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The robustness of Montane irrigation systems of Thailand in a dynamic human–water resources interface

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Abstract: This paper examines the dynamism and robustness of two irrigation systems of the Kok River system within the Mekong River basin in northern Thailand in the context of changing governance mechanisms and evolution of technological and market forces. It analyzes both temporal and spatial dynamism of the irrigation systems. The temporal dynamism was analyzed over three phases: before intervention, initial operation, and long-term. The before intervention phase analysis examined the effect of various attributes of users on starting an irrigation system, whereas the initial operation phase inquiry included the process of development of rules and level of autonomy in developing the users' own rules over time. The long-term phase analysis focused on external factors affecting the sustainment of these irrigation systems. Spatial dynamism was examined across upstream and downstream systems and within different locations of the system. The analysis was centered on linkages and relationships between five entities: resource, resource users, public infrastructure, public infrastructure providers, and external disturbances. Both systems were still robust, owing to the sustainment of local customs and the role of local leaders still vital, albeit in different forms. The group efforts, their self-governing capabilities, and local institutions, including the changed role of leaders in dealing with external forces, have played an important role in maintaining the robustness of these systems.

1. Introduction

Globally, 17% of the world's cropland is irrigated, producing one-third of the world's food.[1] Out of this irrigated area, almost three-quarters are in developing

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1 The irrigation systems under study fall within the so-called Montane areas. These are found in the southwestern provinces of China, Laos, northern Viet Nam, Myanmar, and Thailand. An earlier version of this paper was presented at the 'Workshop on the Workshop 3' conference at the Workshop in Political Theory and Policy Analysis, Indiana University, Bloomington, Indiana, USA, 2–6 June 2004. We appreciate the comments made by Marco Janssen, Elinor Ostrom, and two anonymous reviewers on the earlier version and the editing assistance provided by Patty Lezotte and Shiddi G. Shrestha. Funding for this research was provided by the Ford Foundation (Grant # 1015: 'Asian Irrigation Institutions and Systems in Transition: Sustainability Implications' made to the Asian Institute of Technology) and the Research Grants Council of Hong Kong (Grant # HKU7233/03H), which are duly acknowledged.

countries and 60% in Asia (Geijer *et al.*, 1996). The total irrigated area in the world has expanded rapidly since the 1950s, with almost three-fold of its increase between 1950 and 1980 and 50–60% of its contribution to a huge increase in agricultural production in developing countries from 1960–1980 (Ostrom, 1992). The expansion of irrigated land has greatly affected the quantity of rice produced in Asian countries such as India, Indonesia, Pakistan, the Philippines, Sri Lanka, and Thailand (ibid.). Due to the large-scale contribution on the national economy of Asian countries, irrigation development and management have been the main agenda in these countries' national development plan (Barker and Molle, 2005).

Previous studies in some of these countries have shown that farmers in different settings tend to adopt various strategies to cope with the changing environment through the diverse patterns of institutional designs and development (Lam, 1998; Ostrom *et al.*, 2002; Shivakoti and Ostrom, 2002). The level of irrigation system performance is directly related to the capacity of appropriators' self-governing abilities and their individual level of participation based on the 'design principles' of governing the commons. The importance of the principles in 'long-enduring' self-organizing irrigation institutions was highlighted by Ostrom (1990, 1993, and 2005), in which she cautions against the blanket approach of policy recommendations.

The large number of case studies documented over the nearly three decades suggests that improvement in the performance of irrigation and other resources was enhanced by systems of polycentric governance with some degree of autonomy rather than centralized institutions (McGinnis, 1999, 2000). Also, several variations in interventions and in performances of irrigation systems have been documented extensively, together with the major policy lessons learnt (Medagama, 1987; Shivakoti, 1992; Tang, 1992; Pradhan, 1989; Lam *et al.*, 1997; Lam, 1998; Hilton, 2002; Shivakoti and Ostrom, 2002). However, a very large proportion of early work on irrigation, as well as other common-property institutions, focused on static arrangements and on analysis of cross-section data. Few studies were carried out over time for an innovative intervention approach of farmer-to-farmer training adopted by the Water and Energy Commission Secretariat and the International Irrigation Management Institute in Sindhupalchowk district of Nepal (Lam and Shivakoti, 2002).

The issue of the study of irrigation management dynamism has become important to facilitate policies that have to be evaluated in light of the changes that have taken place during the last several decades and that have direct bearings on the performances of irrigated agriculture in Asia. These include population growth, urbanization, globalization, integration of local communities into national society or economy, commercialization of agriculture, labor mobility, movement of younger generations out of agriculture, increasing competition for land and water resources, high costs of irrigation system development and rehabilitation, and environmental degradation (Vermillion *et al.*, 2005). Vermillion *et al.* (2005) further warn that socioeconomic and ecological changes,

in general, are racing well ahead of the pace of institutional change, based mainly on the principles of quick-fixes and panaceas.

