MULTI-FUNCTIONALITY OF IRRIGATION WATER TO INCREASE THE WATER AND LAND PRODUCTIVITY

CONCEPT A FONCTION MULTIPLE DE L'EAU D'IRRIGATION POUR AUGMENTER LA PRODUCTIVITÉ DE L'EAU ET DE LA TERRE

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ABSTRACT

The multi-functional concept of agriculture vis-à-vis irrigation was first articulated in the 1992 Earth Summit, in the context of discussintg the contribution of agriculture/ irrigation to environmentally sustainable development. Since then the concept of multi-functional roles has been applied more generally not only to environmental benefits but to all the various functions of agriculture/water and land productivity that extend beyond the production of food and fibre.

The term `multi-functionality' refers to an agricultural (irrigation) activity that could have multiple outputs besides providing food and fibres and, therefore, may contribute to several objectives at once. The multiple roles of irrigated agriculture include food security, maintaining and ensuring viability of rural communities in environmental protection, such as land conservation, sustainable management of renewable natural resources (water), preservation of bio-diversity, landscape etc. (OECD, 1998).

The objective of this paper is to summarize country/ institutional experiences on understanding and analyzing multiple roles of irrigation to increase the water and land productivity in Asian region and paddy field irrigation. The main issues discussed are: (i) Mechanism of multiple role manifestation (Primary – environment etc; secondary – culture etc.), (ii) Method of quantifying multiple roles, (iii) Method of valuing benefits/ negative impacts, (iv) Approach to enhancing beneficial roles – reuse, circulation etc. (v) use of agricultural land for other purposes – wetlands etc. and (vi) policy and trade implications.

Chen and Facon (2005) show that multi-functional aspects of agricultural water management systems have wide regional variations. For the systems in Asia, especially paddy irrigation systems in monsoon Asia, functions can be grouped into three main categories: (1) Livelihood

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and economic functions, (2) Hydrological cycle and ecosystem functions, and (3) Social and cultural functions.

It is well known fact that irrigation yields social benefits beyond crop productivity. But there is considerable dispute about the magnitude of those benefits. The dispute results in part from lack of relevant data and in apart from use of inappropriate methodologies. Some methodologies have been highlighted.

A comparison of multi-functionality of irrigation (Paddy) in Japan, Korea and Taiwan has been made and discussed which covered flood mitigation, preventing soil erosion, and cooling air, among other functions.

In conclusion, there are modern irrigation systems which are solely there as a means of carrying economic activities, whereas the irrigation systems of historic civilizations have been least understood. Therefore, we should now engage in more analytical deliberations to mitigate environmental impacts of modern irrigation along with improving water and land productivity to feed the world.

Key words: *Multi-functionality of irrigation water, water and land productivity, paddy.*

RESUME

Le concept à fonction multiple d'agriculture vis-à-vis l'irrigation a été d'abord lancé en 1992 au Sommet de la Terre pour discuter la contribution d'agriculture / d'irrigation dans le développement durable environnemental. Depuis lors, le concept des rôles à fonction multiple a été appliqué plus généralement non seulement aux avantages environnementaux, mais aussi à toutes les diverses fonctions de la productivité d'agriculture/d'eau et de terre qui s'étend au-delà de la production de nourriture et de fibre.

Le terme 'la fonction multiple' attribue à une activité agricole (irrigation) qui pourrait avoir des productions multiples outre la fourniture de nourriture et de fibre et, donc, peut contribuer simultanément à plusieurs objectifs. Les rôles multiples d'agriculture irriguée incluent la sécurité alimentaire, la maintenance de la viabilité des communautés rurales dans la protection de l'environnement, telles que la conservation de terre, la gestion durable des ressources naturelles renouvelables (eau), la conservation de biodiversité et du paysage etc. (OECD, 1998).

