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## **Aiding Adaptive Co-management in Irrigation**

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### **ABSTRACT**

Shared governance of water flows and infrastructure poses a critical challenge for institutional design by water users and state agencies. Programs for participatory irrigation management (PIM) and irrigation management transfer (IMT) are often insufficient to achieve equitable water distribution and adequate infrastructure maintenance. If future responses to local and global challenges such as water scarcity and agricultural transformation only repeat past approaches, then they are likely to result in familiar frustrations and disappointments. Insights into potential solutions can be derived from understanding irrigation waterscapes as complex adaptive systems and from analysis of "Samaritan's dilemmas" and other social dilemmas affecting aid.

While participatory design and construction have often proved possible and devolution has been feasible under some conditions, continuing cooperation between water users and state agencies is essential to the performance of many irrigation systems. Many systems remain trapped in vicious cycles of deferred maintenance, degradation, poor performance, and inefficient rehabilitation. Perverse incentives discourage timely maintenance and local resource mobilization. Experiences from PIM and IMT programs illustrate some of the difficulties of deliberate social engineering, and suggest the need to focus on improving institutions for joint problem-solving in water distribution and infrastructure maintenance.

Irrigation waterscapes are complex systems, perturbed by variable river flows, rainfall, and gate adjustments. As emphasized in recent work on irrigation modernization, current design doctrines and management methods are often inadequate to deal with unpredictable dynamics and deliver reliable services. Tail-end problems are not simply symptoms of social struggles, but also of the difficulty of adjusting management of complex systems amidst constantly changing conditions. Strategies for improving performance require recognition of technical constraints together with open exploration of how modified structures and rules influence management.

Game theory models such as Samaritan’s dilemmas clarify the need to carefully design aid programs so they will encourage rather than discourage local efforts. A polycentric governance perspective helps identify ways to make better use of available institutional capacity. Better analysis and design of cost-sharing rules for irrigation system repair and improvement can align incentives and make commitments more credible. Shifting external investments from single-shot rehabilitation to progressive improvement aids adaptive problem-solving in irrigation co-management.

Key Words: irrigation, adaptive management, co-management, participation, rehabilitation, modernization

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# Aiding Adaptive Co-management in Irrigation

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## INTRODUCTION

The latter decades of the twentieth century saw a multitude of efforts to increase participation in irrigation management (PIM). Pioneering efforts in the Philippines and Sri Lanka (Korten and Siy 1988, Uphoff 1991) inspired a range of similar initiatives. Irrigation management transfer (IMT) has been pursued on an ambitious scale in Mexico, Turkey, India, and elsewhere (for recent discussion and references to earlier literature, see Rap 2006; Vermillion 2005, 2006; Hassan et al. 2007). While thousands of water user associations (WUA) have been established, many fade away soon after special project support disappears. IMT programs have often been partial and incomplete (Vermillion 1997). Some IMT programs seem to have yielded significant benefits, but assessment suggests that results have been much more mixed than hoped. It appears that programs for institutional reform in irrigation have often underestimated the difficulty of “transplanting” institutional innovations and overestimated the potential benefits (Rap 2006, Shah et al. 2001).

Many irrigation systems remain trapped in vicious cycles of inadequate investment in maintenance and declining performance, only partially offset by periodic pulses of subsidized rehabilitation (Araral 2005, 2006). In many cases, whether IMT has been tried or not, it appears that key problems in reliably and equitably delivering water and assuring adequate infrastructure maintenance remain unresolved, and threaten the capacity of irrigation systems to respond to future challenges. Some insights into potential solutions can be derived from understanding irrigation waterscapes as complex adaptive systems and from analysis of “Samaritan’s dilemmas” and other social dilemmas affecting aid.

*Organization of the paper.* Irrigation system co-managers must cope with complex flows of water and funds. The next section highlights the continuing need for joint decision-making and action in water distribution and infrastructure maintenance. The third section discusses the application of ideas about adaptive management and complex adaptive systems to redesign processes for irrigation improvement. The fourth section use the game theory models of Samaritan’s dilemma to analyze the institutional design challenges of altering aid so that it encourages better service delivery and infrastructure investment. The conclusions summarize the key ideas of the paper, particularly the need to concentrate on more careful and creative crafting of irrigation co-management.

