Bounding the System: Precursors to Measuring Performance in Networks of Farmer-Managed Irrigation Systems

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ABSTRACT

EFFECTIVE MEASUREMENT OF farmer-managed irrigation requires not only that the goals of farmer managers be understood in relation to their practices, but also that the boundaries of their physical and social fields be well specified. In hilly areas of Indonesia — which provide the field data presented in this paper — apparently independent irrigation canals are often hydrologically and socially interconnected with one another. The ways in which one canal is managed directly affect management in lower canals in the vicinity. A case study from highland West Sumatra shows how this interconnectedness has been traditionally acknowledged and actively managed by farmers in both space and time through different physical and managerial techniques. These practices included staggering of planting time between canals, prohibitions on certain types of building materials in canal headworks and rules for sharing water during times of scarcity. Thus, each canal was simultaneously both an individual entity and a part of a larger network of canals with an expanded social and physical boundary. This configuration was inadequately understood by the Irrigation Department, which sought to improve the canals. By defining the boundaries of the irrigation systems too narrowly — that is, by not appreciating the canal network and the rules of intersystem water rights — the performance of existing farmer-managed canals was underestimated and suboptimal physical and managerial interventions were implemented. Analysis of the effects of these interventions reveals that farmer technologies and rules were considerably more intricate than were first believed, and that understanding management boundaries as well as management practices is a prerequisite for accurate performance measurement.

INTRODUCTION

Performance measurement of farmer-managed irrigation systems (FMIS) in hill environments poses a special set of operational and definitional problems. One common error is to misspecify system boundaries. Failure to understand local irrigation networks and management goals and the rigid application of externally constructed standards can lead outsiders to mismeasure FMIS performance and misprescribe action to improve outputs. Here an example is drawn from West

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Sumatra, Indonesia. Lack of space prevents the extending of the analysis to other types of irrigation networks, such as tanks in series (e.g., in South India) and clusters of wells (e.g., in India and Bangladesh), where issues of user-defined system boundaries are also more important than have been generally recognized.

Internal Goals and External Standards

At a fundamental level, performance measurement in any irrigation system refers to identifying the managers' goals, and assessing the degree to which the managed system actually meets those objectives.[2] In this sense, performance measurement begins not by specifying particular output measures (standards) and achievements (performance), but rather by defining the multiple goals of the managers, which themselves may change across seasons and over years. Having identified these *internal* goals, then specific performance measures can be developed (see, e.g., Bottrall, 1981). When outsiders are involved in performance measurement of FMIS, it is even more critical to start by first understanding these internal or local goals.

Performance measurement may also refer to comparing the level of various outputs of a system against generally accepted standards. This type of *external* performance assessment compares individual systems to generalized norms. Formal evaluations and performance appraisals are commonly of this type. General standards also change over time, but usually in response to developments in technology, to changes in resource endowments or to external demands on the system to produce, but not usually in response to changes in local goals.

A major difference between internal and external evaluation is that in the former the managers of the irrigation system itself set the goals. Managers choose between complex sets of possible objectives and make decisions accordingly. Not all of these objectives may be benign or even mutually compatible, and different groups may have conflicting goals.[3] But whatever the mix of options, in internal assessment the dynamic of setting goals and evaluating how well the group meets those goals is negotiated locally.

External performance measurement, on the other hand, stresses more absolute standards. Criteria such as yield and production, irrigated area, cost per unit of water, etc., are examples. External measures draw heavily on standards and conventions in civil engineering, agronomy and economics. These indicators are important, but they cannot encompass all the complex sets of local constraints and opportunities that influence how system-specific management goals are set and met. Managerial options in the field may be strongly influenced by local factors such as labor availability, water rights, risk-taking behavior, microecologies, etc. A system may appear mediocre against many external standards, but may perform quite well (i.e., "efficiently") according to farmer-set performance measures.[4] The reverse, of course, is also possible.[5]

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[2] Scott (1989, 321–332) discusses evaluating the effectiveness of organizations in relationship to their goals in three dimensions: output (end product of the organization's efforts), process (the way in which the outputs are achieved, including the quality of the outputs), and structures (the capacity to produce outputs and to continue to produce).