Dynamism in the resource-use pattern can be analyzed by examining the changes in institutional arrangements within a Social Ecological System (SES). The SES is defined by society–environment relations that are relevant to sustainable development within a certain problem area (IAE, 2005). The SES is based on the belief that social and ecological systems are linked and cannot be considered independent of each other. Thus, a SES is an ecological system intricately linked with, and affected by, one or more social systems. Both social and ecological systems contain units that interact independently, and each may also contain interactive subsystems. The entities in a SES include the resource itself, the resource users, public infrastructure providers, public infrastructure, and external disturbances (Anderies *et al*., 2004). Moreover, the over-time flow of people, money, and markets – which are the defining features of the regional, political, and economic landscapes in which the irrigation systems respond – takes place at varying levels. These dynamic factors have influence both during the beginning of the construction as well as operation and maintenance of these systems (Baker, 2004).

SESs are dynamic systems, undergoing continuous transformations. The transformation of SESs is characterized by complex interactions among heterogeneous elements (IAE, 2005). The SES is influenced by external disturbances as defined by 'any relatively discrete event in time that disrupts ecosystem, community, or population structure and changes resources, substrate availability, or the physical environment'. A disturbance regime is defined in terms of the scale, frequency, predictability, and severity of disturbances (Turner *et al*., 1998). Many long-lived SESs have adapted their institutions to the disturbance regime they have experienced over time as well as to the broader economic, political, and social systems in which they are located (Ostrom, 1990; Chakravarty-Kaul, 1998; Agrawal, 1999).

Similarly, various long-lived SESs are affected by changing global social-ecological processes that challenge the internal robustness of the SESs. Baker (2004) analyzed the robustness of 39 *kuhls* (irrigation systems) in the Kangra Valley of Himachal Pradesh in India. These *kuhls* are facing two types of disturbances: natural events and changes in the political economy of the region. Out-migration, due to effects of the market economy, has created acute labor shortages for communal water management tasks and has challenged regime capacities for mobilizing labor for annual repair and maintenance. Similarly, the complexly nested irrigation institutions of Taiwan have attracted considerable attention from the scholarly community over time (Moore, 1989; Lam, 2001). In some cases of multi-level SESs, relatively robust local SESs have been seriously challenged by a lack of understanding of how they operated and why an effective linkage between resource users and public infrastructure providers is so important. Due to the cancellation of irrigation service fees, farmers are much less likely to volunteer work activities, to pay voluntary group fees, or to pay much

attention to what is happening on the canals and in the ecological environment around them as they had done earlier (Wade, 1995).

The nature of the collective actions required in constructing irrigation systems is different from maintaining them over time. In the beginning, the resource is a relatively untamed water source. The infrastructure may not be very well-developed, either in terms of physical or institutional development. The users may be able to act as their own public infrastructure provider or they may have to draw on others. Therefore, a meaningful analysis of irrigation dynamics can be divided into three phases: before intervention, initial operation, and long-term. In these phases, several external factors affect the performance and sustainability of irrigation systems. These dynamic responses are both related to broad economic and political changes as well as to the subsequent changes in the operational, collective-choice, and constitutional levels of rules governing these irrigation institutions.

This paper addresses the issues of the dynamics of irrigation systems by examining two irrigation systems diverting water from the Fang River, one of the tributaries of the Kok River system in Fang district within the Mekong River basin in northern Thailand, in the context of changing governance mechanisms and evolution of technological and market forces. Basically, the level of inquiry focuses on the operational and collective-choice levels within the irrigation systems themselves as they exhibit the robustness to external disturbances, such as changes in economic prices and labor mobility *vis-à-vis* changes in the authority over irrigation and the availability of funding. However, at the constitutional-choice level, the analysis also tried to relate irrigation management with broader economic and other changes.

2. Methodology

Study area and irrigation systems

There are several traditional irrigation systems in the northern part of Thailand. This study comprises the Mae Sao Community Irrigation System (MCIS) and the Thai Yai Community Irrigation System (TCIS) that are located in Fang and Mae Ai districts in the northern part of Chiang Mai province of Thailand respectively. Both systems draw irrigation water from the same Kok River within the Mekong River basin. During the 1950s, the Government of Thailand provided financial and technical assistance to the development of several existing, traditional irrigation systems. With such assistance, the weirs of some Muang Fai Systems (MFSs) (farmer-managed irrigation systems) were made of concrete or were reinforced at their foundation. In this way, the MFSs were gradually integrated into new technology and materials. Changes in either the whole or part of the structure may lead to adjustments in the relationship patterns among water users. The changes were rapid when a government-sponsored and centrally planned irrigation system was established to cover the area of

Table 1. Types and sources of data

Types and sources of data	Mae Sao ($n = 43$)			Thai Yai ($n = 18$)		
	Before intervention (1981)	Initial operational phase (1981–84)	Long-term phase (2003)	Before intervention	Initial operational phase	Long-term phase (2003)
1. Temporal						
Secondary	√	√	–	–	–	–
Primary	–	–	√	–	–	–
2. Spatial						
Primary			√ Head ($n = 22$) √ Tail ($n = 21$)	–	–	√ ($n = 18$)

Note: n = Sample size.

the several existing MFSs. A direct approach introduces a new technological, social, and institutional arrangement to local communities. The government irrigation organization under the Royal Irrigation Department (RID) was usually established to manage the irrigation activities required by the small working units in the fields. Furthermore, when the government began extensive development activities in agriculture around 1959, the irrigation administration in several areas was transferred to the central administration under the RID.

