

**POTENTIALS OF WATER-SAVING TECHNOLOGIES IN RICE  
PRODUCTION: AN INVENTORY AND SYNTHESIS OF  
OPTIONS AT THE FARM LEVEL**

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A proposal submitted to the

**Comprehensive Assessment of Water Management in Agriculture  
(Special Projects)**

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## **FULL PROPOSAL**

**TITLE:** Potentials of water-saving technologies in rice production: an inventory and synthesis of options at the farm level

**DURATION:** 2002-2005

### **SUMMARY**

Water-saving technologies are needed in rice production to mitigate the effect of water shortages at the farm level, increase water productivity, safeguard food security, and alleviate poverty. This project aims to carry out a stock-taking and synthesizing exercise of various water-saving technologies for rice in Asia. It will (1) produce an inventory, description, and comparative analysis of farm-level water-saving technologies; (2) study in detail the biophysical and socioeconomic aspects of three novel technologies (aerobic rice, alternate wetting and drying, and raised beds) and monitor their adoption and impact at pilot sites in China, India, and the Philippines; and (3) synthesize the potential and target domains for these three technologies and explore effects of adoption at higher spatial aggregation levels. The project will last for 3 years, be implemented in Asia, and executed by the International Rice Research Institute (IRRI) in cooperation with the International Water Management Institute (IWMI), the Centro Internacional de Mejoramiento de Maiz y Trigo (CIMMYT), the Wageningen University and Research Centre, the Commonwealth Scientific and Industrial Research Organisation (CSIRO) – Land and Water (Griffith), and various NARES (national agricultural research and extension system) partners in Asia.

### **BACKGROUND AND PROBLEM DEFINITION**

Asia's food security depends largely on irrigated rice fields, which produce three-quarters of all rice harvested. But rice is a profligate user of water, consuming half of all developed fresh water resources. The increasing scarcity of water threatens the sustainability of the irrigated rice production system and hence the food security and livelihood of rice producers and consumers. In Asia, 17 million ha of irrigated rice areas may experience "physical water scarcity" and 22 million ha may have "economic water scarcity" by 2025 (Tuong and Bouman 2001). Therefore, a more efficient use of water is needed in rice production. Several strategies are being pursued to reduce rice water requirements, such as saturated soil culture (Borrel et al 1997), alternate wetting and drying (Li 2001, Tabbal et al 2002), ground cover systems (Lin Shan et al 2002), system of rice intensification (SRI, Stoop et al 2002), aerobic rice (Bouman et al 2002), and raised beds (Singh et al 2002). Experimental research on individual technologies is ongoing, but no attempt has yet been made to take stock of where we are at the moment or to synthesize and compare the performance of the different technologies. The relative advantages and disadvantages of the various technologies are not known and so are the potential or typical target domains in biophysical (climate, soil, hydrology) and socioeconomic terms. Despite the amount of research spent on the development of water-saving technologies, it is thought that

actually very few of them are being adopted by farmers, with the exception of alternate wetting-and-drying techniques in China (Tuong and Bouman 2002). Recently, there are signs of adoption (or at least 'technology testing') of aerobic rice in China (Wang Huaqi et al 2002), raised beds in India (Gupta et al 2002) and alternate wetting and drying in the Philippines (IRRI; unpubl. data). Following and analyzing cases of adoption is needed to further our understanding of socioeconomic conditions at the farm level for successful adaptation and adoption of water-saving technologies. For example, though the SRI promises yield increases and water savings, Moser and Barret (2002) found that very high labor and knowledge requirements already lead to non-adoption in the country of origin, Madagascar.

Finally, effects of water-saving at the field and farm levels on overall water savings at irrigation system or watershed level are hardly known. Water losses from one field may be used in adjacent fields so that any gains from reducing losses at a particular field may negatively affect the water balance of another field (Seckler 1996). Whether local water savings affect overall water productivity at higher scale levels depends on whether current water losses are being reused and on the possibilities to effectively use water savings elsewhere. Such an analysis is complex and requires careful and detailed hydrological studies (e.g., IWMI 2000, Dong Bin et al 2001).

## **PROJECT PURPOSE AND LOG FRAME**

The project aims to take stock of current, field- and farm-level water-saving technologies in rice production and to quantify their biophysical and socioeconomic potentials and farmer-adoption. The goal, purpose, outputs, activities and milestones of the project are given in the log frame in Annex 1.