[3] A discussion of these multiple goal-setters can be found in Walker, 1981 (in Jurriens and de Jong 1989).

[4] Failure to account for local goals and constraints also tends to overestimate the "gap" between a system's assessed performance on standard dimensions and its imputed potential performance. If local goals are taken into account, many irrigation systems may actually be performing better than they might otherwise appear.

[5] Some studies of the early adoption of green revolution technologies in Northern India, for example, illustrate the conflict between agricultural systems that achieved national food production goals, but which performed poorly against local goals of equity or sustainability.

In the case of FMIS, government agencies usually do not directly set system goals, and they may have little experience with understanding farmers' internal performance objectives. Yet, because of the desire to assist FMIS — a desire that itself is usually related to national food policy and employment objectives — governments tend to rely on external standards rather than on internal goals to judge FMIS and to prescribe interventions. It is here that failure to distinguish between the external and internal dimensions of FMIS performance measurement often arises.

When judging how an FMIS can be improved, outsiders assume that they can accurately measure water availability, irrigable area, benefit-cost ratio, etc. Yet, even these apparently straightforward measures are dependent on farmers' internal management goals and options. Failure to understand the system qua system can lead to a misspecification of the boundaries of the "target" system and a consequent mismeasurement of performance.

HYDRAULIC INTERCONNECTEDNESS AND BASIN PERFORMANCE

The hydraulic interconnectedness of large irrigation systems located along a common river has long been recognized. Indeed, "overappropriation" of waters is a frequent source of regional and international dispute. However, what is less well appreciated in FMIS is that many of the same basin-wide issues of goals, rights, and management are of equal importance.

The Case of Hill Irrigation Networks

Networks of small, hydrologically interconnected canals are not uncommon in hill irrigation. Figure 1 shows an example from the highlands of West Sumatra, Indonesia. In many hill areas of Asia, these canal networks were originally developed entirely by farmers. To serve the limited irrigable land in hill environments farmers have often built a series of small parallel canals, rather than one large canal.[6] Besides reducing the landslide risks that large canals pose in steep terrain, a series of canals can also tap springs and seepage that would not be captured if farmers relied on just one large diversion structure.

Understanding irrigation performance goals and outputs in the hills requires a knowledge of inter-canal relationships within this network. Standard external performance measures are easy to be misapplied here. Take, for example, the engineering concept of "conveyance efficiency" (the amount of water that reaches the plant root zone divided by the amount of water diverted into the system multiplied by 100). This indicator is practicable to apply when a system stands in isolation and when all major sources of the system's water supply can be measured, a situation most commonly found in flat areas. It also assumes, as with other system-wide performance measures, that the boundaries of the system are well understood.

One of the first technical impediments to using such a measure of efficiency in hill irrigation is that water supply for the system is *not* limited solely to the water that is diverted from the stream at the headworks. The command area of a higher system frequently abuts the supply canal of the next lower system in the series. Losses from an upper system, whether as leakage or drainage,

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[6] For examples of such networks, see Pradhan 1991 (pp. 105–106); Pande 1991 (pp. 62–74); and Ambler 1989 (p. 292).

become supply for the lower system. Springs, seepage and rivulets from hillsides also augment supply.

Depending on the nature of these augmenting water sources and the season, canal discharge in hill systems may actually be higher at a point lower down than it is at the headworks, especially during the rainy season when water supply exceeds demand, and farmers may even temporarily close the headworks. Conversely, during spells when river water may be a canal's only source of supply, headworks become structures for both water acquisition and for water distribution to lower canals. Thus, the performance of any individual canal and its command area must be measured not only against farmer objectives in that particular canal, but also against the influence of its management on a larger network of neighboring canals and farmer groups.

So what "is" the "system" in these cases? As the case below shows, "system" boundaries for maintenance may be different from those for operations. It is this possible local distinction between boundaries for different tasks that most external performance measurements fail to appreciate. A study of irrigation developed by the Minangkabau people in a mountain valley in West Sumatra illustrates how farmers traditionally adjusted technology and management to control water on a basin-wide basis. The impact on "performance" in this basin by a state program designed to assist FMIS is discussed.

