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Institutional nesting and robustness of self-governance: the adaptation of irrigation systems in Taiwan

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Abstract: Rapid social-economic development has posed serious challenges to irrigation management in Taiwan. Drawing upon data collected through in-depth interviews with farmers and local irrigation officials and an appraisal survey, this study compares the processes of adaptation that have taken place in irrigation systems in four distinct ecological-institutional settings in the Chianan area of Taiwan. We have found that different modes of institutional nesting have affected farmers' choice of adaptation strategies and the way self-governance has played out in the adaptation process, and that different adaptation strategies have brought about different impacts on system robustness and the sustainability of self-governance.

Keywords: Institutional nesting, irrigation management, self-governance, social-ecological systems, Taiwan

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1. Introduction

Taiwan arguably has some of the best-performing irrigation systems in the world, which have made significant contributions to the country's economic development (Liao et al. 1986; Williams 1994; Chen 1997). Prior research suggests that the excellent irrigation performance can be attributed to the design of the country's irrigation institutions. Irrigation in much of Taiwan is governed by seventeen Irrigation Associations (IAs) – parastatal organizations collectively owned by farmers, supervised by governments at multiple jurisdiction levels, managed by professional managers, led by local politicians chosen by farmers, and supported by a network of Irrigation Groups (IGs) through which farmers organize collective action for irrigation operation and maintenance (O&M) at the local level. This design combines professional management and government support on the one hand, and farmer participation and self-governance on the other.[1]

Since the early 1980s, Taiwan's irrigation has been facing substantial challenges as agriculture lost its economic importance[2]; the decline of agriculture has come with drastic changes to the country's social-political contours (Wu Huang 1993; Williams 1994). As a result, irrigation in Taiwan has taken on new features including a dominance of part-time farming, an increasingly heavy reliance on groundwater, and a growing integration of irrigation into the national water management regime; all these have reduced farmers' incentives to engage in self-governing activities for irrigation management (CAEA 1995; Chen 1999; Lam 2001). There has long been a policy debate on whether self-governance is a viable mode of governance for irrigation and other public goods in a developed or transitional economy (Barker et al. 1984; Burns 1993). In Taiwan and elsewhere, many have argued that economic development and globalization have rendered community-based collective action irrelevant (Chen 1996, 1999; AERC 1999, 2000, 2001; Meinzen-Dick and Hoek 2001; Pritchett and Woolcock 2004; Gulati et al. 2005; Shivakoti et al. 2005; Meinzen-Dick 2007).

The question concerning the sustainability of self-governance is relevant not only to irrigation management in Taiwan but also to the governance of common-pool resources (CPRs). CPR research has suggested that local self-governing groups are better able to adapt to external disturbances through changing their rules and behaviours if they are nested effectively with institutional enterprises at higher jurisdiction levels (Ostrom 1990; Berkes and Folke 1998; Berkes 2002). The literature has identified mechanisms through which the nesting of institutions affects farmers' ability and incentives to engage in rule-crafting activities as a strategy to adapt to the changing environment; this study contributes to the literature by elaborating how some of these mechanisms and dynamics are in evidence

[1] For detailed studies of the functions, duties and institutional designs of the IAs and IGs, see Wade (1987), Moore (1989), Lam (1996b, 2006).

[2] Beginning in the early 1980s, agriculture has accounted for less than 1.45% of Taiwan's GDP (COA 2007).

and manifested themselves in the context of irrigation management in Taiwan. Drawing upon data collected through intensive fieldwork and an appraisal survey, we compare the processes of adaptation that have taken place in irrigation systems in the Chianan area of Taiwan over the past three decades. Particular attention is given to how different modes of institutional nesting have affected farmers' choice of adaptation strategies, and how different adaptation strategies impact on system performance and self-governance.

1.1. The origin and design of irrigation institutions in Taiwan

Farmers in Taiwan have a long history of developing small-scale irrigation for agricultural purposes.[3] When the Japanese took control of the island, they embarked on large-scale irrigation infrastructure projects, and also institutional reforms that integrated the existing local irrigation systems into parastatal organizations – Irrigation Groupings (Ka 1995). When the Nationalist government established an authoritarian regime in Taiwan in 1949, other than constructing large-scale irrigation infrastructure and undertaking extensive land consolidation programs, the government merged the loosely organized Irrigation Groupings into a smaller number of IAs (Chen 1996, 1997). These IAs were given the legal status of a "public entity," which vested in them mandates, resources, and authority regarding irrigation management; they were also put under government scrutiny and supervision (Lam 1996b, 2006). Despite the parastatal status, the IAs remained "farmers' organizations" enjoying a high degree of autonomy in their operation.

The availability of storage facilities and lined canals as a result of the infrastructure projects fostered the development of a "Rotational Irrigation System" (RIS). The RIS is in essence planned irrigation that rationalizes water delivery through large-scale integration and meticulous coordination of irrigation management. Every year each IA prepares a grand irrigation plan for its service area which stipulates meticulously the kinds of crops that a farmer is supposed to grow at a particular time of the year, and also the amount and timing of water that the farmer is allocated. The implementation of the plan is then carried out by the Working Stations (WS) – the IA's branch offices – in different hydraulic areas, usually in collaboration with the IGs. Successful implementation of the RIS requires effective coordination of farmers' actions within and between irrigation systems.

2. Analytical framework and methods

2.1. Social-ecological systems, institutional nesting, and robustness

To examine the processes of adaptation and institutional change and to gauge the performance of irrigation systems,[4] this study draws upon theories and

[3] For a detailed analysis of the political economy of Taiwan's irrigation, see Lam (2006).

[4] Local irrigation institutions include both the rules that sustain the operation of the IGs and the rules that the IGs adopt to manage irrigation operation and maintenance (O&M) at the local level.

concepts developed in a Social-Ecological System (SES) framework. Janssen and colleagues (2007, 309) define an SES as "composed of biophysical and social components where individuals have self-consciously invested time and effort in some types of physical and institutional infrastructure that affects the way the system functions over time in coping with diverse external disturbances and internal problems." An irrigation system composed of a resource (sources of water), physical infrastructure (storage and canals), actors who manage and appropriate from the resource (farmers and irrigation managers), and a governance structure that regulates the action and interaction of the actors (irrigation institutions) is an example of an SES (Lansing 1991; Miller and Page 2007; Mitchell 2009).

Adaptation of an SES to the changing environment can take on different forms and may involve different components of the SES as well as the links between these components (Anderies et al. 2004; Ostrom 2007). In irrigation, one way for system users to cope with water scarcity is to construct engineering works such as reservoirs to control the stock and flow of water. Yet another, often more effective, way is to craft and re-craft institutions (rules-in-use) to regulate and coordinate the users' water appropriation activities (Dinar et al. 1997; Baker 2005; Lam 2010). The effectiveness of the rule-crafting efforts hinges on mechanisms through which new, alternative rules are generated, selected, and retained in the system (Denzau and North 1994; Jones 2003; Janssen et al. 2007; Ostrom 2009). In an irrigation system where farmers are given the liberty and incentives to generate a repertoire of potential alternative rules from which they can choose to adapt to the changing environment, one would expect to see more vibrant rule-crafting activities among the farmers (Lam 1996b, 1998; Ostrom 2005b).