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## CO-MANAGEMENT IN IRRIGATION

PIM and IMT have often been seen as a means for reducing government roles and expenditures in irrigation, as if success would be measured mainly by how much less government does and how much more farmers do. This risks neglecting key questions about performance in delivering water, efficiency of investment, and the sustainability of cooperation in key activities. In almost all countries, government is expected to play a continuing role in major repairs and rehabilitation.<sup>2</sup> In larger irrigation systems, government agencies usually still operate diversion dams and major canals, even after smaller sub-units have been transferred.

Co-management of irrigation systems involves interlinked arenas for decision-making and action, in water distribution and infrastructure maintenance. Irrigation system performance concerns water delivery, and the production and profits of irrigated agriculture. Inadequate maintenance impedes performance and increases needs for repair and rehabilitation. Flows of water and funds are key resources. In many cases, agreement and cooperation between government and water users continues to be essential to deal with the central problems of equitably delivering water and providing adequate maintenance, particularly in larger irrigation systems encompassing many users and multiple communities. Irrigation bureaucracies and water user associations act as agents for farmers and government respectively. Additional stakeholders may include those using water for household use, fisheries, and aquaculture, while politicians, consultants, NGOs, researchers and others may take part in attempts to change irrigation institutions and infrastructure.

Even with various forms of PIM or IMT, many irrigation systems have a continuing need for co-management, with performance that depends on agreement and cooperation between both government agencies and water users. Tradeoffs and fungibility in investments in maintenance and repair, rehabilitation, and improvement pose questions of who will pay, the incentives and capacity to make those investments, and potential problems of crowding out local investment and moral hazard to neglect maintenance (Ostrom et al. 1993, Bruns 1993). While participatory design and construction have often proved possible and devolution has been feasible under some conditions, continuing cooperation between water users and government agencies is essential to the performance of many irrigation systems. Many systems face continuing challenges in trying to achieve equitable water distribution and adequate maintenance. In cases where IMT has been rejected (as in Indonesia) or implemented in ways that fall short of achieving expected outcomes (as in the

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<sup>2</sup> The main exception is Australia, where water user organizations are supposed to set aside allowances for depreciation sufficient to fully fund future infrastructure replacement.

Philippines and elsewhere) there is a need to reconsider strategies, and examine what might be done if the strategy is no longer to rapidly restructure institutional relationships. A focus on key tasks for co-management, in a problem-solving process offers one alternative.

*Adaptive co-management.* In contrast to earlier conceptions of co-management frequently focusing on formal agreements between two-parties, Carlsson and Berkes (2005) emphasize *adaptive co-management* as processes of iterative problem-solving among networks of stakeholders, with co-management emerging as the result of these shared efforts. Their broad definition of co-management covers a variety of processes for interaction between various stakeholders. Such co-management may occur through various existing local organizations, rather than necessarily requiring a new organization to be established. It may evolve through a series of joint efforts, rather than a single discrete contract or act of authoritative devolution.

The scope of co-management can be and sometimes is used to describe almost any form of management in which there is some form of participation by users. However, if the concept of co-management is expanded too broadly, then it risks becoming synonymous with any resource governance shared among multiple actors. This paper will focus on situations that involve a significant degree of joint decision-making and shared power. In terms of a spectrum of participation (IAP2 2007, Bruns 2003), participatory irrigation management can be seen as a more general term, including weaker forms of participation where users may be informed, express their views or engage in discussion but have little or no power over the final decision. Co-management could take the form of explicitly requiring joint agreement, or situations where one side formally holds the final authority to decide, but extensive collaboration in considering decisions and potential ability to lobby against or resist an unacceptable decision may produce with a significant degree of power sharing.