Le rapport vise à récapituler les expériences du pays et des institutions tout en mettant l'accent sur la compréhension et l'analyse des rôles multiples d'irrigation pour augmenter la productivité de l'eau et de la terre dans la région asiatique et l'irrigation de rizière. Les questions principales discutées ici sont : (i) Mécanisme de manifestation du rôle multiple (Principal - environnement etc.; secondaire - agriculture etc.), (ii) Méthode d'évaluer les rôles multiples de manière quantitative, (iii) Méthode d'estimer les avantages/les impacts négatifs, (iv) Approche à l'amélioration des rôles avantageux - la réutilisation, la circulation etc., (v) Utilisation de la terre agricole pour d'autres buts - les zones humides etc., et (vi) Politique et implications commerciales.

Chen et Facon (2005) constatent que les aspects à fonction multiple des systèmes de la gestion d'eau agricoles détiennent des larges variations régionales. Dans les systèmes en Asie, particulièrement les systèmes d'irrigation de paddy en Asie de mousson, les fonctions peut être groupées dans trois catégories principales : (1) Moyen de vie et fonctions économiques, (2) Cycle hydrologique et fonctions d'écosystème, et (3) Fonctions sociales et culturelles.

Il est bien connu que l'irrigation est source des avantages sociaux au-delà de la productivité agricole. Mais, il existe des conflits sur l'ampleur de ces avantages. Le conflit résulte en partie dû au manque des données appropriées, et de l'autre dû à l'utilisation des méthodologies inopportunes. Certaines méthodologies ont été présentées.

1. INTRODUCTION

The multi-functional concept of agriculture vis-à-vis irrigation was first articulated in the 1992 Earth Summit, in the context of discussing the contribution of agriculture/irrigation to environmentally sustainable development. Since then the concept of multi-functional roles has been applied more generally not only to environmental benefits but to all the various functions of agriculture/irrigation that extend beyond the production of food and fibre.

However, due to the exceptionally rapid escalating economic development, compounded by the escalating conflicts amongst water, land and environment within the last few decades, it becomes apparent that the extinction of paddy irrigated agricultural heritage under the continuously fragmented land is not impossible in the immediate future.

To prevent the potential threat of extinction, one of the most plausible efforts that can be put into practice is to enhance and to vitalize the multi-functionalities of irrigation for paddy such as food security, maintaining and ensuring viability of rural communities and environmental protection, such as land conservation, sustainable management of renewable natural resources (water), preservation of bio-diversity, landscape, etc. (OECD, 1998).

Accordingly, the objectives of this paper are to summarize country/institutional experiences on understanding and analyzing multiple roles of irrigation water in Asian region and paddy field irrigation.

2. WORLD PADDY CULTIVATION AND WATER USE

Asia accounts for only 24% of the world's land area. However, it holds more than 62% of the world's population. About 54% of the world's population lives in a region known as humid Asia, or the Asian monsoon region, that covers only about 14% of the world's land area.

Irrigable land in Asia occupies some 72% of the world's irrigable land area of about 300 million ha. The majority of this irrigable land under paddy extends over the whole of the Asian monsoon region. Similarly, Asia accounts for roughly 60% of the world's water use and 50% of its agricultural water use.

Paddy cultivation in the Asian monsoon region is not only an excellent form of agriculture offering high land productivity and stable yields, but it could also be seen as a sustainable and environmentally friendly economic activity that suits the climatic and topographical conditions of this warm and humid region. This form of agriculture, an economic activity, has continued to evolve for hundreds to thousands of years at many sites, as witnessed by archaeological traces of 7,000 year-old paddy cultivation in China. And still today, it forms a unique natural feature and cultural setting by the endeavour of people living in harmony with water.