2.1.1. Nested actions and dynamics across scales and levels

Except for very small irrigation systems, irrigation involves a chain of social-technological processes organized in a hierarchical manner. Water from a source runs through the main channel to reach the laterals, from there it is diverted to different sublaterals that bring water to disparate regions; within a region, water passes through a network of small canals (ditches) to reach farmers' fields. Water delivery at different stages incurs tasks of different scales, of which each faces unique problems specific to the particular scale that calls for different institutional arrangements and organizations (Chambers 1988; Meinzen-Dick and Hoek 2001). As the tasks at different levels and scales are nested within one another, one often finds positive and negative feedback loops operating across tasks at different scales, affecting the operation of irrigation systems nested within the broader water management regime (Young 2002).

Different nesting structures tend to give rise to different patterns of interaction of actors within an irrigation system and the way the system relates to other SESs across different levels. In a system where the users' rights to organize themselves are duly recognized by government officials, for example, the users tend to have stronger incentives to engage in rule-crafting activities (Lam 1996a, 1998; Ostrom et al. 2011). An effective nesting structure should allow the crafting and enforcement of rules to be carried out at a most appropriate level and scale; and a scale of governance can be considered appropriate if users at that particular level can have access to the most relevant information, and be able to respond quickly to disturbances (Evans 2004; Pritchett and Woolcock 2004; Ostrom 2005b).

2.1.2. Robustness and adaptive capacity

An SES usually performs multiple functions. Irrigation, for example, pertains not only to food production but also to ecological diversity, sustenance of rural communities, and other purposes (Meinzen-Dick and Hoek 2001; Molden 2007). Given the multifaceted functionality, an evaluation of irrigation performance has to be multidimensional. Moreover, a dynamic SES defies a static assessment of performance; instead of focusing on an SES's performance at a particular time point, it is more appropriate to look at its robustness – the system's ability to continue to function and adapt to the changing environment over a period of time.

The concept of robustness draws one's attention to possible trade-offs between different dimensions of irrigation performance (Carlson and Doyle 2002; Walker and Salt 2006; Ostrom et al. 2007). Two types of trade-offs are particularly important. The first is the trade-off between control and flexibility. In irrigation, for example, the service area of an irrigation system could be maximized through careful control of water delivery. Meticulous control, however, always hinges upon, and hence is sensitive to, assumptions about the ecological processes involved, such as the range of precipitation levels. When major deviations from the assumptions occur, a tightly controlled system will lack the agility required for adapting to the changing environment.

Second, robustness is always construed with reference to specific dimensions of system performance (Janssen et al. 2007). Building robustness in regards to a particular dimension could make the system vulnerable to other dimensions. For instance, building irrigation infrastructure and institutions specifically in accordance with the needs and growth cycle of paddy will couple the system with paddy cultivation; such a lock-in effect inevitably reduces the system's versatility and its ability to adapt to changes in the agricultural sector.

2.2. Research design and methodology

Prior research suggests that task environment and the degree of nesting of local irrigation institutions into the broader water management regime are two major factors affecting the operation and evolution of local irrigation institutions (Burns 1993; Dietz et al. 2003). In Taiwan, the degree of institutional nesting is largely determined by the extent to which a system follows the RIS that, as explained earlier, seeks to integrate irrigation in disparate locales into a grand irrigation plan. Successful implementation of the RIS is possible only if the concerned IA has good control over the amount and flow of water. It means that, compared with river-fed systems, reservoir-fed systems are better able to follow the RIS and, hence, more integrated with the irrigation plan. As for task environment, in Taiwan land consolidation, through land-levelling, canal development, and alignment of fields in grids, is considered a major element of effective irrigation management and hence has been conducted to the extent possible. Areas that remain unconsolidated are mostly those where the physical conditions are so disadvantaged that consolidation is deemed infeasible, either technically or economically. Thus, irrigation management in the unconsolidated areas is much more challenging in terms of not only infrastructure but also the physical environment.

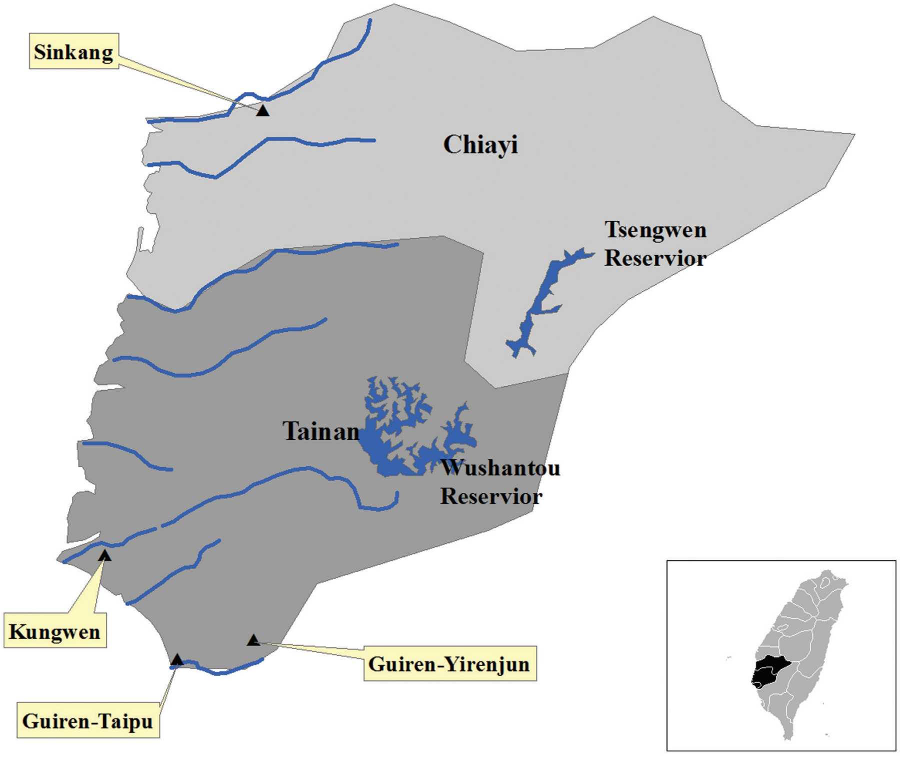
Using the dichotomous variables of "reservoir-fed/river-fed" and "consolidated areas/unconsolidated areas" as two dimensions, we constructed a matrix of four ecological-physical settings (Figure 1). On the basis of the matrix, we identified four areas in three hydraulic regions in the Chianan area[5] that are representative of the four ecological-physical settings; the hydrological and agricultural characteristics of the settings are described in Appendix 1, and their locations are shown in Map 1. The four groups of irrigation systems, each operated by an IG, are all located at the tail end of their respective water systems; water scarcity is always a major concern for them, although the degree of uncertainty varies across the systems. The four settings constitute what Bennett and Elman (2006) call explanatory typologies, which posit possible causal relationships between particular patterns of adaptation and the configurations of ecological-physical variables associated with the settings. Such a design enables us to conduct a careful comparison of the patterns across different settings, and thus examine how different modes of nesting might condition institutional adaptation and institutional change and performance (Ragin 1987; Goertz and Mahoney 2012).

