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The Politics of PVC: Technology and Institutions in Upland Water Management in Northern Thailand

Nathan Badenoch

Northern Agriculture and Forestry Research Center/Ramboll Natura, Vientiane, Lao PDR; baideanach@gmail.com

ABSTRACT: Conflict over water has grown in the mountainous areas of Thailand since the replacement of opium with alternative crops. PVC-sprinkler irrigation has enabled dry-season expansion of these cash crops on sloping lands, intensifying demand for water when it is most scarce. The technology and institutions that form the backbone of these irrigation systems have evolved simultaneously in a process of adaptive governance, in which local farmers draw on local social resources to balance competition and cooperation. Common conceptions of upstream – downstream conflict, pitting Thai against ethnic minorities in a struggle for resources, dominate the discourse of watersheds in Thailand. Upland water users themselves are diverse and their resource management systems are dynamic, even if they are not recognised as legitimate users of water. Understanding how upland communities create local systems of resource governance through dry-season irrigation is highly relevant for governance at higher levels, such as in the efforts to establish watershed networks and river basin organisations.

KEYWORDS: Water management, adaptive governance, sprinkler irrigation, institutional development, Northern Thailand

INTRODUCTION: UNPACKING WATER MANAGEMENT IN THE THAI UPLANDS

PVC-sprinkler irrigation has become a common component of complex market-oriented upland agricultural livelihoods in post-opium northern Thailand. While a politically charged debate over the impacts of land-use change on hydrology has raged on at the national level, upland farmers have become direct users of water, notably dry-season water. This has brought an element of direct competition between upstream and downstream communities where, previously, tension was centred on a scientifically more tentative, and emotionally charged, public perception of forest-water relationship. Indeed, water supply and forest protection have dominated the popular understanding, but the rapid growth of demand for water, particularly in the dry season, opens up the upstream-downstream resource competition for re-examination (Walker, 2003).

The advent of water management in upland fields involves a co-evolution of technology and institutions. These innovations have created new challenges in the upland resource governance landscape. As water managers, upland farmers interact with each other in new ways, and have added a level of complexity to upstream-downstream relations as well. Indeed, the rapid and widespread adaptation of PVC-sprinkler irrigation has brought about a "silent revolution" (see Molle et al., 2003 on the spread and impacts of small-scale pump irrigation), in which technology has provided greater and more flexible access to water. For the most part, the implications of these upland developments have been overlooked or ignored.

Meanwhile, upland communities are still most commonly known simply as either protectors or destroyers of the forest, depending on which side of the watershed discourse one stands. Moving beyond this simplistic dichotomy is key to understanding the nature and causes of environmental change (Forsyth and Walker, 2008). Examination PVC-sprinkler irrigation systems sheds light on how

upland farmers manage resources within their own ecological and social settings to meet livelihood needs.

Water and watersheds in northern Thailand

Well-known and documented conflicts between upland and lowland communities over water in Thailand, such as the Chomthong incident of 1997, helped solidify a framework in which lowland water access was threatened by the upland agricultural practices of ethnic minority people. In this case, the expansion of fruit trees into previously forested land and the extraction of water from upland streams were cited as the source of perceived downstream water shortage (Hengsuwan, 2003). In this conflict, already, uplanders' water management practices had become a point of tension, bringing an additional layer of complexity to the previous supply-side biased criticism of upland agriculture as upsetting the hydrological functions of upper watershed areas.

Watershed policy in Thailand has long focused on upland communities – predominantly ethnic minority people – as responsible for the problems of dry-season water shortages faced by the lowlands. The watershed discourse in northern Thailand has used these perceptions of lowland water shortages as a political tool by which the predominantly ethnic Thai lowlanders assert rights over upland resources (Laungaramsri, 2000). In the politics of hydrology in northern Thailand "various forms of ethnic manoeuvre" define some groups as less legitimate users of resources (Walker, 2003). In general, upland minority communities in Thailand struggle for access to resources, as they often lack title to their agricultural land and are not recognised as users of water.

But as agriculture in the mountainous areas of northern Thailand has been transformed, does 'upland resource users' provide a useful social unit of examination? In the ethnically diverse Thai uplands, where complex landscape mosaics along the forest-field continuum dominate, water management practices show a high level of variation (Sangkapitux and Neef, 2006). Emergent upland water management systems are community-based regimes, in that they have evolved locally, without support from government or other external sources, and rely on the existing social institutions of the local communities. There is a need to further unpack the diversity of upland water management, in order to understand not only how upland-lowland relationships have developed but also to re-examine how upland groups secure access to vital livelihood resources.

Researching upland sprinkler irrigation

This paper¹ introduces the PVC-sprinkler irrigation systems of northern Thailand and the institutions that have evolved in parallel with the technology. In doing this, the analysis takes two approaches. The first is to treat PVC-sprinkler irrigation as emergent social-ecological systems, in which two-way interactions between the resource and the people are mediated through an interplay of technology and institutions. The second is to unpack the very general social category of 'upland water users', giving particular attention to ethnicity and inter-ethnic relations. The data were collected through an ethnographic approach to fieldwork, and are presented here as such. Discussion of this co-evolution identifies some of the key challenges to understanding upland water governance at multiple levels.

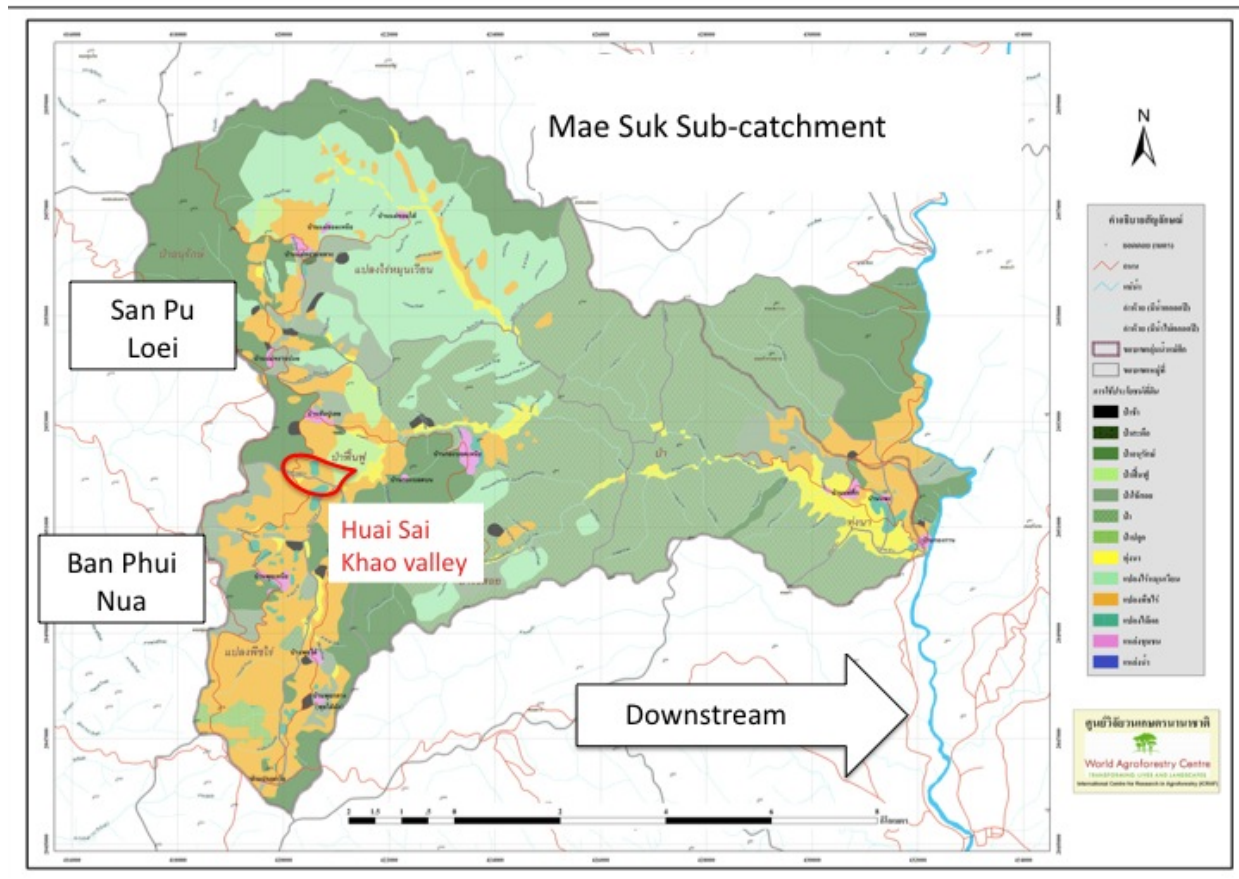
Research on water management in Thailand has given much attention to the technology and practices of irrigation in the north of the country (for example, Tanabe, 1994; Surarerks, 1986). Analysis of *meuang faai* (traditional irrigation systems), and the user groups that manage them has made a major contribution to the understanding of community-based resource management in Thailand. At the same time, research has also failed to recognise the creative tensions inherent in the co-evolution of technology and institutions in the uplands, as a tool for understanding how local resource governance regimes are created. One particularly interesting dynamic is the balance and struggle between

