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Water Pricing and Valuation in Indonesia: Case Study of the Brantas River Basin

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ABSTRACT

The increasing demand for water and limited degree of cost recovery for irrigation water delivery are important challenges for policymakers in Indonesia. To meet the increasing demand for water, it is important to reduce water use in irrigated paddy cultivation, long the dominant consumptive user, and to divert water away from agriculture to domestic and industrial sectors. Reducing water use in irrigated agriculture can be achieved through various means, including rationing, improved user management, and water markets. The appropriate method depends on the situation specific to each basin. In the Brantas Basin in East Java, rationing is already practiced, but often leaves the non-licensed, (non-paying) irrigators with insufficient supplies. Moreover, very low irrigation service fee recovery rates hamper ongoing water sector reforms, which seek to strengthen the capacity of local institutions to co-manage water resources. In the Brantas Basin the average value of water in the production of important irrigated crops substantially exceeds estimated water supply costs and current ISF. However, increased water use fees would impose a substantial burden on farm economic welfare, while water savings would be relatively modest. Therefore, to conserve water and enhance the financial autonomy of irrigators alternative management systems are proposed, including 'Integrated Crop and Resource Management' and a water brokerage mechanism.

Key words: institutions, water pricing, cost recovery, value of water

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Charles Rodgers[1] and Petra J.G.J. Hellegers[2]

1. INTRODUCTION

Indonesia is the world's fourth largest nation with a population of 217 million (2002), and growing at 1.3 percent per year; 57 percent of the population live in rural areas. Agriculture accounts for 17.5 percent of GDP, and 2004 GDP per capita was $780 (constant 2000 USD, World Bank, 2005). Although Indonesia is a vast archipelago with a total land area of 1.9 million km^2, roughly half of the population is concentrated on the island of Java (132,500 km^2) due historically to the island's extremely favourable climate and soils. About 64 percent of Java (and Bali) falls within moist rainfall zones (1,500-3,000 mm per year) and 30 percent are wetter (3,000-5,000 mm per year). Potential crop evapotranspiration rates average around 1,400 mm per year.

Java has 3.3 million ha of irrigated area, 43 percent of Indonesia's total irrigated area. Almost 60 percent of this area is served by either *technical* or *semi-technical* irrigation systems. Renewable water in Java is only 1,540 m^3/person/year, compared to the Indonesian average of 15,600 m^3/person/year, reflecting high population density. In Indonesia, roughly 93 percent of utilized freshwater resources are withdrawn for irrigation, 6 percent for domestic and 1 percent for industrial use.

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Paddy (wet rice) is the most important irrigated crop. More than half of all paddy produced in Indonesia is harvested on Java, and Javanese yields are around 15 percent higher than the Indonesian average, reflecting the concentration of technical and semi-technical irrigation systems, favourable soils and climate, and the historical accumulation of experience in paddy cultivation.

Harvested paddy area expanded steadily between 1951-2000, actually accelerating, particularly during the final two decades of record. Yields, by contrast, were stagnant during the decade of the 1950's, took off in the 1960's and grew rapidly through the 1970's and 1980's, contributing almost 70 percent of total output growth during the period 1961-1990. However, yield growth stagnated in the 1990's, suggesting a combination of transient adverse climatic conditions, impacts of recent declines in investments in irrigation and agricultural research, and near-exhaustion of the gains from the "green revolution" crop improvement programs of the 1960's–1980's. The share of rice output growth during 1969-1990 explained by public investment in research, extension, and irrigation was estimated at 85 percent, of which extension accounted for 33 percent of output growth, followed by irrigation at 29 percent and research at 23 percent (Rosegrant et al., 1998). A more recent study estimated that between 1985 and 2000, expanded irrigation and improvements in its quality accounted for about 23 percent of rice output growth in Indonesia (Rodgers, 2004).

Irrigated paddy cultivation, long the dominant abstractive and consumptive user of water, is facing increased competitive pressure from other sectors. These include municipal and industrial users, aquaculture, as well as the natural environment via demand for waste dilution flows. Investment in water supply augmentation, specifically in dams, weirs and related structures, remains an important strategy to counteract increased pressure on water resources. However, opportunities for economically rational investment in large-scale physical infrastructure are increasingly scarce on the densely settled and extensively developed island of Java. Therefore, the focus of this paper is on the role that economic instruments, including water charges and tradeable water rights, as well as enhanced crop management systems, can play in managing the demand for increasingly scarce water in agriculture.

The document is organized as follows: Section 2 outlines the challenges, policies, and legal and institutional frameworks for water management and irrigation infrastructure in Indonesia. Section 3 examines important components of the water demand management framework: the price, cost and value of water in irrigated agriculture. Data are presented for the Brantas Basin in East Java. In Section 4 alternatives to volumetric irrigation water pricing, including recent research on water-saving techniques and the water brokerage mechanism are reviewed. In Section 5 some concluding remarks are drawn.

2. WATER PROBLEMS, POLICIES, INSTITUTIONS, AND INFRASTRUCTURE

WATER PROBLEMS AND POLICY OBJECTIVES

Currently there is a low rate of utilization of renewable freshwater resources in Indonesia, mainly due to 1) the highly seasonal distribution of precipitation and resulting runoff, 2) the steep and short topography of catchments, and 3) the limited surface and groundwater storage capacity. The same topographic factors limit the number of suitable sites for dams capable of storing large shares of annual discharges. As a consequence, much of the wet-season runoff remains unused, while dry-season flows are often insufficient to meet demand. This situation is exacerbated by ongoing deforestation and related degradation of upper catchment areas, in particular on Java.

A recent study of global food production and water use (Rosegrant et al., 2002) projects that total water consumptive demand in Indonesia will increase by 11.7 BCM over the period 1995-2025, of which irrigation will comprise 7 percent, and municipal, industrial and livestock demand 93 percent. These projections indicate that the irrigation sector's relative share of total consumption will decline. This is also reflected in Java's ongoing net decline in irrigated area. In East Java alone, 102,000 ha were taken out of agricultural production during 1994-1999 as a result of competition for both land and water resources. These land use conversions are largely due to urban-industrial development and take place largely without government interventions. Moreover, agriculture is increasingly diversifying on Java. In particular, maize area for animal feed has increased rapidly in East Java, which helps to reduce pressure on irrigated paddy. In spite of these trends, irrigation will remain the dominant water-using sector in Indonesia for the foreseeable future. To meet the increasing urban demand for water, it is important to reduce water use in irrigated rice production, which can be achieved through various means, including administrative or agency allocation of water, for example, in the form of quotas, through user management of water, or through water markets, based on secure water use rights for irrigators.