The fieldwork of this study, which was conducted in the period between 2007 and 2009, with follow-up data collection carried out in 2010 and 2011, includes a series of in-depth interviews and an appraisal survey on IG leaders. For the in-depth interviews, we visited the WS in each of the areas and conducted focus group discussion with irrigation officials at the WS as well as farmers from the area. The focus group discussion was then followed by a series of individual in-depth interviews with a number of IG leaders in the area. For the appraisal survey, a questionnaire was designed to capture different dimensions of irrigation operation and performance. As the unit of analysis of this study is the Irrigation Groups (IG), we set out to conduct the survey on all IGs (a total of 37) in the four ecological-physical settings. When we contacted the 37 leaders, three of them declined our request for an interview, citing poor health and other personal reasons. As a result, we included only 13 out of a total of 14 IGs in Sinkang, 8 out of 9 in Kungwen, 5 out of 6 in Guiren-Taipu, and all the 8 IGs in Guiren-Yirenjun

[5] The Chianan area is located in the southwestern part of the island of Taiwan where the largest plain is located. Although Chianan's agricultural potential was substantial, a full materialization of the potential was severely constrained by the uneven distribution of rainfall during the year.

	Consolidated Areas	Unconsolidated Areas
Reservoir-fed	***Setting I*** Hydraulic area: Sinkang No. of IGs: 14	***Setting II*** Hydraulic area: Kungwen No. of IGs: 9
River-fed	***Setting III*** Hydraulic area: Guiren-Taipu No. of IGs: 6	***Setting IV*** Hydraulic area: Guiren-Yirenjun No. of IGs: 8

Figure 1: Irrigation systems by ecological-physical settings.



Map 1: Locations of the four ecological-institutional settings.

in the survey. The total N for the appraisal survey was 34.[6] The summary of the survey results are shown in Appendix 2.

[6] Given the relatively small sample size, we were cautious about the possible impact of leaving out the three IGs whose leaders had declined our interview request on subsequent statistical analysis and results. As a practice of due diligence, in 2010–2011 we conducted rounds of supplementary interviews with select local farmers in the three IGs who had good local knowledge of irrigation management; these farmers were recommended by the WS.

3. Results

3.1. Setting I: Sinkang

Irrigation systems in Sinkang are located at the tail end of the Wushantou-Tsengwen reservoirs system. The Wushantou Reservoir was the only source of irrigation water when reservoir irrigation was first introduced in Sinkang in the early 1950s. In those days, water was limited; most of the irrigation systems in Sinkang received water only sufficient for growing one crop of paddy every three years. To fully utilize the water, canals were lined and gated to the extent possible; all the irrigated lands in the area were consolidated. Irrigation management was characterized by active farmer participation and a meticulous implementation of a "water-slip system." Under the system, every farmer was issued a water-slip at the beginning of a planting season that specified the time slots during which water would be delivered to the sublateral passing by the farmer's fields. The water-slip system was essentially an operationalization of the RIS, turning water delivery into an ordered sequence of coordinated yet individualistic acts of water appropriation.

In Sinkang, farmer's participation focused primarily on the provision rather than the production of irrigation management. Other than an IA fee which formally defined a farmer's membership with the IA and hence his entitlement to the water provided by the IA, every farmer had to pay an IG fee to support the operation of the IG to which he belonged. Members of an IG would collectively decide the level of the fee and the kind of irrigation operation and maintenance activities on which the fee would be spent.

The completion of the construction of Tsengwen Reservoir in 1979 substantially increased irrigation water supply in Sinkang, enabling farmers in the area to grow two crops of paddy per year. With abundant water, farmers in many IGs came to perceive the water-slip system as too stringent and labor-intensive for the new task environment. However, under the RIS, the amount and timing of water available to the systems was determined by an overall irrigation plan; any rule change at the IG level would be viable only if the overall parameters of water availability were duly adjusted. Moreover, the irrigation plan implicitly provided each farmer an entitlement to irrigation water provided by the IA; any deviations from the order specified on the water-slips could potentially affect the entitlement. Understandably, the farmers were extremely cautious about making changes.

As changing the rules at the local level was considered non-viable, farmers in Sinkang began to modify the implementation of the rules with a view to reducing the effort and time required of them for water delivery. In many IGs, farmers chipped in to hire water guards to manage water delivery according to the order stipulated on the water-slips on their behalf. Once the "burden" of using, following, and enforcing the rules was relieved, farmers quickly forgot not only about the rules but also the potential for crafting and re-crafting rules as a means for collective problem solving. The cascading dynamics were startling; it did not take long for farmers in Sinkang to abandon the water-slip system altogether. Interestingly, farmers began to perceive that improving the irrigation infrastructure was a quick-fix for ensuring a predictable supply of irrigation water. Lobbying the IA officials for more infrastructure investment became a major adaptation strategy.

In Sinkang, farmers have largely failed to change local irrigation institutions to adapt to the changing physical environment. In almost all systems, water delivery has become loosely managed since the early 1990s. Water in the sublaterals is allowed to flow continuously. Farmers at the head end will appropriate as much water as they can before they allow the water to flow down the canal for farmers at the tail end; no rules are in place to attain a fairer allocation of water.

3.2. Setting II: Kungwen

Irrigation systems in Kungwen are also located at the tail end of the Wushantou-Tsengwen reservoir system. Kungwen is one of the few reservoir-fed areas in Chianan that did not go through any land consolidation programs. Paddy fields there are characterized by irregular boundaries and loose alignment with canals; cross-field irrigation is commonplace. As Kungwen is located near the sea coast, irrigation systems are faced with the problem of soil salinity as a result of seepage of sea water. Irrigation is important not only for agricultural purposes but also for reducing soil salinity.

To cope with the unique ecological setting, instead of closely following the formal irrigation plan, the WS in Kungwen developed its own *de facto* irrigation plan that took into account the ecological conditions. Unlike in other areas in Chianan, farmers at the tail-end areas were given priority for irrigation water; such a reversed irrigation order was formally recognized by the WS. Enforcing the reversed order of water delivery required that farmers at the head end resist the temptation of water theft.

Farmers facing the problem of soil salinity found themselves in a social dilemma situation. In order to reduce soil salinity, farmers must keep water flowing through their fields – a practice called “field washing” in Taiwan. Effective field washing, however, depends on the synchronization of actions of individual farmers whose fields are adjacent to one another. If a farmer fails to maintain a reasonably deep level of water in his field in a timely fashion, or to coordinate with his neighbors on the schedule of field washing, his fields could easily collect all the salt coming from the adjacent fields.