¹ An earlier draft of the paper was presented at the 2006 Sloping Lands and Sustainable Watershed Management Conference in Luang Prabang, Lao PDR.

customary and new institutions. Developments in technology and institutions continually feed back into the tenuous balance between competition and cooperation. As emerging forms of local governance, upland irrigation systems will provide an interesting look into the process through which local populations and resources interact.

The research focused on the Huai Sai Khao stream valley where ethnic Hmong and Karen farmers use water from the same source for dry-season irrigation. Huai Sai Khao is located in the upper Mae Suk sub-catchment of the Mae Chaem watershed in Chiang Mai province. The study was carried out as part of a 2-year programme of doctoral fieldwork, which focused on resource governance in a multi-ethnic setting of upland northern Thailand. The author spent an extended period of time (2003-2004) in the upper Mae Suk sub-catchment conducting research in the villages of Ban Phui Nua (Hmong) and San Pu Loei (Karen). The Huai Sai Khao stream is located on the border between these two villages. The general location of the research site is shown in figure 1.

Figure 1. Location of the research site in Mae Suk sub-catchment.



The data presented here were collected through participant observation, farmer surveys, GPS data collection, semi-structured interviews and group discussions in the farmers’ fields. Fieldwork was carried out directly in Hmong, Karen and the Kam Meuang dialect of Thai. General support of the research, including assistance with GPS and GIS data analysis, was provided by the International Center for Research in Agroforestry (ICRAF), Chiang Mai office.

HUAI SAI KHAO VALLEY: COOPERATION AND CONFLICT OVER UPLAND IRRIGATION WATER

The end of the 1980s saw the final plantings of opium in the upper watershed areas of Mae Chaem district in Chiang Mai province. Government and international efforts to eradicate opium and promote alternative cash crops were particularly strong in the area. In 1986, Ban Phui Nua village was the second largest producer of opium in Chiang Mai province (DAI, 1987), but is now a major centre of cabbage cultivation in Mae Chaem. Before the introduction of upland irrigation, crop production in sloping fields was limited to the rainy season. Since it was introduced in the mid-1980s, the flexible and inexpensive infrastructure of PVC pipes and sprinklers has enabled farmers in the area to crop during the dry season as well. Dry-season production has become a critical component of upland livelihoods in many areas that have relatively good access to markets.

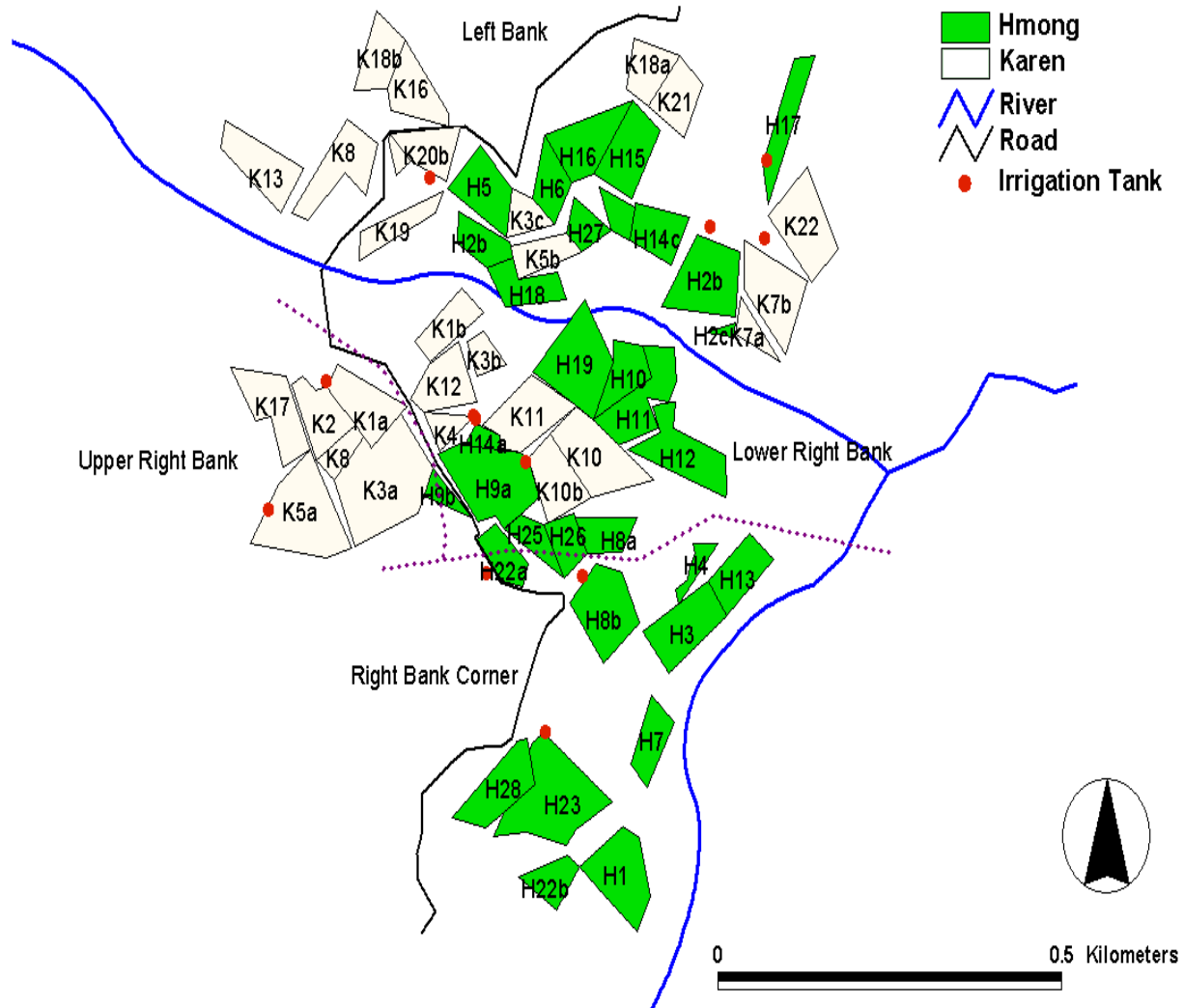
The Huai Sai Khao valley is an example of small-scale dry-season irrigation in which technology and institutions have evolved in tandem, resulting in cycles of cooperation and competition at multiple scales of management. The Huai Sai Khao stream is located between Ban Phui Nua and San Pu Loei, a Karen village where farmers struggle to balance their strong preference for rice self-sufficiency against pressures to increase their production of vegetables for the market. The Hmong began to acquire land here in the early 1980s, when opium was still being planted, and continued to gain access through the 1980s and 1990s. The Hmong and Karen have struggled over resources in this area, echoing a larger dynamic between the two groups across northern Thailand. During the opium producing years, many Karen farmers worked as wage labourers in Hmong fields. Often receiving payment in opium, Karen addiction became a serious problem. The Hmong, relatively recent arrivals in northern Thailand, have been viewed with suspicion. However, although the relationship has been tense, there are also elements of cooperation throughout the history of the two villages in the research site.