A case study from West Sumatra. The Tampo River provides water directly for 61 small canals located along a 15-kilometer stretch of the stream (see Figure 1). Average distance between weirs is only 250 meters. Mean command area per canal is 25 ha, with the largest being about 150 ha. Ownership of irrigated rice lands averages less than one-half hectare. Irrigated fields in the valley are situated between 250 and 1,000 meters above sea level. All canals in the valley were originally constructed by farmers, beginning at least 650 years ago.

Precipitation is bi-modally distributed and ranges from 2,000 mm per year in the tail of the valley to about 2,800 mm at the head. Monthly rainfall during the periods September-January and April exceeds 200 mm; during July-August it is less than 100 mm per month. Precipitation during February, when the rice plants are in the crucial grain-filling stage, may also be low.

Before the introduction of high input varieties in the late 1960s, one crop of slow-maturing rice was grown annually. The land was left fallow during the dry season. Now, most farmers with good irrigation are able to harvest two crops per year. Those in the most favored locations — i.e., those with good water supply and at an altitude less than 600 meters — are able to harvest five crops in two years. Yields of unhusked rice today range from about 3.5 mt to over 6 mt rice per hectare per crop.

Coordinating mechanisms and network performance. During low rainfall periods, the discharge in the river in the central part of the valley (zones B, D, and E), falls drastically, and most supplementary rivulets and springs go dry. (Discharge in the river in zone A also falls, but as it is located at the head of the valley, water supply is still sufficient while systems in zone C benefit from the inflow of a small stream, Bt. Kawai.) At those times, all available water in the Tampo River is diverted for irrigation. That is, the discharge in the river at point x in Figure 1 is negligible. Thus, on a basin-wide basis, there is no surplus water in the network, and the network performs the function of capturing water very efficiently.

Although there was no formal written system governing the apportionment of water among the canals, farmers had mechanisms for sharing and conventions regarding water rights.[7] Accord-

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[7] Written texts of "traditional" intersystem water rights codes in FMIS are rare, but not unknown. See Coward, 1990, for an example of the *riwaj-i-abpashi* record in Himachal Pradesh, India.

ing to *adat* (custom) in zones here labeled A, B, C, and D, farmers enjoined against building permanent masonry weirs, permitting instead only loose stone construction. These weirs were also not allowed to extend to the opposite bank, but rather were permitted only to jut part way into the river. During times of water scarcity, it was further prohibited to chink the spaces between the stones with mud or straw. Labor requirements for rebuilding washed out weirs in this stretch of river were not onerous.

In zone E, farmers allowed permanent weirs because the dry-season water supply to this area was never sufficient for a rice crop anyway. Canals higher along the river took all the dry-season water, in accordance with their acknowledged rights, so there was no coordination problem to sort out. In zone E, permanent weirs, which began appearing in the 1930s were better suited to capturing surplus rainy season flows, and they reduced the labor burden for reconstructing the stone and brushwork weirs, which here needed to be taller than in the upper reaches of the river.

Higher along the river, however, the stone weirs acted as water division as well as diversion structures. "Leakage" at the headworks of one canal automatically flowed to downstream weirs. When downstream canals needed additional water, each evening small groups of farmers took turns walking upstream (*manjapuik aia*) to ask for a "stone's worth of water" (*mintak aia sabatu*). A few rocks from each of several upstream weirs were removed. The group walked upstream as far as the "mother canal" (*banda induak*), the largest canal in the vicinity. Within each command, priority turns for the night's irrigation went to the group that made the trek.

What constituted a "reasonable" height of weir, and what was a "reasonable" request from downstream users for additional water was more a matter of mutual agreement than strict measurement. Although higher systems were acknowledged to have priority rights over lower systems, what might be called a "first in line, first in right" arrangement,[8] their powers of appropriation were also tempered by a cultural ethic that prescribed moderating one's own demands to take into account the needs of others (*lamak di awak katuju di urang*).