Moreover, while returns to irrigation investment have been high in the past, cost recovery of these investments has been low, hampering new, more expensive developments, as the most suitable locations have been exhausted. Poor O&M recovery rates also undermine attempts to give irrigators greater control over management functions of irrigation systems under the current decentralization and water sector reform efforts.

The reallocation of water and increase in water productivity are therefore important policy objectives. Another policy objective that needs to be addressed is improved cost recovery.

EXISTING POLICY INSTRUMENTS

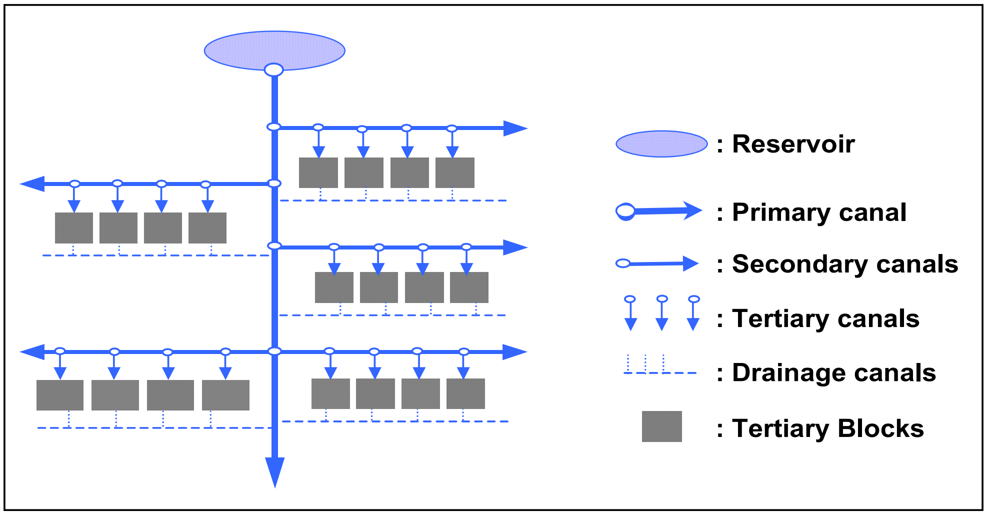
In many areas of Java, a *de facto* quota system is currently in place. For example, farmers in the Brantas basin who plant irrigated rice in the second dry season (*unauthorized*) know they will not necessarily receive sufficient additional water to maintain crops, since during a shortage it will be delivered to paying (non-irrigation) permit holders. Small irrigators under Indonesia's basic water law do have putative rights senior to industrial users. A quota system can work, as farmers know in advance how much water they are entitled to, and thus can adapt their cropping plans accordingly. However, farmers are currently not compensated if they receive less water as they do not have a license and are not paying for bulk-water deliveries, contrary to other use sectors. This was particularly visible in the 2003 drought when farmers in the Citarum basin had to watch water passing by in full canals on its way to Jakarta for municipal water supply—they had no recourse under the imposed quota/rationing system, apart from social unrest and protests.

THE IRRIGATION INFRASTRUCTURE

KIMPRASWIL (Ministry of Human Settlements and Regional Infrastructure), acting through district and sub-district offices of the Water Resources Service (*Dinas Pengairan*), is responsible for the construction and maintenance of primary and secondary irrigation canals, and controls distribution up to the first 50 meters of tertiary canals in technical systems. Farmers and local government or informal organizations are responsible for O&M of tertiary canals and field channels.

KIMPRASWIL classifies irrigation systems as *technical*, *semi-technical* and *village* systems. Technical systems have permanent canals, control structures and measuring devices, and drainage networks are distinct from canal networks. Systems usually consist of main, secondary and tertiary canals, the latter delivering water to a tertiary block (the basic water management unit). Semi-technical systems have permanent canals, but few controls or measuring devices, and the government generally controls only the source and main canal. The distinction between technical and semi-technical systems is not always clear. A typical surface irrigation system network is illustrated schematically in Figure 1.

Figure 1--Standard surface irrigation system network



Village systems are usually smaller than technical or semi-technical systems (< 50 ha), have few permanent control and distribution structures, and are usually farmer-managed. The performance and effectiveness of village systems are not necessarily inferior to those of technical or semi-technical systems, since in each instance the system efficiency will reflect both the care with which infrastructure is maintained and the skill with which it is operated. The reliability of water supply is typically higher for technical and semi-technical systems.

While the rainy season in Indonesia typically supports one primarily rainfed crop, technical and semi-technical systems permit, on average, around 1.8 crops per year, and village systems between 1.6 and 1.7 crops, whereas other types of systems, for which dry season water supplies are not as reliable, only average 1.1 to 1.2 crops per year.

Local topography strongly influences the layout of plots and the hydrology of paddy cultivation. In areas of low topographic relief, plots are often laid out in long, narrow configurations with axes at right angles to the tertiary canals. This promotes equity in allocation, minimizing advantages that would otherwise accrue to plots immediately adjacent to canals. In areas of steeper topography, fields are arranged along contours as terraces, and water moves down grade from field to field, typically through orifices or breaches in the bunds separating up-slope from down-sloping plots. Only the uppermost plots have direct access to canals, in contrast to low-gradient layouts that attempt to link as many plots as possible.

The distribution of irrigation water from the source (river, reservoir) down to individual rice fields can be summarized as follows. Water released to the river from the reservoir enters primary canals at diversion structures (weirs, barrages) and is subsequently partitioned to secondary canals and tertiary canals via gates. Tertiary canals convey the water to blocks of irrigated fields, varying in size from 10 to 300 hectares depending upon topography and system design. In order to reach land parcels located in the middle of tertiary blocks or far from tertiary canals, farmers organize into groups to develop field channels. In most technical and semi-technical systems, primary, secondary and tertiary canals are paved. Field channels are not lined since they are located within a tertiary block, so that seepage is largely utilized.

INSTITUTIONS AND GOVERNANCE

The range of demand management policies and strategies available to policymakers, as well as the effectiveness of such strategies, is largely defined and constrained by the laws and institutions (both formal and traditional) that govern and regulate access to, allocation, and use of water resources.

Water Sector Legislation and Reforms

During the first 25-year phase of Indonesian water resources development policy, (*Pembangunan Janka Panjang*, PJPI - 1969-1994), the primary emphasis was placed on the irrigated agricultural sector around the objective of achieving national self-sufficiency in rice production (which was temporarily achieved in 1984). Investment policy focused initially on the rehabilitation of large and medium-scale irrigation systems, subsequently on the construction of new systems and on improvements in system operation and management. In the second water resources development plan (PJPII - 1994-1999), emphasis shifted to sustainable water resources development and, in particular, to the holistic and integrated management of water resources at the river basin scale for multiple purposes.