The Thai government, in cooperation with the German government, completed the construction of a permanent structure in MCIS in the Fang River basin in 1981. This project consisted of three main canals and used the same administrative organization as before the intervention. But due to the increased number and the lengths of the canals, the number of Kae Muang (local irrigation leaders) and assistants became unknown. With changes in social, economic, technical, and institutional arrangements over time, the need for water has also changed dramatically in both MCIS and TCIS, thereby, affecting water balance in the river.

Data collection and analysis

This study used both primary and secondary data for analyzing the temporal and spatial dynamism of MCIS and TCIS in the context of changing governance mechanisms and the evolution of technological and market forces. The secondary information for MCIS was mainly drawn from Viriyasakultron (1984) – specifically, his analysis on different aspects of irrigation management in the before intervention and during the initial operational phases. The primary information was collected from 43 households, 22 from the head ends and 21 from the tail ends of MCIS, to analyze the long-term temporal dynamism and the spatial analysis (Table 1). Primary information was also collected from TCIS

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to analyze upstream and downstream spatial dynamism and system robustness in the long term, since it shared irrigation water with MCIS from the same Kok River. A census survey of all 18 households was done in TCIS. The primary data were collected during 2003 through household surveys, with some moderation in the questionnaire used by Viriyasakultron in 1984. Some historical information about TCIS was collected through key informants on a recall basis.

The analysis focused on dynamism and robustness of these irrigation systems. Dynamism in this case means the pattern of change over time in different aspects of management of irrigation systems. Institutional and other management aspects of irrigation systems are influenced by endogenous and exogenous factors and also shape the direction of management change. The analysis of dynamism covers the institutional evolution process over time and space, considering both endogenous and exogenous factors.

Since the processes involved in the collective action initially were different from those of maintaining them over time, the temporal dynamism was examined over three phases: before intervention, initial operational, and long term. The first phase analysis examined various aspects of SES before intervention, whereas the initial operational phase analysis examined the process of development of rules and the level of autonomy in developing their own rules over time. The long-term phase analysis focused on external factors affecting the sustainment of these irrigation systems.

The spatial dynamism was examined between upstream and downstream systems as well as head and tail ends within the Mae Sao system. The spatial dynamism mainly captured the effect of changes in user participation in terms of resource mobilization and management between and within different parts of the irrigation systems. Spatial analysis was an attempt to analyze the long-term impact of changes in different elements of the irrigation systems.

In the case of examining robustness, our focus was mainly on the interaction of irrigation systems with external forces. The analysis focused on the inter-linkages among changes in the characteristics of the resource itself (structural improvement of irrigation system), changes in different aspects of resource users, role of public infrastructure providers, and the effect of external disturbances.

We, therefore, have analyzed the dynamism in the resource use pattern by examining the changes in the institutional arrangements within a SES. The entities in the case of these irrigation systems, a SES, are resource and resource users, public infrastructure providers, public infrastructure, and external disturbance. We centered our level of enquiry on the linkages and relationships among five entities: resource, resource users, public infrastructure, public infrastructure providers, and external disturbances. The summary of variables examined, three periods of times used for analysis, levels of analysis, external variables; and important interacting elements and linkages between them are presented in Table 2.

Group effectiveness was measured through Weighted Average Index (WAI) of the following indicators based on farmers' perceptions of: judgment about system

Table 2. Summary of variables examined in this paper

Variables examined
Dynamics of irrigation institutions reflecting robustness over time
Three periods of time
Before intervention
Initial operational phase
Long-term phase
Levels of analysis
Operational level
Collective-choice level
Constitutional-choice level
External variables
Changes in economic prices
Labor mobility
Changes in the authority over irrigation
Availability of funding for irrigation
Important interacting entities
Nature of resource
Resource users
Public infrastructure
Public infrastructure providers
External disturbance
Linkages between
Resources and resource users
Resource users and public infrastructure providers
Resource users, public infrastructure providers, and public infrastructure
Public infrastructure and resource
Public infrastructure and resource dynamics
Resource users and public infrastructure
External forces and resources
External forces and resource users

design and construction; water sufficiency in their own and neighbors' fields and by location of their fields; water use efficiency by location of fields and system as a whole; farmers' familiarity with and assessment of system rules; farmers' assessment of the system in regard to resource utilization and benefit distribution; and farmers' perceptions on rule enforcement and equal treatment. From the response of these indicators, WAI of effectiveness of group was constructed. Based on these indices, effectiveness was divided into four categories: hardly effective, limited effective, effective, and most effective.