Thus, the Hmong and Karen farmers of the valley utilise the same land and water resources. Figure 2, based on GPS data, shows the extent of shallot fields for the dry season of 2004-2005. In this setting, it is normal for Karen and Hmong to farm adjacent fields. All of the fields depicted here are irrigated by sprinklers with water from the Huai Sai Khao stream. The land-use type of these fields was classified as 'permanent field crop'² in an ICRAF analysis of land use change in the Mae Suk watershed, meaning that the fields are not part of the forest-fallow rotational system that exists in other adjacent areas. These fields are cultivated almost continually, with occasional half-year fallow periods. In addition to shallots, farmers grow cabbages, carrots, potatoes and tomatoes. During the research period, there was a total area of approximately 247,400 m² under cultivation, of which 53% was farmed by Hmong and 47% by Karen. The average plot size is approximately 4,200 m², and there are no significant differences between the two groups. Of a total 59 plots, the Hmong (green) held 32 and the Karen (white) 27 plots.

Sprinkler irrigation has largely removed the seasonal constraints of cash crop production in Huai Sai Khao, opening a new range of economic options for upland livelihood portfolios. But competition for water has increased as a result, and tensions in the valley have been high over the past eight planting seasons.

² Thai *rai thaworn*, in contrast to *rai mun wian*, rotational swidden fields; Hmong *teb* are traditionally used for any upland field, although recently these may be referred to with the Thai word *suan*, garden or orchard; Karen *taj soof lauz*, in contrast to *hsgi*, rotational upland rice fields.

Figure 2. Irrigated dry-season shallot fields in Huai Sai Khao.



THE TECHNOLOGY: PVC PIPES AND SPRINKLERS

The farmers of the upper Mae Suk watershed first began to irrigate their upland fields in the mid-1980s. The transition from poppy to cash crops had already begun among the Hmong, and related expansion of cash crops within the Karen livelihood portfolio followed closely. Upland farmers first observed the irrigation technology employed by lowland Thai farmers in the district town, who had begun using sprinklers for some dry-season crops grown in fallow paddy fields, rather than releasing irrigation water from the meuang faai system into the fields.

The irrigation system in Huai Sai Khao is driven by gravity, a particular benefit in this landscape of steep slopes. The basic components of the system include: a small weir made of stone, wood or concrete, usually near the source of the stream; PVC pipes to transport water to the cultivated area, down (and often up) slopes; storage tanks of dug earth or concrete located above the recipient fields; pipes delivering water to individual fields; and hoses connected to sprinkler heads that are attached to

bamboo poles. Sprinklers are manually rotated around individual fields throughout the day, keeping the soil moist. In other places in Mae Chaem district, farmers have begun to use diesel and electric pumps to lift water from larger streams to adjacent fields as well. Upland irrigators in Mae Chaem do not pay for their irrigation water. Figure 3, 4 and 5 show diversion weirs, temporary storage, and sprinkler irrigation in upland fields in the Huai Sai Khao valley.

Figure 3. Weirs and diversions in small streams.



Figure 4. Storage facilities.



Figure 5. Sprinkler irrigation in shallot fields.



The technology is not entirely different from the traditional Hmong system of supplying water by gravity to their villages through bamboo aqueducts. The Karen have used similar methods to deliver drinking water to their villages and into paddy fields. But the replacement of these structures with PVC pipes, and the extent to which they have spread across the landscape, have brought in a host of new engineering and management issues.

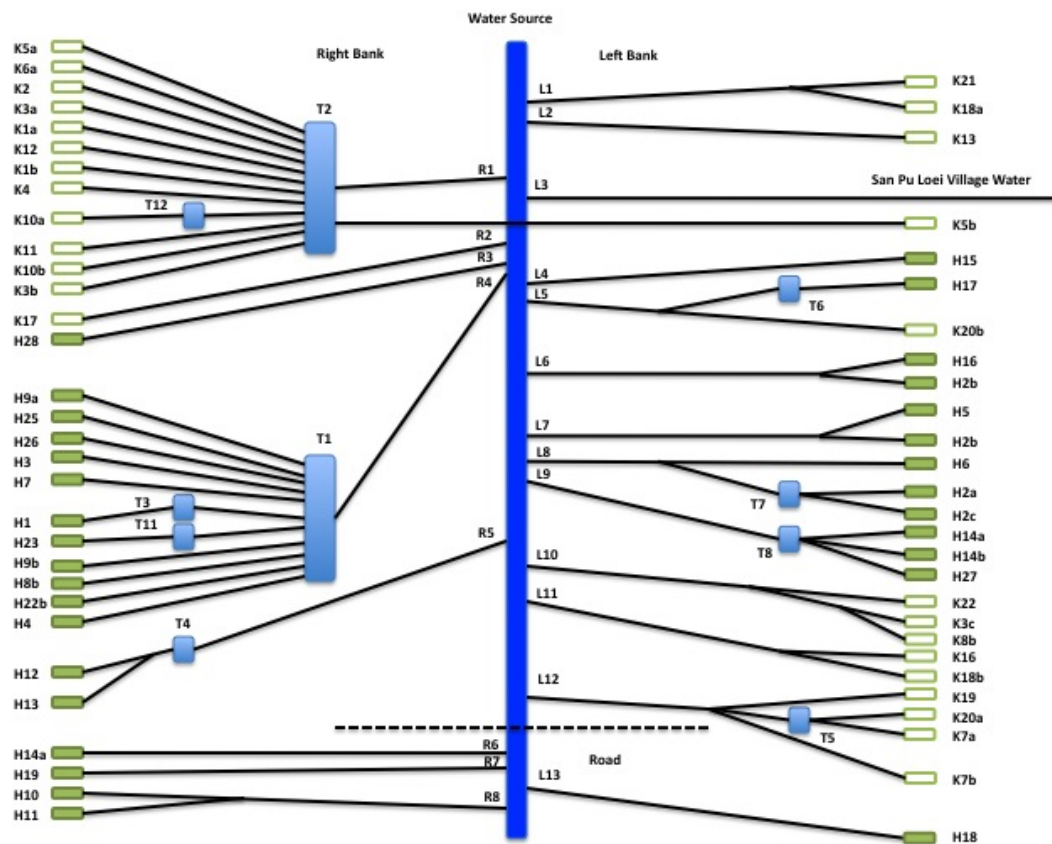
Accessing, storing and delivering irrigation water

The Huai Sai Khao stream springs forth from the rock face in a forested area above the cultivated area. The valley lies within the administrative territory of San Pu Loei village and the water source is treated as a community watershed forest by the Karen. This area has traditionally fed a small area of paddy fields.

In the Huai Sai Khao valley, the distance from source to field is approximately one kilometre, and the route travelled by water follows the natural contours of the valley topography. The engineering practised by local farmers can bring water from as far as 10 or more kilometres, and the pressure created by steep slopes at the headwaters enables farmers to lift water and accommodate natural barriers in the landscape. Pipes are frequently buried in the earth, which gives a certain degree of security, but can make monitoring and repairing leakages difficult.

In 2004-2005, there were 21 abstraction pipes in the Huai Sai Khao stream. Of these, 13 belonged to the Hmong, while the Karen own eight, including a village water supply pipe (figure 6). In the figure, Hmong fields are shown in green and Karen in grey. Storage tanks are shown in light blue. The actual locations of the withdrawal pipes in the stream are not precise, but do represent the relative upstream-downstream relationships.

Figure 6. Water management system in Huai Sai Khao.



Source pipes are usually shared by two or more farmers, as there is general agreement among both groups that strict individual use of pipes is not efficient. Farmers sharing abstraction pipes jointly maintain the weir and pipes. Most pipes were originally installed by one farmer, and access was subsequently granted to more farmers as more people began dry season cultivation. In this way, user groups linked by shared infrastructure were formed. Table 1 provides basic data on water abstraction.

The capacity to store water in small field ponds is a critical feature of the system. Field ponds are usually filled at night or early in the morning and represent an important step in the development of more complex management arrangements within user groups. Field pond characteristics, in terms of number and size, are the clearest aspect of differentiation between the left and right banks. Farmers on the right bank have developed large concrete storage facilities (T1 and T2) to supply user groups of ten or more. Storage on the left bank has not developed to a similar degree. Part of the left bank of the valley is somewhat steeper than the right bank, which may explain some of the difference. However, farmers themselves recognise that there is potential for developing much more storage capacity. Even the largest tanks can store only enough water for a day of irrigation. In this sense, the current individual water storage capacity does not provide a long-term guarantee of water access across the valley. It does, however, allow the regulation of supply and thereby provides a mechanism for more equitable water allocation of available water.

