WORKING PAPER 68

Accounting of Agricultural and Nonagricultural Impacts of Irrigation and Drainage Systems

A Report of Research in Taiwan and Sri Lanka in 2003

International Water Management Institute

FUTURE HARVEST
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COMPREHENSIVE Assessment of water management in agriculture

Working Paper 68

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Executive Summary

The research in 2003 consists of two components. First, research in Taiwan continues on estimating the positive and negative externalities of paddy-rice production. Second, research is being conducted in Sri Lanka to assess more broadly the impact of water resource development. In addition, two extensive literature reviews have been completed.

Part I. Taiwan

Research on the non-commodity benefits of paddy irrigation continued with analysis being conducted at the Agricultural Engineering Research Center (AERC) and the Cornell University.

The objective of this research is to develop the methodology for assessing some of the possible positive and negative externalities of paddy irrigation. This relates to establishing price and subsidy policies that are compatible with the WTO (World Trade Organization) guidelines, while at the same time establishing an appropriate level of support for the farm water users.

A paper containing the initial findings was presented at World Water Forum III in Kyoto, Japan in March 2003 and an updated version was presented at the ICID (International Commission on Irrigation and Drainage) Asia Regional Workshop in November 2003.

At the annual meeting of our research group in November, plans were developed for holding a workshop in April 2004, in Taipei, to develop a methodology protocol for estimating and valuing specific externalities such as groundwater recharge or erosion control.

Part II. Sri Lanka

The research in Sri Lanka focused on the Uda Walawe Irrigation Project in the southern part of the country. While the principal commodity in the project is rice, the assessment of direct benefits includes other crops as well. Assessment of indirect benefits includes: domestic use of water, irrigation of home gardens, fisheries, national parks, and spillover or multiplier effects in terms of indirect benefits to the nonfarmer community.

Two literature reviews have been undertaken. The first is an update of the Irrigation Impacts Assessment: draft presented in the 2002 mid-term report. The second is a new literature review of the Effects of Irrigation on Wetland Ecosystems in Developing Countries.

Part I. Report on Work in Taiwan

This year we have continued field research and analysis of positive and negative externalities in paddy-rice production in Taiwan. At our annual workshop in November, we agreed to hold a methodology workshop in January 2004 to establish protocols for measuring specific externalities such as groundwater recharge, erosion, or methane emissions.

A. Refining positive and negative externalities

A paper containing the initial findings was presented at World Water Forum III in Kyoto, Japan in March 2003 and an updated version presented at the ICID (International Commission on Irrigation and Drainage) Asia Regional Workshop in Taipei, in November 2003. The abstract from the latter paper is presented below.

Rice is often singled out as the largest consumer of irrigation water. There is also an increasing acceptance of the fact that paddy irrigation yields social benefits, beyond those directly resulting from rice production. But, there is considerable dispute about the magnitude of those benefits. The dispute results in part from lack of relevant data and in part from the use of inappropriate methodologies. This paper outlines the issues associated with the valuation of externalities, identifies the sources of external benefits and costs in paddy-rice culture, and reviews the problems associated with various methodological approaches. The authors conclude that there is a general misconception of the amount of water depleted by rice cultivation, and that return flows from rice cultivation generate important positive as well as negative externalities. However, existing studies may overestimate the potential benefits of paddy- rice cultivation. There is a need for a new, and a more objective methodological approach, but in many instances data may often be lacking for the successful application of this approach.

B. Annual meeting 2003—minutes of the meeting—Nov. 12–14

(i) Participants:

Ming-hua Tsai, Hai-Sheng Ko, Chih-Hung Tan, Cheng-Chang Huang, Yi-Lun Sung, Yutaka Matsuno, Gilbert Levine and Randolph Barker.

(ii) Venue:

Prior to the formal discussions of our project, we attended the ICID (International Commission on Irrigation and Drainage) Asian Regional Workshop held at the Grand Hotel in Taipei Nov. 10-12.

In the afternoon of Nov. 12 and 13, we met at the Council of Agriculture (COA) to discuss our research project.

On Nov. 14, we continued the discussion at the Agricultural Engineering Research Center (AERC).

(iii) Key issues discussed:

a. Concept note

The August 12 concept note was accepted as the general framework for our research in the coming future. In general, we agreed to broaden and deepen our research on the externalities of paddy-rice production.

b. Workshop

We agreed to hold a workshop in January from 12-15. The workshop will be held in Taipei on *Determining Paddy Irrigation Multi-functionality* and will involve several researchers from Taiwan, plus participants from IWMI, Japan and Korea, with specific knowledge regarding the methodologies for evaluating externalities used in these two countries. The workshop has three objectives:

(i) To establish the methodology protocols for estimating and valuing the half dozen or so key externalities (e.g., groundwater recharge, erosion control, flood control, and subsidence);

(ii) To discuss methodologies for using the data from (i) above to analyze the policy options for internalizing the externalities, and also to discuss methodologies to assess how the benefits of irrigation are shared between the farm and nonfarmer segments of society; and

(iii) To set the guidelines for our research in the coming year. The purpose of this research is to provide Council of Agriculture, the Water Resource Bureau and other agencies in Taiwan with information that will facilitate the establishment of sound polices and support levels for the paddy-rice sector in keeping with World Trade Organization regulations.

All three objectives are linked closely to research being conducted by Hung-hao Chang and Richard Boisvert at the Cornell University designed to develop a model using Taiwan data to analyze policy options.

Hung-hao Chang will be in Taiwan from January 6–20.

c. Study Tour

The next study tour will be to the Philippines in April. It will consist of two to three days in Central Luzon north of Manila and one day at the International Rice Research Institute at Los Banos south of Manila. Randolph Barker will make arrangements for the field trip to the Philippines during his visit there in the first week of December.

(iv) ICID Asian Regional Workshop, November 11–12, Grand Hotel, Taipei

The ICID workshop was held just prior to our project meeting. It was extremely well organized. IWMI (International Water Management Institute) was pleased to be one of the co-sponsors. IWMI staff presented several papers including two dealing directly with our research on externalities and two dealing with IWMI's research in China.

Part II. Report on Work in Sri Lanka

This year in Sri Lanka, we have been completing a case study of direct benefits and indirect benefits (externalities) of irrigation in the Uda Walawe Irrigation Project. Also, two extensive bibliographies/ literature reviews have been developed. The first, Irrigation Impact Assessment: An Annotated Bibliography of recent literature on Methods and Findings (Literature Reviews) is an update of the version in last year's mid-term report. The second literature review, still in process is: The Effects of Irrigation on Wetland Ecosystems in Developing Countries – A Literature Review (Literature Reviews).