3. Findings and discussions

Structural improvement and reduction in collective action

The government, as a public infrastructure provider, extended assistance to the downstream MCIS through the construction of a permanent weir and partial

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Table 3. Participation of farmers in irrigation activities during different periods in Mae Sao Community Irrigation System, Chiang Mai, Thailand

Activities	Participation, %		
	Before intervention (1981)	Initial operational phase (1981–84)	Long-term phase (2003)
Building of weir	86.4	10.7	25.6
Reconstruction or repair and cleaning of weir	88.3	23.3	48.8
Clearing and repairing of the ditch	98.0	62.2	67.4
Offering to the spirit of weir	37.9	2.9	18.6
Meeting to elect weir leader	93.2	73.8	67.4
Membership of water management committee	4.8	1.9	20.9
Participation in the resolution of conflict about water use	8.7	2.9	23.3
Requesting water from another weir	1.9	1.9	14.0

Source: Viriyasakultron (1984) and Field Survey (2003).

canal lining. It also assigned technicians to carry out maintenance. However, the upstream TCIS within a kilometer distance did not receive any assistance due to its location within the protected area. While the traditional labor contribution system for maintenance continued in the upstream system, it was replaced by staff hired by the government in the downstream system. In MCIS, the collective action was strong and pronounced for system maintenance before rehabilitation, but it disappeared considerably both from the main and branch canals after the assignment of government staff to the system.

The immediate impact of intervention on the traditional irrigation system was a substantial decline in people's (resource users) participation in irrigation activities. The sharp decline was from 86.4% to 10.7% in the building of the weir and from 88.3% to 23.3% in the reconstruction or repair and cleaning of the weir (Table 3). Participation in activities such as cleaning and repairing of ditch and offering to the spirit of weir also declined considerably after intervention.

Declining participation in collective action was mainly due to people's perception that construction of a new weir virtually eliminates maintenance efforts. In fact, maintenance is needed even after the construction of a new weir. Several community members were found to have been sending hired people in lieu of their own labor contribution for maintenance work. However, the people who participated after the completion of a new weir felt that the maintenance of the weir should be the joint responsibility of community members using the irrigation water.

There were variations in the contribution within a system. In MCIS, those at the head-end location of water distribution were involved in building the weir more than those from the tail-end location. Different ritual activities, such as

offering to the spirit of the weir and praying for rain ceremonies, have decreased considerably in MCIS, whereas such rituals were still continuing almost at the same level as before in the traditional TCIS. A decline in ritual practice was observed since the concrete canals provided much convenience in the delivery of irrigation water.

In all, the external intervention in terms of improving the resource condition (the structural improvement of the system) has in fact reduced people's participation in the long run. Before intervention, farmers themselves used to perform almost all activities related to irrigation management in both TCIS and MCIS collectively. Their collective actions were guided by Sanya Muang Fai and traditional customs under the leadership of Kae Muang. They used to contribute to the construction of the weir as well as the reconstruction, repair and maintenance of the weir. Considerable decline in such collective action was observed in the downstream MCIS after intervention, mainly relying on government-appointed employees for managing those activities.

Role of local leader in changing context

Kae Muangs have played a very important role in the water management of traditional irrigation systems, both in administrative and mechanical works. They were either elected or selected by the water users to supervise all activities concerning irrigation and to enforce rules. Their role was most prominent in the traditional irrigation system before, as well as even after the construction of a new weir and intervention in operation and maintenance work. A majority of the people still emphasized the role of Kae Muang and opined that management is not possible without them. Hence, their role was considered essential in both TCIS and MCIS, especially in tail ends of the latter.

Participation of resource users was also reduced to some extent after government intervention. Previously, they were reported to have been found actively participating with more emphasis on group work in irrigation management. The role of group work did not change much during the initial operational phase, in which 50% of the people responded that group work was key to the effective management of irrigation systems (Viriyasakultron, 1984). In the long-run phase, the effectiveness was measured through weighted index of effectiveness, constructed using the response of different indicators of effectiveness. Interestingly, effectiveness of group efforts in managing irrigation systems was higher in MCIS as compared to TCIS (Table 4).

The WAI value of effectiveness is higher in TCIS (WAI = 2.78) as compared to both the head-end (WAI = 2.59) and the tail-end (WAI = 2.71) of MCIS. However, if we only consider the responses on 'effective' and 'most effective' categories together, the effectiveness of groups in managing irrigation systems was reported by 59.1% and 66.6% respondents in head and tail sections of MCIS respectively and 55.5% respondents in TCIS (Table 4). The lower level of group responsibility and effectiveness in TCIS was attributed to the prevalence of

Table 4. Effectiveness of groups in managing irrigation systems

	Mae Sao		
Effectiveness	Head ($n=22$)	Tail ($n=21$)	Thai Yai ($n=18$)
Hardly effective	2 (9.1)	1 (4.8)	0 (0.0)
Limited effective	7 (31.8)	6 (28.6)	8 (44.5)
Effective	11 (50.0)	12 (57.1)	6 (33.3)
Most effective	2 (9.1)	2 (9.5)	4 (22.2)
WAI	**2.59**	**2.71**	**2.78**

Notes: n = Sample size; figures in parentheses indicate percentage.

Table 5. Response on importance of *Kae Muang* in the modern and traditional irrigation systems

	Mae Sao		
Response	Head ($n=22$)	Tail ($n=21$)	Thai Yai ($n=18$)
Yes, to a certain extent	5 (22.7)	1 (4.8)	0 (0)
Yes, definitely	7 (31.8)	4 (19)	5 (27.8)
Yes, very much so	10 (45.5)	16 (76.2)	13 (72.2)

Notes: n = Sample size; figures in parentheses indicate percentage.

contract farming with less incentive for contractors for group efforts and investment on the fixed assets like irrigation infrastructures. The increasing level of contract farming was attributed to the influence of globalization and market economy with dramatic change in communication. Hence, traditional upland self-farming has changed to contract farming by making use of market information.

