The Politics of PVC:
The co-evolution of technology and institutions in upland communities in Northern Thailand

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1. Introduction: technology, institutions and new governance challenges

Sprinkler irrigation has become a common component of upland agricultural livelihoods in northern Thailand. The advent of water management in upland fields involves a co-evolution of technology and institutions. This co-evolution has created new challenges in the upland resource governance landscape, as upland farmers are now significant users of water. As water managers, upland farmers interact with each others in new ways, and have added a level of complexity to upstream-downstream relations as well. 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. The implications of these developments have been for the most part overlooked or ignored. Where it has received attention, upland irrigation has been conveniently incorporated into larger discourses of watershed.

Watershed policy in Thailand has focused on the communities – predominantly upland ethnic people – in the uplands as responsible for the problems of dry-season water shortages being faced by the lowlands. The watershed discourse in northern Thailand has thus turned lowland water shortages as a political tool involving ethnicity by which the predominantly ethnic Thai lowlanders claim rights over upland resources (Pinkaew, 2000). An overwhelming emphasis has been given to deforestation, but increasingly, upland farmers are becoming important managers of water. The technology and institutions, and associated rights systems and forms of organization have not been adequately recognized by official policy.

At the same time, research has also failed to recognize 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 customary and new institutions. Developments in technology and institutions continually feed back into the tenuous balance between competition and cooperation. As emerging forms of adaptive governance, upland irrigation systems provide an interesting look into process through which local populations and resources interact.

This paper[1] introduces the sprinkler irrigation systems of northern Thailand and the institutions that have evolved in parallel with the technology. The analysis treats 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 data was collected through an ethnographic approach to fieldwork, and is presented here as such. Discussion of this co-evolution identifies some of the key challenges to understanding upland water governance at multiple levels. The data presented is from the upper Mae Suk River, a tributary of the Mae Chaem River in Chiang Mai province.

[1] This work is adapted from the author's doctoral dissertation, *Natural Resource Governance and Social Networks in a Multi-Ethnic Watershed of Northern Thailand*, Kyoto University 2006. Field-based research was conducted with support from ICRAF Chiang Mai. The full text is available in pdf at http://www.worldagroforestry.org/sea/Publications/searchpub.asp?publishid=1476

2. Huai Sai Khao valley: Cooperation and conflict over upland irrigation water

Previous to the introduction of upland irrigation, crop production in sloping fields was limited to the rainy season. The flexible and inexpensive infrastructure of PVC pipes and sprinklers has enabled farmers 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 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 was the second largest producer of opium in Chiang Mai province (DAI, 1987), but is now a major center of cabbage cultivation in Mae Chaem.

Drawing on small, upper tributary streams, the early stages of irrigation technology development were driven by individual households. As the technology spread and irrigated agriculture was intensified, investments in infrastructure grew and institutions for managing water at levels larger than the individual began to emerge. This institutional development was driven by the need to manage competing demands on limited water resources. The interaction between technology and social institutions is a key component of an emerging system of adaptive water governance. Local water users move through cycles of competition and cooperation at different scales of management, from the individual user and local user group to larger stream and watershed levels.

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 San Pu Loei, a Karen village where farmers struggle to balance their strong preference for rice self-sufficiency and pressures to increase their production of vegetables for the market. Hmong farmers from the neighboring village Ban Phui Nua farm in the Huai Sai Khao valley as well. The Hmong began to acquire land here in the late 1970s, when opium was still being planted, and continued to gain access through the 1980s and 1990s. Figure 1 (ICRAF Chiang Mai GIS data) shows the land use trends in the Huai Sai Khao area, marked in red, between the Karen village of San Pu Loei and Ban Phui Nua.

The Hmong and Karen farmers of the valley utilize 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.

These fields were 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 m^2 under cultivation, of which 53 percent is Hmong and 47 percent is Karen. The average plot size is approximately 4,200 m^2, without significant differences between the two groups. Of a total 59 plots, the Hmong held 32 and the Karen 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*, 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.

3. 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, and initial experimentation yielded promising results. The streams of the upland areas would come under management for the first time.

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 transporting the 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; hoses connected to sprinkler heads that are attached to bamboo poles. Sprinklers are rotated around individual fields, keeping the soil moist. In other places in Mae Chaem district, farmers have begun to use diesel and electric pumps to lift water from streams to adjacent fields as well. Farmers do not pay for their irrigation water.