Under this arrangement, then, the permitted materials and design of weirs served to reduce conflict during the dry season, while still utilizing all available water in a relatively equitable manner. The headworks did not need to be constantly adjusted, as the "leakage" downstream was automatic supply for downstream users, even under very low discharge conditions.

Finally, at a more macro level, farmers coordinated planting time throughout the valley. Fields at the colder head of the valley were planted three to four months earlier than those at the tail. Traditional cultivars of rice in these highest reaches took nearly nine months to mature. The staggered planting schedule helped spread out the demand for water during land preparation. Harvest throughout the valley occurred in May, thus helping to minimize pest infestations.

Maintenance for each canal and weir is performed only by those farmers directly served by that canal, which makes a strong correlation between physical and social boundaries. Thus, in Figure 1 there are 61 separate maintenance systems. However, the boundary for operations in the network surpasses the individual canal during water scarce times. Thus, the boundaries of the social fields operative for different irrigation tasks expand and contract according to water supply conditions, even though the physical boundaries appear to be the same.

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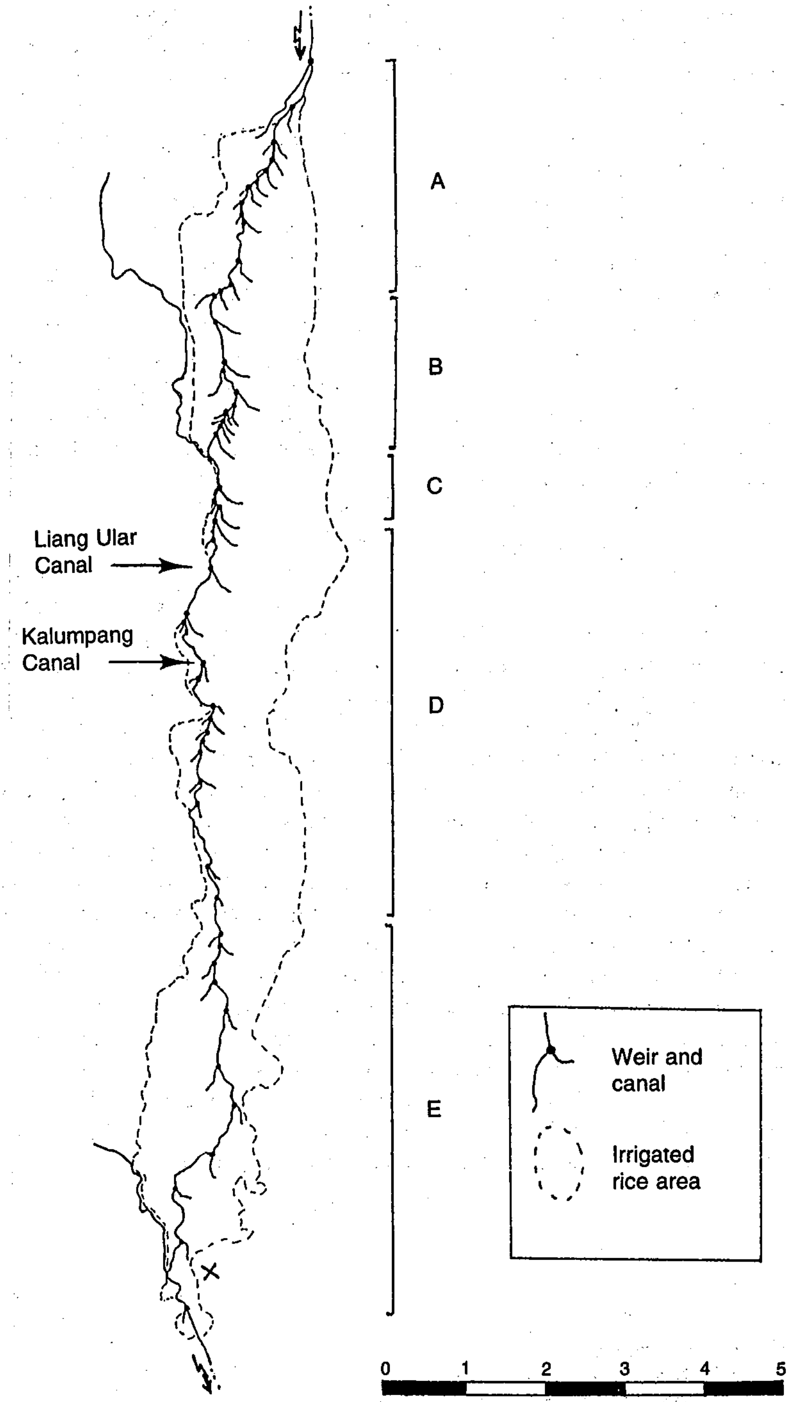
[8] This differs from a "first in time, first in right" rule. Construction of some of the highest canals in the Tampo Valley may postdate that of those in the middle reaches.