Even though most water users responded that they were responsible and could manage the system effectively, they still thought Kae Muang was necessary for managing the irrigation system. Their role was reported equally important and effective in both the government-intervened MCIS as well as the traditional TCIS. As to the issue of whether the traditional leaders are still important in a modern and government-intervened system or not, a majority of the respondents emphasized Kae Muang's importance in managing the irrigation system (Table 5). Viriyasakultron (1984) has reported similar findings on this issue in his analysis for an initial operational phase immediately after intervention. Thus, the role of Kae Muang was found relevant and important even in a modern irrigation and contract farming system. It was also reflected through their role on these irrigation systems after the construction of a new weir. A majority of the respondents reported that the role of weir leader has not changed.

From these facts, it can be concluded that the role and the importance of Kae Muang was least affected in the changing context. They have, rather, gained importance in the centrally planned modern irrigation system. Thus, the fact that people thought the water users could not manage without Kae Muang, although the groups were responsible and capable of managing irrigation effectively by

Table 6. Conflict in water management at present

Conflict in water management	Mae Sao		Thai Yai ($n = 18$)
	Head ($n = 22$)	Tail ($n = 21$)	
No	13 (59.1)	4 (19.0)	10 (55.6)
Yes	9 (40.9)	17 (81.0)	8 (44.4)

Note: n = Sample size; figures in parentheses indicate percentage.

Table 7. Kinds of conflict at present

Kinds of conflict	Mae Sao		Thai Yai ($n = 8$)
	Head ($n = 9$)	Tail ($n = 17$)	
Not enough water	2 (22.2)	13 (76.5)	4 (50.0)
Available in head area only	2 (22.2)	2 (11.8)	1 (12.5)
Overuse of water	1 (11.1)	0 (0.0)	1 (12.5)
Chemical disposal in water	2 (22.2)	0 (0.0)	0 (0.0)
Delivery of water	1 (11.1)	2 (11.8)	1 (12.5)
Open and close gate	1 (11.1)	0 (0.0)	1 (12.5)

Note: Figures in parentheses indicate percentage, and total numbers include only those who responded.

themselves, might have resulted precisely from the existing conditions where the water users were organized in groups and guided by Sanya Muang Fai, under which they have institutionalized the supervision by Kae Muang. Another important aspect in this situation was the performance of Kae Muang. The majority of the respondents in both systems reported that Kae Muang was doing a good job in assisting the people in irrigation management. Similarly, regarding the level of satisfaction for the way in which Kae Muang was carrying out his duties and responsibilities, a majority of the people were satisfied with the performance of Kae Muang.

Conflict in water management

The change in resource mobilization and user participation over the three time periods has resulted in different conflicts in water management. Usually, conflict arose due to different factors, with considerable spatial variation in conflict within and across the systems. Conflict was seen more in tail water distribution areas (81.0%) of MCIS, and it was relatively low in TCIS and head water distribution areas of MCIS (Table 6). Conflict in water management was prominent in both systems.

Only a few respondents talked about conflict (except in tail water distribution areas of MCIS) owing to its sensitivity for communal harmony and integrity for irrigation system management. The most frequent water management conflicts resulted from inadequate irrigation water, water distribution biased towards the head area, overuse of irrigation water, water pollution by chemicals, water delivery in the field, and operation of water-regulating gates (Table 7). Among

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Table 8. Changes to be made for future improvements in conflict resolution

Changes	Mae Sao		Thai Yai ($n = 4$)
	Head ($n = 10$)	Tail ($n = 8$)	
Changes in law and order	3 (30.0)	2 (25.0)	0 (0.0)
Administrative change at higher level	1 (10.0)	1 (12.5)	0 (0.0)
Administrative change at lower level	0 (0.0)	1 (12.5)	2 (50.0)
Personal qualities of officers at higher level	2 (20.0)	1 (12.5)	0 (0.0)
Others	4 (40.0)	3 (37.5)	2 (50.0)

Note: Figures in parentheses indicate percentage, and total numbers include only those who responded.

these conflicts, as reported by a majority of the farmers in both systems, the most prominent one was not having enough water, followed by water availability only in the head distribution area, and water delivery in the field. Among them, the most severe causes were water scarcity followed by the water delivery mechanism. The other causes were stealing of water, drainage problems, irrigation schedule, and ineffective law. Water stealing and free-riding behavior were observed mainly in contract farming and in downstream systems. Poor monitoring was attributed to reduced farmer's role in monitoring, which was now done by public infrastructure providers. It has also resulted in increased free-riding problems.

Water management conflicts were among different kinds of people, ranging from water users within the village to local officers of the relevant agencies. Generally, water users from the same village were involved in the conflict followed by conflict between users from different villages. Kae Muangs played an important role in resolving the conflict. In conflict situations, water users preferred consultation with Kae Muang. Similarly, few people consulted with the Irrigation and Local Government officers. Among them, as reported by a majority of the respondents, Kae Muang was the most effective in solving conflicts. The people usually relied on Kae Muang for the best solution regarding conflicts.