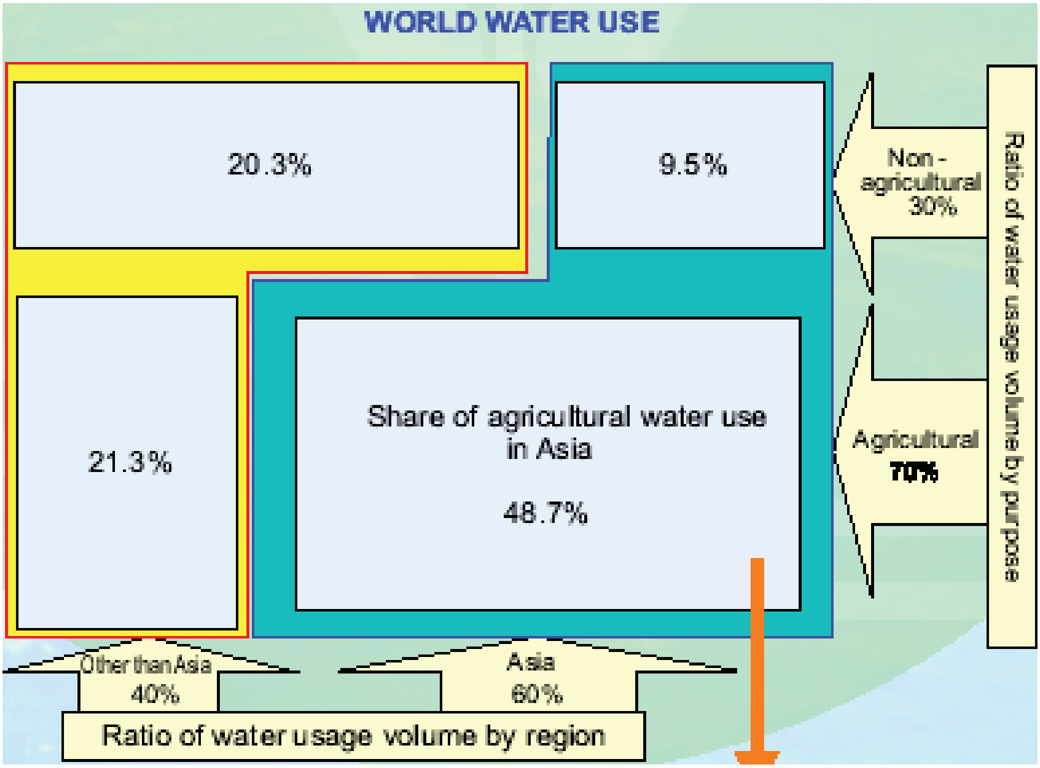

Figure 1. World water use

Paddy, a member of grass family, is the world's most important food crop next to wheat and corn. To date, there are around 120 rice producing countries in the world ranging from the mountainous Himalayan to the lowland delta areas. The total area under paddy is estimated at about 150 million hectares spread over all the six continents

3. MULTIPLE ROLE MANIFESTATION

The term "Multifunctional agriculture" has rapidly emerged from obscurity into common use in environment, agriculture and international trade circles, often placed at the center of heated discussion. What is the meaning of 'Multifunctional Agriculture'? Proponents of multi-functionality in agriculture generally are pointing to benefits other than food and fibres benefits, often not rewarded in marketplaces and which vary tremendously depending on farming practices is the given region.

Like all rapidly developing ideas, multi-functionality in agriculture can take on notably different meanings coming out from different speakers into the ears of different listeners; therefore, there is not set, definite definition mutually agreed and accepted worldwide.

In order to arrive at some consensus, OECD Agricultural committee has been implementing the most comprehensive and analytical study on multi-functionality of agriculture since 1998. Based on various materials collected and data published by OECD Secretariat, the concept of multi-functionality can be thus described as follows. Firstly, multiple commodity and non-commodity outputs that are jointly produced in conjunction with agricultural production exist, secondly , some portion of non-commodity outputs exhibit characteristics of externalities or public goods, with the result that, at present, markets for these goods neither exist not function properly.

On the other hand, accordingly to Romstad et al. (2000), multi-functionality implies that agriculture entails more than what is traditionally perceived as its main function; producing food and fiber. Lankoshi (2000) suggested that multi-functional agriculture could be defined as an economic activity, which, aside from its primary function to produce food, contributes to the well being of society by also producing multiple non-food benefits or costs jointly with food production. These benefits include contribution to the vitality of rural communities (through maintenance of family farming, rural employment and cultural heritage), biological diversity, recreation and tourism, soil and water health, bioenergy, landscape, food quality and safety, and animal welfare.