The technology is not entirely different from the traditional Hmong system of supplying water to their villages through bamboo aquaducts. 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.

3.1 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. This area is treated as community watershed forest by the Karen of San Pu Loei, and has traditionally been the source of water for a small area of irrigated paddy.

In the Huai Sai Khao valley, the average length of the pipe system is approximately one kilometer, and the route traveled by water follows the natural contours of the valley topography. The engineering practiced by local farmers can bring water from as far as 10 or more kilometers, 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 leakages difficult.

In 2004-2005, there were twenty abstraction pipes in the Huai Sai Khao stream. Of these, 14 belonged to the Hmong, with the Karen owning six. Source pipes are usually shared by two or more farmers, as there is a general agreement among both groups that strictly individual use of pipes is inappropriate. Farmers sharing abstraction pipes jointly maintain the weir and pipes. Most pipes were originally installed by one farmer, but access was subsequently granted to one or more farmers as more people began dry season cultivation. The Huai Sai Khao irrigation system is shown in Figure 3.

The capacity to store water in small field ponds is a critical feature of the system. Capacity to store water has implications for perceptions of water scarcity. Field ponds also represent an important step in the development of more complex management arrangements among individual users. The number and size of field ponds provides the clearest 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 10 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 side, which may explain some of the difference, but farmers themselves recognize 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 solution to water scarcity across the entire valley.

It does, however, provide a mechanism for more equitably allocating water among a larger number of users.

The concrete field ponds were originally simple earth ponds, shared by three or four farmers. With intensifying 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 actual 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 amount to a total width of 35.1 in^2, while the Karen pipes have 32.4 in^2 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 access to water, 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 user within the valley.

3.2 Dealing with water scarcity

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. When water first becomes scarce, farmers in a user group will use a day-on/day-off system of rotation. When water shortages start to get more serious, the group will move to a half-day rotation of day-on/day-off. 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 afternoon users frequently run out of water before they 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.

Starting in mid-January, tail-end users may experience severe water shortages. The rotational allocation of water by upstream users often consumes all available water during the day. In these cases, it is not uncommon, particular from the users of R5, L9, L10, L11 and L12 to switch to night[3] irrigation. Those farmers with farm ponds begin to fill them in the evening after upstream users have closed their pipes, and 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 streamflow enough to serve the tail-end users. However, all farmers agree that it is impossible to expand water abstraction below the R8 and L13.

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 free 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 excluded from access to irrigation water

[3] It is likely that the loss of water to evaporation and wind is significantly lower at night. However farmers avoid irrigating at night when possible. Night irrigationg is more of a burden on Karen farmer than Hmong. This is because night irrigation is done primarily by Shan laborers working for the Hmong. Night irrigation is a potentially interest topic for further study.

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 has not materialized yet. 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. In many Hmong villages in the area, village water committees are charge households for domestic water consumption, based either on a flat rate per household or by the number of household members.

Irrigators in the Huai Sai Khao valley are managing their water a several levels – from the individual to larger user groups. Technological approaches to water scarcity have enabled farmers deal with water scarcity and develop increasingly complex water management arrangements.

4. The institutions: Managing cooperation and competition

The Karen and Hmong have been managing irrigation water with this technology for over 10 years. But because this is a relatively new addition to the 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 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. It is interesting to note that there is only one case of water sharing between the Karen and Hmong. This arrangement is actually a water-for-land swap, but was only valid for 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.

Indeed, there is an underlying ethnic component to this tension, as much of the conflict is described locally in terms of Karen and Hmong management practices. However, a review of the history of irrigation infrastructure development in the Huai Sai Khao valley uncovers a more nuanced view of the limits of local institutional capacity.

4.1 Underlying social institutions and water sharing arrangements

Given the newness of the technology, traditional institutions for managing upland irrigation do not exist per se. The management challenges posed by a new form of resource competition and the demands for institutional innovation are based on other broader social institutions in the local societies. Kinship networks play a large role in determining how decisions are made, disputes settled and information flows. 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 typically been centered 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 at within lineages, and at times across clan boundaries (Badenoch, forthcoming 2007). 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).