Before the 1980s, due to the importance of irrigation to the cultivability of the paddy fields and the relatively high economic values of agricultural produce, farmers were willing to put in tremendous efforts to sustain a certain level of management order. Such efforts, however, dissipated rapidly when farmers could no longer afford a high level of management inputs. The well-intentioned fallow programs that aimed at providing the farmers with a buffer to extreme water scarcity inadvertently turned agriculture into a leisurely activity for many old farmers.

Unlike in Sinkang where the unraveling of the management order has been rapid and across the board, in Kungwen one can find much diversity in the adaptation strategies adopted by farmers. Generally speaking, the IGs located at the tail-end areas have had greater success in maintaining a viable irrigation order to cope with the problem of soil salinity and to manage water delivery. As irrigation systems in Kungwen followed the RIS, designing new rules to cope with the macro changes was not viable. Instead of re-crafting the local rules, the strategy adopted in these more successful systems was to further perfect the modified water-slip system and the water delivery order that they had developed over the years. In Sixuejaliu IG, for example, farmers nowadays still manage water appropriation according to the *de facto* irrigation plan, with irrigation working from the tail end to the head end.

In sharp contrast, the IGs located at the head-end areas in Kungwen have witnessed a rapid, complete unraveling of irrigation order. Cultivation was mostly abandoned in these systems. As reported earlier, the salinity problem in Kungwen puts the farmers in a highly interdependent and hence a dilemma situation. As the paddy fields in Kungwen are not consolidated and well-aligned; when some farmers in a system fail to get water to wash their fields, the salt in the soil of their fields can easily spill over to the adjacent fields. Such a spillover effect can then trigger a cascading dynamic leading to a complete demise of cultivation in the system.

3.3. Setting III: Guiren-Taipu

Guiren-Taipu is located near the city of Tainan, and is one of the areas that went through farmland consolidation programs in the 1950s. Irrigation water in Guiren-Taipu mainly comes from river streams; the uncertain water supply rendered a strict implementation of the RIS impossible. With minimal control over water supply, water delivery requires an effective use of local knowledge. Farmers in Guiren-Taipu were well-aware of the uncertainty they faced, and of the importance of working out an effective order with one another. A key to utilize the available water was to uphold a principle of "minimal sufficiency" – every farmer should only appropriate what they need and restrain from taking an excessive amount of water. To put the principle in practice, the IGs in the area strictly enforced the IA membership[7]; only IA (and hence IG) members were allowed to appropriate water from the canals. In some IGs, four to five water guards were hired to take care of different tasks of water delivery during the times of scarcity.

As Guiren-Taipu is located near the city of Tainan, farmers could easily find jobs in factories or the city. By the mid-1980s, part-time farming had become the

[7] Non-members are farmers whose fields are located outside the service areas of the irrigation systems managed by the IA. The non-members are not entitled to irrigation water from the IA; they, of course, do not pay water fees. Usually they appropriate water from small streams and also groundwater.

norm in the area. As farming only contributed a small percentage of the farmers' income, many farmers were no longer willing to spend money on hiring water guards. Without the water guards to maintain an order of water delivery, water in the sublaterals was allowed to flow continuously.

Different IGs in Guiren-Taipu experimented with different rules to cope with the changing environment in a search for balance between an acceptable order of water delivery on the one hand, and minimal management input on the other. Some IGs, for instance, tried to address the problem of asymmetry between the headenders and the tailenders by reversing the water delivery order. Ironically, as the canal system to a large extent fixated the order of water delivery, any rules that sought to rearrange the turns of water delivery would not be viable.

In 2000, after enduring a period of a lack of management order in water delivery, the IG leaders in Guiren-Taipu realized that, to prevent the situation from further deteriorating, they had to work together to put in place rules that can coordinate water allocation among the IGs. Realizing that they did not have control of the water supply and that the systematic canal system arranged in grid largely constrained the possibility of an alternative order of water delivery, the farmers agreed that instead of trying to have meticulous fine-tuning of water allocation among canals, which had often triggered conflicts among users of different canals, water would be diverted to two canals at a time in turns so that farmers were assured of a minimal level of certainty and equity in water distribution. Also, the IG leaders decided that they would oversee water delivery to ensure that it was conducted impartially.

3.4. Setting IV: Guiren-Yirenjun

Systems in Guiren-Yirenjun divert water from nearby streams or discharge canals. The Guiren-Yirenjun area has never been included in any of the government's farmland consolidation programs; the fields in the area are scattered with irregular boundaries. Cross-field irrigation is commonplace, which defies even a minimal degree of implementation of the RIS. In cross-field irrigation, water has to go through farmers' fields to reach a destination. The issue of property rights is involved, as irrigation water is allowed to pass through a farmer's field only if the farmer who owns the field is willing to let that happen. Even if the farmers agree to perform cross-field irrigation, they have to resolve a whole array of coordination problems regarding planting scheduling and the synchronization of water delivery (Sparling 1990; Ostrom and Gardner 1993).

The complexity involved in managing cross-field irrigation and the benign neglect by the IA created an environment that allowed farmers in Guiren-Yirenjun a high degree of autonomy in managing irrigation at the sublateral level. The IGs in Guiren-Yirenjun had experimented, developed, and enforced a large array of innovative rules to cope with the irrigation problems they faced in particular situations. Different IGs also cooperated with one another to deal with problems pertaining to their collective interest. Although the Guiren-Yirenjun WS still put together an irrigation plan at the beginning of every planting season, both the staff and the farmers were fully aware that the plan was not meant to be followed seriously.

Beginning in the early 1980s, industrialization in Guiren-Yirenjun brought not only job opportunities but also serious water-pollution problems. As a result, some farmers chose to quit farming. The perturbations as a result of macro changes mentioned earlier have further reduced farmers' incentive to engage in irrigation management, which often resulted in a free flow of irrigation water in canals. Unlike irrigation systems in other areas of Chianan, however, farmers in the Guiren-Yirenjun area have been eager to rebuild a working order through efforts of renovating and innovating local irrigation institutions. It would be impossible to provide a catalogue of these institutional innovations, suffice here to provide a number of exemplary examples that hopefully could illustrate the scope of the institutional innovations.

The Shengkang IG in Guiren-Yirenjun had been plagued by serious conflicts between member-users and non-member-users. The farmers in Shengkang IG decided that they could better defend their collective interest against the non-members if they could enforce a certain degree of rotation of water appropriation among themselves. To make it possible, they relegated their individual water rights to the IG leader, who was given full authority in managing water delivery in the fields. In Beibeitzetau IG, the prevalence of part-time farming rendered the existing rule – that farmers should appropriate water by turns – impracticable. Instead of sticking to the existing rule, members of the IG decided that each of them would report their water-use preferences to the IG leader on a regular basis. Based upon the information, the IG leader would determine the overall water delivery schedule. A caveat is warranted. The institutional change and innovations that have taken place in many IGs in the Guiren-Yirenjun area did not just happen in an institutional vacuum. The rule-crafting activities were possible only because the WS acquiesced, if not actively supported, farmers' rule-crafting efforts.