The people believed that agency intervention in resolving the conflict was not required. The majority of the respondents in MCIS reported that disputants themselves agreed to compromise if there was no agency to settle the conflicts. At the same time, they urged for the need to make certain improvements in conflict resolution for the future. Among such possible changes, those in MCIS emphasized the need for changes in the existing law and order for better conflict management in future, whereas those in TCIS emphasized more on administrative changes at the lower level (Table 8).

The occurrence of conflict also varied by season, owing to variation in water requirements in different seasons. The highest priority season for irrigation water was the dry season, followed by the rainy and cool seasons. Since the top-priority season for irrigation water requirements was the dry season, most of the water management-related conflicts occurred during that season. However,

the conflicts did not escalate because people managed the conflicts by different means, such as compromises made through a group meeting. The group leaders played an important role in conflict resolution. Often the farmers discussed among themselves and/or with leaders, and sometimes the leaders themselves decided after examining the cases of conflict.

Crafting and conforming the rules

The initial operational phase analysis focused on the process of development of rules and the level of autonomy to develop the users' own rules over time. The analysis showed that people have developed their own rules over time, as and when necessary, and that those rules have become a part of their customs and institutions. The common types of rules are those related to the overuse of water and maintenance of water quality.

There are old customs in northern Thailand concerning water management that the people still respect. The water users of MCIS did not use irrigation laws issued by the government but, as a matter of fact, conformed to their water management customs. Although these underwent certain alterations, they remained basically unchanged. These consisted of agreements between water users locally, called Sanya Muang Fai. These agreements contributed decisively towards effective water management by defining regulations to ensure a just distribution of water and system maintenance work, and establishing a social contract between people in the community.

The people were not very aware of these rules because only slightly more than half of them knew about the existence of rules and regulations relating to water management at the farm level. Less than half of the people were able to mention a few examples of the rules existing at the farm level. But, it is not true that there were no rules and regulations regarding water management at the farm level. The fact was that, in practice, these rules were known and respected in their totality, but that people considered these rules as customs that have become a part of the institutions of the community.

People still respect local customs more than modern laws in irrigation water management. They responded that Sanya Muang Fai and local customs are still in use even after the completion of new weir. The local customs and rules related to water management are: pay fines, inform before the use of water, opening and closing of outlet, participation in canal cleaning, distribution of water in equal amounts, time of meeting, and others. The rules and local customs are not only in use but they are also very effective in managing the irrigation system. Some respondents reported these rules and customs as less effective than before. The people who considered these rules and customs still effective gave as the reasons that the rules are obeyed by everyone and that the water users feel more responsible with these rules. Similarly, those who thought these rules and customs were less effective than before felt that these rules are too old and thus are no longer important since such customary law was abolished.

Table 9. Mode of contribution for water use

	Mae Sao		
Mode of payment	Head ($n = 22$)	Tail ($n = 21$)	Thai Yai ($n = 18$)
In cash	19 (86.4)	21 (100)	5 (27.8)
In labor	1 (4.5)	0 (0.0)	8 (44.4)
Others (kind)	2 (9.1)	0 (0.0)	5 (27.8)

Note: Figures in parentheses indicate percentage.

Another important feature of the local rules and regulations was that they were crafted and stipulated by the people themselves over the course of time. Over a longer period of time, after stipulating different rules and regulations, the users adapted them to Sanya Muang Fai and later they became a part of their institutions and customs. While doing so, a majority of the people accepted them willingly.

Resources for operation and maintenance

Another long-term impact of external intervention was on resource contributions for operation and maintenance. The users of these irrigation systems used to make their contribution either in cash or labor or in-kind. In the long-term, it was observed that the mode of contribution was changed mainly from labor to cash. It was found that a majority of the users in MCIS made their contribution in cash to be used for operation and maintenance of the irrigation system (Table 9), and thus the labor contribution was very low.

The scenario was different in TCIS, where people were found to be contributing slightly more labor for operation and maintenance of the system. There was a noticeable change in the labor availability pattern in upstream systems due to out-migration. The upstream TCIS inhabitants are mainly indigenous people. Their livelihood mainly depended on upland paddy farming with supplemental food from forest gathering. Later, farmers from outside areas started migrating into these areas for contract farming. They established fruit orchards and did vegetable farming. Orange and tea plantations dominated the orchards and the products were transported to Chiang Mai for export. Another visible change in this area was restrictions on forest activities in the protected areas. Similarly, there was increasing demand for labor in downstream MCIS, due to a shift from traditional food crops to orchards and vegetable farming. These changes in farming practices, restrictions on forest activities, and high demand for labor for downstream orchards and vegetable farming triggered seasonal and permanent migration from upstream to downstream areas. This has ultimately affected labor availability in the upstream areas.