Currently, no single model of water resource allocation is universally applied throughout Indonesia, as statutory law dominates in certain settings and traditional law prevails in others, exemplified in the Balinese *subak* system. Certain broad principles of water management clearly apply, however. According to Article 33 of the Basic Constitution, natural resources are governed by the State in public trust for the people. Law No. 11 (1974) on water resources additionally establishes water allocation priorities for drinking water, followed by agriculture, and then energy. It further states that direct beneficiaries, including corporations and associations, participate in bearing the cost for water resources O&M activities, along with central and local governments. This is an important provision with respect to irrigating farmers and water users' associations (WUAs), which may or may not meet the strict definition of corporations and associations subject to cost sharing. Moreover, the recently (February 2004) adopted Indonesian Water Law distinguishes between non-commercial or basic usage rights and commercial exploitation rights[3]; and places special consideration on "traditional communities".

Indonesia is currently engaged in two major reform programs with profound implications for water use, allocation and management practices. The first is the broad program of decentralization or regional autonomy, which was enacted following the demise of Suharto's administration in 1998. The main thrust of decentralization was implemented in 2001, which is often referred to as the *Big Bang*. Over 2 million civil servants were transferred from central to regional offices, along with a substantial number of service facilities and administrative functions, and regional expenditures expanded from 17 to over 30 percent of total government expenditures by 2001/2002 (World Bank, 2003).

The second major reform is more specific to the water resources sector. Following the Asian economic and financial crisis, international financial institutions disbursed funds contingent upon a wide range of institutional reforms. These include the $300 million Water Resources Sectoral Adjustment Loan, now known as WATSAP, approved in 1999. The WATSAP program has four broad objectives: (i) coordinated water policy; (ii) integrated river basin management; (iii) water quality management; and (iv) user-managed, sustainable irrigation development. Primary principles of the WATSAP reforms include: (i) enhanced role of the local and regional level in resources and implementation authority; (ii) public-private partnerships the regional and local levels; and (iii) a participatory irrigation management system with responsibility of irrigation management in the hands of water user groups (World Bank, 1999).

[3] The elucidation of the Water Law spells out 2.0 l/sec as the usage threshold that distinguishes small-scale from commercial abstraction. In East Java, this would correspond to between 0.5 and 1.0 ha of irrigated paddy, approximately, but mean holdings are below 0.5 ha.

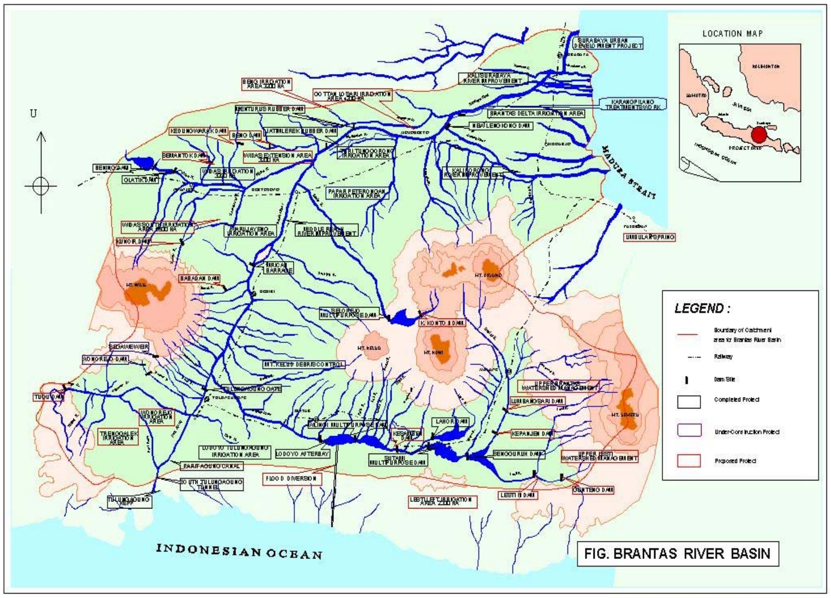
One expected WATSAP outcome is a national framework for an enforceable water use rights system for both surface and groundwater, and a framework for water abstraction licensing by provincial governments. Industrial and municipal abstractions are already regulated by license and subject to associated bulk water tariffs in some basins (including the Brantas), but irrigation abstractions, in general, are not. This would appear to confer an unambiguous advantage on irrigated agriculture, the dominant user of Indonesian water resources by far, but the absence of licensing arrangements (and thus susceptibility to tariff) in fact also translates into a low *de facto* allocation priority and poor service to irrigated agriculture during periods of water shortage, when permit-holders are preferentially supplied. The introduction of water use rights applicable to irrigation water users holds the potential to alter this dynamic, but in ways that are as yet uncertain. The statutory endorsement of irrigators' water use rights in the new Water Law appears limited to small-scale or subsistence irrigators, defined as those withdrawing less than 2 litres per second per family. Such small-scale irrigators do not require abstraction licenses, and thus appear exempt from the bulk water tariffs accompanying commercial licenses. The implications for associations of irrigators, like WUAs or HIPPAs *(Himpunan Petani Pemakai Air)*, are unclear, however. Moreover, the new Water Law as finally enacted made no provision for water transfers, although the DGWRD (Director General of Water Resources Development, KIMPRASWIL), has hinted that rights-based redistribution might occur so long as the government of Indonesia were involved in the process (Rodgers, personal communication, February 2004).

Another expected outcome of the water sector reforms includes a national framework for the establishment by district governments of autonomous and self-financing WUAs and WUA federations (WUAFs) to manage irrigation networks, as well as a nation-wide framework for Irrigation Service Fees (ISF) to finance O&M and asset amortization of irrigation schemes by the local government, WUAs and WUAFs. Thus, WUAs would assume many functions that are currently the responsibility of the Water Resources Service Office under KIMPRASWIL. The ISF envisioned in this context is conceptually distinct from a bulk water tariff. It would be collected locally, by or under the authority of the WUA, calibrated to the desired or required level of anticipated O&M expenditure. Neither the Water Resources Service nor river basin authorities would, in principle, have direct access to funds generated by the ISF, although it also seems apparent that the collection of ISF to cover local recurrent costs would not eliminate the fundamental rationale for bulk water tariffs, which is the recovery of costs of maintaining dams, barrages and hydraulic infrastructure external to irrigation systems, but nonetheless required to facilitate reliable water delivery.