As pointed out by the OECD (2000), multiple functions are linked to agricultural production activities. As major portion of farmland in Asian monsoon region is tilled land and about 60% of it is used for paddy, it can be concluded that most multiple functions occur through wet paddy agriculture. For this reason, multi-functionality in this paper is focused on paddy farming.

For many years, a large number of research institutions is Korea and Japan have been conducting multi-disciplinary agricultural technology studies on the existence of multi-functionality. In addition, characteristics and categories of farming practices and areas where the multi-functionality occurs, as well as the conditions of its occurrence, were identified. From technical and agricultural economic viewpoints, items listed in Table 1 have been presently agreed upon among the Asian monsoon countries.

Table 1. Hierarchical Structure of the Multi-functionality Derived by Paddy Rice Farming

<table>
<tr><th colspan="5">Group of functions with economic externality Derived by Paddy Rice Farming</th></tr>
<tr><td>Rural vitalization</td><td colspan="4">Encouragement of local rice related industries and job creation</td></tr>
<tr><td rowspan="3">Social security function</td><td colspan="4">Food security and safety</td></tr>
<tr><td colspan="4">Safety management of local community</td></tr>
<tr><td colspan="4">Natural disaster prevention</td></tr>
<tr><td rowspan="13">Preservation of nature and environment</td><td rowspan="3">Biological preservation</td><td colspan="3">Preservation of biological diversity</td></tr>
<tr><td colspan="3">Preservation of wildlife</td></tr>
<tr><td colspan="3">Preservation of ecosystem</td></tr>
<tr><td rowspan="10">Preservation of national land and environment</td><td rowspan="4">Land preservation</td><td colspan="2">Preservation of disaster due to sediment</td></tr>
<tr><td colspan="2">Soil erosion prevention</td></tr>
<tr><td colspan="2">Landslide prevention</td></tr>
<tr><td colspan="2">Soil purification</td></tr>
<tr><td rowspan="5">Water preservation</td><td rowspan="2">Water control</td><td>Flood control</td></tr>
<tr><td>Water retention</td></tr>
<tr><td colspan="2">Stabilization of river flow</td></tr>
<tr><td rowspan="2">Water resources recharge</td><td>Surface water recharge</td></tr>
<tr><td>Groundwater recharge</td></tr>
<tr><td>Air purification</td><td colspan="2">Preservation of atmospheric composition
Climate alleviation</td></tr>
<tr><td rowspan="6">Social and cultural function</td><td rowspan="4">Preservation of amenity</td><td colspan="3">Dwelling environment preservation</td></tr>
<tr><td colspan="3">Recreation and relaxation</td></tr>
<tr><td colspan="3">Disaster relief</td></tr>
<tr><td colspan="3">Landscape preservation</td></tr>
<tr><td>Local community viability</td><td colspan="3">Support of local community</td></tr>
<tr><td>Local culture preservation</td><td colspan="3">Preservation of traditional cultures</td></tr>
</table>

When the outflow of rainwater from paddy fields is properly controlled, various multiple functions could occur. Which of these will happen depends largely on the geography and soil conditions.

For the systems in Asian countries, current studies reviewed by Chen and Facon (2005) show that multi-functional aspects of agriculture water management systems have wide regional variations, depending on the climate, social, cultural and economic conditions as well as on the infrastructure and management of the systems. For the systems in Asian countries, especially Paddy irrigation systems in Monsoon Asia, functions can be grouped into three broad categories : (1) livelihood and economic functions, (2) hydrological and ecosystem functions and (3) social and cultural functions.

3.1 Livelihood and economic functions

Farmhouse water supply : Rural people, mostly farmers, in the Chao Phraya Plain (Thailand) settle their houses along the water courses, rivers and irrigation canals with the vast paddy fields in between. This living style makes them depend mostly on the irrigation water for their household water uses especially in dry season.

Aquatic resources and aquaculture : The characteristics of flat floodplain and the function of the irrigation system, originally designed to spread the floods more evenly, provide the favourable condition for fish living in the paddy fields. In a depressed area, where farmer can only grow a low-yield floating rice, a production from fish can make an additional income.