A. Case study of Uda Walawe Irrigation, Sri Lanka

At the outset, proposed irrigation projects promise substantial benefits. While they have made substantial contributions to economic development, the price paid to secure these benefits has often been higher than expected, not only in terms of capital outlay, but also in terms of social and environmental costs. Questions are being raised about the distribution of benefits and costs from irrigation projects and their real contribution to meeting development needs.

This paper examines the history of water resource development investment decisions for the Uda Walawe Irrigation and Resettlement Project (UWIRP), located in the southern dry zone of Sri Lanka, which was initiated just after independence in the early 1950s. It seeks to tell the story of "what happened" and "why" by examining planned versus actual outcomes of successive investment phases. A variety of qualitative and quantitative measures are used including, a detailed historical account of activities, quantitative performance measures (such as planned versus actual command area, cropping patterns, implementation period, etc.), estimation of project benefits and costs, and an analysis of the decision-making process.

UWIRP was part of Sri Lanka's new post-colonial vision for economic development and modernization; a vision that was supported by multi-lateral funding agencies and other countries in the region, because irrigation was seen as an engine of growth in the 1950s. The original plan for UWIRP is most aptly described as a highly ambitious social, economic and physical engineering project aimed at creating a modern and profitable agricultural sector. This plan envisioned bringing 32,779.5 hectares of arid land into highly efficient agricultural production by constructing a reservoir and irrigation facilities, and moving landless farmers in to newly developed lands. Given agronomic constraints and prevailing macroeconomic policies that emphasized import substitution and food self-sufficiency, cropping patterns emphasized non-paddy field crops such as chillies and cotton. Beyond cropping patterns, detailed plans laid-out production practices, water use, settler selection, and design infrastructure to promote modernization and social cohesion. The original visions for UWIRP have not yet been achieved.

An analysis of the successive phases of water resource development in the UWIRP pinpoints some key historical factors, which changed the course of the original plans, including the lack of a downstream development plan until the headworks were constructed and many settlers were on the land, massive land encroachment problems by squatters that were essentially ignored for well over a decade, and interference by a high level government official resulting in inefficient crop/ soil combinations in the area.

Rather than adaptively adjust to these unforeseen changes, planners continued to return time and again to the original plan and launch successive attempts at development. For each phase, investment was justified based on specified outcomes. Typical ex post irrigation assessment performance measures (projected versus actual capital costs, implementation schedules, and achievement of objectives such as irrigated area and crop output) were used to identify the extent of divergence between planned and actual outcomes. These measures underscored the rather poor performance detailed in the historical analysis. However, a comparative analysis of performance measure from UWIRP with other developing country irrigation projects revealed that UWIRP's relatively poor performance, as measured by typical indicators, was on par with other projects. These results support research from earlier comprehensive studies (e.g., WCD, 2000) that ex ante irrigation plans tend to systematically overstate the proposed outcomes.

The rather grim history of UWIRP, coupled with poor performance measures, is met with some unanticipated results in the preliminary analysis of the costs and benefits for UWIRP. Despite rapidly escalating cumulative project costs, the growth in cumulative direct benefits from agricultural production continued to outstrip costs. The growth in benefits was unanticipated and stemmed primarily from two factors—a surge in international paddy prices in the late 1970s and early 1980s, and the successful introduction of banana cultivation and associated marketing channels due to the outstanding vision and efforts of local agricultural extension agents.

Since the UWIRP irrigation system is used for many other purposes than crop irrigation, we provide preliminary estimates of these other non-irrigation benefits such as reservoir fisheries, drinking water, and tourism. In addition, we provide some preliminary estimates of the secondary economic benefits of irrigation investments to the region using existing estimates of economic multipliers from the literature.

These benefits need to be compared to other costs imposed by the project beyond capital investment costs such as environmental and social costs. Although only limited information exists on the environmental costs of UWIRIP, the social costs of UWIRP have been low in comparison to other large-scale dam and irrigation projects, which frequently involved reallocation of local populations usually with adequate compensation and support. The UWIRP project area was sparsely populated and those living in the designated area were made into project beneficiaries as settlers. In addition, most squatters who encroached land earlier on were eventually given legal settler status. Further research is needed on indirect project costs, such as human health effects. Perhaps one of the great potential hidden costs is human health risk from unsafe drinking water and bioaccumulation of agro-chemical byproducts through regular consumption of reservoir fish in the project area. Other questions related to the distribution of benefits among project beneficiaries and the onus of costs. Finally, it is unclear what gains could have been achieved if the money invested in UWIRP had been invested elsewhere.

The final section of the report seeks to understand the decision making process for various interventions over the years and the outcomes of those decisions. It involves identifying the various decisions that have influenced the project's evolution, the rationale behind these decisions, and how these decisions were implemented. It shows, in particular, the interplay between how projects are perceived, planned, implemented and managed by various actors (donors, government, implementing agencies, and consultants) given their strategic interests and accountability. Particular attention is given to the gap between what the planners' envision, reality on-the-ground, and the implementers' ability to effectively bridge this gap.

Overall, this research illustrates the difficulties of assessing project performance, both ex ante and ex post, but also that the outcome of the project is governed by the evolution of the behavior and choices of the different actors concerned, in which their interests, mindsets and strategies are embedded. It highlights the serious shortcomings of viewing development as a set of technical and social engineering endeavors, and uncovers underlying processes that shape the evolution of the project.

B. Literature Reviews

First Review: Irrigation Impacts Assessment: An Annotate Bibliography of Recent Literature on Methods and Findings

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Second Review: The Effects of Irrigation on Wetland Ecosystems in Developing Countries—A Literature Review

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Annex I. April 2004 Methodology Workshop—Draft Program

Taiwan Council of Agriculture
International Water Management Institute
Agricultural Engineering Research Center

Workshop on Determining Paddy Irrigation Multi-functionality
April 2004

Tentative Agenda

There is widespread recognition in Taiwan and other countries that there are many non- trade outputs associated with paddy-rice irrigation. It is also recognized that failure to incorporate consideration of these into decision-making about land and water policies results in less than optimum utilization of these resources. Thus, there is substantial interest in determining the magnitudes and values of these outputs from an internal country perspective. At the same time, these values have implications for the level of support that can be provided to the rural sector without violating the World Trade Organization (WTO) free trade rules.

