*
	(19.57)	(20.30)	(23.52)	(24.56)
Family size	-8.56**	-9.11**	-39.92***	-27.16***
	(3.59)	(3.85)	(8.88)	(9.52)
Manager	-19.82	-27.01	-124.57***	-85.85**
	(27.27)	(28.14)	(38.16)	(40.38)
Farmer	10.36	58.82	130.46**	123.65**
	(45.24)	(48.44)	(54.13)	(57.72)
Businessman	12.88	24.37	116.67***	82.45**
	(23.60)	(25.13)	(35.50)	(37.60)
News	12.76	1.82	13.57	2.43
	(11.41)	(11.65)	(11.28)	(11.60)
Flood	9.76	20.10	-159.52***	-75.03
	(26.96)	(26.91)	(51.06)	(53.16)
Mill's ratio	—	—	7046.71***	4035.91**
			(1824.21)	(1948.97)
Constant	352.83**	301.97	4322.64***	2577.48**
	(109.93)	(113.50)	(1034.22)	(1104.94)
Log likelihood	-1081.26	-1131.21	-1073.87	-1129.08
Number of obs	705	707	705	707
Model chi^2 (15)	12.65	18.31	27.42	22.57
Prob>chi^2	0.562	0.1932	0.0255	0.0936
Medium WTP	3253.08	3228.00	3370.92	3360.36

Notes: 1.1, 5, and 10% levels of significance are denoted by ***, and **, respectively.
2. Standard errors are given in parentheses.
3. Education, income and tenure year are in natural logarithm form.
4. The variable "News" represents the number of news sources where the respondents obtain their environmental knowledge.

estimates incorporating Heckman's two-step correction. Since the estimated coefficient for the inverse Mill's ratio is significant at 5 percent level, it appears that the appropriate estimates are those contained in columns 3 and 4. That is, incorporation of the selection bias correction is important.

The estimation results show that education and income level have a negative significant impact on the respondents' WTP for both functions of paddy fields, and both are statistically significant at 0.1 percent level. Also, respondents with larger family sizes tend to be willing to pay less for both environmental protection functions of paddy fields. Other variables that have negative impacts on the households' WTP toward paddy fields include urban residential location, manager status, respondents having more knowledge about paddy field's wildlife, and respondents with flood experience. The latter two variables seem to give counter intuitive results. They are, however, statistically insignificant. Male, married respondents, and farmers, and respondents who work in the business sector in general tend to pay higher for both types of functions, and the results are statistically significant at 5 percent level.

The coefficients of the Mill's ratio in both estimate results are positive and statistically significant at 5 percent level, meaning that the regression without selection-bias correction may be upward biased. The overall estimated WTPs for each regression function are shown at the bottom of table 5, noted as medium WTP. They are estimated as the mean value of the explanatory variables. The results show that average households in Taiwan are willing to reallocate their tax money from other public services to maintain paddy rice fields for their water preservation function by the amount of NT$3370.92 (about US$102) annually. For land protection purposes, average households in Taiwan are willing to reallocate NT$3360.36 of their tax money. The total WTP for the paddy fields maintenance in the form of reduction of other public services from their annual tax payment is NT$6731.28 per household. With a total of 6,592,549 households in the Taiwan area, the total amount of tax money needed to be reallocated for paddy fields maintenance is about NT$4.66 trillion , equivalent to 1.26 folds the value of rice production for the same period.

Conclusion

In this study, the importance of the environmental protection functions of farmlands was stressed and the value of these external benefits was estimated. Besides agricultural production purposes, farmlands are also recognized for their environmental functions. For simplicity, those benefits were roughly categorized into two types: water preservation and land protection functions, for further investigation. To evaluate the value of these external benefits, a double-bounded dichotomous CVM was employed. The majority of survey respondents felt that paddy rice fields exert a significant positive effect on water preservation and land protection. For water preservation and land protection the associated percentage of positive WTPs exceed three-fourths and two-thirds, respectively. The total willingness to pay obtained from tax reallocation for paddy fields is NT$4.66 trillion, which is equivalent to 1.26 folds the market value of rice production in Taiwan. Also the WTP's are positively related to the respondents' tenure year, marital status, business sector status and male gender status. They are negatively related to the respondents' education and income level, family size, urban status and manager status.

The results of this paper indicate that the majority of the households are aware of the external benefits of farmlands and are willing to pay a certain amount of money out of their tax payment to maintain them. With technological improvements and economic structural shifts, farming areas are gradually shrinking, especially in small open economies. These economies even consider abolishing agricultural production and relying mainly on imported products. In the context of rapidly decreasing farmland areas in many present-day societies, this paper calls to attention that focusing on the internal value of this sector is insufficient. When evaluating priorities for development of a nation, the external benefits of farmlands and the external costs of industrial development need to be evaluated along with their internal values. It is hoped that this paper can serve as a useful reference to agricultural authorities for future policy considerations.

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