Rural enterprises : In most rural communities where domestic water supply networks are not established or completed, agriculture water management system still severs as the major water supplier to the rural enterprises, such as agro-processing, small manufacturing, shops and restaurants.

Domestic water supply : Rivers and canals feed by irrigation water in the Central Plain (Thailand) are the major sources of water supply for municipal uses.

Hydropower generation and navigation : At the early stage of multipurpose dams operation, hydropower is a major source of the region’s electrical energy. It plays an important role in supplementing power generation during the daily peak demand. Navigation is a very important function where irrigation systems could support shipping out travel. Navigation, however, is not so popular these days due to extensive road / rail networks.

3.2 Hydrological and ecosystem functions

Flood control : The area of the paddy field that plays a natural retarding function roughly amounts to 20,000 km2 in the flood inundation area. Estimated the maximum was volume stored in the inundation area without inflicting significant damage of about 6 billion mcm. With this volume, the river discharge could be decreased considerably. In the case of 1995 flood, the total inundation volume amounts to about 16 billion. With this volume the river discharge could be decreased considerably. In the case of the 1955 flood, the total inundation volume amounts to about 16 billion mcm. From recent study on integrated plan for flood mitigation in Chao Phraya River Basin (CTI, 2000) proposed a system improvement for better floodwater distribution in the paddy field of 5,600 km2 in the Northern Chao Phraya area through the improvement of irrigation channel and flow control structures.

Groundwater recharge : The hydro-geological condition of the Central Plain indicates that at the delta area the thick layer of clay formation lies over the aquifer where the recharge area in which the aquifer layer approach to the ground surface is located a hundred kilometer further in the upstream direction. The recharge area is also in the rice growing irrigation service area. Though the contribution of irrigation water to the ground water have not been yet investigated.

Water purification : The formation of Chao Phraya floodplain (Thailand) and river morphology indicate that the sediment transport by river when flooding over the plain gradually forms and alluvial deposit. The sedimentation on the paddy field on one hand purifies the water by reducing turbidity and on the other hand increases soil fertility which favours the yield. In case of man made water pollution, the quality of the water leaving the paddy fields may be improved as a result of the absorptive capacity of the soil to hold contaminants such as heavy metals.

3.3 Social and Cultural Functions

Throughout the rice producing regions of South East Asia, the integration of paddy cultivation and local cultures has been evolving for thousands of years. Religious rituals are tied to the rice cycle and cultural identity is tied to rice production.

Community empowerment : For centuries, small-scale irrigation projects or tanks have been operated in many countries. These tank projects, organized by small farmer groups, are constructed operated, and maintained by local farmers. Water rights are strictly observed among farmers who share the water.

Employment

There is no question that irrigation creates employment, not only on-farm but also in the manufacture and sale of irrigation equipment, the manufacture and sale of fertilizers and pesticides, the supply of seed, and other industries. The significant benefit of irrigated agriculture compared with dry land agriculture is that it is more certain and thus provides far greater security to associated industries. This in turn encourages more certain and continuous employment in those industries, attracting workers and adding to the regional development.

Eco-tourism and Landscape Presentation

One potential way of harnessing the landscape for economic purposes is through eco-tourism. In Bali, rural hotels located in the midst of paddy lands use this as a feature to attract tourists, and arrange farm visits for the guests. Among the packages being studies are special trekking tours in paddy fields, introduction to paddy farming activities, and home stays with paddy farmers. These are designed to be both educational as well as holiday experiences especially for the urban population and school children.

Other benefits

Apart from the above, paddy fields can bring about other benefits. As a mechanism to diversify and to increase the income of paddy farmers, the traditional practice of rich-fish farming is being reintroduced. In rice-fish farming, rice and fish are produced simultaneous in the same flooded fields. The fish eats algae, rice pollen, weeds and insects while also fertilizing the soil more effectively than the commercial products. Fish also reduces pests by eating leafhoppers, stem borers and aphids and lower the incidence of several rice diseases. Rice-fish farming also creates a reliable source of protein. In addition, the local municipalities are reintroducing duck / chicken farming in paddy fields. The introduction of ducks / chicken has enhanced the rice-fish ecosystem. Ducks eat crabs and insets and their droppings add to soil fertility. Rice-fish and duck/chicken culture can actually increase the yields of rice (up to 25 to 30%) while providing farmers with extra income and reduced application of fertilizers and pesticides.