To obtain the best measures of these values, the Council of Agriculture (COA) has supported a wide range of studies, some of which have been carried out by Taiwanese scientists and scholars in collaboration with the International Water Management Institute (IWMI) and the Cornell University; and others have been carried out independently. These early studies provided estimates of some of the multi-functional outputs, but not others.

The importance and political sensitivity of the use of multi-functional outputs are such that there is a recognized need to have the most accurate and precise estimates possible, to obtain the confidence of those policymakers charged with responsibility for land and water decisions. There has been sufficient research completed that it should be possible to recommend measurement and valuation protocols to produce the required information. This workshop is intended to develop those methodology recommendations and to identify those questions that need further study.

The workshop is organized in four sessions: 1. determination of the magnitudes of multi-function outputs; 2. determination of the values of multi-function outputs; 3. internalization of the values of multi-functional outputs into the exploration of policy options; and 4. identification of research needs.

The format of the workshop is informal and the presentation of formal papers is not anticipated. Brief statements of some of the questions that have arisen in the context of the existing studies of multi-functional outputs will be used to initiate the discussions, but are not intended to define or limit the discussion. The workshop is intended to draw upon the research and experience of the participants to identify the best available methodology for the determination of potential paddy irrigation nonmarket outputs. It also should identify those areas where there is a critical need for improved methodologies.

Day 1

Magnitudes of Potential Multi-functional Outputs:

1. Recharge of aquifers

   - Should "total" or "effective" recharge[1] be the basis for the determining the magnitude of functional output?
   - What is the impact on accuracy if national averages are used, instead of aggregating results for individual aquifers?
   - What data are required if individual aquifers are to form the base of the output determination?
   - Are these data available in Taiwan?

2. Flood reduction

   - Should the flood protection magnitude be based upon the calculation of physical storage alone, or should it relate to the potential for damages to occur?
   - Can the geographic locations of potentially significant damages be delineated?
   - What irrigation policy should be used in calculating physical storage available in the paddies?

3. Erosion reduction

   - How should the geographic areas of potentially significant erosion be identified? (Slope? Soil type?)
   - What aspect(s) of paddy irrigation provide erosion reduction? (Change in effective slope of the land? Reduction in volume of flows?)

4. Change in water quality

   - Are the types and amounts of chemicals used in paddy irrigation such, that pollution of percolating and/or surface water runoff occurs?
   - Is wastewater or sludge used in connection with paddy-rice production? If so, where? In what amounts?
   - Water used for irrigation may be polluted by industrial and/or municipal sources. Are data available to estimate the magnitude of this pollution?

[1]Total recharge would be the estimate of water volume that infiltrates into the soil; effective recharge would be the volume of infiltrated water that replaces groundwater used for social purposes (irrigation, municipal, industrial, or environmental.)

5. Change in air quality

- Methane results from the decomposition of organic matter during paddy-rice production. Is the use of organic fertilizer changing? If so, in what way?

- Two different coefficients have been used in the existing studies related to paddy production, resulting in approximately 30 percent difference in magnitude of methane emissions. Which is more appropriate for Taiwan conditions?

- Are there other effects on air quality than methane?

6. Subsidence reduction

- Are data available to delineate the areas subject to subsidence?

- Is the nature of subsidence in Taiwan such that it would be affected by paddy irrigation practice?

7. Maintenance of aesthetic landscape

- Are there data to indicate how much of a reduction in paddy area would be considered detrimental to the rural landscape?

- Are there data to indicate different levels of appreciation of the paddy landscape in different parts of the country?

A number of the foregoing functions are jointly produced; How should their magnitudes be combined?

Day 2

Values of Potential Multi-functional Outputs

1. Recharge of aquifers

- What method (s) should be used to determine the value —"substitution" and/or "contingent valuation?"

- If substitution is used, how should the value of the replacement water be calculated? Raw water price from other sources? Amortized reservoir storage?

- If contingent valuation is used, how can the respondents be accurately informed of the aspect(s) being evaluated?

- If contingent valuation is used, what type of valuation should be used?

- Are phone and/or mail surveys appropriate for estimation of paddy production valuation, or are personal interviews necessary?

2. Flood reduction

- What method (s) should be used to determine the value – “substitution,” “contingent valuation,” “damage reduction?”

- Do data on flood damages exist? Urban? Rural?

- Are there estimates of the percent of rural flood damages covered by the government flood insurance program?

3. Erosion reduction

- What method(s) should be used to determine the value —“substitution,” “contingent valuation,” and “damage reduction?”

- Do data exist about siltation of reservoirs?

- Do data exist on agricultural impact of erosion?

4. Change in water quality

- What method (s) should be used to determine the value — “substitution;” “contingent valuation;” and “damage reduction?”

- If substitution is used, how should the value of the replacement water be calculated? Raw water price from other sources? Amortized reservoir storage?

5. Change in air quality

- Which method of valuation should be used (change in organic matter management? Dry nursery? Use of hybrid seed?

6. Subsidence reduction

- What method (s) should be used to determine the value – “substitution,” “contingent valuation,” “damage reduction?”

7. Maintenance of aesthetic landscape

- Are there methods other than “contingent valuation” for determining the value of the landscape?

Day 3

Internalization of M-F Outputs into Policy

1. Political considerations

   - Are there political considerations other than food security that should be included in policy models?

   - To what extent should the type of beneficiary from the stream of outputs (market and nonmarket) be a factor in decisions about land and water policies?

2. Policy models

   - What factors should be included in policy models for internalizing nonmarket paddy-rice outputs?

   - Can models optimize the international as well as internal needs of Taiwan?

Output

As an output of the workshop we plan to develop a manual on the evaluation of Paddy-rice externalities.

Annex II: Proposal for Research 2004

Comprehensive Assessment of Paddy Irrigation Impacts and Their Distribution in Taiwan

A Proposed Collaborative Research Program

The Agricultural Engineering Research Center and the International Water Management Institute

Abstract

Growing demands on water resources, World Trade Organization (WTO) rules on agricultural payments, and increasing stress on the country's economy make the accurate assessment of the full role of paddy irrigation critically important in Taiwan. Research being carried out in Taiwan and other Asian countries is clarifying and placing values on the externalities, both positive and negative, associated with paddy irrigation. The research proposed here is to extend that research to place the results in the larger national economic context, to identify the multiplier impacts and to indicate the beneficiaries of the investment in irrigation systems.