## **METHODOLOGY AND ACTIVITIES**

This project proposes to carry out its stock-taking and synthesizing exercise using literature information and experimental results from ongoing, so-called "contributing" projects and experiments in Asia. The contributed projects and experiments include but are not limited to:

- "Growing more rice with less water"
- "Aerobic rice to ensure sustainable irrigated agriculture" (submitted for funding in May 2002)
- "Water Workgroup of the Irrigated Rice Research Consortium"
- IRRI and IWMI activities in the Rice-Wheat Consortium
- "Permanent beds for irrigated rice-wheat and alternative cropping systems in northwest India and southeast Australia"
- Own IRRI field experiments

The project will carry out limited extra measurements and surveys in the ongoing field experiments and study sites to gather complementary data. The methodology is further detailed in the description of the three main activities of the project (see below).

The spatial scale levels addressed are those of the field and the farm, while limited attention is paid to consequences of adoption at higher spatial-scale levels (a full analysis of upscaling effects is beyond the scope of this project).

*Activity 1: "Inventory"*

In year 1, an inventory will be made of water-saving technologies and their current state-of-art, at the field and farm levels. The inventory will be based on presentations made at the international workshop "Water-Wise Rice Production" held at the International Rice Research Institute (IRRI), 8-11 April 2002 at Los Baños, the Philippines. The inventory will include technical descriptions of the technologies, recent experimental results, any information on adoption, and tools and methodologies for exploring consequences of water savings at field scale to higher aggregation levels. The inventory will be documented in a book entitled "Water-Wise Rice Production" (output 1 in the log frame, Annex 1).

*Activity 2: "Detailed analysis"*

In years 1-3, a detailed analysis will be made of the potentials of three novel water-saving technologies: aerobic rice, alternate wetting and drying, and raised beds. The analysis will have a biophysical, a socioeconomic, and an upscaling component:

- 2.1. In the biophysical component, crop-water relations and field water balances will be quantified using experimental data from the "contributed" field experiments in China, India, and the Philippines. The simulation model ORYZA2000 (Bouman et al 2001) will be applied to support the data interpretation and to extrapolate the experimental results to other environments (characterized by weather, soil, and hydrology at field scale). A course on the use and application of ORYZA2000 will be developed and given to NARES partners in year 1. Potential and typical target domains for the three technologies will be derived in terms of biophysical and environmental parameters (tables). We will make predictions of 'under what environmental conditions which of the three technologies is most appropriate'. Whereas aerobic rice and alternate wetting and drying are technologies for rice only, the raised bed technology typically addresses the rice-wheat system (in India) and the analysis will include crop rotations as well.
- 2.2. In the socioeconomic component, we will monitor the adoption and quantify the socioeconomics of the three technologies. We will use three case-study areas: (1) aerobic rice in northern China (Fengtai and Kaifeng area); (2) alternate wetting and drying in northern China (Zanghe near Wuhan, and Liuyuankou near Kaifeng) and Central Luzon, the Philippines; and (3) raised beds in northern-central India (Ghaziabad and Ludhiana). Cost-benefit analyses will be made and the use of labor will be evaluated. Socioeconomic conditions for successful adoption of water-saving technologies will be quantified. Using secondary data and survey results, the wider extent of adoption will be estimated.
- 2.3. At three case-study sites, — Zanghe Irrigation System (near Wuhan) and Liuyuankou Irrigation System (near Kaifeng) in China, and Bhakra Irrigation System (Karnal, India) — an analysis will be made of upscale effects of water-savings at the field level. Detailed case-study analyses will be made in the contributing projects "Growing more rice with less water" and the Karnal case

study of the Rice-Wheat Consortium, and a synthesizing analysis will be made in this project.

### *Activity 3: "Synthesis"*

In year 3, a synthesis will be made of the detailed analysis of the three water-saving technologies addressed in activity 2 (aerobic rice, alternate wetting and drying, and raised beds). A workshop will be organized to present and discuss the results of activity 2. The synthesis will be documented in a book (output 3 in the log frame, Annex 1). The synthesis will include technical descriptions of the technologies, socioeconomic analyses of adoption at farm level, a definition of target domains, results of the upscale analysis, and a research agenda for further technology development and dissemination.

## **BENEFICIARIES AND IMPACT**

There are four types of beneficiaries.

1. The ultimate users of the project results are rice farmers in water-short irrigated areas (with spin-off to farmers in rainfed areas). Water-saving technologies can help mitigate on-farm water shortage and improve farmers' livelihood.
2. Intermediate beneficiaries are agricultural extension agents and irrigation managers who will have an overview of options of water-saving technologies.
3. Scientific beneficiaries are researchers developing water-saving technologies for rice production who will have more insights on the potential of various water-saving technologies.
4. When water savings at the farm level spill over to higher spatial scales, indirect beneficiaries are the environment, cities, and industry to which more abundant water supplies can be diverted.