Transformation in farming systems

Intervention in existing traditional irrigation systems has affected different aspects of agricultural production in the long run. Since the irrigation systems

Table 10. Changes in agricultural production after intervention

Changes in agricultural production	Mae Sao		Thai Yai (n =18)
	Head (n = 22)	Tail (n = 21)	
Same kind of crops as before	4 (18.2)	3 (14.3)	4 (22.2)
Increase in number of crops	6 (27.3)	3 (14.3)	3 (16.7)
Decrease in number of crops	1 (4.5)	0 (0)	0 (0.0)
Productivity unchanged	0 (0.0)	3 (14.3)	0 (0.0)
Increase in rice productivity	1 (4.5)	2 (9.5)	1 (5.6)
Decrease in total rice production	2 (9.1)	2 (9.5)	2 (11.1)
More than one of the above	8 (36.4)	8 (38.1)	8 (44.4)

Note: n = Sample size; figures in parentheses indicate percentage.

were rehabilitated during the early 1980s and the community at large was operating at a subsistence level with only one minor crop produced, the social structure was very egalitarian rather than feudal. It was only after an assured supply of water that the lowland farmers started contracting lands for vegetable cash-oriented production systems and there was gradual emergence of the 'haves' and 'have-nots'. This was similar to the case of upland farmers, who either invested in or rented out their land for long terms to the lowland farmers and outsiders for orchard development, which changed the equation of economic disparity.

In the long run, the effect was mainly on the types and number of crops grown, their productivity, and the cropping pattern (Table 10). Considerable changes were observed in the number of crops grown. People established orchards mainly in the head-water distribution area of MCIS. In TCIS, the level of contract farming and number of orchard establishments was observed to be increasing, being replaced by the similar high water demanding rice crop. This has resulted in higher competition for irrigation water. Though some respondents reported that there was some increase in rice productivity; the total production has declined because it was replaced by orchards and vegetables crops. Likewise, in tail-water distribution areas of MCIS, people have shifted their cropping pattern from paddy to commercial vegetable farming.

Contract farming was on the rise for orchards and vegetable cultivation as well. The agro-processing units and the retailers provided inputs and technical advice to farmers. Farmers were paid in advance both in-kind and in cash with a pre-agreed price for their product. Such an arrangement was believed to have kept farmers in a disadvantageous position for obtaining optimal prices. Similarly, vegetable farmers required a lot of inputs and cash investments. The middlemen were reported to have taken advantage of such situations. The government had no control yet over private entrepreneurs and, thus, farmers were mostly in a disadvantageous position. Farmers were not only losing their share, but the water quality was also deteriorating every year due to the increasing use of pesticides.

The greater formal security of land tenure in the downstream MCIS has enabled the transformation of farming systems from the upland paddy cultivation to the establishment of fruit orchards. In the lowland area, the shift was from paddy to vegetable cultivation. Water demand has been very high due to this shift. Farmers were reported to have started pumping water from the main canal as well from the groundwater. This has increased the competition for water, thus reducing water in the stream. The situation was further aggravated when contract farmers from other provinces started contracting the transfer of land use rights of local farmers in the TCIS community and establishing orchards in the upland areas. These farmers diverted water from springs to their orchards, whereby the drinking water supply started to decline. There was also a visible decrease in water flow in the Mae Sao River. This has not only created conflict between these two communities but also tension among indigenous people and outside contract farmers.

Robustness of irrigation systems

The analysis of the inter-linkages among changes in the characteristics of the resource itself (structural improvement of the irrigation system), changes in different aspects of resource users, the role of public infrastructure providers, and the effect of external disturbances pointed out some important issues in these irrigation systems. The model put forward by Anderies *et al*. (2004) on important linkages among different entities of SES, along with different issues and emerging problems, have been examined in relation to the montane irrigation systems in northern Thailand and are summarized in Table 11. It was observed that various changes in water users, public infrastructure providers, and several external factors have significantly reduced collective action regarding the management of irrigation systems.

The public infrastructure providers' intervention in terms of structural improvement of resource systems and their role on operation and maintenance has affected the resource users' collective action in the maintenance of the resource systems. It has affected the aspect of resource contribution and the participation of resource users. Similarly, competing resource use and increased demand for the resource itself in the long run – due to transformations in farming systems (resource use dynamics) triggered by several external forces – have resulted mainly into water conflicts among resource users. The poor monitoring by public infrastructure providers has also resulted in free-riding problems and overexploitation of water resources. Different cases of rule breaking were also observed due to competing water demands among upstream and downstream users. In the long run, it was also observed that the condition of the resource was not good due to lack of proper maintenance.

In spite of these, the irrigation systems under study have shown their robustness in adjusting to those influences and impacts faced over time. The important fact to note here is that the group effort of resource users, their self-governing