Background:

Recent research has provided estimates of the value of a number of the direct externalities associated with paddy irrigation (Tsai 1993). These are sufficiently large as to have impacts on the larger national economy, and research is continuing on the policy implications of alternative ways to internalize these effects. When the direct externalities, primarily environmental, are combined with secondary externalities such as the multiplier effects on the service and industrial economies, the implications for the national economy may be very significant. Obviously, knowledge of the magnitudes of impacts and their distribution among the population is important for appropriate agricultural policy.

The AERC (Agricultural Engineering Research Center) –IWMI (International Water Management Institute) collaborative research has evaluated the various methodologies for determining the values of the direct externalities, and has developed such values using primarily national-level data. It is clear, however, that both the magnitude and value of many of the effects are influenced by the local context. Thus, part of this proposed project will be to examine the implications of using geographically disaggregated data in contract to national data.

Proposed Research:

The primary goal of the research program is to provide a comprehensive assessment of the roles of paddy irrigation in the Taiwan economy. A secondary goal is to evaluate the implications of using local versus national data in that assessment. For this latter effort, the study will use the data from a large Irrigation Association (either Kaoshung or Chi Nan).

The specific objectives of the research are:

1. To couple rice production values with the positive and negative externalities of paddy irrigation to determine their impacts on Taiwan's economy;

2. To evaluate quantitatively and qualitatively the multiplier effects of paddy irrigation on the Taiwan economy;

3. To identify, and to evaluate the impact stream on different groups; and

4. To determine the value of paddy-rice production externalities using local-level data, to compare with values determined with national-level data.

Research Methodology:

1. National data for rice production will be coupled with the externality data previously determined to produce a comprehensive evaluation of impact of paddy irrigation on the national economy;

2. The share of the benefits received by the rice producers and other segments of the population will be determined; and

3. Paddy-rice irrigation externalities will be determined for at least one large Irrigation Association (either Kaoshung or Chi Nan) using data reflecting the local environment.

Anticipated Outputs:

1. Report on the impact of paddy-rice irrigation in Taiwan;

2. Comprehensive assessment of a major irrigation system in Taiwan; and

3. Evaluation of the relative merits of using local versus national data for determination of the values of externalities.

Annex III.

Refining the Positive and Negative Externalties of Taiwanese Paddy-rice Production[2]

R. Boisvert, H. Chang, R. Barker, G. Levine, Y. Matsuno and D. Molden

ABSTRACT

Rice is often singled out as the largest consumer of irrigation water. There is also an increasing acceptance of the fact that paddy irrigation yields social benefits beyond those directly resulting from rice production. But there is considerable dispute about the magnitude of those benefits. The dispute results in part from lack of relevant data and in part from the use of inappropriate methodologies. This paper outlines the issues associated with the valuation of externalities, identifies the sources of external benefits and costs in paddy-rice culture, and reviews the problems associated with various methodological approaches. The authors conclude that there is a general misconception of the amount of water depleted by rice cultivation, and that return flows from rice cultivation generate important positive as well as negative externalities. However, existing studies may overestimate the potential benefits of paddy-rice cultivation. There is a need for a new, more objective methodological approach, but in many instances data may often be lacking for the successful application of this approach.

1.0 Introduction

Paddy-rice is the primary food production industry in many Asian countries and accounts for approximately 50 percent of the irrigated area in Asia. As a result countries have paid close attention to the rice industry and have employed multiple market intervention policies to promote farmers' welfare and protect the food supply for the public.

Over time the range of non-trade concerns (externalities) has broadened to include food security, food safety and quality, and animal welfare and rural development, in addition to the collection of attributes encapsulated in the term "multifunctionality." While the latter concept has many interpretations, the intent is to recognize the multiple-output nature of agricultural production in which many commodity as well as non-commodity outputs are produced jointly. In addition to food, fiber, and agricultural raw materials, these multiple outputs may include environmental effects, landscape amenities, and cultural heritage (aspects of how land is used) that yield "social" benefits or impose "social" costs not traded in organized markets.

The interest in valuing the range of externalities has increased recently with the desire of many countries to meet the free trade objectives of the World Trade Organization (WTO). Under WTO rules government efforts to support the domestic agricultural sector must rely less on price supports and other domestic policies that distort international trade.

[2]This paper is based on a progress report, "Refining the Non-Agricultural Values for Multifunctional Non-Commodity Agricultural Outputs for Trade Policy Analysis: The Case of Taiwanese Paddy-rice" prepared by Boisvert et al. (2003) and on materials from IWMI Working Paper 43, "Accounting of Agricultural and Non-Agricultural Impacts of Irrigation and Drainage Systems: A Study of Multifunctionality in Rice" prepared by Matsunto et al. (2002).

This paper is based upon ongoing research on the non-commodity benefits and costs of paddy irrigation in Taiwan. The research is being undertaken by the International Water Management Institute (IWMI) in collaboration with the Agricultural Engineering Research Center (AERC) in Taiwan, and the Department of Applied Economics and Management, Cornell University. The objective of this research is to evaluate the methodological options both in determination of the magnitudes of paddy irrigation externalities and in their valuation.

The next section of the paper deals broadly with the issue of identifying and valuing non-commodity outputs. The third section is concerned with non-commodity externalities in the context of paddy-rice production in Taiwan. The fourth section summarizes and compares previous studies estimating the value of multifunctional outputs from Taiwan paddy-rice and identifying the strengths and weaknesses of these approaches. Additional research currently being undertaken to develop more rational estimates of the benefits of multifunctional outputs of paddy-rice is discussed in the summary and conclusions.

2.0 The *Multifunctionality* Valuation Issue

Although not a universally held view, 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 multifunctionality can be reconciled with free trade and the reform of domestic agricultural policy. The issues surrounding multifunctionality have global, country-specific, regional, and local dimensions that are just too complex to resolve within traditional commodity-oriented domestic agricultural policy. Rather what is needed is a new domestic agricultural policy paradigm that focuses directly on the sector's importance as a user of land and other highly valued natural and environmental resources.

According to the OECD (2001) the definition of *multifunctionality* 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 *multifunctional* 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 multifunctional agriculture, we must derive values for these non-commodity outputs using one or more of some well-established nonmarket valuation techniques. Application of these methods in the case of jointly produced multiple outputs is not an easy task.