4. Discussion

4.1. Nesting and adaptation strategies

By nesting irrigation systems with the RIS and the integrated irrigation infrastructure, irrigation in Chianan was meticulously planned and designed to be tightly controlled by the IA. The viability of the tight control hinges upon a close alignment between the processes of irrigation management on one hand, and parameters of the task environment pertaining to the structure of agriculture and its role in the economy on the other. Specifically, irrigation management in Chianan is designed with a view to maximizing water utilization for paddy cultivation. As paddy cultivation declined, both the RIS and the integrated irrigation infrastructure ceased to be relevant to problem-solving in the new task environment. For instance, part-time farmers could no longer afford to follow strictly the water allocation schedule specified in the irrigation plan. Farmers faced the tremendous challenge of adapting to the changing environment.

In Table 1 we array and compare the modes of nesting, strategies of adaptation, and patterns of institutional change in irrigation systems in the four ecological-physical settings. The pattern that emerges is in line with our expectation that there is a trade-off between control and adaptive flexibility. The more tightly a system is nested, the less likely the system is to adopt institutional change as an adaptation strategy, and the lesser the extent to which institutional diversity has evolved. Specifically, farmers in Sinkang where irrigation systems are tightly nested through the RIS and the integrated irrigation infrastructure have been largely dependent on the IA for resolving the problems brought about by the changing environment; they have been most reluctant to engage in institutional change at the local level as a strategy of adaptation. As the local irrigation institutions became increasingly irrelevant to problem-solving in the new task environment, they were ignored and deteriorated rapidly. In sharp contrast, farmers in

Table 1: Nesting structure and adaptation strategies.

	Extent and structure of nesting	Farmers' adaptation strategies	Patterns of change of local institutions
Sinkang	**Tightly nested** Through strict adherence to RIS and heavy infrastructure investment.	Seeking help from IA for more intensive management and infrastructure investment.	A rapid deterioration of local institutions.
Kungwen	**Disjointedly nested** Through adherence to RIS with major modifications with a view to strengthening horizontal complementary among farmers.	Responses falling into two extremes. While some farmers take the initiative to perfect the existing rules, some simply give up.	Rigorous yet unstable rule-crafting efforts in pockets of systems, resulting in a certain degree of institutional diversity.
Guiren-Taipu	**Weakly nested** Through infrastructure investment from the IA and complementary actions from farmers and IA officials.	Seeking help from IA for continual infrastructure investment with farmers fine-tuning the local rules to cope with contingencies at specific locales.	Relatively minor institutional changes with narrow scopes.
Guiren-Yirenjun	**Minimally nested** Through a recognition of autonomy and farmers' collective action.	Crafting and re-crafting rules for better collective action.	Rigorous rule-crafting efforts with a high degree of institutional diversity.

Guiren-Yirenjun where irrigation systems are minimally nested have shown significant willingness to take problem-solving in their own hands; they have been most aggressive, and also most successful, in adjusting and re-crafting local rules to cope with problems brought about by the macro changes.

Irrigation systems in Kungwen are nested institutionally through the RIS but lack the integrated irrigation infrastructure. Farmers in the area adopted strategies of two extremes; while some tried hard to stick to the RIS, often with minor fine-tuning of local rules, others simply gave up completely. As a result, one can find in Kungwen confined rule-crafting efforts in pockets of systems resulting in a certain degree of institutional diversity at the local level on one hand, and a total demise of some irrigation systems and institutions on the other.

Irrigation systems in Guiren-Taipu are nested mainly through the integrated irrigation infrastructure but not the RIS. Farmers in Guiren-Taipu also perceived lobbying the IA for more infrastructure investment as a good coping strategy. Yet unlike systems in Sinkang that received water from reservoirs, systems in Guiren-Taipu are river-fed which does not allow a strict implementation of the RIS. Farmers in Guiren-Taipu had to coordinate among themselves in water delivery, which often required them to engage in rule-crafting activities. When faced with the changing environment, farmers in Guiren-Taipu have shown some readiness to adopt rule-crafting as an adaptation strategy. The integrated irrigation infrastructure, however, limited the scope of the rule-crafting efforts. As a result, only minor institutional adjustments have taken place in systems in Guiren-Taipu, usually with a narrow scope.

4.2. Adaptation strategies and performance trade-offs

The choice of adaptation strategy has serious implications for trade-offs between dimensions of irrigation performance and, hence, system robustness and self-governance. The irrigation performance of systems in the four settings is detailed in Table 2. To examine the performance trade-offs, we shall compare different dimensions of performance across irrigation systems in the four ecological-physical settings. In consideration of the non-normal distribution of the parameter values, we adopt non-parametric methods to gauge the statistical significance of the differences in performance between systems across the four ecological-physical settings. The 95% confidence intervals of the difference in the paired group-medians are displayed in Figure 2.[8]

[8] We apply the Mann-Whitney U test in the R statistical program to estimate the difference between the medians of the response between paired systems, where the two-tailed alternative hypothesis is defined as $m_1 - m_2 \neq 0$, m_i being the median of the response of group i. We heed the advice from Cohen (1994) and Gill and Meier (2000), and focus the interpretation on the interval estimates of the value of $m_1 - m_2$ instead of subjecting the small dataset to null hypothesis significance testing (NHST). This method is also suitable, as it follows the analytical emphasis on relative rather than absolute differences across the systems.

*Table 2: Multiple dimensions of irrigation performance.**

	Mean				Median			
	Sinkang (N=13)	Kungwen (N=8)	Guiren-Taipu (N=5)	Guiren-Yirenjun (N=8)	Sinkang (N=13)	Kungwen (N=8)	Guiren-Taipu (N=5)	Guiren-Yirenjun (N=8)
Percentage of fallowed lands (%)	21.46	62.25	47	36.75	18	57.50	50	47.50
Reliance on groundwater in late 1990s (%)	3.31	–	16	17.50	1	–	20	17.50
Reliance on groundwater in 2008 (%)	16.23	–	23.60	16.88	10	–	25	17.50
Change in reliance on groundwater** (%)	+12.92	–	+7.6	−0.62	+9	–	+5	0
Farmer involvement in early 1980s (%)	21.79	25.16	38	32.50	17.50	18.75	37.50	27.50
Farmer involvement in 2008 (%)	9.13	2.03	23.25	21.19	6.25	0	23.75	16.25
Extent of mutual help among farmers (%)	18.23	2.13	18	25.63	8	0	10	20
Extent of deprivation	0.69	0.25	1.40	0.75	0	0	2	0
Extent of conflicts	0.15	0.50	0.80	0.63	0	0.50	0	0
Social capital	2.38	2.125	2	2.38	3	2.50	2	3
Management order	2.08	3.25	2.60	4	2	4	3	4

*For details, refer to Appendix 2.

**The score of 'change in reliance on groundwater' is calculated by subtracting the 1998 figure from the 2008 figure for systems in each ecological-physical setting.