Water Allocation in the Brantas Basin

The model for water resource allocation studied here is the one in use in the Brantas Basin on East Java (see Figure 2), since it is often held up as a potential model for other important basins.

Figure 2--Location of the Brantas basin in East Java (Indonesia)



The management responsibility for water in the Brantas River and important tributaries has been vested in one institution (Brantas Water Authority, Perum Jasa Tirta I), a public corporation that is in principle self-funding with respect to recurrent costs, but which continues to rely on the central (and foreign) governments for capital expenditures.

Perum Jasa Tirta I (PJT I) is responsible for estimating available supplies and the volume and quality of water demand by the agricultural and non-agricultural sectors (domestic/municipal, industrial, power generation, social facilities, flushing, etc.), and then allocating the water among users or sectors. PJT I performs this duty, from planning through implementation, in coordination with other institutions. These include the Office of Water Resources Services, the Office of Agricultural Services, the Office for Regional Water Resource Management, and related institutions at the ministerial level. PJT I determines bulk water tariffs based on the amount needed for operation and maintenance and the quantity of water supplied. As no bulk water tariff can be charged to irrigation supplies, a cross-subsidy is determined and allocated to municipal and, in particular, industrial tariffs accordingly.

Given the importance of irrigation in overall water management, the government has established the Irrigation Committee as a cross-sectoral coordination mechanism for irrigation water management. The Committee is a coordination forum among water-related organizations and headed by the Governor at the provincial level and the district head (*bupati*) at the district level or mayor (*walikota*) at the city level.

The Committee typically holds a coordination meeting before each planting period. It receives information from various higher-level institutions on current government priorities, e.g., programs for increasing food production, predictions on climate, and projections of water supply. The Committee also obtains information from local organizations on farmers' proposed cropping patterns. Utilizing these two sources of information, the Committee establishes a plan for irrigation water supply for each cropping season, which includes both volume and timing of water supply to tertiary blocks located in areas under its responsibility. Since the demand for and supply of water cannot be predicted with perfect accuracy, planting in the dry season is classified as either "authorized" or "unauthorized." [4]

The Irrigation Committees thus use a supply management approach, with the planning of water distribution across time and location based on farmers' demand for

[4] Authorized planting refers to dry season crops that, based on the calculation of the Committee, are likely to receive sufficient water and are therefore included in the cropping pattern plan. Unauthorized planting refers to plantings for which water supply cannot be assured, and therefore are not included in the plan. Paddy planted in the second dry season (July-September) typically falls within this category. Farmers planting unauthorized crops normally have no right to ask for additional supply if water in the field is insufficient.

water. It is, however, more accurate to conceptualise the pattern of water distribution as a quota system. A true supply management approach (irrigation on demand) is hard to implement for two reasons. First, it is almost impossible to obtain accurate estimates of real water demand in all locations and all periods due to the large number of farmers and the variation in cropping patterns. Second, in areas with terrace irrigation, water within a tertiary block flows naturally from one field to another on the basis of topographic gradient, without canals, making accurate measurement difficult. The modified cropping/water allocation plan as developed by the Irrigation Committee is ultimately forwarded to the Provincial Water Resources Committee (PTPA). Similar plans are submitted by municipal and industrial users, many of whom hold long-term permits or licenses. Based on these plans PJT I prepares an initial pattern of allocation for 10-day intervals taking projected supply conditions in the basin into account. The final plan is submitted to the Basin Water Resources Committee (PPTPA), which evaluates it and sends it to the Provincial Water Resources Committee (PTPA) for legal endorsement. PJT I is then responsible for implementing the plan.

The provision and monitoring of agreed-upon irrigation water supply is the responsibility of the Water Resources Service Office. Local irrigation workers, assisted by local gate tenders, are responsible for direct supply of water to the field. In general, one irrigation worker covers 5 to 10 tertiary blocks, depending on the area of the blocks and the configuration of the network. Within tertiary blocks, the farmers themselves manage irrigation collectively. The smallest level of organization is the farmer group. To perform effectively in technical and economic terms, farmer groups join together, either voluntarily or via government encouragement, to form a WUA at the tertiary block level.

Although the performance of higher-level institutions (WUAF, provincial irrigation office) in large-scale irrigation systems also affects overall irrigation management, WUAs are the institutions that directly engage farmers in everyday irrigation.

3. THE PRICE, COSTS, AND VALUE OF WATER

PRICE PAID FOR CANAL WATER

Irrigating farmers in the Brantas currently pay no volumetric tariff for water. The basin water allocation agency, PJT I, recovers recurring costs via higher tariffs to municipal water supply companies and industrial users. This policy has a double edge, since when water is scarce, farmers are the first to see supplies curtailed.

Brantas farmers are subject to an irrigation service fee (ISF), payable to the local WUAs (*HIPPA)*. The ISF program was intended to generate operating funds for system maintenance and rehabilitation. Irrigated land (sawah) is subject to a flat, area-based fee (ISF) calibrated to reflect (i) desired level of O&M, (ii) land productivity and (iii) the ability of farmers to pay. In practice, the target ISF fall in the range of $1.4–1.6 (Rp 12,000–14,000)[5] per hectare per season for wetland crops, mostly rice, and a lesser amount for dry-footed crops. From its introduction in the early 1990's through the mid-1990's both ISF area coverage and collection efficiency improved, reaching a maximum in 1994/95 with a collection efficiency of 53.5 percent. Following the Asian Financial Crisis (1997/98), collections were effectively suspended in the Brantas. Recognizing that ISF are predicated on local O&M and not on costs of water provision per se, the equivalent volumetric price of water would be $0.00025/m^3 during the wet season and

[5] Ratio of CPI 2000/CPI 1997 is roughly 2.0; 2000 nominal exchange rate is Rp. 8500/$1, approximately.

$0.00012/m^3 during the dry season, based on mean irrigation demand at the field level of 6,000 m^3/ha during the wet and 12,000 m^3/ha during the dry season.

The ISF collections—or lack thereof—do not convey the full extent to which Brantas farmers currently pay for water service, however. Other “hidden” payments include HIPPA administrative fees, which include officers’ salaries and contingency funds; payments for pumping, including both private well and pumpset investment costs and purchases of privately pumped water; and other informal fees. The latter are extra-legal payments to various local officials in order to secure favourable treatment in the distribution of irrigation water, particularly when water is scarce. Formal ISF themselves represent only around 15 percent of actual water-related charges, HIPPA fees are 46 percent, cost of pumping 38 percent, and informal fees 2 percent. Total sample-average payments for irrigation are $4.5/ha in the wet season (November–February), $5.8/ha in the dry I season (March – June) and $13.3/ha in the dry II season (July–October), see Table 1. This range of informal and hidden charges is seldom examined, but it is critically important in the design of water tariffs. Irrigation costs account for 1.4 percent of total production costs during the wet season, 1.7 percent during the dry I and 3.7 percent during the dry II season.