Table 1. Chronology of pipes.

Pipe	Owner	Year	Diameter	No. of users	Ethnicity
L1	K18	2004	3"	2	Karen
L2	K13	2005	2"	1	Karen
R1	Karen Group	1986	3"	11	Karen
L3	Village Water	2004	2", 1"		Karen
R2	K17	1992	1.5"	1	Karen
R3	H28	1992	1.5"	1	Hmong
R4	Hmong Group	1987	3"	10	Hmong
L4	H15	1986	2"	1	Hmong
L5	H17	2001	2"	2	Hmong
L6	H15	1986	2"	2	Hmong
L7	H11	1988	1.5"	2	Hmong
L8	H6	1988	1.5"	3	Hmong
L9	H14	1986	1.5"	2	Hmong
R5	H12	1990	2"	2	Hmong
L10	K20	1988	2"	2	Karen
L11	K3	1988	2"	3	Karen
L12	K19	2002	2"	4	Karen
R6	H2	1987	1.5"	1	Hmong
R7	H19	1987	1.5"	3	Hmong
L13	H18	1992	1.5"	1	Hmong
R8	H10	1987	2"	1	Hmong

The concrete field ponds were originally simple earth ponds, shared by three or four farmers. With intense competition for water in the late 1990s, the original users upgraded and expanded the ponds with concrete. To do this, they invited other individual water users to invest in the infrastructure in return for use rights in the new field pond. This process was fundamentally the same for both the Hmong T1 and Karen T2. Secondary pipes delivering water from field ponds and main abstraction pipes are owned by individuals and feed single fields. These pipes are usually not buried, because they may be moved occasionally to accommodate occasional short fallow rotations when needed.

Actual water use in the Huai Sai Khao system has not been measured. In fact, there have been no studies of water use in upland irrigation systems to date. Given that water is abstracted unequally throughout the system, with upstream users enjoying greater access, it is very difficult to estimate volumes of water. One proxy indicator for abstractive capacity in the system is total cross-section area of the pipes at the source of abstraction. The Hmong pipes have a total width of 35.1 in², while the Karen pipes have 32.4 in² of abstractive capacity. These figures, which give the impression of a fairly equitable capacity to access water among the two groups, are deceptive. In fact, they tell nothing about actual abstraction, but give a general idea of access to the technology. This was prompted by the frequent statements made by both Hmong and Karen that the other group had inserted many more

pipes in the stream. The imbalance in access to water is masked in the location of each pipe in the stream.

Although Hmong and Karen fields are adjacent to each other in the valley, there are no examples of Hmong and Karen together in a user group. There is only one case of cooperation in water management between the Karen and Hmong, and this arrangement is actually a water-for-land swap, valid for only one season. When asked why there has been no direct Karen-Hmong collaboration, farmers from both sides mentioned that the lack of trust between the two groups prohibits any concrete action in joint investment or allocation negotiation.

Dealing with water scarcity

As the dry season progresses, there is not enough water for each farmer to use as he would like to. In response to this, user groups sharing field ponds or pipes make arrangements to manage water allocation during times of scarcity, mostly in late February and March. There are three main allocation methods, implemented according to the degree of water scarcity. First, when water first becomes scarce, farmers in a user group will divide themselves into sub-groups and use a day-on/day-off system of rotation. Second, when water shortages start to get more serious, the sub-groups only have access to a half-day of irrigation. For the large Karen user group (T2), the schedule of rotation is discussed each morning at the field house of one of the elders. This mechanism is an attempt to maintain equity in access because the water stored in the tank is exhausted before the afternoon irrigators have completed their irrigation. The Hmong water users of T1 tend to make adjustments to the rotation as needed, in a more reactive strategy to relieve tension among the users.

This helps the upstream users manage their water more equitably. However, when tail-end users – particularly R5, L9, L10, L11 and L12 – begin to experience severe water shortage, they resort to night irrigation. This is because those downstream farmers with farm ponds can only begin to fill them in the evening after upstream users have closed their pipes. They then rotate their sprinklers throughout the night. The users of T2 have also resorted to night irrigation when necessary. Below the road, a second spring replenishes stream flow enough to serve the tail-end users. However, all farmers agree that it is impossible to expand water abstraction below R8 and L13.

In this third strategy for dealing with scarcity, it is likely that the loss of water to evaporation and wind is significantly lower. However, farmers avoid irrigating at night when possible. Night irrigation is more of a burden on Karen farmers than on Hmong farmers. This is because night irrigation is done primarily by Shan labourers from Burma working for the Hmong. Because they are constantly rotating their sprinklers, night irrigators spend the cold mountain nights wet and frequently get sick.

Access to water in Huai Sai Khao is 'free', in the sense that there are no charges for water use. Access to technology does not necessarily result in unlimited access to water. For example, the Hmong of T1 have begun basic land use planning to limit the number of users at the beginning of the dry season. In the 2004-2005 season, it was agreed that one user would be refused access to irrigation water because he had large landholdings in other areas and his claim on water in the Huai Sai Khao valley would upset the overall equity of access to the scarce resource. All farmers in the valley, both Karen and Hmong, agree in principle that such land-use planning at the stream level is necessary, although it had not materialised at the time of the research. In other areas, one first step to controlling demand has been limiting the number of sprinklers allowed for each parcel of land. The farmers of Huai Sai Khao have not tried this mode of regulation.³

³ In many Hmong villages in the area, village water committees charge households for domestic water consumption, based either on a flat rate per household or by the number of household members.

THE INSTITUTIONS: MANAGING COOPERATION AND COMPETITION

The Karen and Hmong have been managing irrigation water with this technology for over ten years. But because this is a relatively new addition to their livelihood technologies, there are no specific customary institutions for irrigation management in upland fields. Nevertheless, local institutions to manage the physical and social dynamics of this new technology have emerged and are continually adapting. The two major demands for institutional adaptation observed in the Huai Sai Khao valley are the need to collaborate to secure adequate water resources for each group and the need to manage the growing competition among groups of water users. The institutions observed here encompass two types of evolution. First, existing social institutions are adapted to meet the needs of managing scarce water resources. Second, new institutions are created to address the increasingly complex social relations encompassing the ecosystem.

Underlying social institutions and water-sharing arrangements

Traditional institutions for managing upland irrigation do not exist per se. Even in the Karen villages of the area that have adopted the technology of meuang faai irrigation systems for rainy season paddy production, the management institutions have not been taken on because there is no shortage of water and the systems are small enough to manage and maintain through individual inputs. With dry-season irrigation, there are new management challenges posed by water scarcity. Options for institutional innovation are naturally based on other broader social institutions in the local societies. For example, kinship networks play a large role in determining how decisions are made, disputes settled and information flows in both Hmong and Karen societies. The institutions governing related land and forest management influence the process of upland irrigation management, as well.

Hmong kinship networks and resource management

Hmong kinship relations, governed by exogamous and patrilineal clans, provide the basic foundations for the social patterns observed in their resource management practices. Hmong agriculture has been typically centred on the household as the basic unit of economic decision-making, although the shift from opium to temperate fruit and vegetable crops has stimulated new modes of cooperation within lineages, and at times across clan boundaries (Badenoch, 2008). A similar expansion of the social domain of cooperation was observed among Hmong communities who adopted paddy rice cultivation that relies on canal irrigation (Cooper, 1978).

Most Hmong water users in the Huai Sai Khao valley are members of the Tsaab clan, with the remainder belonging to Yaaj and Kwm clans residing in Ban Phui Nua. The Tsaab began farming in the Hua Sai Khao valley because they were late-comers to the village and most of the good land in the village had already been occupied. In 1986, two brothers introduced sprinkler irrigation, which developed into water-sharing arrangements between brothers of the next generation. At first, sharing of pipes was the most common form of cooperation, but collaborative water management was taken to the next level with the construction of farm ponds. Water-sharing agreements are made based on location of fields and kinship relations. In some cases of close kinship relations, farmers jointly invest in the storage construction and then share the water equally. In other cases, farmers reach specific arrangements to share water from existing ponds, including agreements about how water will be allocated in the event of water shortage. The closer the kinship relation the higher the likelihood of joint investment in infrastructure.