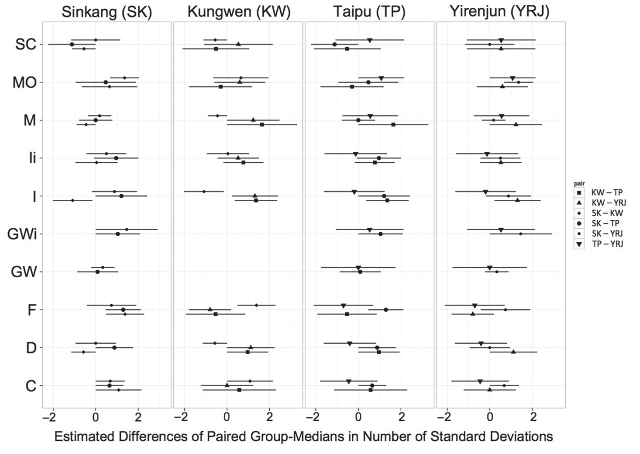


Figure 2: Estimated differences of paired systems on social capital (SC), management order (MO), mutual help (M), farmer involvement-past (I), farmer involvement-present (Ii), groundwater-past (GW), groundwater-present (GWi), fallowed lands (F), deprivation (D), and conflicts (C).
Note: Each graph pairs one region with the other three. Groundwater measures are not available for Kungwen.

4.2.1. Availability of a predictable supply of irrigation water

Farmers' choice of adaptation strategy affects water delivery and hence whether the farmers are able to receive a predictable supply of irrigation water. One measure of the availability of a predictable supply of water is the extent of fallowing in a particular area – farmers who face an unpredictable water supply are more likely to fallow their lands. Data presented in Table 2 suggest that systems in Sinkang stand out as having the lowest level of fallowing among systems in the four settings; the differences in the level of fallowing between Sinkang and the other three ecological-physical settings are, in general, significant (see Figure 2). To cope with the problems brought about by the changing environment, farmers in Sinkang chose to lobby the IA for more infrastructure investment. The better irrigation infrastructure seems to have paid off; systems in Sinkang have been robust in regards to water adequacy, and have enjoyed a predictable water supply in recent years.

Does putting in place better irrigation infrastructure guarantee a predictable water supply? Our data suggest not. While farmers in Guiren-Taipu have adopted a similar strategy of aggressively lobbying the IA for infrastructure investment, their systems have not performed as well in terms of the availability of a predictable water supply; a typical system in Guiren-Taipu has about 47% of its farmlands fallowed (see Table 2). What could have caused the difference?

Although canals in Guiren-Taipu are lined and meticulously constructed in grids, systems in this area are all river-fed. Given that the IA has only limited control over water flow in rivers, a strict implementation of the RIS is impossible. As a result; whether farmers are able to coordinate among themselves for water delivery became an important factor affecting the availability of a predictable supply of water. Unfortunately, the physical rigidity embedded in the integrated irrigation infrastructure has often constrained farmers' rule-crafting efforts. Guiren-Taipu's experience suggests that infrastructure alone might not be sufficient to bring about a predictable supply of irrigation water; the strategy of putting in place better infrastructure would work only if it is complemented by a strict implementation of the RIS.

Among systems in the four ecological-physical settings, those in Kungwen had the lowest performance in terms of the availability of a predictable supply of water; an average system in Kungwen has 62% of its farmlands left fallowed. Systems in Kungwen are nested through the RIS but without the support of the integrated irrigation infrastructure. With the RIS in place, farmers in Kungwen had limited flexibility in adjusting local irrigation institutions to adapt to the changing environment. While some systems managed to maintain water delivery through following closely the RIS, others failed and demised. It is warranted to point out that the extent of fallowing in Kungwen has a high level of variance across individual systems and a large range of performance (see Table 3), reflecting the bifurcation of strategies adopted by different systems.

Instead of sticking to the RIS; farmers in Guiren-Yirenjun have taken an alternative path – focusing on crafting and re-crafting local rules that cope with the macro changes. The more they re-craft the rule, the more they deviate from the RIS. One would have expected that a deviation from the RIS and an absence of infrastructure investment would render the systems vulnerable to water inadequacy. Our data, however, suggest otherwise. An average irrigation system in Guiren-Yirenjun has about one-third of its farmlands fallowed. This level of fallowing is lower than those of Kungwen and Guiren-Taipu, suggesting that the self-governing effort of farmers in Guiren-Yirenjun has somehow made up for a lack of infrastructure investment, and been able to generate innovative rules to cope with novel problems in the new task environment.

Table 3: Fallowed lands in Kungwen.

Irrigation group	Fallowed lands in percentage of total cultivated areas
Sher Tien	25
Tu Cheng Tze	90
Xue Jia Liu	30
Sha Lun Jiao	90
Xi Nan Liu	50
Xi Pu Liu	98
Si Kung Chin Liu	65
Si Xue Jia Liu	50

4.2.2. Reliance on groundwater

The strategy of substituting farmers' collective action with irrigation infrastructure has its limits; when farmers perceive that better engineering works can spare them from irrigation management chores, a return to the infrastructure investment will only increase in a decreasing rate before leveling off (Ostrom and Gardner 1993; Lam 1996a, 1998). In Chianan, except for areas such as Kungwen where groundwater is not available, farmers usually appropriate groundwater to supplant or supplement surface water provided by the IA. Given that surface water is free of charge but the appropriation of groundwater incurs costs, groundwater is used only when farmers do not receive a stable supply of surface water. Therefore, the pattern of groundwater use can be taken as a proxy to gauge if the water provided by the IA can meet farmers' need.

Our appraisal survey collected information about the percentage of farmlands in the irrigation systems that relied on groundwater to supplant surface irrigation in 1998 and 2008, respectively. A comparison of the two percentage figures allowed us to chart the trend of groundwater use in irrigation systems (see Table 2). We also gauged the statistical significance of the longitudinal change in reliance of groundwater for systems in each of the four ecological-physical settings which, together with the 95% confidence intervals of the difference, is shown in Figure 3. The data suggest that, despite a predictable supply of surface irrigation water made available by infrastructure investment, groundwater use in systems in Sinkang increased almost four times during the period from 1998 to 2008. Such a counter-intuitive pattern is indicative of a high degree of wastage, probably due to a rapid deterioration of irrigation management order and institutions at the local level (these issues will be further discussed in the following section). Similar situation can be found in Guiren-Taipu where farmers have lobbied the IA very hard for more infrastructure investment. Over the last decade, the use of groundwater to supplement surface irrigation in Guiren-Taipu has increased by over 7%.

With scattered paddy fields and meandering canals that are mostly unlined, cross-field irrigation has put farmers in Guiren-Yirenjun in a highly interdependent situation. The need to collaborate with one another has provided ample opportunities for farmers in Guiren-Yirenjun to practice self-governance and to work out local institutions for problem solving. Of course, a willingness to work with one another per se is insufficient for collective action; farmers are able to engage in rule-crafting activities only if they are given the liberty or the institutional space to do so. Ironically, the seemingly less "sophisticated" canals in Guiren-Yirenjun allow irrigation systems to be decoupled from one another, and inadvertently provide individual systems the necessary flexibility for institutional innovation that suits the local situation best. While some farmers have given up farming, those who chose to continue seem to be able to manage water delivery rather effectively. In fact, Guiren-Yirenjun stands out as the only area among the four settings in which irrigation systems have actually reduced their reliance on groundwater over the last two decades.