Table 1--Formal and informal water charges, Brantas basin

	Wet season		Dry I season		Dry II season	
	1000's Rp/ha	%	1000's Rp/ha	%	1000's Rp/ha	%
ISF fee[1]	11.7	0.42	12.6	0.44	5	0.16
HIPPA fee	22.3	0.81	24.1	0.84	46	1.52
Payments for pumping	3.4	0.12	11.7	0.41	60.5	2.00
Informal fee	1.0	0.04	0.9	0.03	1.4	0.04
Total payments for irrigation	38.3	1.39	49.3	1.72	112.8	3.73
Total (cash) cost of production	2756.6	100.00	2860.7	100.00	3025.4	100.00

Source: Sumaryanto, et al. (2002)
[1]data ca. 1997; since 1998 temporarily not collected by HIPPA.

COSTS OF WATER DELIVERY

A lower-bound estimate of the cost of irrigation water can be derived from an analysis of accumulated investment in water resources infrastructure in the Brantas Basin, based on data assembled by JICA (1998) in preparing the fourth Master Plan for the Basin.

The procedure for estimating water delivery costs, shown in Table 2, is described as follows.

To estimate water delivery costs, first, investment costs for all currently existing water storage and control infrastructure are resolved to a common metric, and summed. An adjustment is made to reflect the differing times of project completion and the opportunity cost of capital. Investments include dams, weirs, intakes and river improvement works. The latter are primarily investments in flood control. Cumulative investment costs through 1997 were Rp 1,299,857 million and total O&M cost Rp 11,439 million [in 1997 local currency units] (JICA 1998). Investment costs of irrigation works below the primary off-takes are not included, in part because project records were not readily available to Brantas authorities, and in part because many of these investments date from the Dutch colonial period. As a consequence, investments underlying the provision of irrigation service are understated, and subsequent cost estimates must be viewed as lower bounds.

Investment costs are then allocated between categories of beneficiaries, including hydropower generation, irrigated agriculture, municipal water supply, industrial water supply, flood control and river maintenance. This was done on the basis of estimated benefits accruing to each sector. Irrigated agriculture's share of benefits from accumulated investment was estimated as 68.3 percent, which is below its share of gross volumetric abstractions.

In a third step, investment shares and annual O&M charges are annualised and divided by the volume of water abstracted by each sector. Standardized costs for the four sectors to which benefits can be directly imputed are summarized in Table 2.

Table 2--Derivation of water costs by sector

	Investment Share	Annualised Cost[1]	Annual O&M	Annual Total	Water Use[2]	Full Costs[3]
Sector	Rp 1997 millions				MCM	Rp/m^3
Hydropower	180,844	7,034.8	1,591.5	8,626.3	753,809	11.4
Irrigation Water	887,841	34,537.0	7,813.2	42,350.2	1,738	24.4
Domestic Water	21,236	826.1	186.9	1,013.0	108	9.4
Industrial Water	65,075	2,531.4	572.7	3,104.1	104	29.8

[1]assuming 50 year project lifetime; 3 percent discount rate, CRF = 0.0389
[2]units MCM, except hydropower, in GWH
[3]units Rp per cubic meter, except hydropower, in Rp per KWH

The cost of water to irrigated agriculture, equivalent to the full capital and O&M recovery cost, is roughly Rp 25/m^3 in constant 1997 currency units. This is equivalent to approximately Rp 50/m^3 in constant 2000 units, or around \$0.006/m^3. O&M costs are \$0.001/m^3 in constant 2000 units. If accumulated investments in irrigation distribution and drainage networks were included, the cost would be higher, but would likely not exceed \$0.02/m^3.

VALUE OF WATER

The mean gross and net values of water, respectively, in irrigated agriculture can be estimated on the basis of data collected by the IFPRI/CASER 2000 sample survey of 480 farm households within four major Brantas irrigation systems (Sumaryanto et al., 2002). These systems were selected to reflect conditions in the upper-, middle- and lower- Brantas Basin. Within each system, 2 to 4 tertiary blocks were selected as representative with respect to crop allocation and rotation patterns on the basis of available cropping records, and 40 farm households were selected within each of the 12 tertiary blocks. Input use, management and output data was collected for each plot. Socio-economic data was collected for each household.

The mean value of water is calculated for four primary irrigated crops by dividing net returns per hectare by estimated field-level water demand. The latter cannot be measured directly, but rather were estimated using locally collected precipitation and canal discharges and a one-dimensional field water balance model (Rodgers and Zaafrano, 2003). Two measures of water value are estimated: gross value, including effective precipitation, and net value, relating to supplemental irrigation only. In the case of paddy, water supply includes water used for soil saturation, water layer development and losses to field percolation. Demand estimates exclude conveyance and distribution losses, and system-wide losses. Estimated values are summarized in Table 3.

Table 3--Average value of irrigation water, Brantas basin 1999/2000

Crop	Season	Total Revenue	Total Cost	Profit	Gross Water	Gross Value	Net Water	Net Value
		1000 Rp/ha			m^3/ha	Rp/m^3	m^3/ha	Rp/m^3
Paddy	Wet	5,415.1	2,756.6	2,658.5	11,650	228	5,794	459
Paddy	Dry I	5,483.3	2,860.7	2,622.6	11,301	232	10,938	240
Paddy	Dry II	5,241.6	3,025.4	2,216.2	12,095	183	11,252	197
Maize	Dry I	4,832.0	2,395.1	2,436.9	3,256	749	2,565	950
Maize	Dry II	4,651.8	2,243.4	2,408.4	3,849	626	3,392	710
Soybeans	Dry I	2,439.1	1,231.3	1,207.8	3,495	346	2,653	455
Soybeans	Dry II	2,518.0	1,279.9	1,238.1	4,151	298	3,816	324
Groundnuts	Dry I	3,062.5	1,831.3	1,231.2	3,919	314	3,223	382
Groundnuts	Dry II	4,523.3	2,178.8	2,344.5	4,529	518	3,509	668

Source: IFPRI/CASER Farm Sample Survey (2000) and model simulation.