Research on the valuation of nonmarket goods is largely in the domain of environmental economists. As Cropper and Oats (1992) indicate in their review article, there are both direct and indirect methods for measuring the benefits or costs of nonmarket goods.

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

Cost avoidance or substitutive cost: water infiltration 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 complementarity: 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 nonmarket 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 nonmarket goods and how to measure or articulate the characteristics to be valued.

3.0 The Paddy-rice Context

Most of the recent studies on *multifunctionality* deal with the specific context of *paddy-rice production* rather than the more general context of crop irrigation. Almost half of the irrigation in Asia is devoted to rice production. Rice is often viewed in the context of *culture* and *food security* rather than the narrower context of *crop production.* Some Asian countries are concerned with protecting paddy-rice production in the face of WTO requirements to move toward free competition and remove rice price supports.

Before moving to the discussion of multifunctionality, we comment briefly in the next section on common misconceptions regarding water requirements for paddy-rice production (Barker and Molden 1999). Many people believe that there is considerable wastage of water in rice irrigation, because the quantity of water delivered to a rice field typically far exceeds that of other crops. Based on this point of view, rice irrigation is the target for efficiency improvements, or labeled as an inappropriate crop in many contexts, because of water scarcity.

3.1 How much water does rice consume?

The question is how much water can be saved from rice irrigated areas? Related to this question is how much water does rice really consume? The answer is that there is much less opportunity for saving water in rice irrigated areas than expected, because rice does not consume as much water as commonly believed. Return flow water, that is not consumed by crop evapotranspiration is the source of many positive and negative externalities. Let us consider them in some detail.

Consider the flow of water in a river basin where rice irrigation is practiced. Rainfall that is not immediately evaporated flows to aquifers or the river system. Water is diverted from rivers to rice irrigated areas. Conveyance structures carry water to farmers' fields, where it is applied to the soil. Water evaporates directly from the surface of the field, or by crop transpiration. The remaining water either flows horizontally as surface runoff, or as lateral seepage, or vertical deep percolation.

What happens to runoff, deep percolation, and seepage? Are these losses? Common in rice irrigated areas is the movement of water from field to field, either as surface runoff or seepage. One farmer's drainage is another farmer's supply. Eventually excess water may reach a larger drain that removes excess water from the irrigated area. Drains represent another source of water for irrigated rice farmers who ingeniously divert water or pump water from these drains. Similarly, aquifer water, recharged by deep percolation, is pumped to fields. Water truly follows a "tortuous path" within rice irrigated areas, and in many cases is applied several times. This use and reuse of water is referred to as recycling of water.

Eventually, water drains out of the irrigated area. Drainage flows that re-enter the river system are known as "return flows." Return flows are very often an important source of water for downstream users, and can be the source of water for wetlands, so there is yet another possibility of recycling. Eventually, return flows cannot be reused, either because (a) they flow into a sea or other sink, or (b) there are no users downstream that could use this water.

To help conceptualize water savings it is useful to consider: *delivery* to a use, and *depletion* of water by that use (Molden 1997). Water is delivered to a field and applied to land. Water is depleted when there is no further opportunity for reuse downstream. Depletion occurs either when water is vaporized by evaporation or transpiration, or flows to a sink such as a sea, or an inland lake with no drainage outlets.

Deliveries to rice fields often far exceed other crops such as maize or cotton. But importantly evapotranspiration is only a small amount higher, on the order of 20 percent higher than for these other crops. The difference between deliveries and evapotranspiration are return flows, and the amount of depletion depends on what happens to the return flows. Many rice-based systems are adapted to reuse return flows for many purposes.

Two general water saving scenarios occur with respect to return flows:

Scenario 1: Return flows can be reused, and depletion is only transpiration and evaporation.

Scenario 2: Return flows cannot be reused because they flow into a sink, and depletion is the combination of evapotranspiration and flows to sinks.

Diversions and return flows are the main causes of positive and negative externalities of rice cultivation. Diversions from river systems for rice have significantly altered river flow patterns. This may be considered positive in terms of flood reduction, but negative in terms of destruction of aquatic habitats. On the positive side, return flows can recharge aquifer or create other wetland environments. On the negative side, return flows can direct polluted waters to unwanted places.

In short, in a basin context, rice does not use as much water as is it may first seem based on an observation of deliveries. Evapotranspiration of rice is only slightly more than other grain crops. Rice irrigation tends to generate more return flows than other crops requiring special consideration. There is often considerable reuse of water in rice systems, so that when viewed from a larger basin perspective rice irrigation can be quite efficient (Dong et al. 2001). To determine the actual amount of water that can be saved from rice practices needs careful accounting of the temporal and spatial patterns of flow within the basin. Careful consideration needs to be given to the externalities generated by rice irrigation to maintain or enhance positive benefits of rice cultivation, yet reduce negative impacts.

3.2 Potential Non-commodity Externalities

Rice in monsoon Asia typically is grown in saturated soil, often flooded through most of the growing season. This generally is accomplished with a combination of bordered parcels (paddies) and irrigation. In addition to providing optimum growing conditions for the rice, this has the potential to affect (positively and negatively) the natural environment. These effects, non-commodity externalities, may include: (i) recharge of underground aquifers, (ii) amelioration of land subsidence; (iii) reduction of flooding; (iv) minimization of erosion; (v) change of water quality; and (vi) change in air quality. In addition, there may be important social and economic environment externalities relating to landscape and recreation, and food security. A more complete list of potential externalities in agriculture is presented in a number of publications (OECD 2001, Parts 2 and 3).

Recharge of underground aquifers: The “ponded” conditions of paddy-rice production result in percolation of water into the soil. The rate of percolation will vary, depending upon the soil type, but the water moving downward should have a recharging effect on the groundwater. This effect will be to: (i) replace water withdrawn from the aquifer, (ii) raise the water table, or (iii) increase the outflow from the aquifer to springs, streams, or the sea. In some cases a rise in the water table will be sufficient to impede drainage, resulting in *waterlogging* with the potential for *salinization*.

Amelioration of land subsidence: Land subsidence occurs when water is withdrawn from underlying aquifers. The subsidence may be essentially irreversible when it is accompanied by significant changes in the soil structure (reorientation of soil particles to result in a more dense structure.) It may be partially reversible when the subsidence is due to the reduction in pressure of a confined aquifer underlying the area. Increasing the pressure through restoration of the original water conditions can result in reduced subsidence. Recharge of the groundwater may have this effect.