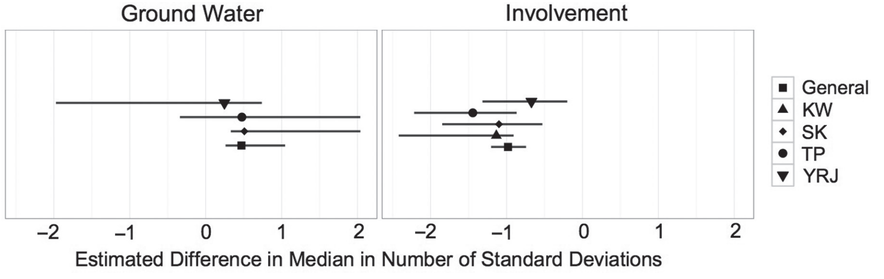


Figure 3: Longitudinal comparison of groundwater and involvement.
Note: The median farmer involvement has decreased universally. The pattern for groundwater suggests greater cross-system variation in groundwater use, with the increase in consumption more pronounced in Sinkang (SK) and Taipu (TP) but less so in Yirenjun (YRJ).

4.2.3. Management order, deprivation and conflicts

Our data suggests that the strategy of substituting farmers' collective action with infrastructure investment seems to have compromised farmers' self-governing capability. Specifically, while farmers in Sinkang have always been minimally involved in irrigation operation and maintenance (O&M); the level of involvement has further decreased substantially over the last decades. In the survey, we also asked the IG leaders to evaluate the extent to which some order of water delivery was maintained in the systems. Interestingly, while farmers in Sinkang have always insisted on clinging to the irrigation plan and the RIS, they were in general the ones who have been least able to maintain a management order in their systems.

With a low level of farmer involvement and relatively poor water delivery order, one would have expected that conflicts and disputes among farmers in Sinkang would be most prevalent. Such an expectation, however, could not be further from what we found. Irrigation systems in Sinkang have the significantly lowest level of irrigation conflicts among systems in the four ecological-physical settings. As far as the farmers are concerned, it is the IA that should ensure a predictable water supply and solve any irrigation problems. In Sinkang, the low level of conflicts is more a reflection of farmers' dependent mind-set than a good management order.

In Guiren-Taipu, with the lined canals in grid, a high degree of interdependence of farmers is literally built in the physical setting of the systems. The effectiveness of rule change in one system often hinges upon correspondent adjustments made by the other systems in the area. Interdependency is a double-edged sword. It could be a major source of conflict if farmers distrust one another, but if farmers could develop a level of mutual commitment, interdependence provides incentives for farmers to cooperate with one another. As either one of these two scenarios (mutual distrust vs. mutual commitment) is equally plausible, one can observe an oscillation between chaos and order in irrigation management in the area. Our data suggest that while farmers in Guiren-Taipu have always been heavily involved in irrigation O&M at the local level, they did not receive very good payoffs, and have largely failed to develop and sustain a productive working relationship. The extent of deprivation, measured by the proportion of farmers who are consistently placed in a disadvantaged position, is substantially higher in systems in Guiren-Taipu than those in the other ecological-physical settings.

The combination of the high stakes involved in irrigation and a hostile task environment has posed to farmers in Kungwen two drastically different options of adaptation strategy. They could either further increase their efforts to comply with the RIS so as to maintain a level of management order, or give up irrigation completely as the incentive for free-riding in the social dilemma situation was overwhelming. Our data show that systems in Kungwen have been doing relatively well in maintaining some order of water distribution and allocation. Bearing in mind that many systems in Kungwen are not even functioning, the data actually suggest that those that remain functioning are doing well in maintaining working order in the field. As mentioned earlier, the strategy adopted by farmers in the relatively successful systems is to adhere to the RIS to the extent possible. As the RIS implicitly stipulates individual farmers' entitlements to water, it has effectively helped the farmers to minimize conflict. Our survey data suggest that systems in Kungwen, on average, have the smallest number of farmers who are consistently put in a deprived situation; and the differences between Kungwen and the other ecological-physical settings are significant at a 95% interval.

The RIS focuses on turning water allocation into a series of individualistic acts of water appropriation; the more strictly the farmers stick to the RIS, the less likely they see the need to engage with one another for collective action. In other words, a counter-intentional outcome of a strict implementation of the RIS is that it has taken away farmers' incentive and opportunities to engage in collective action. If one compares the levels of involvement in Kungwen between the early 1980s and 2008, one will see a rather substantial drop. The extent of mutual help among farmers in Kungwen is also the lowest among irrigation systems across the four settings. With the substantial deterioration of the farmers' ability to engage in collective action, it is dubious as to whether farmers in Kungwen would be prepared to cope with further external shocks.

Farmers in Guiren-Yirenjun have always been heavily involved in irrigation operation and maintenance (O&M) activities at the local level. Although the absolute level of involvement has decreased over the last two decades, it remains one of the highest in the Chianan area. Farmers in Guiren-Yirenjun are also shown to be better able and willing to help one another. As shown in Table 2, among the systems in the four ecological-physical settings, those in Guiren-Yirenjun have been able to maintain the best irrigation management order, though, due to high variance, the differences do not pass the 95% confidence interval test (See Appendix 2).

5. Conclusion

In this study we have shown that ecological-physical factors, such as whether a system is reservoir-fed or river-fed and whether sophisticated integrated irrigation infrastructure is in place, affect the way an irrigation system is nested into the broader water management regime. We have analyzed how different modes of nesting have affected the farmers' choice of adaptation strategies in Taiwan; and examined the patterns of performance trade-offs incurred in the adaptation. Several lessons have been identified. First, for farmers in systems that are tightly nested within the broader ecological-physical setting, rule-crafting could be a rather risky adaptation strategy with uncertain outcomes. Second, even if farmers in the tightly nested systems decided to engage in rule-crafting as an adaptation strategy, they could only choose from a rather limited set of potential rules for institutional change. Third, the extent to which an irrigation system is coupled with other systems in the same hydrological region also affects the viability of institutional change as an adaptation strategy. Systems that are heavily coupled tend to have lower degrees of autonomy in making institutional choices at the local level. Fourth, irrigation institutions that are designed to maximize control of water delivery often risk the loss of adaptive flexibility in regards to changing rules at the local level. Last but not least, the multiple dimensions of performance do not necessarily respond to a particular adaptation strategy in a consistent manner (Gibson et al. 2005; Ostrom 2005a; Lam and Ostrom 2010).