4. QUANTIFICATION AND VALUATION ISSUE

Traditionally people assigned cultural and social values to water and other resources, which eventually evolved into social norms and customs of managing these resources. However, in determining appropriate approach or policy or managing resources, qualification and valuation of all the functions (economic, environmental, social, cultural etc.) of water use and farming are needed. Research has been carried to establish rational methods of qualification and valuation, including replacement cost method, Contingent Valuation Method, and others, but there still is a lot of controversies over its accuracy, due to the problems of double counting or variations of the manifestation in time and place. One example of such efforts is shown in Figure 2, which shows that multifunctional value of paddy production is 1.4-4.9 times higher than the production value of paddy farming in Chinese Taipei, Japan and Korea.

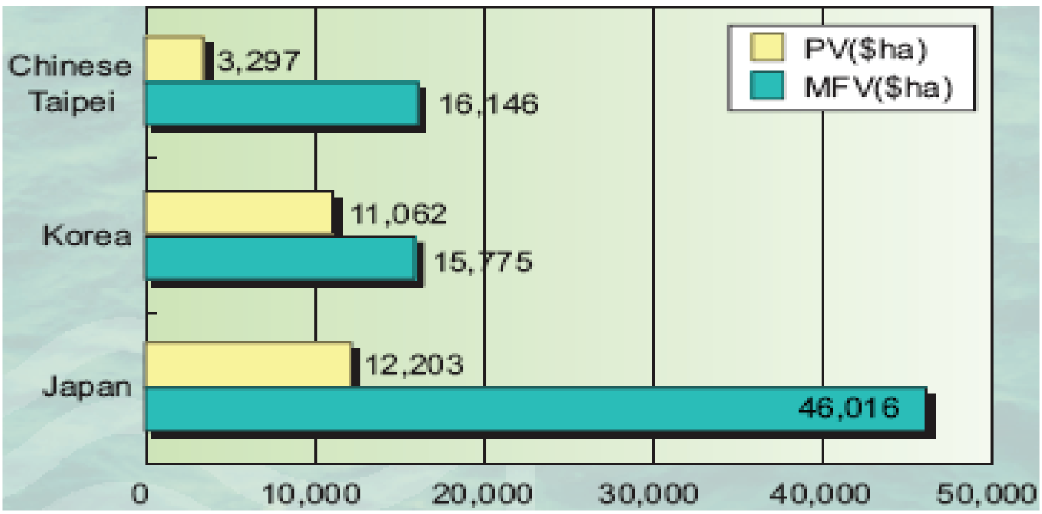

Figure 2 Comparison of production value (PV) and multifunctional Value (MVF)

This section of the paper deals broadly with the issue of identifying and valuing non-commodity outputs.

Although not universally accepted many would agree that the demand for amenities, environmental quality, and other multi-functional outputs of agriculture is substantial, and it is likely to increase in countries where incomes and wealth are on the rise. There is however, no consensus on how multi-functionality can be reconciled with free trade and the reform of domestic agricultural policy. These issues surrounding multi-functionality have global, country specific, regional and local dimensions that are just too complex to resolve within traditional commodity oriented domestic agricultural policy.

According to the OECD (2001) the definition of multi-functionally is :

Beyond its primary function of supplying food and fiber, agricultural activity can also reshape the landscape, provide agricultural benefits such as land conservation, the sustainable management or renewable resources and the preservation of bio-diversity, and contribute to the viability of many rural areas.

The non commodity outputs of multi-functional agriculture can be positive or negative externalities. The distinguishing feature of the non commodity outputs is that they are not traded in organized markets. Thus, in order to reformulate policy to recognize explicitly this new role of a multi-functional agriculture, we must derive values for these non commodity outputs using one or more of some well-established non market valuation techniques.

Cropper and Oats (1992) indicate in their review article that there are both direct and indirect methods for measuring the benefits or costs or non market goods.