The adoption of water-saving technologies at the farm level will contribute to increasing water productivity, safeguarding food security, and alleviating poverty. Assuming an average farm size of 1 ha, some 17 million farmers who face physical water scarcity and 22 million farmers who face economic water scarcity in 2025 will benefit from water-saving technologies. Two examples are given of early results of adoption of water-saving technologies. At two sites in northern China, farmers who adopted aerobic rice for the first time in 2001 realized net economic returns of US\$400-600 ha<sup>-1</sup> on fields where water scarcity prohibited the growing of lowland rice (Bouman et al 2002). The returns on water use, both physical (grain harvest) and financial, were 50-100% higher than in no water-limited lowland rice. Moreover, mechanization cut labor needs by half to three-quarters. In the Philippines, farmers who for the first time adopted alternate wetting and drying in 2001 in a deepwell pump irrigation system saved on average 20% water and improved their farm income from rice by \$25 ha<sup>-1</sup> (IRRI, unpubl. data).

## **DISSEMINATION OF RESULTS**

Scientific dissemination will be through the two books produced by the project, and by national and international publications and participation in conferences,

workshops, and seminars. At the end of the project, we will organize a workshop to present the results to a wider audience. The project will link with other projects, networks, and consortia on water saving in rice production in Asia through the International Platform for Saving Water in Rice (IPSWAR), which was created at the international workshop “Water-Wise Rice Production” in April 2002, Los Baños, the Philippines.

The delivery-impact pathway to disseminate results to farmers is addressed in the contributing projects by linkages with extension and delivery services. In China, the results of aerobic rice development flows into two dissemination networks: the China National Aerobic Rice Regional Trial and Demonstration Network (CNARRTDN) and the National Aerobic Rice Extension Association Network (NAREAN). The CNARRTDN has activities in farmer areas in 25 provinces through a total of 64 local agricultural technology extension centers and stations. The NAREAN combines partners such as agricultural academies, universities, regional extension centers and stations, seed companies, farmers’ associations, and demonstration farmers from the whole country. The NAREAN and local governments organize on-the-spot meetings in important aerobic rice farming areas with farmers and local extensionists. In the Philippines, an important delivery mechanism for water-saving technologies is the project Technology Transfer for Water Savings (TTWS), which combines PhilRice, the National Irrigation Administration (NIA), and IRRI. Links are being established with the Agricultural Training Institute Center of the Department of Agriculture. In India, dissemination of raised-bed technologies is taken up by Krishi Vigyan Kendra centers such as in Ghaziabad.

Delivery of water-saving technologies to irrigation system administrators will flow through the participating irrigation systems and agencies in the contributing projects: Zanghe Irrigation System and Liuyuankou Irrigation System in China; Bhakra Irrigation System in India; and the NIA in the Philippines.

## **RESOURCE SUMMARY**

The project will last for 3 years. The main location of the project is IRRI, with experimental data collection (through contributing projects) in China, India, and the Philippines.

- IRRI is project leader and responsible for all three activities.
- IWMI will contribute to activity 3 by synthesizing the upscaling work at the three case-study sites in China (ZIS, LIS; jointly with CSIRO) and India (BIS).
- CIMMYT will contribute to activity 3 on the analysis and synthesis of raised bed systems in India (jointly with IRRI and CSIRO).
- Wageningen University and Research Centre (WURC-Group Plant Production Systems, and Group Crop and Weed Ecology) will contribute to modeling and detailed data analysis in activity 2. The WURC is also responsible (with IRRI) for calibration, evaluation, and use of the ORYZA2000 model, and for the development and delivery of a model training course to NARES partners.
- CSIRO Land and Water (Griffith) will contribute to activity 3 on the analysis and synthesis of raised bed systems in India (jointly with IRRI and CIMMYT), and on

the synthesis of the upscaling work in the LIS (China) case study area (jointly with IWMI).

- NARES partners are collaborators in the ongoing experimental projects and will be responsible for additional data collection and analysis of experimental data in activity 2. For this project, the key partners are China Agricultural University, Beijing; Wuhan University of Hydraulic and Electric Engineering; Huazhong Agricultural University, Wuhan; PhilRice, Philippines; IARI-Water Technology Centre, Delhi, and the various partners of the Rice-Wheat Consortium in India.

Staff requirements include water scientists, agronomists, economists, and modeling experts at IRRI; modeling experts from WURC; hydrologists from CSIRO and IWMI; agronomists from CIMMYT; and various staff members from the NARES participants. Travel will include IRRI staff travel between IRRI and WURC and the project sites in China, India, and the Philippines, and IRRI staff travel to selected conferences and workshops; WURC-staff travel to IRRI and China; and NARES staff travel to IRRI. No large equipment will be used, but only small materials for additional field measurements. Local travel is required in all case-study areas for surveys and field visits.