## **COMPLEX ADAPTIVE SYSTEMS**

*Adaptive Management.* Concepts of complex adaptive systems and adaptive management of integrated social and ecosystems have received increasing attention in the past few decades (see, for example, Berkes et al. 2003, Olsson et al. 2004, and for an early introduction, Vayda and McCay 1975). Among other things, these represent a conceptual shift away from an emphasis on ecosystems in stable equilibrium. The emphasis instead is on to the inherent unpredictability of non-linear systems with webs of interactions. Ecosystems are continually perturbed by external changes and the emergent results of their own internal dynamics. Thus disequilibrium is the normal state of affairs. Systems may have no single equilibrium point, and instead have multiple possible states or follow paths sensitively dependent on minor variations. Under such circumstances, and with greater understanding about the limits of scientific knowledge and prediction, it is argued that the appropriate approach is one of

adaptive management, testing and adjusting, exploring what is possible and worth pursuing. If there is no “one best solution” that can or should be imposed, then performance and the sustainability of performance over time become more a matter of robustness and resilience in the face of continuing shocks and uncertainties.

In irrigation as elsewhere, recent literature on natural resources governance has argued the need for adaptive management approaches, able to flexibly learn and adjust in dealing with complex systems where deterministic prediction is impossible (Ostrom 1999, Meinzen-Dick 2007). Analysts have been particularly critical of the tendency to impose standardized blueprints, creating “institutional monocultures,” (Ostrom 2008). Past patterns of aid, and the assumptions underlying them, have often promoted top-down technocratic approaches that assumed the need was to put in place a single “best way” solution. This could be these case even if a learning process (Korten 1980) was pursued to identify the solution. If such standardized approaches disrupt and discourage existing local institutions then they may become counterproductive, as well as conflicting with aspirations for local democracy and empowerment. Critics have argued the need to go “beyond panaceas,” not pursuing a single simple solution or a silver bullet.

The common recommendation in much of the recent literature is for more adaptive, decentralized, and institutionally diverse approaches. Reforms in recent decades have often emphasized devolution, sometimes phrased as shifting from top-down to bottom-up approaches, transferring authority, or at least some kinds of initiative and involvement to local participants. This can mobilize knowledge, incentives, management capacity and other resources. Decentralized approaches offer the potential for greater institutional diversity (Ostrom 2005) allowing polycentric organization in multiple forms and scales, with multiple experiments to “tinker” with different rules, exploring what works under different circumstances. Learning through experience, imitation and exchange between different groups is a central part of what is expected. Learning may be facilitated through forums and networks that aid exchange of ideas, and through provision of technical advice, as well as through the kind of decentralization discussed above that improves the potential for local adaptation and learning.

*Complex systems.* The subaks of Bali have long been known as an example of highly organized self-governance. Recent research has deepened insights into the dynamics of how patterns of self-organization can emerge in irrigated landscapes, and how external intervention may disrupt them (Lansing, 1991, 2006). When traditional crop scheduling was upset by the imposition of continuous cropping patterns intended to maximize production from high-yielding “Green Revolution” rice varieties, severe pest outbreaks erupted. Water temples had functioned as forums for coordinating cropping schedules that balanced the demands of allocating water with the prevention of pest outbreaks. Such a system could work without requiring centralized planning and control, and instead

benefited from decentralized management at multiple levels, integrating information about local conditions and priorities.

The diversion and distribution of water across landscapes creates a waterscape of flows, especially in paddy rice systems, grown on terraced paddies with extensive reuse of surface and subsurface flows. Such systems are not unique to Bali. Elaborate systems, representing massive amounts of construction effort can result from long-term processes of step-by-step expansion, without a single master planner (Leach 1981).

A better understanding of the complexity of water flows across irrigated landscapes (waterscapes) suggests the need for a much more careful and cautious approach to reengineering irrigation systems. This need not mean that the response must be a blind perpetuation of tradition. The unpredictability of complex systems does suggest that a purely deterministic approach, imposing standardized operational rules may be very inadequate and far from optimal. Instead, there may be a much greater need to allow exploration and adjustments. In the case of rehabilitation, this implies a need to pay more attention to existing operational procedures, as actually practiced, to learn from how they may be adapted to local conditions, and what needs to be considered in order to try to improve performance.