Our study provides some evidence on the importance of self-governance in irrigation management. Self-governance may not be a panacea that can solve all the problems of irrigation in all places at all times (Meinzen-Dick 2007; Ostrom 2007; Lam 2010; Ostrom et al. 2011), yet as our study has shown, it is at the core of a system's ability to continue to adapt to the changing environment. One could rely on continual infrastructural investment and perhaps intensive management control to keep an irrigation system running; yet without farmers appreciating their roles in irrigation management and taking the challenges of crafting and re-crafting local rules to cope with the changing environment, the seemingly high level of control over water delivery is only built on sand and highly fragile to external disturbances.

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Appendix 1. Physical and agricultural characteristics of the ecological-institutional settings.

		Sinkang	Kungwen	Guiren-Taipu	Guiren-Yirenjun
Hydrological/physical characteristics	A. Planned water supply (cms)*	274.08	191.23	118.05	75.29
	B. Actual water supply (cms)	196.69	98.39	70.00	34.30
	Water shortage percentage (A-B/A*100%)	28.23%	48.54%	40.70%	45.6%
	Total length of canals (m)	198,397	101,779	60522.5 (including a 9126 m lateral shared with Yirenju)	80590.5 (including 9126 m lateral shared with Taipu)
Social-agriculture information	Service area (ha)	1600.33	5052.00	448.26	522.56
	Production of paddy per hectare in 2008 (ton/ha)	10.31	6.67	8.50	7.50
	Total number of farmer-members	6006	5343	2684	2894

Note: All data are as of 2008.
*cms refers to "cubic meter per second", which is used to measure the amount of water a particular area will receive during the water delivery periods for the area as specified in the Irrigation Plan.
Sources: Chianan Irrigation Association Headquarters, Sinkang Working Station, Kungwen Working Station, and Guiren Working Station.

Appendix 2. Results of appraisal survey conducted in 2008.

What is the percentage of the service area in your irrigation system that was fallowed this year?

Ecological-institutional setting	N	Mean (%)	Median (%)	Max (%)	Min (%)	Standard deviation
Sinkang	13	21.46	18	65	0	20.57
Kungwen	8	62.25	57.5	98	25	28.17
Guiren-Taipu	5	47.00	50	55	35	7.58
Guiren-Yirenjun	8	36.75	47.5	70	3	26.5

What is the percentage of the service area in your irrigation system that needed to appropriate groundwater to supplement surface irrigation 10 years ago?

Ecological-institutional setting	N	Mean (%)	Median (%)	Max (%)	Min (%)	Standard deviation
Sinkang	13	3.31	1	20	0	5.97
Kungwen	8	–	–	–	–	–
Guiren-Taipu	5	16.00	20	30	0	11.4
Guiren-Yirenjun	8	17.50	17.5	55	0	24.01

What is the percentage of the service area in your irrigation system that needs to appropriate groundwater to supplement surface irrigation?

Ecological-institutional setting	N	Mean (%)	Median (%)	Max (%)	Min (%)	Standard deviation
Sinkang	13	16.23	10	70	1	25.4
Kungwen	8	–	–	–	–	–
Guiren-Taipu	5	23.60	25	50	0	17.95
Guiren-Yirenjun	8	16.88	17.5	55	5	18.1

In the early 1980s, what was the percentage of members in your IG who participated in (1) weeding, (2) canal upkeep, (3) water delivery, and (4) canal clearing and repairs?
(The maximum score for each activity is 100%; the aggregate score for this variable is the average percentage of the four activities, with a maximum of 100%.)

Ecological-institutional setting	N	Mean (%)	Median (%)	Max (%)	Min (%)	Standard deviation
Sinkang	13	21.79	17.5	56.25	1.25	16.30
Kungwen	8	25.16	18.75	60	12.5	15.70
Guiren-Taipu	5	38.00	37.5	52.5	28.75	8.87
Guiren-Yirenjun	8	32.50	27.5	61.25	10	17.92

What is the percentage of members in your IG who have participated in (1) weeding, (2) canal upkeep, (3) water delivery, and (4) canal clearing and repairs?
(The maximum score for each activity is 100%; the aggregate score for this variable is the average percentage of the four activities, with a maximum of 100%.)

Ecological-institutional setting	N	Mean (%)	Median (%)	Max (%)	Min (%)	Standard deviation
Sinkang	13	9.13	6.25	25	0	8.24
Kungwen	8	2.03	0	16.25	0	5.74
Guiren-Taipu	5	23.25	23.75	37.5	5	12.80
Guiren-Yirenjun	8	21.19	16.25	52.50	2	18.84

What is the percentage of members in your IG who still help out their fellow members in agriculture-related matters, including irrigation?

Ecological-institutional setting	N	Mean (%)	Median (%)	Max (%)	Min (%)	Standard deviation
Sinkang	13	18.23	8	100	0	26.71
Kungwen	8	2.13	0	10	0	3.64
Guiren-Taipu	5	18.00	10	60	0	24.9
Guiren-Yirenjun	8	25.63	20	80	0	29.21

What proportion of members in your irrigation system has been put in a disadvantaged position, such as consistently receiving inadequate water?

0 – None; 1 – Only a few; 2 – Some; 3 – Quite many

Ecological-institutional setting	N	Mean	Median	Max	Min	Standard deviation
Sinkang	13	0.69	0	3	0	1.03
Kungwen	8	0.25	0	1	0	0.46
Guiren-Taipu	5	1.4	2	3	0	1.34
Guiren-Yirenjun	8	0.75	0	3	0	1.16

How often do conflicts concerning irrigation arise?

0 – Never; 1 – Occasionally; 2 – Quite often; 3 – Very often

Ecological-institutional setting	N	Mean	Median	Max	Min	Standard deviation
Sinkang	13	0.15	0	1	0	0.38
Kungwen	8	0.5	0.5	1	0	0.53
Guiren-Taipu	5	0.8	0	3	0	1.30
Guiren-Yirenjun	8	0.63	0	3	0	1.06

How would you describe the way members in your IG interact with one another?

0 – They don't really know one another well; 1 – They know one another, but do not get along; 2 – They know one another, but only a small number of them get along; 3 – They know one another and a majority of them get along well

Ecological-institutional setting	N	Mean	Median	Max	Min	Standard deviation
Sinkang	13	2.38	3	3	1	0.87
Kungwen	8	2.13	2.5	3	1	0.99
Guiren-Taipu	5	2	2	3	1	1
Guiren-Yirenjun	8	2.38	3	3	1	0.92

How would you describe the pattern of water delivery in your system?

1 – Free flow of water; 2 – Free flow of water, with scattered water-management efforts; 3 – Turns of water delivered to canals; 4 – Turns of water delivered to canals, supplemented by management efforts to deliver water to farmers' fields; 5 – A specific amount of water delivered to farmers' fields at a specific time

Ecological-institutional setting	N	Mean	Median	Max	Min	Standard deviation
Sinkang	13	2.08	2	4	1	1.04
Kungwen	8	3.25	4	5	1	1.98
Guiren-Taipu	5	2.6	3	4	1	1.14
Guiren-Yirenjun	8	4	4	5	1	1.31