Figure 1. Tampo River and its canals.



Furthermore, the managerial and technical parameters of the network developed not as a rigid code of "water law," but rather as a negotiating "text" — that is, a basic foundation of shared principles that undergird the flexible negotiations needed to respond to complex fluctuations in resource conditions and management objectives. The concept of equity in water distribution, while not strictly a "goal" of the network — for that implies anthropomorphic characteristics that organizations do not have — was an important part of this cultural text. The invisibility to outsiders of both this text and the different social fields in the network had implications for the pattern of state assistance to improve irrigation performance in the Tampo Valley.

State Intervention to Improve Performance. Beginning in the early 1970s, as part of its drive to increase rice production, the Government of Indonesia stepped up efforts to improve the physical facilities of many FMIS in the Tampo Valley. Although there was little additional area that could be irrigated in the valley, the state felt that farmers' "primitive" structures needed to be "upgraded." Farmers were not consulted in specifying the problems or solutions for improving their systems.

The engineers' first priority was to replace the loose stone weirs with concrete gated structures. Based on their training in lowland irrigation systems, state engineers were predisposed to think of permanent gated headworks as essential in any irrigation system. Second, they observed that during the rainy season the traditional weirs were washing out and not diverting as much water as a permanent structure could, while during the dry season these farmer-made weirs "leaked."

This evaluation of traditional weirs missed the mark on several counts. First, addressing the condition of the headworks is essential where the only source of water is that obtained via the weir. In the case of the Tampo Valley network, however, during the rainy season, overland drainage from higher systems, springs and seepage all act to supplement most irrigation systems from points other than the weir. Thus, the apparently poor performance of the headworks during the rainy season was incorrectly assumed to translate into poor system performance. The presumed need for a permanent weir was predicated on the erroneous assumption that the system must be water-scarce because the headworks leaked or washed out.[9]

Second, the new designs assumed that leakage at the weir was a loss to the "system." While it was a loss to an individual canal, there was no loss to the larger network of canals. Recall that even before the government program, all available water in the river during the dry months was being utilized. Because the boundaries of the "system" were too narrowly circumscribed, the weir was seen only in its diversionary capacity and not in light of its additional inter-canal water distribution functions.

State intervention raised the overall performance of the assisted canals by increasing their ability to capture water. During the rainy season this caused no problems because there was a net surplus of water for the whole valley, and in a few cases it allowed the extension of the state-assisted canal into limited areas that had previously been rainfed. However, during times of water shortage, these select canals monopolized the water, making some previously dry areas wet and other formerly wet areas dry — a recipe for conflict.

For example, farmers located below the Liang Ular System, one of those "upgraded" with a permanent weir by the government, became particularly upset. After improvements by the state, Liang Ular *de facto* began to control the fate of all canals in zone D during the dry months. Not only could it disrupt downstream water distribution during times of low discharge in the Tampo,

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[9] Combining small adjacent irrigation systems into one system under a larger weir has frequently been attempted in hill areas on the grounds of increasing efficiency, especially for canal maintenance. Experience has shown that these efforts are often unsuccessful because of complex inter-canal water rights and hydraulic issues. See WECS/IIMI 1990, p. 4; and Ambler 1989, p. 489.

but its location significantly disadvantaged farmers in zone D. Farmers now had to travel up past their original "mother canal" (the Kalumpang System) and trek up past three more headworks, an additional distance of 1.5 km, to ask for water from Liang Ular. It also meant that they now had to cross into another *nagari* (a cultural, and formerly political unit), where the traditional elites were less accommodating.