Gross water requirements for paddy at field level are 11,000 – 12,000 m^3/ha assuming a fairly high level of field application efficiency (90 percent), roughly three times the requirements for irrigated crops other than paddy. The gross and net value of water is lower for paddy than for maize, soybeans and groundnuts. Irrigation water has a value of \$0.02-0.05/m^3 for paddy, \$0.08-0.11/m^3 for maize, \$0.04-0.05/m^3 for soybeans and \$0.04-0.08/ m^3 for groundnuts. These are observed to be higher than the estimated full cost of irrigation water of \$0.006/m^3. One clear implication of this disparity is that volumetric tariffs set at or near cost-recovery levels are unlikely to alter levels of consumption dramatically, as values substantially exceed costs.

DISCUSSION OF PRICE, COST AND VALUE OF WATER

When faced with increased water tariffs, Brantas irrigators have the following options: (i) they can change the cropping pattern, growing less paddy and more low-consumption crops; (ii) they can alter the timing of planting, to more effectively exploit rainy season precipitation; (iii) they can apply less irrigation water, effectively moving down the water-yield curve (but keeping in mind lower-lying fields that depend on upper-terrace flows); (iv) they can substitute other factors (like labour, fertilizer) for water, to a point; and (v) they can switch to rainfed cultivation, or fallow land. In the medium term, farmers can select cultivars that are more drought- or salt-tolerant, or that mature in shorter periods. They can also elect to invest in private pumpsets, or in irrigation technologies that increase the precision of water delivery, thereby increasing field application efficiency. In the Brantas, however, the dominant cropping practice is wet-transplant paddy, and no technical alternatives to flood irrigation in paddy cultivation have been proven for large-scale application in this region.

Data for the Brantas Basin in East Java suggest that the average value of water of \$0.04/m^3 in the production of important irrigated agricultural crops substantially exceeds the estimated costs of provision of \$0.006/m^3. In this case, the introduction of volumetric tariffs that recover costs would not necessarily lead to substantial water savings, although they would clearly have adverse effects on farm sector income. Results of simulation modelling in the Brantas[6] (Rodgers, 2004) suggest that charging farmers a volumetric tariff approximating full cost recovery levels would indeed impose a substantial burden on farm economic welfare, while resulting water savings would be relatively modest. Very little real savings in gross and net irrigation water withdrawals occurs at low volumetric prices (\$0.001-0.004/m^3 at the tertiary block level), but such savings become significant at around \$0.005/m^3, exceeding 20 MCM (net) at \$0.006/m^3. This is roughly 1 percent of gross irrigation abstractions under historical and baseline conditions, which may appear inconsequential but would in fact provide a substantial additional buffer to municipal and industrial water demand, and would also provide additional flows for environmental purposes. Unfortunately, tariffs in excess of \$0.005/m^3 would likely impose serious economic hardship on farmers, as they represent substantial increases in costs. The latter assertion is supported by evidence that farmers already incur substantial informal costs to secure reliable water supply, which would not necessarily be reduced or eliminated in the event that volumetric tariffs were introduced.

[6] The analysis was carried out with a basin-scale, integrated economic-hydrologic-agronomic simulation-optimisation model of the Brantas basin developed by Rodgers and Zaafrano (2003).

4. RECOMMENDED POLICY INSTRUMENTS

While volumetric irrigation fees would help recover costs, they would be difficult to implement at the farm level and conserve little water up to a very high level, while adversely impacting farmer incomes. Alternative instruments to save water in irrigated agriculture, particularly paddy cultivation, are discussed in the following.

Enhanced irrigation efficiency

Volumetric costs and other incentives only succeed in inducing significant changes in levels and patterns of irrigation water use, if inefficiencies in water allocation exist that can be eliminated. Three types of inefficiency are discussed: physical inefficiency, operational (or managerial) inefficiency, and allocative (or economic) inefficiency. The potential for real water savings was analyzed based on the Brantas simulation model. Agricultural land area in the basin cannot be expanded; additional irrigation would be possible in the dry season, however.

Physical efficiency is defined as the ratio of water used beneficially to water withdrawn for that purpose, here at the irrigation system scale. It is a statement about the quality of design and construction and the existing condition of the infrastructure itself, and by implication, the accumulated investment in the maintenance of that infrastructure. SRPCAPS (1999) estimated overall Brantas Delta irrigation efficiency at 27 percent, with an intake efficiency of 61 percent, a system operation efficiency of 56 percent, and a tertiary and on-farm efficiency of 79 percent. These estimates embody both physical and operational sources of inefficiency.

Operational efficiency refers to the effectiveness by which system managers are able to match the spatial and temporal pattern of demand with effective supply. It encompasses their knowledge of these patterns of demand, of the hydraulic behavior of the system, and the flexibility with which they respond to transient circumstances such as meteorological events. An estimate of water savings from removing operational inefficiency can be obtained through optimizing the pattern of gross abstractions based on observed historical patterns of planted area. Under this comparison, gross abstractions to Brantas irrigation systems can be reduced by 640 MCM per year. Assuming that roughly 30 percent is returned as drainage, net savings of roughly 450 MCM per year can be obtained. These are, however, not fully realizable savings, due to remaining uncertainty of basin operators regarding cropping pattern and climate data, among others, and due to the impossibility to achieve near-perfect operational efficiency within irrigation systems. However, even if current losses to operational inefficiency could be reduced by around 45 percent, it might be possible to divert roughly 200 MCM per year from irrigated agriculture to other uses.

Finally, economic efficiency is a statement about the effectiveness of water allocation across categories and locations of use, each having unique average and marginal unit value products. An economically efficient allocation is one in which it is not possible to improve aggregate “welfare” by transferring a unit of water from one location or use to another. Based on the Rodgers and Zaafrano (2003) model, an estimate of the extent of overall allocative inefficiency on the Brantas Basin can be obtained by comparing the historical pattern of water allocation with an optimized baseline pattern of allocation, where the model incorporates municipal and industrial uses, hydropower generation, and environmental flows in addition to irrigated agriculture. Under the baseline economic optimization scenario, irrigation abstraction falls from 88.7 percent of total off-takes to 81.4 percent, while municipal withdrawals increase from 7.6 to 13.8 percent and industrial withdrawals from 3.7 to 4.8 percent of total off-takes, respectively.