Kinship plays a particularly clear role in the mediation of disputes within the Hmong community over water in Huai Sai Khao. Conflicts over rotational water allocation, insertion of new pipes and construction of new storage facilities are common. In their customary capacity, clan elders provide a forum for discussion between disputants and the authority to arrive at and enforce solutions.

Negotiation of a dispute between two cousins in the dry season of 2002-2003 involved two elders in the valley and was assisted by the previous village headman, also an elder of the Tsaab clan.

Sangkapitux and Neef (2006) have described how the Hmong of Ban Mae Sa Mai, a village with a history of intensive and ongoing development interventions, has developed novel collective action arrangements that effectively allocate water. In Ban Phui Nua, where external development support disappeared after the initial opium replacement interventions of the mid-1980s, the traditional authority of the elders has been most effective in conflict resolution, but it seems to be less so in establishing new norms to govern emerging collaborative management.⁴ Water sources are exploited primarily on an individual basis, and then expanded through the storage and delivery system, where financial resources were available and kinship networks could provide support. This approach is based on a customary Hmong norm of resource management in which the first individual to develop a resource (such as opening upland fields, and now inserting irrigation pipes) enjoys the rights to its use, but then may enter into resource-sharing arrangements with kin. The adaptive capacity of the kinship system mediates the dynamics of competition and cooperation as the complexity of the resource management system increases.

Karen social networks and resource management

The Karen, who have lived in the Huai Sai Khao area for more than 100 years, are well known for their communal management of rotational fallow fields and the relative ease with which they have adapted the cooperative institutions to manage paddy rice irrigation. Karen kinship is typically organised along matrilineal lines, with a high degree of inflow and outflow of people in the village (Hayami, 2004). Collaborative resource management is based on a mixture of kinship and marriage relationships, often across the boundaries of Karen villages in a certain area. The exchange of information, labour and resources within this extended social network is an important form of Karen social capital.

As described above, the development of dry-season irrigated agriculture in the Karen community of Huai Sai Khao was sparked by two local leaders. Neither held official posts at the time, but both were active members of the community and were leading the way in experimentation with new cash crops among the local Karen. From these initial innovators, the technology spread across kinship boundaries to include individuals with origins outside of the village. The expanded social network encompassed a more diverse range of individuals including some from other villages, compared to the Hmong who were almost exclusively from the dominant local clan lineage. The social map of Karen resource management in the area is a complex mosaic of water- and land-sharing overlays, reflecting a horizontally disbursed, regional Karen social network of high density.

Conflicts within the Karen irrigation community are also frequent, especially in recent years of intensified competition. Local elders – the two individuals mentioned above, one now the village headman and the other the leader of the village Catholic congregation – play the central mediating role. Despite the comparatively dense social networks, the Karen experience similar difficulties in regulating the expansion of infrastructure and allocation of water. The strongest cohesion can be found among the water user groups sharing field ponds.

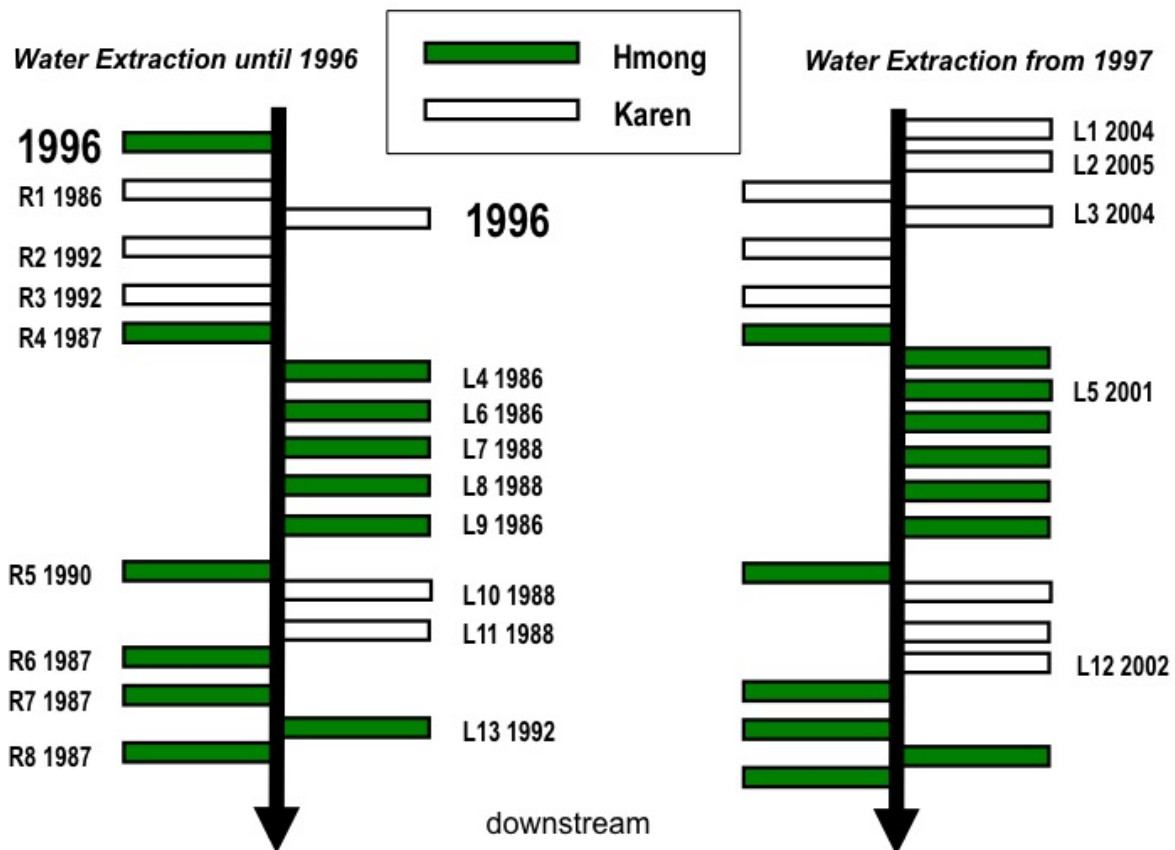
Management committee: Stream-level institution

As discussed above, institutional arrangements for sharing water are developing at the user group level. User groups in both the Hmong and Karen communities, forming around field ponds and shared pipes, are developing increasingly complex ways of allocating water and performing operation and maintenance tasks. However, tension has risen continuously among user groups and individual users,

⁴ See Badenoch (2008) for more on village governance in Ban Phui Nua and the competing sources of authority to manage village matters.

catalysing the first experimentation with stream-level institutions. Figure 7 shows the historical development of pipe irrigation in the Huai Sai Khao valley.

Figure 7. Historical development of irrigation and creation of water scarcity.



The introduction and expansion of PVC irrigation in the valley can be divided into two periods. In the first period, from 1986 to 1996, pipes were inserted by individuals who gradually expanded the area of cultivation according to access to water. According to farmers, during this period, there was a general understanding that new pipes could only be inserted downstream from the lowest existing point of abstraction. Reconstruction of the historical process shows that, in fact, this norm did not function, as pipes were frequently added in upstream areas. Nonetheless, the narratives from this period explain that the demand for water was well within the limits of the stream’s capacity. Conflict over access to water was not a concern, as the perception of sufficiency was widespread.

This situation changed in 1997 when the insertion of two large pipes, one Karen and one Hmong, set off a dispute about the lack of regulation of new exploitation (although they are not shown in the diagram, as they were removed). Reaching crisis, the disputants fell out along ethnic lines. Physical violence was narrowly avoided but several pipes and weirs were destroyed. Under these conditions, it was not difficult for the Karen and Hmong to agree on the need for management at the stream scale. A meeting of all the farmers resulted in the formation of a management committee, comprising the two Hmong and two Karen elders who were the main decision-makers in water allocation in their own respective groups. The committee facilitated an agreement requiring the removal of the offending pipes and prohibiting new abstraction pipes in the stream. The committee was not given any special

name, nor was there any ceremony or symbolic start to its functioning. It had emerged out of informal roles played by the elders.