The situation was further complicated by changes in management authority. The placement of a government-paid gatekeeper at the Liang Ular weir transformed the canal from an FMIS into a government-controlled system. On the basis of wet season water availability, the Liang Ular Canal had been extended and the government operators were keen to supply water to the entire area even during dry months. Farmers downstream were understandably upset that their traditionally honored water rights were now abrogated, and they had to repeatedly request water from an unsympathetic bureaucracy. Even farmers served by the canal just below Liang Ular complained because new lining in Liang Ular's canals reduced overland drainage to their canal. Increasing acquisition and conveyance efficiencies in Liang Ular did not necessarily increase net efficiency throughout the larger network. The new weirs and canals gave farmers and government operators in the assisted canals the physical capability to overappropriate dry-season flows in the valley. Liang Ular is only the most dramatic case. Lesser but similar dramas involving other new government-built weirs now interspersed among the traditional weirs are being enacted all along the river.

For the first time, the introduction of new varieties of rice and multiple cropping made irrigation during the height of the dry season an option. This accentuated farmers' demand for scarce water and would have put even the traditional arrangements under strain. The government missed an opportunity to act as an independent agent who could broker updated water rights texts for the whole basin under the new agricultural technology. However, the blindness to farmers' traditional inter-canal water rights and their supporting physical and managerial technologies led the government to too narrowly define system boundaries and led to sub-optimal interventions for increasing performance.

Comparing farmer priorities in managing canal irrigation with those of the government brings out several striking differences. First, traditionally, farmers took a wider basin perspective that sought to minimize conflict during times of water scarcity. Inter-canal water distribution during the rainy season was not an issue because water was plentiful. Diametrically opposed was the government's approach to performance that centered on the potential of certain individual canals to appropriate wet season flows, with little consideration for the impacts this would have on water distribution during the dry season.

Second, farmers had embedded into their apparently "simple" technology a number of management considerations that supported the overall performance goals of operation in the basin. All elements of the basin-wide network were formerly under farmer authority, and local technologies were mutually agreed upon, automatically operative regardless of discharge levels in the river, and objectively verifiable to all concerned.[10] The government, on the other hand, took over some canals, thus opening the door for a divergence in performance goals that spawned conflict. Furthermore, government gatekeepers are not accountable to farmers or to the larger network, and the performance goals of those assisted canals have been defined unilaterally by government staff. In the end, the government a) had failed to properly identify the collectivity of irrigators by misspecifying the boundaries of the network of social relations among the farmers from different

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[10] Some of the design characteristics of these loose stone weirs are also found in traditional proportioning devices often located at canal branches in hill irrigation systems (Ambler 1991).

canals, and b) had not properly understood the normative order regarding water distribution applicable to the participants linked by the network.[11]

RECOMMENDATIONS

From this case study follow the recommendations regarding performance measurement in FMIS hill irrigation listed below:

* The link between existing techno-managerial arrangements and local performance goals must be understood before measuring performance or proposing interventions. External performance evaluators should seek to form partnerships with farmers and their leaders to identify locally appropriate performance goals and measures within locally defined boundaries.

* Performance measures in irrigation networks must take into account inter- as well as intra-canal goals, potentials and constraints. The boundaries of "the system" may be a function of management tasks, water supply conditions and water rights texts, and may include more than an individual canal and its command area.

* Existing codes of water rights must be factored into defining the performance goals of the basin. To the extent that local water rights are often formulated to deal primarily with situations of scarcity — not of abundance — performance-enhancing measures that empower certain parts of the network will have to include appropriate conflict-resolution mechanisms for dealing with the other members of the social field.

* Physical structures to increase output performance must be accompanied by mechanisms to promote or maintain high social performance. Management authority should be structured in such a way that a local negotiated order is possible when defining canal and network boundaries and larger performance goals.

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[11] For a further analysis of the concept of boundaries in collectivities see Scott (1981, 180–181).

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