To summarize the efficiency estimates, (i) the technical (physical) efficiencies of Brantas surface irrigation systems are below realizable potential levels, but not unusual for Asian surface irrigation standards; (ii) there is a substantial degree of operational inefficiency in bulk irrigation deliveries, as evaluated at system offtake points, representing a significant opportunity to increase effective Basin supplies through improvement in operational protocols, including interagency cooperation; (iii) there is a modest degree of inter-sectoral allocative inefficiency, specifically a relative under-supply of municipal water supply companies and, to a lesser extent, industrial demand and corresponding over-supply to irrigated agriculture. These results indicate that the primary sources of inefficiency are beyond the influence of individual farmers, or WUAs. Moreover, on-farm efficiency improvements, like field level irrigation technology improvements and alternative cropping schedules, do not work well in the Brantas, particularly in areas with steeper topography, depending on field-to-field water flows. In that case, the introduction of tariffs is likely not only to fail in achieving management objectives, but may have substantial negative impacts on farm incomes and rural welfare.

Enhanced crop water management of paddy

Studies on the trade-off between water and yield for paddy have been carried out for some time. According to Bouman and Tuong (2001) who synthesise the results of 31 studies, field-level water productivity can be improved substantially, with the most significant marginal increases obtained at relatively high levels of application, i.e., modest reductions relative to conventional (full) water input levels results in little loss of yield. For techniques that reduce ponded depths while keeping soil near saturation, water savings averaged 23 percent while corresponding yield reductions averaged only 6 percent.

A more recent but growing body of research indicates that it may be possible to expand rice yields while simultaneously reducing water requirements under *high* levels of management and technical control. In the System of Rice Intensification (SRI), for example, the soil is kept well drained through the vegetative period, and shallow flooding is only introduced upon panicle initiation. The SRI also involves transplanting of young (8-12 day) seedlings and wide spacing of transplants (Uphoff and Fernandes, 2002). Integrated Crop and Resource Management (ICM) as practiced in research facilities in Indonesia involves many of the same strategies as SRI—young transplants, wide spacing and alternating periods of submergence and drainage—and in addition the management of soil organic material and monitoring of soil nutrient status via color charts (Gani et al., 2003). The impact of new water-saving rice cultivation techniques is summarized in Table 4.

Table 4--Yield and water use impacts of new water-saving rice cultivation techniques

Study	Year	Location	Method[a]	% Change in:[b] Yield	% Change in:[b] Water	Comments
Gani, et al.	2003	W Java	INT	3.7	-54.0	
Gani, et al.	2002	Sumatera	SRI	41.2	-	Dry matter as yield proxy
Wardhana, et al.	2002	Indonesia	ICM	16.0	-	Four Provinces
Makarim, et al.	2002	S Sulawesi	SRI	-0.2	-	
Gani, et al.	2002	Indonesia	SRI	13.5	-	Seven Provinces
Uphoff, et al.	2002	15 Countries	SRI	68.3	-	Compare SRI to national average
Shi, et al.	2002	China	INT	2.8	-27.4	Excludes precipitation
Belder, et al.	2002	China	ASNS	-1.9	-9.7	
Thiyagarajan, et al.	2002	India	SRI	-1.4	-40.3	Tamil Nadu
Dong, et al.	2001	China	AWD	7.2	-12.6	Gross water productivity
Hauqi, et al.	2002	China	AER	-30.9	-60.4	Guanshuang, Beijing
Xiaoguang, et al.	2002	China	AER	-46.4	-59.9	
Castaneda, et al.	2002	Philippines	AER	-24.6	-44.8	IRRI
Lin, et al.	2002	China	GCRPS	-18.6	-51.1	

[a]cultivation methods: INT Intermittent Irrigation, SRI System of Rice Intensification, ICM Integrated Crop and Resource Management, ASNS Alternate Submerged – Non submerged, AWD Alternate Wet-Dry, AER Aerobic Rice and GCRPS Ground Cover Rice Production System
[b]Change measured relative to conventional flooded rice cultivation

The trade-offs between yield and water vary across studies, but typically a reduction in water supply does lead to lower yield. Moreover, all of these systems are highly knowledge-intensive, and an extensive farmer learning curve is likely involved. The feasibility of practicing such management-intensive cultivation techniques on wider scales will depend critically on the redesign of surface irrigation systems and management protocols to permit greater precision and coordination in water control.

Aerobic rice cultivation currently appears less promising with regard to yield, but results show substantially reduced water inputs, often by more than half, so that the productivity of water is still higher than under conventional flooded cultivation systems. As genetic selection is an important component of the aerobic rice approach, yields will likely improve as research progresses at the International Rice Research Institute (IRRI) and elsewhere. Other approaches, including the Ground Cover Rice Production System (GCRPS), reduce water use directly by covering the soil with plastic film after irrigation and can produce potential water savings of the same order, although environmental externalities may present new challenges.

Water Rights-Based Allocation and Brokerage Mechanism

Rationing by quantity is an alternative to rationing by price. The Government of Indonesia is currently working to establish a framework of water use rights for non-commercial users, primarily small irrigators, expressed in volumetric terms. Rodgers and Zaafrano (2003) examined the combined impacts of volumetric rights and market mechanisms on allocative efficiency and farm sector welfare. Three scenarios were developed and compared with the baseline optimization (BASE), under which water is allocated on the basis of marginal value alone. In the first scenario, Fixed Water Rights (FWR), each user is allotted a quantity of water, by 10-day period, corresponding primarily to historical usage levels. For irrigators, this was adjusted to reflect the removal of apparent "excessive" inefficiencies. Farmers are here assumed to be Water Users' Associations organized at the tertiary block, which is the lowest level of irrigation system management at which point water deliveries can be measured accurately. Under FWR, users can utilize all or part of their entitlement in each period, but additional water cannot be obtained nor surplus water sold; nor can unused allotments be carried over into other periods. Under the second scenario, Water Right with Brokerage (WRBRK), users again are allocated the same entitlement, but they are now assumed able to purchase additional water from the broker (PJT I, the Brantas Basin bulk water manager) at a fixed, flat rate of Rp 35/m^3 subject to system-wide water supply constraints and competition from other demand sites; and they are also free to sell a portion of their own entitlement back to PJT I at the same price.[7] PJT is, in effect, the buyer/seller of last recourse, and may either gain or lose revenue depending on the net volume of transactions. In the third scenario, Water Rights-Market Clearing (WRMC), users are again assigned the same entitlement, but parties are permitted to engage in private, two-party transactions without brokerage. In this scenario, markets must clear—there must be a buyer for every unit sold.