Table 11. Entities involved and linkages in irrigated social ecological systems

Linkage between entities	Montane irrigation issues	Emerging problems
Resources and resource users	Water availability and timelines	Too little water available due to competing demand
Resources users and public infrastructure providers	a. Resource contribution b. Monitoring providers' performance	a. Water stealing, free-riding by contract farmers b. Free-riding by downstream users
Resource users, public infrastructure providers, and public infrastructure	a. Regular maintenance b. Monitoring and enforcing	a. Reduced b. Higher cost but reduced allocation
Public infrastructure and resource	a. Engineering works and water availability b. Institutional rules and water availability	a. Ineffective due to lack of maintenance b. Rule-breaking due to competing water demand among upstream-downstream users
Public infrastructure and resource dynamics	Impact on water harvest dynamics	Ineffective due to overexploitation by pumping
Resource users and public infrastructure	Coproduction of water infrastructure, monitoring and maintenance	No incentive/free-riding outside contract farmers
External forces and resources	Occurrence of landslides, soil erosion, and flash floods	Increasing frequency and mostly uncertain strength/severity
External forces and resource users	Major changes in economic prices, new roads and infrastructure	Conflict among early settlers, lowlanders, and migrants; out-migration of marginal farmers; high labor demand but labor scarcity

capacities, and the local institutions have played an important role in maintaining the robustness of these systems. Despite reduced collective action, water users are still participating effectively in irrigation management, and the local leaders have extended their role in coordinating management of these systems ad have become a link between the public infrastructure providers and the resource users. Moreover, the increased importance of local leaders in managing the irrigation systems and people's continued belief in local customs and traditions have jointly played an important role. While the water users have been able to manage conflicts internally through different means, the local leaders, on the other hand, have found a new role in representing their users in bargaining both with the public infrastructure providers and other emerging, competing external forces for the use of resources. They have developed and modified their own rules as and

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when necessary, both to deal with resource dynamics problems over time and the pressure exerted by the external forces on resources and resource users as well.

4. Conclusions and implications

This paper has examined the dynamics of two irrigation systems in the Kok River basin of the Fang district in the context of changing governance mechanisms and the evolution of technological and market forces. The downstream MCIS received government assistance for construction of a permanent weir and partial canal lining, while the upstream TCIS did not receive any assistance owing to its location within the protected area. The traditional labor contribution custom for system maintenance continued in the upstream irrigation system, but it was replaced by staff hired by the government in the downstream MCIS. In MCIS, collective action has deceased considerably at the main and branch canal levels after the rehabilitation and assignment of government staff to the system. Several changes were seen in the upstream TCIS in the long run. After construction of new weir, farmers in the upstream system also suffered from the higher competition for water that resulted in increased water scarcity. An increasing involvement of people, mainly from the plain areas of Chiang Mai, also resulted in a decline in collective action.

In both MCIS and TCIS, Kae Muangs were found to have played an important role in the management of the irrigation systems. The traditional farmer-managed TCIS, as well as the government-intervened and managed MCIS, equally recognised the effectiveness of Kae Muang. The importance of Kae Muang and their role has not decreased due to the changing context; rather, they have gained importance in centrally planned, modern irrigation systems. Similarly, there were several water management conflicts resulting from the different uses of irrigation water and sharing the same sources for irrigation. In cases of conflict, people consulted with Kae Muang, who relied on their own rules for solving the conflict. They managed the conflicts in various arenas with wider scope for minimizing and resolving conflicts.

The people within the systems believed that they did not require agency intervention for solving conflicts. However, they urged for the necessity of making changes in law and order for future improvements in conflict resolution. Those in both systems still respected the local rules, regulations, and traditional customs for water management. Rather than using the irrigation laws issued by the government, they were found to have modified these laws to conform with their own water management customs. They relied on local rules and customs with necessary stipulations over time.

Similarly, other socioeconomic and policy-related changes have also influenced irrigation management in both of the systems. The changes in farming practices, restrictions on forest activities, and high demand for labor in downstream orchards and on vegetable farms pushed the upland farmers towards seasonal

and permanent migration to the downstream areas. This has ultimately affected the labor availability in the upstream areas. There has been a transformation in the farming system from upland paddy cultivation to the establishment of fruit tree orchards and cultivation of vegetables. This induced farmers to pump water from canals and groundwater to meet increasing demands for water, which has ultimately reduced the supply of drinking water. Similarly, the establishment of orchards in the upland Thai Yai area by migrants has resulted in a decrease in water flow in the Fang River. This has created conflict between upstream and downstream communities, as well as tension among the indigenous people and migrant contract farmers.

This analysis has documented both temporal and spatial dynamism in the irrigation systems. The temporal dynamism revealed the fact that the processes involved in collective action for systems maintenance have changed over time. During the initial stage of irrigation system development, various factors, such as the benefits that the users could obtain from starting an organization and the skill of public leaders (both community traditional leaders and agency intervention entrepreneurs) in bringing them together affecting trust, have played a crucial role. For the initial operational phase, the process of development of rules and the level of autonomy to modify the farmers' own rules over time were documented. For the long-term phase, the focus was on the analysis of external factors affecting the sustainment of these irrigation systems with special reference to the impact of changes in economic prices and labor mobility on the one hand and changes in the authority over irrigation and the availability of funding for irrigation on the other. Similarly, the spatial dynamism showed variation in the long-term impacts of changes in resource mobilization, participation of users, and other external factors within and across the irrigation systems.

The various changes in water users, public infrastructure providers, and several external factors have considerably reduced collective action in managing the irrigation systems. However, the user group efforts, their self-governing capabilities, and local institutions, including the changed role of the leaders in dealing with external forces, have played an important role in maintaining the robustness of these systems. Therefore, while devising any policy related to intervention, policymakers should give due attention to existing local institutions, including their long-term dynamics and diversity, in the development of coping mechanisms for the long-term sustainment of the irrigation systems.

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