Reduction of flooding: The characteristic basin paddy-rice culture provides opportunity for temporary storage of water during rainfall periods. Depending upon the area in paddy, height of the borders (bunds), and irrigation policy there may be significant storage volume. For example, in the Taiwan case, this is estimated to be approximately 145 million cubic meters, the equivalent of a major reservoir. This can result in reduction of flood peaks, particularly in the areas immediately downstream from the paddy areas. For relatively short duration moderate storms this reduction can materially affect the extent of flooding. For areas further downstream, longer duration storms and those with larger magnitudes the effects will be reduced.

Minimization of erosion: The construction of paddy areas provides a micro-topography that is level. This, combined with the bunds essentially prevents any soil movement from the area. In hilly or mountainous areas, this topographic change can radically reduce erosion. The Ifugao terraces in the Philippines are classic examples of the potential for erosion control in mountainous areas. However, the labor involved in maintenance of paddy terraces in the mountains is substantial and increasingly difficult to mobilize. Structural failure of terraces has the potential to accelerate erosion due to the release of the "ponded" water.

Change in water quality: As with other forms of agriculture, fertilization and pesticide use in paddy-rice culture can have negative impacts on the natural environment. The fertilization effect usually takes the form of pollution of runoff water (frequently nitrogen and phosphorous) or of the groundwater (usually nitrogen.) Pesticide use can pollute both surface and groundwater, the specific nature of the pollution is dependent upon the pesticides used, their volumes and timing of application, as well as upon the soil and topography. Paddy culture, however, has the potential for some positive effects on the quality of water. Sediments do not leave the paddies to pollute the water. In addition to the effect on turbidity of surface water, soil particles carry nutrients and/or pesticide components, which lower stream quality. The chemically reduced soil conditions that exist under the flooded conditions inhibit the formation of nitrates and the movement of nitrogen into the groundwater. Additionally, the soil can act as a purifying medium when polluted water is used for irrigation. When the pollutant is primarily organic, as in the case of domestic sewage, there is substantial cleaning of the water resulting from irrigation use. While there may be health risks associated with the water, there are benefits from the standpoint of the environment. Similarly, when the pollutants are industrial in origin there often are benefits derived from the deposition of heavy metals and other chemicals into the soil matrix. In this case there are questions of the long-term impacts on soil productivity and health, but in the short-term there are improvements in the water recharging the aquifers and streams.

Change in air quality: Paddy agriculture has both positive and negative externalities related to air quality. The rice plants take in carbon dioxide and release oxygen during the growing cycle—a benefit to air quality. At the same time, significant quantities of methane are produced contributing to the global warming problem.

Landscape improvement: The presence of an agricultural landscape often is an important aspect of the visual environment that is valued by a nation's population. This is especially true in those countries that are industrialized or industrializing rapidly. In Europe this is evident; in monsoon Asia, with rapidly increasing urban populations, there is an increasing awareness of the scenic value of agricultural land.

Food Security: The ability to provide rice sufficient to meet a nation's food needs during periods of emergency often is an important part of public policy. In Taiwan, for example, the area devoted to paddy-rice production is determined as a matter of government policy on food security.

3.3 "Jointness" of Externalities

There is an increasing recognition that the non-commodity outputs of agriculture (externalities or multi-functions) and the commodity outputs are inexorably linked. Thus, agricultural policy, at both national and international levels, must consider both types of outputs jointly. This is not easily accomplished because some of the outputs are traded in the marketplace and others are public goods for which no market exists. The problem is further complicated because there often are "technical" interdependencies between and among the factors producing the outputs. For example, the level of water in the paddies influences both the available storage for flood amelioration, and the rate at which percolation occurs. In this case they have opposite effects, with less water resulting in greater storage and a lower rate of infiltration. Efforts are being made to develop methodologies to deal with the "jointness" of agricultural outputs, and this will be explored further in section four.

3.4 National versus Location-specific Evaluation

The determination of the magnitudes and values of agricultural externalities is markedly influenced by data availability. Many, if not most of these externalities are functions of the local environment and, therefore, the accuracy and precision of the estimates of their magnitudes (and values) are dependent upon the degree to which the data reflect this environment. For example, *recharge* is a function of the infiltration and percolation capacities of the soil. Clay soils have low percolation rates (1–2 mm/day) and those for gravelly soils may be as high as 40–50 mm/day. While the soils used for paddy culture typically are clayey, there may be a ten-fold difference in percolation rates among those soils. Thus, the determination of the magnitude of recharge resulting from paddy areas is a function of how well the different soil types are reflected in the evaluation. Taiwan, Japan and Korea have the type of soil information that permits them to either consider recharge on a location-specific basis or to develop reasonable weighted averages for percolation on a national basis.

Similarly, the unit values of specific externalities often are location-specific. Again, using recharge as the example, the value is influenced strongly by the status of the underlying aquifer. If the aquifer is in overdraft, i.e., the phreatic surface is declining over time, the recharge water may be considered to have a value equal to that of water stored above ground. If the aquifer is not being stressed, the influence of recharge may be to replace extracted water and/or to sustain the base flow of springs and streams fed from the aquifer. This latter may have significant environmental value, e.g., maintaining fish populations, but is likely to be much lower than that for the aquifer in overdraft. Thus, the value determined for the recharge externality based on national-level data is likely to be significantly in error. In the case of Taiwan, data from five aquifers in the country show only one to be in overdraft. Assuming the same unit value for the recharge water on a national basis would very likely lead to a significant error in the estimate of the total value.

Land subsidence is, perhaps, even more of a location-specific example. Subsidence usually occurs in relatively unique locations—areas where sediments were deposited and developed in a relatively unconsolidated form, or where an underlying confined aquifer is subject to compression. In the case of those areas where subsidence is due to consolidation of unconsolidated formations, recharge from paddy agriculture is not likely to have a significant amelioration benefit other than to slow the rate of subsidence. There may be more benefit in those situations where recharge re-pressurizes confined aquifers. The evaluation of the benefit from subsidence amelioration, therefore, is highly dependent not only on the specific area affected, but also on the nature of the subsidence in each area. Since the damage due to subsidence may be substantial, the use of national or generalized information is almost sure to lead to inaccurate results.