The four committee members had two intentions in setting up the new body. First, there was a short-term need to solve the immediate conflict over unregulated pipe insertion. Small-scale disputes among the Huai Sai Khao farmers over land and water were a constant part of dry-season production from the beginning. Second, the elders recognised that with incomes from cash-cropping rising in both villages the financial constraints to expanding the infrastructure were disappearing. They felt that this increased the chances of more serious conflict among the farmers. In addition to being leaders within each group, these elders enjoyed a significant amount of respect across ethnic lines, and it was genuinely hoped that the committee would be an effective dispute-prevention mechanism.

But in the following years of 2004 and 2005, new pipes appeared in the upstream area, returning the valley to an atmosphere of tension. Cabbage and shallot prices had both declined in the previous years, and the intensive year-round farming of steep slopes meant that chemical inputs were necessary. Payments for pickup trucks purchased for transporting produce to markets became increasingly difficult. A looming debt crisis meant that income from dry-season activities was ever more important, and there was a need to bring more land into production through irrigation.

The new pipes, in fact, improved the overall balance of access to water between the Karen and Hmong farmers, in terms of abstraction capacity. However, the resulting water shortage increased tension within the Karen community more than in the Hmong. The post-1997 expansion of pipes was primarily by Karen farmers, but it was ironically the tail-end Karen of L10, L11 and L12 that experienced the most significant loss of access to water.

During this period, the competition for water was complicated further by the construction of a village water supply off-take point (L3) to supply Karen households in San Pu Loei. The existing village source was not sufficient, and the Tambon (Sub-District) Administration Organisation (TAO) approved San Pu Loei village headman's proposal to supplement the village water supply with water from the Huai Sai Khao stream. This was discussed in the TAO, but not specifically with the Huai Sai Khao farmers. Although it introduced direct competition between domestic and irrigation water, most local people, Hmong and Karen alike, agree that domestic water must be prioritised. Nonetheless, the result was to increase demand and exacerbate tensions in the valley.

With its failure to prevent the insertion of new pipes, the management committee broke down. Unable to manage the tension among the Karen farmers, the Karen elders tried to convene the management committee to discuss possible solutions. The Hmong members refused to engage in negotiations over what they now perceived to be a Karen problem. As one of the Hmong elders remarked in frustration, "The Karen can't manage their own problems, so why should we be involved in any more discussion. The committee will function again after they solve their own internal problems". The farmers did not consider themselves to have any direct role in the committee, and thus did not perceive any opportunity to pressure the committee to act. With the rising tension, individual farmers lost the mutual trust needed to negotiate individual solutions to localised problems. At the same time, the farmers realised that individual solutions would not solve the stream-level problems.

Despite the breakdown of the management committee, water users in the Huai Sai Khao valley have refused to bring the problems to the attention of the official village leaders. Interviews with Karen and Hmong villagers found that there was an almost universal general agreement that resource management problems between villages should first be addressed in the locality within the framework of kinship networks, and then taken to the village committee if no solution could be reached. In practice, however, Huai Sai Khao farmers have said that they do not want to elevate the local water problems to the level of an official inter-village dispute. Village leaders hold the same view, for slightly different reasons. There is a history of conflict over land and forest between the two villages, and no one wants to exacerbate the situation. At the same time, the Hmong village headman is from a different clan from the Huai Sai Khao farmers, and preferred that they use their own clan mechanisms to negotiate among themselves and engage with the Karen, because his capacity to influence the affairs

of other clans in the village was limited.⁵ For the Karen, San Pu Loei has not fared well in past negotiations with the Hmong of Ban Phui Nua. In his point of view, a longer-term strategy to align Karen interests with those of the downstream Thai villages was preferable. He believed that creating closer linkages downstream would strengthen his position vis-à-vis the Hmong, and soften the general perception of the Karen as part of the water shortage problem in the area.⁶

Adaptive management: Feedback loops between technology and institution

Technology and institutions are evolving together in a continuous process of adaptation. Feedback loops guide the processes of adaptive governance – the ongoing efforts to adjust to change and uncertainty, experiment with management arrangements and foster institutional learning based on social networks (Folke et al., 2005). At first, the introduction of new technology may have been considered an external factor, but the resulting irrigation infrastructure is based on farmers' intimate knowledge of the landscape, markets and cropping methods. At the same time, institutional developments around upland irrigation may appear new, but in most cases they are based on the foundation of existing social institutions.

As seen above, developments in technology and institutions can result in both competition and cooperation. Likewise, the dynamics of both competition and also cooperation can result in technological and institutional change. Changes are mediated by existing social institutions, and greatly influenced by the capacity of social networks and natural resources. As local user groups move through the cycles of competition and cooperation, the technological and institutional changes may bring about changes at larger scales of resource management.

In some cases, a technological development has allowed an institutional development. For example, the construction of the large Karen field pond (T2) led farmers to develop a set of rules for water allocation in a place where irrigation management practices had previously been fragmented. In the case of the large Hmong field pond (T1), however, the close and effective cooperation on water allocation encouraged the group to jointly invest in an upgrade of water storage facilities and further integrate neighbouring irrigators whose pipes had not been connected to the field pond. Thus, as technological and institutional adjustments are made, new patterns of competition and cooperation are observed. In Huai Sai Khao, there are two main determinants of the outcomes of innovation.

First, water management is continually challenged by the availability of water in the stream system. Not surprisingly, conflict and resulting adaptations in technology and institutions are most acute in dry years. Although the exact quantity of water available is not known (not to mention sustainable levels of exploitation), these temporal fluctuations are closely monitored by individual farmers and small user groups. As water becomes increasingly scarce through the duration of the dry season, the balance between cooperation and competition is affected. This has impacts on the technological and institutional choices that farmers make. Monitoring systems have not been introduced into upland irrigation systems, so data on who uses water, how much and when are lacking. Local monitoring of the situation is, of course, carried out by farmers, but they themselves admit that their decisions and negotiations are based on only a partial understanding of the entire stream system.⁷ During the

⁵ The village headman and the clan leadership are often two distinct arenas of authority in Hmong villages (Badenoch, 2008). The village headman, whose main responsibilities are for dealing with official administrative and external matters, was unwilling to challenge the clan leaders' authority even when the dispute influenced inter-village relationships and caught the attention of tambon and district officials.

⁶ The Karen have been characterised as a group living in the middle, occupying the slopes between the lowland Thai and the Hmong. In the mainstream watershed discourse, the Hmong have been vilified as destructive, while the Karen are portrayed as having more ecologically sustainable natural resources management. For more on this discourse, see Hayami (2004) and Walker (2001).

⁷ Huai Sai Khao farmers responded very well to discussion of the shallot mapping exercise, and were surprised to learn that several of their basic assumptions about the Karen-Hmong distribution of cultivated area were wrong. Farmers also showed interest in mapping the irrigation system, which stimulated many substantive discussions of the problem. Committee leaders

fieldwork, there was a general feeling that tensions would culminate the next year in physical violence. As it turned out, a random rainfall event alleviated the perception of scarcity, 'postponing' the next rounds of technical and institutional adaptation.

Second, the levels of trust and capacity for reciprocity influence the trends towards cooperation and competition among farmers. These factors of social capital are reflected most strongly in kinship and marriage relations, and form the basic foundation for much of the collaboration found in the valley. However, it is clear that there are limits to local farmers' ability to achieve cooperation between user groups, and more generally at the stream level. Trust between the Hmong and Karen seems to have deteriorated over the years and as the cumulative impacts individual decisions began to be felt throughout the system. Trust within the Hmong and Karen communities has proven thin, as well. Most notably, the insertion of new pipes since 1997 has dealt a heavy blow to the cohesion of the Karen farmers. In the Huai Sai Khao valley, it seems that relationships of trust were overly focused on the four elders, but these proved too weak when water scarcity reached critical levels.