*Designing Adaptive Systems.* One approach to understanding and improving irrigation systems as complex adaptive systems has been developed as part of approaches to irrigation modernization (Renault et al. 2007). Earlier work on irrigation modernization had concentrated on diagnostic methods, using a specialized Rapid Appraisal Process to look at internal and external performance indicators (Plusquellec 2002, Burt 2004). Recommendations typically focused on improved water measurement and flexible control.

Recent extensions to these methods pay greater attention to how fluctuations in water flows and levels propagate within irrigation canals, often resulting in tail-end areas suffering the greatest fluctuations, with consequent shortages or excesses of water (Renault et al. 2007). Analysis clarifies that existing operational procedures and infrastructure are often incapable of assuring reliable supplies, even if canals and control structures were fully rehabilitated to the original state to which they were designed. Instead, modifications need to be planned and implemented based on assessment of operational targets and how particular structures contribute to increasing or reducing fluctuations. This requires operational procedures that can adjust to the relatively unpredictable dynamics of how the system responds to different water conditions and gate settings. It involves a paradigmatic shift away from assumptions of stable, deterministic flows, with a rigid set of times and levels for gate adjustments, towards a more flexible and responsive approach, with corresponding adjustments in operations and hardware.

Proponents of irrigation modernization usually accept the value of water user organization. However, they have often criticized what they portray as unworkable attempts to improve irrigation system performance purely through institutional changes. They argue that institutional changes alone are insufficient, and may represent a misplaced and doomed waste of effort. Instead, they have emphasized the necessity of changes in hardware and operations. While this may be seen as a debate between proponents of institutional reforms and proponents of technical modifications, it seems more fruitful to look at the potential for synthesis, acknowledging both the need to address the complexities of water flows and the need for greater user involvement, treating farmers not simply as clients receiving water, but as co-managers (and co-producers) of irrigation services.

A key part of the proposed MASSCOT approach is careful definition of subunits for water management. In the language of common property scholarship, this can be seen as reviewing the appropriate boundaries and nesting of governance within the system, to better fit both environmental and social conditions. This becomes a basis for identifying key points for improving measurement and control of flows. Instabilities can be addressed both by prioritizing some gates for more frequent adjustment, as well as by modifying those structures that make the largest contribution to instability. In contrast to conventional cross-regulators, long crested weirs may produce much smaller fluctuations in water levels, installed either on their own or as part of gate structures. Increased storage within canals or ponds can also buffer the impact of fluctuations, weakening the linkages between different subsystems. Augmenting main canal water supplies from supplemental streams, groundwater and reuse of drainage water partially decouples subsystems, which may assist the overall system to become more reliable and robust. More fundamentally, the operational goal shifts from one of implementing a predetermined plan towards learning how to assure better water service delivery, in terms of equity, adequacy, reliability, and responsiveness to user demand.

This implies a shift from rehabilitation as restoration of an original design, towards selective modification to solve the problem of controlling water flows. In principle, this should be a phased and pragmatic process of improvement, based on priorities identified by stakeholders with subsequent changes chosen based on the results of earlier efforts. However, there is also a risk that modernization approaches are oversimplified and misunderstood, as mainly a matter of installing long-crested weirs and measuring flumes. Single-shot approaches to rehabilitation also impel preparation of a single package of changes, rather than a series of modifications in an incremental learning process. There seems to be much potential to combine ideas about adaptive co-management with the systematic approaches to performance assessment, diagnosis and problem-solving improvement. However, the ways in which aid for irrigation rehabilitation is currently provided often discourage rather than encourage joint problem-solving and adaptive improvement.