Flooding presents two types of problems. The first relates to the fact that much of the benefit to "upstream" flood amelioration measures occurs relatively close to the location of the measures. In the case of agricultural measures, such as "ponding" in paddy areas, it is likely that much of the benefit from flood protection will occur on agricultural land. Relatively few countries have good estimates of flood damage to agriculture. In the case of Taiwan, farmers can apply to the government for compensation for flood losses, but compensation is limited by the budgetary allocation given for this purpose. In addition, since there is a degree of bureaucratic complexity in applying for compensation, it is likely that many farmers do not apply.

The second problem relates to the possible impact on urban areas further downstream. While it is possible to make a reasonable estimate of probable flood storage in the paddies, the impact of this type of dispersed micro-storage on flood hydrographs is difficult to determine. There may be a lengthening of the "time of concentration" of the watershed, thus changing the probability of occurrence of a given flood level, but the calculation of this change is very difficult, except for relatively small watersheds. Since both the extent and type of damage in more urban areas is related to both the area affected and the depth of water, the uncertainty about depth effect leads to major uncertainty about valuation.

The determination of the value of erosion prevention also is complex, because some of the value is derived locally, in terms of maintenance of the productivity of the land, and some obtained from amelioration of downstream impacts, such as sedimentation of reservoirs.

The impact on *water quality* has many of the same questions as recharge. The impact is a function of the quality of the water used for irrigation and the quality of the receiving waters. Where the quality of the incoming water is good, the externality may be negative, due to the addition of fertilizer nutrients and pesticides. Where the quality of the irrigation water is poor, there may be a substantial benefit from the filtering action of the soil. Where the receiving water is of good quality, the externality associated with any water leaving the paddy area is likely to be negative; conversely, in areas of poor quality receiving water, there is a likely benefit. Again, locally disaggregated data will result in more accurate evaluations of the benefits and costs associated with water quality impacts.

The dispersed nature of the impacts on *air quality* suggests that aggregated data on a national scale are appropriate for their evaluation.

The *landscape* externality again is difficult to define. While it is probable that the population relatively close to the paddy areas will be the beneficiary of the scenic situation, tourism increases the number of people who might value preservation of the paddy landscape. Given the combination of uncertainty in valuing the landscape on a unit basis and the population affected, national aggregated data may be as appropriate as local information.

In many instances, the question of the use of national versus disaggregated data will be academic. Few countries possess the appropriate information in a disaggregated form that would permit reasonably accurate information. Thus, of necessity, national data will tend to be used, with the recognition that the answers gained are only "first approximations." However, as the issues related to agricultural externalities grow in importance, the need for more accurate estimates will grow. A data collection program to permit these more accurate estimates is imperative.

4.0 Previous Studies Estimating the Value of Multifunctional Outputs from Taiwanese Paddy-rice.

There have been four previous studies in Taiwan estimating the values of multifunctional outputs of paddy-rice in Taiwan. Two of the studies by Chen (2001) and by Chen et al. (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 one by Tan (2002) employ a series of indirect methods to estimate individual values for each of several multifunctional 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 not withstanding, 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 methodology. We discuss the studies associated with each methodological approach separately.

4.1 Contingent Valuation Method

Chen (2001) – This paper estimates the social value of several environmental services of Taiwanese agriculture. A survey was mailed to 800 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 multifunctional 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 students.

Chen et al. (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 made with a 19 percent response rate. The questionnaire was complex, with the respondents being asked a range of questions such as personal experience with flooding and knowledge of 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 in a manner that makes it clear to the individuals being surveyed 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. 2002, 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 multifunctional outputs. Chen's benefit functions encompass a more holistic willingness to pay for 10 multifunctional services. If the two studies are to be compared, then Chen's analysis must be disaggregated to separate the values assigned to groundwater and land protection that are the focus of the Chen et al. 2002, study.

4.2 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 the 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$ (new Taiwan dollars) 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 operations ratio and, therefore, it is nearly double that used in calculating the value of groundwater recharge.

Tan (2002) – Tan employs a similar method in calculating the values for groundwater recharge. He estimates groundwater recharge by multiplying the soil infiltration rate by the number of irrigation days and number of hectares planted. He can thus estimate directly the amount of water reaching deep levels not having to make an 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 operations ratio.

Table 1 summarizes and compares the findings of the four studies. The magnitude of the per hectare valuation of externalities (in 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.

While we document some of the difficulties of these existing attempts, our purpose is not to be overly critical. As Randall (2002) suggests, 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-rice.

Table 1: Value of environmental externalities of Taiwan.

	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

Notes: 1. The value of Tan (2002) only includes groundwater recharge, and flood protection, although they also included land subsidize.
2. Study period of Tsai (1993) was 1992, of Tan (2002) was 2000, of Chen et al. (2002) and Chen (2001) was 1999. The production value of each study is corresponded to the studying period of each study.
3. NT$ = New Taiwan dollars.

5.0 Negative Externality of Paddy-rice Production—Methane Emission of Taiwan

The rice fields of eastern Asia constitute a large proportion of total agricultural land area, and through irrigation most fields have an abundant water supply during the growing season. In Taiwan, for example, the ratio of the rice field area to the total cultivated field is 41 percent in 1999 (COA 2000); almost all fields are irrigated. Because methane is produced during rice production by aerobic decomposition of soil organic material in flooded rice fields, which generated oxidized aerobic bacteria in the soil that reached the atmosphere causing the greenhouse gas problem. For this reason, methane emissions from rice fields are a significant problem in Taiwan.

With increased concern worldwide about greenhouse gas emissions, there is ongoing research into forecasting future methane emissions and into identifying mitigation strategies to reduce emissions (EPA 1999; Lin et al. 2002). For Taiwan, research related to methane abatement has yet to be published, but some research focusing on methane emissions and forecasting had been completed (Wu et al. 1997; Yang 2000; Lin et al. 2002). To gain some perspective on the magnitude of the negative externalities associated with paddy-rice production, we summarize in this section our current knowledge about the level of methane emissions and potential abatement costs.

5.1 Methane Emissions

The results of two Taiwanese studies of methane emission provide most of what we know about methane emissions from paddy-rice. Yang (2000) combined the IPCC (International Panel on Climate Change) 1996, methodology and with local methane emissions coefficients from Taiwanese experimental studies to estimate methane emissions from the agricultural sector, between 1990-1999. His formula for estimating methane emissions in each study year is: M=A*B*C*D, where M = methane emission of paddy-rice field (thousand tons); A = paddy harvest area ($m^2 * 10^{-9}$); B = an adjustment coefficient (ratio of Taiwanese irrigation rice field compared to deepwater irrigation rice field reported by the IPCC method); C = an adjustment coefficient of fertilizer use compared to the IPCC method; D = methane emission coefficient (Taiwanese local coefficient) (thousand tons).