Through the feedback loops of technological and institutional development, farmers adjust the scale of water management to the dynamics of scarcity. The limits to technological and institutional capacity are constantly being tested through adaptive management practices. As of the end of the 2005 dry season, however, it was apparent that the limits to the Huai Sai Khao agreement and management committee had been reached. Local farmers talked frequently of the possibility of linking the whole system with a large storage tank. The key benefit of this technical approach would be to enable allocation rules to achieve greater equity in access to water, in addition to perceived benefits of increased water availability in times of shortage. Meanwhile, both the Karen and Hmong are acutely aware of the suspicion with which their evolving upland irrigation is followed by the lowland Thai.

Irrigators in the Huai Sai Khao valley are managing their water at several levels – from the individual to larger user groups and stream level – with varying degrees of success. Technological approaches to water scarcity have enabled farmers to deal with water scarcity and develop increasingly complex water management arrangements. Re-scaling the management arrangements to address competition at the stream level has been outside the capacity of the emerging institutions. The creation of social capital at the watershed level is crucial to the effectiveness of institutions (Uphoff and Krishna, 1999), especially where institutions have been adapted or newly formed.

UPLAND IRRIGATION AND THE LARGER RESOURCE GOVERNANCE LANDSCAPE

Institutional frameworks for managing upland water are evolving in contradiction to the common perception that upland farmers exploit small streams as an open access resource. Diverse tenure systems based on clear rights to access over water provide the foundation for more complex governance arrangements. The legal pluralism approach to upland water management makes an important call for recognition of the diverse forms of rights evolving at the local level within policy (Neef et al., 2006). The Huai Sai Khao example supports the conclusion that institutional arrangements at the most local level, where the most striking changes in technology are observed, are indeed developing even if many challenges remain. However, at larger scales – particularly the stream and upper tributary watershed – the constant tension between local competition and cooperation highlights the need for ample political space to allow the necessary process of adaptive governance to take place.

Downstream water users, who perceive upstream farmers' development of water management as a step beyond what is acceptable, have been increasingly vocal and at times violent in their expression of

say that installing water meters would result in improvements in the system, but are hesitant because of a lack of technical expertise and concern for the high level of sensitivity associated with gathering data. The Hmong, particularly, have had bad experiences in collaborating with researchers to provide information on chemical inputs in their farming. They are well-aware of how data is used as a political tool at higher levels.

concern. The Huai Sai Khao valley is situated within the Mae Suk sub-catchment, an upper tributary of the Mae Chaem river. The Huai Sai Khao valley is just one small site comprising a larger area of permanent upland fields that represents successful opium crop replacement. Intensive vegetable and fruit cultivation in the upper Mae Suk sub-catchment are linked to markets through individual farmers, informal marketing networks and middlemen. A significant proportion of the total area of permanent upland fields is under dry-season irrigation.

Within the sociocultural and political biases aligned against uplanders in the Thai watershed discourse (Laungaramsri, 2000), the fundamental question needs to be asked: How do upland sprinkler irrigation systems fit into the larger resource governance landscape? The short answer is that they do not have clear linkages to institutional authority at higher levels. The Royal Irrigation Department does not have jurisdiction in these areas, as they are classified as 1A Watersheds; human activities are legally not allowed, and the Royal Forest Department is responsible for enforcing land use restrictions and forest management regulations. However, the government has had to recognise a certain level of human settlement in restricted watershed areas. At the same time, three levels of resource governance are undergoing significant changes, all of which have potentially high relevance to upland water users.

Tambon (Sub-District) Administration Organisation (TAO). Recent reforms to promote decentralisation and democratisation have made the Tambon Administration Organisation (TAO) the central focal point of local governance. The TAO, a level of official governance administratively located between the village and district levels, is seen primarily as an engine of local development, channelling budgetary resources to the most needed projects. However, the mandate of the TAO effectively makes it the primary decision-maker on development and environment questions. The TAO has got involved in financing projects, as was seen in the village water supply project for San Pu Loei. Huai Sai Khao farmers have made a proposal to the TAO for resources to construct a large facility for irrigation water storage as well. This reflects a widespread feeling in many areas that water scarcity problems require technical solutions, and that they should be addressed through the development budget of local government. Despite tensions between administrative villages, the local TAO has hesitated to take an active role in mediating these disputes, since this is still viewed as the domain of village leaders.

Watershed networks. In the 1990s, there was a perceived gap in upland resource governance created by the lack of an institutional framework to facilitate solutions at the upper tributary watershed level. The government institutional framework was not able to provide conflict resolution for upstream-downstream conflict. In fact, various government agencies have been in conflict with upland communities over land use and forest management issues. Watershed management networks, driven by the local stakeholders and non-governmental organisation, then began to appear as a platform for dialogue between upstream and downstream villages. Most watershed networks focused their efforts on addressing watershed forest loss and its potential impacts on the hydrological system. In general, the networks have been slower to recognise the importance of upland irrigation, and can serve to reinforce the upstream-downstream and ethnic differences that exist by focusing only on forest management (Badenoch, 2006), echoing some of the sentiment of the official discourse on watersheds. However, as local initiatives, many of these networks have been successful in establishing a dialogue that is more representative of local stakeholders. For example, in the Mae Ta Chang watershed, also located in Chiang Mai province, the local stakeholders were able to establish both regulations on water abstraction and an effective committee because the stakeholders collaborated to collect information on water usage, thereby establishing a shared platform upon which further discussions could be held (Neef, 2008; Chaiphon, 2005). The Mae Suk watershed management network, bringing together the upstream Hmong and Karen villages with the downstream Thai villages, was formed in 2003, but it has avoided addressing water use issues.⁸

River basin organisations. A national effort to establish river basin authorities has seen the recent completion of a pilot phase of institution-building at multiple levels. The challenge has been to establish

⁸ The Mae Suk Watershed Network is described in more detail in Badenoch, 2006.

a viable mechanism that allows bottom-up processes within a framework to coordinate larger socio-environmental concerns. Discussions under the pilot activities have not recognised upland water users at the higher levels, although local dialogues have tried to address the issue of growing demand for water throughout the landscape. The two prominent points of contact with local communities in these processes are the local watershed networks and TAOs (Thomas, 2005). Clearly, the effectiveness of efforts to achieve dialogue, participatory planning and budgetary support at this level depend heavily on the degree to which the TAO and watershed networks are able to engage upland irrigators. In the Mae Suk watershed, upland leaders have described how the river-basin pilot activities have provided them with a useful channel of communication, in which the Hmong and Karen can extricate themselves from the politically charged conflicts of their locality to take part in negotiations linked with larger sources of authority (Badenoch, 2006). Local participation in the government's efforts to address water conflict is lacking across the northern Thai highlands (Heyd and Neef, 2006).

The institutional framework for upland resource governance has provided interesting opportunities for involving a range of stakeholders at a variety of levels. However, the role of upland irrigators within these remains ill-defined. Upland water users are concerned first with the fragile nature of their own local resource management institutions. With their own internal cohesion in flux in each locality, there is very little basis for making an approach to other centres of authority, such as local government, watershed networks or other larger basin-based activities. TAOs, watershed networks and river basin organisations are the local manifestation of changes within the larger governance framework, but the real implications of these changes will only be seen through interplay with other local institutions, both formal and informal (Garden et al., 2006).

Developments in lowland irrigation have focused on devolving management rights and responsibilities from central agencies to local user groups. In the north of Thailand, traditional muang faai user groups have been effective in managing the infrastructural and allocation issues that support their agriculture. Indeed, much of the mainstream thinking about the governance context of water management is derived from the muang faai experience. However, the upland irrigation system is in a fundamentally different position. These upland systems are not faced with the need to pull back state authority in order to empower local decision-makers from centralised and bureaucratic administration. They are challenged rather by the need to scale up institutional arrangements and link with other levels of resource governance to create new sources of legitimate authority.

This study suggests that the emerging local governance systems lack effective mechanisms for negotiation and problem-solving. These systems are vulnerable to the politics of the area, much the same way that the watershed discourse in Thailand is highly politicised. In Huai Sai Khao, the preference is to keep the politics of PVC localised, but experience has shown that there are limits to the authority of a purely local arrangement based on customary social institutions. Links to external sources of authority are tenuous, and the first step towards strengthening governance processes should focus on consensus-building and problem-solving processes.