Table 1. Active Samaritan's Dilemma

		<b>B</b>	
		1 invest	2
<b>A</b>	1	I  <b>2,2</b>	II  <b>1,1</b>
	2  aid	III  <b>4,3</b>	IV  <b>3,4</b>

Cell contents: A's payoff, B's payoff

### SAMARITAN'S DILEMMAS

On an intuitive level the idea that aid may discourage self-reliance is straightforward, and closely related to other ideas such how subsidies may crowd out local investment and promote dependency. Buchanan's (1977) game theory model of Samaritan's dilemma offers a formal way to analyze the incentive problems and conflicts that may be generated by aid and "strategic" or "opportunistic" behavior on the part of donors and recipients.<sup>3</sup>

Figure 1 presents a game theory model of what Buchanan terms the Active Samaritan's Dilemma. The model follows conventional game theory notation where players A and B each have a choice of moves 1 or 2, with the resulting cell showing their respective payoffs (a,b) ranked from 1 to 4 according to each player's preferences. Buchanan points out the problem that occurs if the game is played repeatedly. Even though the donor would prefer that the recipient also invests, they end up having to accept a situation where their intervention displaces investment by recipients.

In the irrigation context, this could be told as a story where first farmers organize themselves to invest in irrigation, creating benefits for themselves and a situation that also is more favorable from the perspective of government. Next, government aid, for example to build a larger and more permanent weir that

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<sup>3</sup> Wilson et al. 2005 examine Samaritan's Dilemma as one of several interrelated problems of collective action affecting international development, including free riding and principal-agent conflicts. While acknowledging the importance and severity of other problems and their interrelatedness, this paper focuses more narrowly on Samaritan's dilemma as a particular incentive problem in irrigation rehabilitation.

makes irrigation more reliable, creates a situation that both farmers and government prefer. However, expectations about availability of future government aid may then weaken farmers' incentives to invest themselves, making them more inclined to leave maintenance and repairs up to government. If the government feels unable to not provide aid, even if farmers do little or nothing, then a social trap appears, with little local investment and government bearing the burden. Worse yet, if farmers reduce their contributions based on expectations about government, but government actually provides far less than expected, then the result could be one of neglect by both.

In the original article, Buchanan explores the ways a donor might try to claim to have a different preference in order to manipulate the recipient to invest, or how a donor might bind itself to a policy of not providing further aid unless the recipient contributes. However, given the structure of the game and the donor's actual preferences, the donor may be unable to make a credible commitment to withhold aid, in which case, the dilemma persists.

In the irrigation context, the credibility of government requirements that users carry out future maintenance and improvements, or a donor's requirement that a borrowing government ensure adequate maintenance, is weakened by a variety of factors. A new officeholder has stronger incentives to provide patronage than to enforce previous commitments about making aid contingent on adequate maintenance. It can be hard to monitor maintenance investment. It is difficult to distinguish problems due to neglect from those caused by force majeure events such as flood. Ultimately, this derives from the basic set of preferences where the donor prefers the outcome (cell IV), with donor aid and no recipient effort rather than the situation that would result if aid is withheld.

Buchanan then looks at a slightly different model of Passive Samaritan's Dilemma (Figure 2), where the donor would prefer that the recipient exert themselves rather than continuing to receive aid (switching the donor's preferences between quadrants I and III). In repeated play there might be two stable equilibria, in quadrant I or IV, depending on history or whether one player moves first rather than both moving simultaneously. In the irrigation context this would be analogous to a situation where government intervention shifts the situation from a situation of local self-reliance to heavy dependence on external support.

Table 2. Passive Samaritan's Dilemma

		<b>B</b>	
		1	2
<b>A</b>		invest	
		1	2
1	I  <b>4,2</b>	II  <b>1,1</b>	
2 aid	III  <b>2,3</b>	IV  <b>3,4</b>	

Cell contents: A's payoff, B's payoff

Provision of irrigation aid by governments and international donors, particularly when delivered in terms of large, lumpy, infrequent, rehabilitation projects, can have many of the characteristics of Samaritan's Dilemma, where aid discourages further effort by the recipient.

- While there may be policies and commitments stipulating that recipients will be responsible for proper maintenance, it is hard to ensure that these are fulfilled.
- The relatively infrequent occurrence of projects, with changes in local leadership and agency staffing in between, means there are not repeated interactions that would provide a basis for building trust or threatening to punish non-fulfillment of commitments, e.g. to contribute to maintenance.
- The agency's incentives are to move ahead with construction and with disbursement of funds.
- Reduction in local effort may even be in the interest of the agency, if it reduces the transactions cost of planning and carrying out construction and hastens the time when further rehabilitation projects may be needed.
- Increased dependence by beneficiaries may serve to strengthen the need for bureaucratic or political patronage.
- Repayment of capital costs by beneficiaries is rarely required.
- Units responsible for construction are separate from those that have responsibility for operation and maintenance.