## **BUDGET SUMMARY**

The total budget requested from CA is US\$361,852, composed of \$231,852 for IRRI (sourced from CG budget of CA for IRRI), \$15,000 for IWMI and \$15,000 for CIMMYT (sourced from CG budget of CA for these institutes); \$50,000 for the NARES (sourced from NARES budget of CA); \$35,000 for WURC and \$15,000 for CSIRO (both sourced from IARI budget of CA). The own contribution of the project partners totals \$232,500. Annex 2a and 2b give details of the project budget.

## **KEY PERSONNEL**

IRRI: Dr. B.A.M. Bouman (project leader; water scientist); Dr. T.P. Tuong (water engineer), Dr. D. Dawe (economist), Dr. J.K. Ladha (rice-wheat system specialist)

IWMI: Dr. D. Molden, Dr. C.T. Hoanh, R. Loeve

CIMMYT: Dr. R. Gupta

WURC: Prof. Dr. H. van Keulen, Prof. Dr. J.J. Spiertz, H.H. van Laar

CSIRO: Dr. L. Humphreys, Dr. S. Khan, Dr. J. Timsina

Underlined are the project leaders in the participating institutions.

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## Annex 1: Log frame (overarching [long-term] goal, purpose, outputs, activities, and milestones)

Table 1: Goal and purpose

Overarching goal	Long-term (10 years from project) indicators	Assumptions
Farmers in water-scarce areas in Asia adopt water-saving technologies, achieving high yields while sharply reducing their water use, and thereby ensuring food security and alleviating poverty.	<ul style="list-style-type: none"> <li>• Water-saving technologies adopted by farmers in current and future water-short irrigated or rainfed areas.</li> <li>• Farmer income in future water-short areas maintained or restored in current water-short areas.</li> <li>• Rice production sustained in future water-short areas or resumed in current water-short areas.</li> <li>• Water transferred out of agriculture to other uses (domestic, industrial, and environmental).</li> <li>• Price of rice not significantly increased.</li> </ul>	<ul style="list-style-type: none"> <li>• Support for water-saving systems from governments.</li> <li>• Proper water policies in place (laws, markets, incentives).</li> <li>• If proper technology is implemented, water savings at field scale can be translated into water savings at higher spatial scales.</li> </ul>
Purpose	Indicators	Assumptions
To inventory and synthesize the potentials of water-saving technologies in rice production, in terms of biophysical and socioeconomic parameters at the field and farm levels, and to explore the consequences on water use at higher spatial scale levels.	<ul style="list-style-type: none"> <li>• Five to six major current water-saving technologies under development inventoried and described.</li> <li>• Three technologies (aerobic rice, alternate wetting and drying, and raised beds) analyzed in detail in terms of biophysical and socioeconomic (adoption) parameters and an agenda for further research developed.</li> <li>• Two case studies on upscaling water savings at field level to higher spatial scale levels synthesized.</li> </ul>	Results of existing and ongoing projects and case studies are sufficient to allow synthesis after 3 years of project start

**Table 2: Outputs**

Outputs	Indicators	Assumptions
1. "Inventory Book" with chapters on state-of-the-art of water-saving technologies, adoption, and methodologies for upscaling.	1.1 Publication of the book with an estimated 15-20 chapters.	International workshop successfully completed in year 1 and authors are timely with their contributions..
2. In-depth analysis of aerobic rice, alternate wetting and drying, and raised beds.	2.1. Biophysical assessment in terms of water use and yield under various environmental conditions. 2.2. Socioeconomic assessment in terms of income, costs, labor use, etc. 2.3. Description of adoption in three case study areas (Philippines, China, India). 2.4. Two case studies of exploring effects of water savings at field scale and higher scale levels (China).	<ul style="list-style-type: none"> <li>• Experimental data are available from ongoing projects.</li> <li>• Simulation model ORYZA2000 is suitable to extrapolate experimental results.</li> <li>• Large enough number of adopters in case study areas.</li> <li>• Contributed project performs most of upscale analysis.</li> </ul>
3. "Synthesis Book" with biophysical and socioeconomic (adoption) synthesis of aerobic rice, alternate wetting and drying and raised beds, and exploration of upscaling effects of adoption.	3.1. Physical existence of book with an estimated 10 chapters.	Workshop completed in year 3 and authors are timely with their contributions.