In his paper, Yang sets the coefficients B, C equal to 1, and argues that since the temperature of the second crop season is higher than for the first crop season, methane emissions of paddy-rice fields in second crop season are higher. He also summarized different laboratory results from different areas of Taiwan to establish the value for coefficient D.

Lin et al. (2002) argued that the emissions coefficient adopted by IPCC are not compatible to the situation in Taiwanese paddy cultivation; they mention several important differences between Taiwanese current situation and IPCC methodology. First, Taiwanese paddy cultivation is an irrigation system, but not a deepwater irrigation system as found in the United States of America. Accordingly, methane emissions could be reduced significantly. Second, organic fertilizer is used for Taiwan paddy cultivation affecting soil quality differently from the chemical fertilizers used in the United States of America. For these reasons, Lin et al. 2002 adjust the coefficients of fertilizer use, deepwater irrigation, and soil quality from those based on IPCC and Yang's research. Estimates of methane emissions from these two studies are listed in table 2. Based on these adjustments to the coefficients, the annual estimates of methane emissions from the study by Lin et al. 2002 are on average 35 percent lower than those by Yang.

Table 2: Methane emissions for Taiwanese Paddy-rice (thousand tons).

Year	1995	1996	1997	1998	1999
Yang (2000)	44.6 (0.122)[a]	44.7 (0.128)[a]	43.9 (0.120)[a]	42.4 (0.118)[a]	42.8 (0.121)[a]
Lin et al. (2002)	29.1 (0.080)[a]	27.8 (0.079)[a]	29.1 (0.079)[a]	28.6 (0.079)[a]	28.2 (0.079)[a]
Ratio of two studies (Yang 2000/ Lin et al. 2002.)	0.652	0.621	0.662	0.674	0.658

Source: Summarized from Yang (2000) and Lin et al. (2002).
[a] Tons per hectare.

5.2 Potential Abatement Cost of China

Although to date, no abatement analysis for methane emissions have been published for Taiwan, research from other countries provides a good reference point for Taiwan. After careful review of the literature, the methane abatement analysis from China (ADB 1998) is used as this reference point due to the similar irrigation and cultivation practices in rice production. In this paper, the authors suggest three potential ways for estimating methane abatement for rice production. These methods are discussed below.

5.2.1. Manure management

According to experimental evidence, CH_4 emissions can be decreased by 24 to 62 percent when biogas residues, instead of barnyard manure, are used as soil treatment in rice fields. The disadvantage of this methodology for estimating abatement costs is that biogas residue production can only be used in a warm environment. Therefore, in that study the northeast area of China, with its cold weather, was excluded from their analysis. This would have little effect in applying the results to Taiwan. Based on their analysis, the cost of methane abatement is estimated at US$85 per ton of methane.

5.2.2. Seeding on dry nursery and thinning plantings

This is a new technology, which can save labor and water usage of cultivation. The experimental evidence shows that CH_4 emissions can be decreased by 2 to 6 percent with this strategy. This abatement method can applied to areas of early rice harvest and are most applicable to southern China. The cost of abatement using this strategy is estimated at approximately US$400 per ton of methane. However, this new technology requires additional training of rice farmers, as well as some new equipment.

5.2.3. Using hybrid rice with lower emission rates

Under the same cultivation conditions, the experimental evidence shows that methane emissions from some hybrid rice varieties can be reduced by 10 percent. This strategy was thought to be applicable to all rice fields in China, regardless of different geographical features. The seed with lower emission rate methane emission is very expensive, estimated at US$1,334 per ton of methane.

5.3. Abatement Cost of Methane Emission in Taiwanese Paddy Production

It might be interesting to note the potential abatement cost of methane emission by combining the emission quantities of Taiwanese research and the abatement cost of China. Table 3 lists the various estimates of abatement costs for methane emissions based on these three different abatement technologies. The final two columns of the table provide abatement cost estimates based on the different emissions rates estimated by Yang (2000) and Lin et al. (2002).

Table 3: Potential abatement cost of Taiwanese rice production.

Abatement methodology	Average incremental abatement cost	Average abatement cost (Yang)*	Average abatement cost (Lin et al.) **
Manure management	85 US$/ton 2,890 NT$/ton	10 US$/ha. 350 NT$/ha.	6.7 US$/ha. 230 NT$/ha.
Dry nursery	400 US$/ton 13,600 NT$/ton	48 US$/ha. 1,648 NT$/ha.	32 US$/ha. 1,086 NT$/ha.
Hybrid rice adoption	1,334 US$/ton 45,356 NT$/ton	162 US$/ha. 5,497 NT$/ha.	107 US$/ha. 3,622 NT$/ha.

Notes: * Using Yang's methane emission quantity estimates for 1999.
** Using Lin et al.'s methane emission quantity estimates for 1999.
Exchange rate: US$1 = NT$ 34.

6.0 The Way Ahead

We have noted problems in measuring the potential benefits and costs of paddy-rice production. One of the common misconceptions is that rice production is extremely costly in terms of water consumed. However, there are often opportunities for reuse, which is recycling of water “lost” through seepage, percolation, and surface runoff. Return flows from rice cultivation are often the source of positive and negative externalities, so water savings programs must carefully consider the use and value derived from these return flows.

This paper has focused on problems associated with measuring external benefits. The results of the studies in Taiwan noted above and of other studies conducted in Japan and elsewhere (Matsuno 2001) suggest that there is a need to develop a more objective methodology for valuation of externalities. Yet, there are inherent difficulties in whatever approach we choose. If we choose contingency valuation (the direct approach), we must be extremely careful to be sure that respondents to questions have a very clear idea of what they are valuing. This, for example, cannot readily be achieved by telephone or mail questionnaire. If we choose the indirect approach we need to recognize the site-specific nature of benefits. We also need to be careful not to be bias in our findings by ignoring the complementary or competitive nature of some benefits and by ignoring costs that result in this case from paddy-rice farming.

In short, there will always be instances, where for political reasons or other less than objective reasons pressures will be exerted either to overvalue the benefits, for example, to meet WTO objectives, or undervalue the benefits as in the case of the Large Dam Commission, as accused by some in their recent study (World Commission on Dams 2000). The next step for researchers is to develop a methodological approach that assures a more objective valuation, which is an extremely difficult task, given the severe limitation of data in most instances.

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