- Problems of organizing collective action and the limited financial and technical capacity of farmers and local organizations make local investment difficult.

Even if there were no conscious attempt by farmers to avoid contributing, a range of factors would make this less likely. For irrigation rehabilitation, Samaritan's dilemma offers a useful model of how, given donor preferences and difficulty in making credible commitments about conditionality, a dilemma or "social trap" may arise at what for the donor represents an undesirable equilibrium.

## **ALTERING AID**

One way of looking at how to escape the social trap of aid that discourages self-reliance, is by looking at ways of changing the game, changing key characteristics of the action situation.

*Communication.* In the classic game theory model of Prisoner's Dilemma, the problem is compounded by the inability of prisoners to talk to each other and reach agreement on a common strategy of not talking to the police and thereby getting off lightly. Instead, each one may see that if they are silent and the other talks, then they will be far worse off, and instead choose to talk, thereby incurring a somewhat lesser penalty. For single play, the incentive to break a promise would still be the logical choice, but for repeated play, then the potential to offer benefits from cooperation and threaten to punish defection, may change the dynamics.

Buchanan's analysis of Samaritan's Dilemma explores the problems that may occur even where communication is possible. Given the donor's preferences, they have a hard time making credible commitments to withhold future aid. Despite being apparently more powerful in terms of resources, donors are actually in a weak position in some kinds of bargaining. Thus, by itself, communication is not a sufficient solution. However, the possibility of communication, established in the form of water users associations that can represent farmers and opening up agency procedures for consultation and dialogue may still be one element of alternatives.

*Increasing transaction frequency.* Having rehabilitation carried out infrequently, and by units that have little or no ongoing relationship with farmers contributes to the dilemma. Packaging of works into infrequent rehabilitation projects may simplify planning and implementation, but worsens the social trap. More frequent interaction could create the possibility of making more credible promises and threats, since there will be continued interaction in which this can occur. In the language of development this can be seen as part of a shift from a project approach to a program approach. It could also accompany

decentralization of funding to lower levels, which facilitates disbursement of smaller amounts of funding more frequently.

*Reducing project scale.* Rehabilitation projects typically bundle together a large variety of repairs and improvements. In principle different types of irrigation infrastructure require maintenance, repair or replacement at different intervals, as they degrade or break down at different rates. Rehabilitation tries to put together a large package of works, making for a large or lumpy transaction. Unbundling this package creates the opportunity for smaller and more frequent transactions. It could also promote more careful prioritization of works, reducing the temptation in rehabilitation to find ways to use the available budget and avoid worrying about relative benefits and costs of different changes. Within a project, it also offers the possibility of differentiating between various groups of beneficiaries, including consideration of their attention to maintenance, rather than having to treat the entire system as a single actor. Contributing to smaller works is also much more feasible for farmers, while the cost of large-scale rehabilitation dwarfs what they might do at a single time, making their potential sharing much less meaningful. A series of works extended over time allows more opportunities for local resource mobilization.

*Adaptive problem-solving.* As discussed earlier, an understanding of irrigation systems as complex adaptive systems leads to an iterative approach of diagnosis, testing and adjustment. This contrasts sharply with the tendency in irrigation rehabilitation projects to design to uniform standards, assuming that there is one best way, or optimal method for building and managing the irrigation system, so that rehabilitation becomes a matter of restoring the system to its original design condition, or comprehensively upgrading it according to a particular pre-conceived plan. In practice, irrigation rehabilitation projects in the Philippines, Indonesia and elsewhere often have far too little budget to comprehensively restore and upgrade the entire system. Budget constraints may induce some degree of prioritization, as may community participation. However, large-scale rehabilitation projects usually lack the kind of customized diagnostic analysis proposed by advocates of “irrigation modernization.” An adaptive approach to modernization may involve a shift to a problem-solving approach would be highly compatible with aiding smaller, more frequent works.