The simulation analysis of volumetric water tariffs (Rodgers, 2004) suggested that the introduction of a flat Rp 35/m^3 bulk irrigation tariff would reduce net irrigation abstractions by 10 MCM annually, but would reduce farmer incomes by Rp 45 billion in the Brantas irrigated agricultural sector, as compared to BASE, in which no tariff is assumed. Under a rights-based quota system (FWR), where farmers have a fixed, but restricted allocation of water, considerable amounts of water can be saved in irrigation (290 MCM), but net costs to farmers are even higher, at Rp 60 billion, reflecting reductions in crop output. In the WRBRK scenario, the brokerage mechanism leads to annual net water savings of 37 MCM compared to the baseline, roughly half in the dry season, while farm income declines by only Rp 2.5 billion compared to BASE.

[7] In comparison, municipal water supply companies paid a bulk water tariff of Rp 40/m^3 in 2003.

Table 5--Changes in Irrigation Abstractions and Farm Incomes, Alternative Allocation Mechanisms[1]

Scenario	Decrease in Net Irrigation Abstractions		Reduction in Net Income, per Year	
	Annual	Dry Season	AGRICULTURE	
	MCM		Bn Rp	Rp/m^3
Volumetric Tariff, Rp 35/m^3	10	5	44.8	4,450
Fixed water rights (FWR) rationing	289	172	60.4	208
Water right with brokerage (WRBRK)	37	20	2.5	67

[1] changes relative to Baseline optimization (BASE)

Thus, while more water could be saved by the quota system by simply denying water to farmers, the WRBRK achieves significant water savings at very little cost to the irrigated agriculture sector. Moreover, if WUAs use part of the money for investment in on-farm efficiency improvements, both objectives -- water savings and financial autonomy of WUAs -- can be achieved. Well-established water use rights, combined with an economic incentive operating at the margin (water rights with brokerage mechanism) are capable of producing allocative efficiency at nearly the same level as pure markets. In addition, efficiency is gained without penalizing the incomes of poor farmers.

In summary, the best short-term means to conserve water is to improve allocation of water among irrigation systems in the Brantas, i.e. to increase operational efficiency. Secondly, farmers need to secure water use rights/permits, if not individually, then through WUAs, to establish a base for compensation as water is increasingly transferred to urban-industrial users, particularly under drought conditions. Thirdly, farmers need to have more say in cropping strategies and water allocation decisions, and, in that process will likely agree to increase support for O&M of systems. Enhanced canal maintenance will again save water. Finally, in the medium term, improved crop cultivation strategies, particularly for rice, and water marketing at the tertiary block level with other sectors, will help save water while not negatively impacting farm incomes. For example, if

Integrated Crop and Resource Management (ICM; Wardhana et al., 2002) can be shown to work at irrigation system scale, non-recoverable losses as well as the quantity of water lost to evapotranspiration can be reduced. It will take time to introduce ICM, however, as it is highly knowledge-intensive and requires more control over water allocation. The water brokerage mechanism would need to be pilot tested and large-scale application would need to follow the implementation of a new water rights framework based on the new Water Law, which might well take several years.

Complementary strategies include strategically selected new infrastructure developments (one or two more dams) and the already ongoing crop diversification (for example, more maize and less rice) while rice production slowly shifts out of Java (but keeping in mind that rice self-sufficiency remains an important government objective and that rice productivity off-Java is far below yields achieved on Java).

5. CONCLUSIONS

Indonesia possesses soils and climate that are advantageous for irrigated agricultural production, although population pressure and economic development, particularly on densely populated Java, have resulted in increasing competition for available water resources. Paddy productivity is high by world standards, particularly on Java, although yields have stagnated in the mid- to late 1990's. Moreover, while returns to irrigation investment have been high in the past, cost recovery of these investments has been low, hampering new, increasingly expensive developments, as the most suitable locations have been exhausted. Lack of O&M recovery also inhibits irrigators from assuming greater control and management functions of irrigation systems under the current decentralization and water sector reform efforts.

The government of Indonesia holds clear authority over the management of water resources, and has the statutory right to charge beneficiaries for the provision of services related to the management and provision of water resources. Current water sector reforms are intended to strengthen the capacity of local institutions to co-manage water resources. Important aspects of these reforms include the implementation of formal water use rights, the emphasis on integrated water resources management at the river basin level, the strengthening of water users' associations and the improved viability of local water management institutions via enhanced cost recovery. However, the new Water Law exempts small-scale irrigators from obtaining permits as a manifestation of their water use right.

Data from the Brantas Basin in East Java suggest that the average value of water in the production of important irrigated crops substantially exceeds estimated water supply costs, defined as full capital and recurrent cost recovery. Irrigation service fee collections in the Brantas are low, particularly since the Asian Financial Crisis of 1997/98. However, farmers pay a series of local and informal water charges that, while also low, substantially exceed formal ISF.

Charging farmers a volumetric tariff approximating full cost recovery levels would, however, impose a substantial burden on farm economic welfare, while water savings would be relatively modest. The design of the irrigation delivery system and the small size of plots limit the possibility to use volumetric water pricing at the plot level.

All three types of efficiencies discussed, physical, operational, and economic efficiencies have potential for improvement in the Brantas. However, as a result of the relative profitability and limited water-saving technologies for paddy, the existence of terrace irrigation systems in some areas of the basin, where irrigation water flows across fields through terraces and not canals, and the lack of control over water supply reliability at the tertiary block level, farmers have limited actual room for conserving water. If primary sources of inefficiency are beyond the influence of individual farmers, or water users' associations, then the introduction of volumetric water use tariffs will not only fail to achieve its objective, but may also have substantial negative impacts on farm incomes.

Research on water-saving techniques for paddy cultivation indicate that it is difficult to maintain yields if water inputs are substantially reduced; although some highly intensive management methods, like the intermittent irrigation application researched by Gani et al. (2003) can both produce significantly increased yields while saving substantial quantities of water. The feasibility of practicing such management-intensive cultivation techniques on wider scales will depend critically on the redesign of surface irrigation systems and management protocols to permit greater precision and coordination of water control.

A water allocation approach combining water rights with a water brokerage mechanism achieves efficient outcomes and appears to be politically and administratively feasible in the Brantas basin. A fixed base rate would be charged to cover an appropriate portion of O&M costs and depreciation. The base right would reflect close to historical allocation levels, and user groups would be responsible for internal water allocation. The WUA or WUA federation and other users would then be charged (or paid) an efficiency price equal to the value of the water in alternative uses for demand above (or below) the base. This approach requires further development, including pilot testing to overcome the politically difficult, but feasible challenge of establishing base water rights, base charges, and efficiency price. The cornerstone of this approach, and any other means for improving water use efficiency in irrigation while preserving the economic welfare of the irrigated agricultural sector- is the strengthening of irrigators' water use rights, so that farmers can benefit directly from any improvements in irrigation water use efficiency that are passed on to other sectors.

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