Upland irrigation provides an interesting opportunity to examine the subsidiarity principle – that authority over decision-making should be allocated at the level that best represents the relevant stakeholders – from bottom up (World Resources Institute, 2002). In a watershed context, the need to define stakeholders at different levels with reference to ecological scales requires a dynamic process of governance. The institutional framework surrounding watershed management in Thailand has experienced significant changes in the past decade. There is an effort to rethink how institutions at differing scales of governance should be linked in a nested hierarchy. A key element of this challenge is how levels of governance relate to ecological systems at different scales. However, these upland water management groups still fly under the radar of policy discussion.

CONCLUSIONS

The evolving dry-season irrigation systems face the multi-level challenges of mediating allocation of water among farmers in localities across the mountains, competition between domestic and agricultural water users, inter-village conflict over water sources, and watershed-level tensions over perceived changes in hydrological regimes. There is a need for further examination of these dynamics from a combination of technical, ecological and social perspectives. The almost complete lack of information on actual water use in PVC-sprinkler irrigation systems is a high priority area for future research. An improved understanding of the water management and use trends is important not only for the local social-ecological system, but will be a vital component of efforts to support watershed governance at larger scales, as well.

Upland irrigation seems to be evolving towards a more robust social-ecological system, where small user groups develop more complex water management arrangements within a larger system of stream-level rules. Institutions at the stream-level will likely retain a significant degree of flexibility to respond to the demands created by cycles of cooperation and competition within the system. As suggested by Folke et al. (2005) the social features and processes underlying adaptations are often not well understood. Moreover, the evolution of stream-level governance should be considered closely with institutional developments at higher scales of watershed management as well.

The technology and institutions driving the spread of upland irrigation are evolving together in a complex process of adaptive management. It is clear that the widely held view that water is an open access resource in the mountains does not hold with closer investigation. The shifting balance of cooperation and competition over water provides a useful window on the processes of adaptive management. These cycles demonstrate the mutual influence of technological and institutional developments, the importance of existing social institutions for irrigation institutions, and the limitations of customary and novel institutional arrangements.

The observed cycles of competition and cooperation caution against a static understanding of institutions. Similarly, common perceptions of ethnicity and resource management are challenged by examining cooperation and competition in a local context. Three decades of watershed policy have created a general understanding of upstream-downstream, or upland-lowland, conflict at multiple levels in society. This watershed construction has reinforced the older construction of the upland-lowland ethnic divide, and has served to oversimplify the social dynamics underpinning relationships between user groups in mountainous areas. There is no homogeneous or cohesive 'upland' or 'upstream' group. Serious efforts to address resource competition must be based on a more nuanced understanding of interactions between water managers.

Addressing water management issues in the broader landscape of resource governance will require a shift in the popular thinking to view uplanders as not only providers of water, but also as legitimate users and managers of water. Recognition of upland farmers as water users will require a focus on rules governing access to, and use of, water. Although local rights systems that could support complex institutional arrangements may be emerging in many diverse forms (Neef et al., 2006), broad-based consensus on the principles of water management that can be derived and maintained across village boundaries, ethnic boundaries and sector groups, as well as across the local scales of management, are needed before larger policies can begin to provide legal recognition of water rights.

The watershed remains a contentious concept in Thailand. The politics of the watershed are not simply a struggle between state and community, nor are they merely a clash of conservation and development. Similarly, the dominant conception of upstream versus downstream oversimplifies the complexity of water use and interaction between communities. The current reality goes beyond these dichotomies to demand a reconsideration of the local actors, their practices and their interactions. This requires a deconstruction of the assumptions underpinning the perception of watershed problems, in which the diversity of upland communities, and the tensions within them, are examined in light of larger resource relations.

REFERENCES

- Badenoch, N. 2008. Hmong social networks in the upland landscape of Northern Thailand: Village governance in times of resource scarcity. In Leeprecha P.; McCaskill, D. and Buadaeng, K. (Eds), *Challenging the limits: Indigenous peoples of the Mekong region*. Chiang Mai: Silkworm.
- Badenoch, N. 2006. Natural resource governance and social networks in a multi-ethnic watershed of Northern Thailand. PhD thesis. Kyoto: Kyoto University.
- Chaiphon Prabhasavat. 2005. Lessons from Mae Ta Chang watershed. Research report of Mae Ta Chang River Project, Chiang Mai.
- Cooper, R. 1978. *Resource scarcity and the Hmong response: Patterns of settlement and economy in transition*. Singapore: Singapore University Press.
- DAI (Development Alternatives Inc). 1987. Second evaluation of the Mae Chaem Watershed Development Project, Thailand. Report prepared for the US Agency for International Development. Washington, DC.
- Folke, C.; Hahn, T.; Olsson, P. and Norberg, J. 2005. Adaptive governance of social-ecological systems. *Annual Review of Environment and Resources* 30: 441-473.
- Forsyth, T. and Walker, A. 2008. *Forest guardians, forest destroyers: The politics of environmental knowledge in northern Thailand*. Chiang Mai: Silkworm.
- Garden, P.; Lebel, L.; Badenoch, N. and Viseskul, F. 2006. The consequences of institutional density and interplay for local governance in northern Thailand. USER Working Paper WP-2006-03. Chiang Mai: Unit for Social and Environmental Research, Chiang Mai University.
- Hayami, Y. 2004. *Between hills and plains: Power and practice in socio-religious dynamics among the Karen*. Kyoto Area Studies on Asia, vol 7, Center for Southeast Asian Studies. Kyoto: Kyoto University.
- Hengsuwan, P. 2003. Contradictions on the struggles over resources and contesting terrain of ethnic groups on the hill in protected area, Chom Thong, Chiang Mai. Paper presented at the International Conference on Politics of the Commons: Articulating Development and Strengthening Local Practices, Chiang Mai, Thailand, July 11-14, 2003.
- Heyd, H. and Neef, A. 2006. Public participation in water management in northern Thai highlands. *Water Policy* 8(6): 395-413.
- Laungaramsri, P. 2000. The ambiguity of 'watershed': The politics of people and conservation in Northern Thailand. *Sojourn* 15(1): 52-75.
- Molle, F.; Shah, T. and Barker, R. 2003. The groundswell of pumps: Multilevel impacts of a silent revolution. Paper presented at ICID-Asia Meeting, Taiwan, November 2003.
- Neef, A. 2008. Lost in translation: The participatory imperative and local water governance in North Thailand and Southwest Germany. *Water Alternatives* 1(1): 89-110.
- Neef, A.; Chamsai, L. and Sangkapitux, C. 2006. Water tenure in highland watersheds of northern Thailand: Managing legal pluralism and stakeholder complexity. In Lebel et al. (Eds), *Institutional dynamics and stasis: How crises alter the way common pool resources are perceived, used and governed*. Chiang Mai: RCSD/Chiang Mai University.
- Sangkapitux, C. and Neef, A. 2006. Assessing water tenure security and livelihoods of highland people in northern Thailand. *Quarterly Journal of International Agriculture* 45(4): 377-396.
- Surarerks, V. 1986. *Historical development and management of irrigation systems in Northern Thailand*. Bangkok: Ford Foundation.
- Tanabe, S. 1994. *Ecology and practical technology: Peasant farming systems in Thailand*. Bangkok: White Lotus.
- Thomas, D. 2005. *Developing watershed management organizations in pilot sub-basins of the Ping river basin*. Final Report to ONEP under the Participatory Watershed Management Consultancy. Bangkok: Office of Natural Resources and Environmental Policy and Planning (ONEP), Ministry of Natural Resources and Environment.
- Uphoff, N. and Krishna, A. 1999. Measuring and mapping social capital: A conceptual and empirical study of collective action in conserving and developing watersheds in Rajasthan, India. Social Capital Initiative Working Paper No. 13. Washington, DC: World Bank.
- Walker, A. 2003. Agricultural transformation and the politics of hydrology in northern Thailand. *Development and Change* 34(5): 941-964.
- Walker, A. 2001. The 'Karen Consensus', ethnic politics and resource-use legitimacy in Northern Thailand. *Asian Ethnicity* 2(2): 145-62.
- World Resources Institute. 2002. *The World Resources Report: 2002-2004*. Washington, DC: World Resources Institute.