**Table 3: Project activities and milestones**

Project Activities	Milestones after year 1	Milestones after year 2
1. Inventory of water-saving technologies	“Inventory Book” with chapters on state-of-the-art water-saving technologies, adoption, and methodologies for upscaling (= output 1).	None (activity 1 finishes in year 1)
2. In-depth analysis of aerobic rice, alternate wetting and drying, and raised beds	2.1 Links established with ‘contributing’ projects. 2.2 Data from historical and ongoing experiments collected and empirically analyzed. 2.3 Model ORYZA2000 calibrated on experimental data and evaluated on appropriateness for extrapolation; model training course given in China. 2.4 Protocol for monitoring adoption in case study areas established and implemented in year 1.	2.1 Data from second-year field experiments collected and empirically analyzed. 2.2 Extrapolation of experimental results to other environments using ORYZA2000; comparison among the three technologies. 2.3 Protocol for monitoring adoption in case study areas implemented in year 2.
3. Biophysical and socioeconomic synthesis	None (activity 3 starts in year 3)	None (activity 3 starts in year 3); milestone after year 3 is output 3.

**Annex 2a**  
**Proposed budget**  
**in US\$**

	TOTAL						TOTAL
	IRRI	NARES	IWMI	CIMMYT	WURC	CSIRO	
<b>Personnel</b>	122,061	-	-	-	-	-	122,061
<b>Consultant</b>	-	-	15,000	15,000	35,000	15,000	80,000
<b>Supplies and other services</b>	40,000	40,000	-	-	-	-	80,000
<b>Travel</b>	24,376	10,000	-	-	-	-	34,376
<b>Publications</b>	25,000	-	-	-	-	-	25,000
<b>Workshop</b>	20,415	-	-	-	-	-	20,415
<b>TOTAL</b>	<b>231,852</b>	<b>50,000</b>	<b>15,000</b>	<b>15,000</b>	<b>35,000</b>	<b>15,000</b>	<b>361,852</b>

Consultant costs include personnel and travel (incl board, lodging, per diem, local transport) and miscellaneous costs.

**Contributions by IRRI and partners**

	IRRI	IWMI	CIMMYT	WURC	CSIRO	Total
<b>year 1</b>	45,000	15,000	15,000	10,000	15,000	100,000
<b>year 2</b>	45,000	15,000	15,000	10,000	15,000	100,000
<b>year 3</b>	22,500			10,000		32,500
<b>Total</b>	<b>112,500</b>	<b>30,000</b>	<b>30,000</b>	<b>30,000</b>	<b>30,000</b>	<b>232,500</b>

**Other contributing projects of IRRI and partners**

<b>IRRI</b>	Irrigated Rice Research Consortium (IRRC) - Water Workgroup (India, China, Philippines)
<b>IWMI</b>	"Growing more rice with less water" and Rice-Wheat Consortium (RWC) project
<b>CIMMYT</b>	RWC project
<b>WURC</b>	Own labor input H.H. van Laar
<b>CSIRO</b>	"Permanent beds for irrigated rice-wheat and alternative cropping systems " in northwest India and southeast Australia

**Annex 2b**  
**Proposed budget by year**  
**in US\$**

	Year 1							Year 2							Year 3								
	IRRI	NARES	IWMI	CIMMYT	WURC	CSIRO	Subtotal	IRRI	NARS	IWMI	CIMMYT	WURC	CSIRO	Subtotal	IRRI	NARES	IWMI	CIMMYT	WURC	CSIRO	Subtotal		
<b>Personnel</b>	39,589						39,589	40,381						40,381	42,091							42,091	
<b>Consultant</b>				5,000	15,000		20,000				5,000	10,000	7,500	22,500			15,000	5,000	10,000	7,500		37,500	
<b>Supplies and other services</b>	15,000	20,000					35,000	15,000	20,000					35,000	10,000								10,000
<b>Travel</b>	7,965	5,000					12,965	8,124	5,000					13,124	8,287								8,287
<b>Publications</b>	10,000						10,000							-	15,000								15,000
<b>Workshop</b>							-							-	20,415								20,415
<b>TOTAL</b>	<b>72,554</b>	<b>25,000</b>	<b>-</b>	<b>5,000</b>	<b>15,000</b>	<b>-</b>	<b>117,554</b>	<b>63,505</b>	<b>25,000</b>	<b>-</b>	<b>5,000</b>	<b>10,000</b>	<b>7,500</b>	<b>111,005</b>	<b>95,793</b>	<b>-</b>	<b>15,000</b>	<b>5,000</b>	<b>10,000</b>	<b>7,500</b>		<b>133,293</b>	

Consultant costs include personnel and travel (incl board, lodging, per diem, local transport) and miscellaneous costs.