The indirect methods relay on observed choices and there are three basic approaches: cost avoidance, weak complementary and hedonic price. Examples include :

Cost avoidance or substitutive cost : water inflation costs avoided in a household because of specific improvement in water quality; placing a value on the paddy fields for flood control by calculating the cost of additional reservoir capacity to serve the same purpose.

Weak complementary : an improvement in environmental quality results in an increased demand for visitors to the rural area – the value of the environment being measured by the net addition to consumer surplus.

Hedonic price : the price of goods can be decomposed into the prices of various attributes of the good: the size of the house, number of rooms, quality of the environment surrounding the house etc.

The alternative to these indirect methods is to gather evidence on the value of non market goods through surveys based on the contingent valuation method (CVM) or through experiments conducted in a laboratory for experimental economics. According to Randall (2002) the basic idea is :

If we design and ask questions with enough care, perhaps people can provide reliable evidence of amenity values by telling us their willingness to pay (WTP) or willingness to accept directly (WTA); or by telling us what they would do (e.g. buy or not buy…… or choose this alternative rather than that) given well specified choice situations that we construct for them…

In the case if agriculture's supply of these non commodity outputs and attributes (e.g. environmental goods; welfare-friendly production), whether one takes the direct or indirect approach, there are several reasons why the valuation process is particularly difficult. There are two dimensions to the problem: *what to include in the list of non market goods and how to measure or articulate the characteristics to be valued.*

5. VALUE OF MULTI-FUNCTIONAL OUTPUT (TAIWAN)

There have been studies in Taiwan estimating the values of multi-functional outputs of paddy rice in Taiwan. Two of the studies by Chen (2001) and by Chen, Wu and Chang (2002) apply contingency valuation methods to elicit values from a sample of Taiwanese residents. Two others, a somewhat earlier study by Tsai (1993) and a more recent on by Tan (2002) employ a series of indirect methods to estimate individual values for each of several multi-functional outputs of paddy rice. These studies follow quite closely the methodologies used in Japan (MAFF, 2000).

Only positive externalities have been considered in these studies, mainly because there has been an implicit desire to obtain a high value to justify to WTO a high level of domestic subsidies for rice production (even though these may no longer take the form of direct price supports). In fact, externalities notwithstanding, there is a strong political desire in all three East Asian countries (Taiwan, Japan and Korea) to maintain a relatively high level of rice self sufficiency to assure national food security.

Of the four studies described briefly below, two use contingent valuation methodology (CVM) and two use indirect methodologies. We discuss the studies associated with each methodological approach separately.

Contingent Valuation Method

Chen (2001) – This paper estimates the social value of several environmental services of Taiwanese agriculture. A survey was mailed to eight hundred respondents, 200 households of agricultural professionals and 600 households from the general public. Overall response rate was 38 percent. Respondents were asked to provide a holistic willingness to pay for 10 categories of multi-functional services – recreation, resource conservation, flood protection etc. Using probit and logit regression analysis, Chen estimated the willingness to pay for services for different subgroups – households of agricultural professionals, of parents with elementary school students, and of parents with college studies.

Chen, Wu and Chang (2002) - This study uses a survey of households in 21 district areas using a computer assisted telephone interview system. A total of 7,638 calls were attempted with a 19 percent response rate. The questionnaire was complex, with a respondent being asked a range of questions such as personal experience with flooding and knowledge or organisms in the paddy field. Finally, they were asked to separate valuation questions dealing with the groundwater protection function of paddy and the landscape preservation function of paddy. Willingness to pay was in the form of tax money for protection and preservation of paddy fields obtained by reducing taxes for other public services.

The major challenge in contingent valuation is to develop a set of questions such that the individuals being surveyed are clear as to exactly what is being valued. Based on the CVM questions, one would expect to obtain quite different information from the two CVM studies. Particularly in the Chen et al., study where the interview was conducted over the telephone, it seems very doubtful that participants understood clearly both the benefits (preservation of paddy land and water) and costs (reduced taxes for unspecified other services) associated with their willingness to pay. No attempt seems to have been made in this study to make sure respondents are valuing the same multi-functional outputs. Chen's benefit functions encompass a more holistic willingness to pay for 10 multi-functional services. If the two studies are to be compared, then Chen's analysis must be disaggregated to separate out the values assigned to groundwater and land protection that is the focus of the Chen et al., study.