Table 3. Aid with Aligned Incentives

		<b>B</b>	
		1	2
		invest	
<b>A</b>	1	I  <b>3,2</b>	II  <b>1,1</b>
	2 aid	III  <b>4,4</b>	IV  <b>2,3</b>

Cell contents: A's payoff, B's payoff

*Disclosing budget constraints.* The Samaritan's Dilemma model assumes the donor is capable of providing aid repeatedly. If funding limitations are disclosed, this makes statements about not providing future funding more credible. In the case of irrigation officials, there is often a tendency to not disclose budgets and to make promises of future aid according to need, disregarding budget constraints. Secrecy facilitates discretionary and unaccountable decisionmaking by officials, while promises reinforce patronage and dependence. Thus measures to make information about budget more transparent can shift away from the premise of infinite budget inherent in the Samaritan's Dilemma model, toward one or more limited resources.

*Competition for aid.* Samaritan's Dilemma is a two-person game. If the donor faces multiple recipients, then threats to withhold aid from some and allocate more to others, based on behavior, become more credible. This is reinforced if there are hard budget constraints and transparency. With smaller, more frequent transactions, procedures with competitive proposals become much more feasible. It can be credibly argued that there will be opportunities next year or in the next round of funding, in contrast to the difficulty of denying eligibility when the next aid might not come for a decade or more.

In essence, the changes described above offer ways of changing the game, to align incentives of government and farmers so that they would choose joint investments. While each might prefer that the other invest alone, their highest pay-off would come from joint investments, and their incentives could lead them to that outcome, as in Figure 3. As mentioned earlier, a successful outcome might still depend on solving other nested social dilemmas, such as organizing collective action by water users and managing principal-agent relationships for irrigation agencies and water user association leaders.

## CONCLUSIONS

Where irrigation management transfer has occurred but irrigation agencies still carry out main system management, then co-management could form a key part of adaptive approaches to improving existing irrigation systems. Where IMT has not occurred, or has paid little attention to opportunities for adaptively improving irrigation operations, then co-management could have significant potential. Analysis of irrigation systems as complex adaptive systems, leads to the conclusion that learning and phased improvement may be essential to improving the performance of irrigation systems. Samaritan's Dilemma models of aid highlight some the key problems produced by packaging aid into large-scale rehabilitation projects. Alternative approaches to aid may be able to "change the game" by offering smaller, more frequent packages of works, more transparency about budget and competition between potential recipients, and a cooperative problem-solving approach to diagnosis, learning and phased improvement.

This paper has focused on the incentive structure for irrigation rehabilitation, and alternatives for restructuring aid to promote local investment in maintenance and adaptive improvement. However, it is necessary to note factors that could constrain the feasibility of such reforms. Large-scale rehabilitation projects suit the interests of donors and centralized irrigation agencies, including the simplicity of planning, implementing, and monitoring larger packages. From the perspective of donors and agencies interested in the amount of funds they can disburse, a program approach implemented on a wide scale could also move substantial amounts of money. From a political perspective, it would still offer opportunities for patronage. It would be less conducive to the interests of larger contractors and those who would manage large projects, but might benefit smaller contractors and provide opportunities for more project managers. The feasibility of reforms to shift in such a direction may depend on the relative influence of different actors, including politicians who might favor a program with more widespread benefits.

In practice, Indonesia, the Philippines and many other countries often already have programs that allow smaller-scale rehabilitation and improvement of irrigation systems, sometimes with funding managed by irrigation agencies and in other cases as part of more general programs to support rural public works. These can and do incorporate elements of competitive proposals, and conditionality for local contributions. Some of these programs are funded through national budgets, and others such as "social funds" or "community-driven development" by international donors. What does seem possible is to more systematically incorporate a set of shifts in irrigation funding to encourage greater local investment. More explicit incorporation of diagnosis and design for adaptive irrigation modernization through incremental improvements could provide a promising area for improving aid to irrigation.

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