Indirect methods

Tsai (1993) - Tsai used several indirect methods to place value on four separate types of benefits – groundwater recharge, flood protection, land subsidence, and air purification. To illustrate the procedures followed, we focus on methodology for assessing groundwater recharge and flood protection. The basic methodology here is cost avoidance or substitutive cost. For example, the value of the recharge is obtained by estimating the annual dam construction and operating costs required per cubic meter of storage to arrive at a raw water cost. This is then used to estimate the value of groundwater recharge in NT$ per hectare dividing by an average operations ratio. A similar method is used to assess the dam storage capacity needed for flood control and thus to assess the benefits. However, the value of water is not adjusted by an average operation ratio and is hence nearly double that is used in calculating the value of groundwater recharge.

Tan (2000) - Tan employs a similar method in calculating the values for groundwater recharge. He estimates ground water recharge by multiplying the soil infiltration rate by the number of irrigation days and number of acres planted. He can thus estimate directly the amount of water reaching deep levels not having to make adjustment in values as in Tsai's study. Tan uses exactly the same method as Tsai in calculating the value of water stored for flood protection and also does not adjust price by the average operation ratio.

Table 2 summarizes and compares the finding of the four studies. The magnitude of the per hectare valuation of externalities (in New Taiwan dollars, NT$) is compared with the per hectare production value of the rice crop. There is a wide variability in results with the contingency valuation approach having a higher ratio of externalities to production value. The study by Tan using almost the same approach as Tsai but with different assumptions gives the lowest valuation of externalities.

Table 2. Value of environmental externalities of Taiwan

Item	Indirect method		Contingent valuation method	
	Tsai (1993)	Tan (2002)	Chen et al (2002)	Chen (2001)
Items of environmental benefit	Groundwater recharge, flood protection	Groundwater recharge, flood protection	Water preservation, land protection	All of the possible environmental externalities
Total externalities per hectare (NT$/ha)	59,156	50,000	125,668	612,992
Production value per hectare (NT$/ha)	88,595	102,089	104,155	104,155
Ratio	0.67	0.56	1.41	6.91

While we document some of the difficulties of these existing attempts, our purpose is not to be overly critical. As Randall (2002) suggest, there has been some work at developing methodology to resolve the various problems encountered, but these methods are untried. Thus the studies should be seen as pioneering works and an important first step in applying methods to evaluate externalities in paddy cultivation.

7. MULTI-FUNCTIONALITY OF IRRIGATION IN JAPAN, KOREA AND TAIWAN

Comparison of the multi-function values among Japan, Korea, and Taiwan have discussed by Tsai et al. (2005). There are five functions that have been evaluated in all three countries, including preventing flood, fostering water resource, preventing soil erosion, cooling air temperature, and refreshing atmosphere.

Results showed that the total values of the five functions were US$ 28800, 13900 and 6600 for Japan, Korea and Taiwan, respectively. The production values for one hectare of paddy field were US$ 10660, 7520 and 2830, respectively. The ratios of the multi-functional value to the value of rice production were 2.70, 1.85 and 2.33. The average of the three countries was 2.29 which was close to the ratio of Taiwan.

From the mutli-functional outputs of paddy fields, it emerges that the environmental contributions, including preventing floods, fostering water resources, preventing soil erosion, cooling air, and refreshing atmosphere have exceeded the production value of rice. In some cases, the number is more than twice of the production value. This information is important for the policy-makers to decide the future of rice agriculture in their respective countries.

8. THE WAY FORWARD

There are modern irrigation systems which are solely there as a means of carrying economic activities, whereas the irrigation systems of historic civilizations have been least understood. Therefore, we should now engage in more analytical deliberations to mitigate environmental impacts of modern irrigation along with improving water and land productivity to feed the world.

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