The vast majority of water users in the Huai Sai Khao valley are members of the Tsaab clan, with the remainder belonging to the two other 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. 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 storage enabled farmers to enter into water sharing agreements based more on the spatial distribution of fields than the lines of kinship. In some cases, farmers jointly invest in the storage construction and then share the water equally. In other cases, farmers reach individual arrangements to share water, including agreements about how water will be allocated in the event of water shortage.

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 is 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 headman, also an elder of the Tsaab clan.

Chapika et al. (2006) have described how the Hmong of Ban Mae Sa Mai, a village with a history of intensive and on-going development intervention, have developed collective action arrangements that effectively allocate water. In Ban Phui Nua, where external 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 seems to be less so in establishing new norms to govern emerging collaborative management. Exploitation of water sources is done primarily on an individual basis, and then expanded through the storage and delivery system. This is 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) enjoy the rights to its use. The adaptive capacity of the kinship system appears at a later stage to manage the dynamics of competition and cooperation, as the complexity of the social-ecological 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 adopted the cooperative institutions to manage paddy rice irrigation. Karen kinship is typically organized along matrilineal lines, with a high degree of in 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, labor and resources within this extended social network is an important form of Karen social capital.

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, compared to the Hmong, who were almost exclusively from the dominant local clan lineage. In 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.

4.2 Institutional experimentation at the stream level

As discussed above, institutional arrangements for sharing water are developing at the individual level. User groups in both the Hmong and Karen communities, forming around field ponds and shared pipes, are developing increasingly complex ways to allocate water and perform operation and maintenance tasks. However, tension has risen continuously among user groups and individual users. The difficulties in re-scaling the institutional arrangements to address competition at the stream level point to the local frontier of adaptive management.

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 1995 when farmers began to perceive water shortages, which they attributed to the continuing growth of water abstraction. By this point, farm ponds were beginning to play a larger role in water delivery, while providing a platform for collaborative management. In 1996, a new pipe was inserted at the head of the stream, setting off a dispute about the lack of regulation of new exploitation. Reaching crisis, the disputants fell out along ethnic lines. Physical violence was narrowly avoided, but several pipes and dams 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, comprised of the two Hmong and two Karen elders who had already been active in managing competition in their own respective groups. The committee produced an agreement requiring the removal of the offending pipe and prohibiting further development. A dispute resolution mechanism was instituted to avoid conflict from farmers to escalate. In addition to being leaders within each group, the elders enjoyed a significant amount of respect between the groups.

But in the following years of 2004 and 2005, new pipes continued to appear in the upstream area, returning the valley to an atmosphere of tension. During this period, the competition for water was complicated further by the construction of a village water supply off-take point to supply San Pu Loei. This project was supported by budget from the Tambon Administration Organization. Although it introduced direct competition between domestic and irrigation water, most local people agree that domestic water must be prioritized. Nonetheless, the result was to increase demand. It is also interesting to note that the post-1997 expansion of pipes was primarily by Karen farmers, but it was the Karen of L10, L11 and L12 that experience the most significant loss of access to water.

Although the new pipes had actually improved the overall balance of access to water between the Karen and the Hmong, the resulting water shortage caused serious rifts within the Karen community and drove a wedge between the Hmong and Karen. The Management Committee broke down, as the Hmong refused to engage in negotiations over what they now perceived to be Karen problem. The Karen elders tried to convene the Management Committee to discuss possible solutions. But 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." This statement illustrates the fragility of the committee and its agreement, and highlights the basic divide that remains between the two groups.

Throughout the history of tension, 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 say 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 he would prefer that they use their own clan mechanisms to negotiation among themselves and engage with the Karen in the locality. For the Karen, San Pu Loei has not faired well in past negotiations with the Hmong of Ban Phui Nua. From his point of view, a longer-term strategy to align the Karen with the downstream Thai is preferable.

4.3 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 on-going 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 are based on the foundation of existing social institutions.

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. Figure 5 shows the feedback loops.

In some cases, a technological development has allowed an institutional development. For example, the construction of the large Karen field pond (T2) allowed the 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 neighboring irrigators whose pipes had not been connected to the field pond. As technological and institutional adjustments are made, patterns of competition and cooperation are observed. In Huai Sai Khao, there are two main determinants of the outcomes.

First, one boundary that water management continually bumps against is the physical availability of water in the stream system. Although the exact quantity of water available is not known (not to mention sustainable levels of exploitation), these temporal fluctuations are closely monitored by farmers. As water becomes increasingly scarce through the duration of the dry season, the balance between cooperation and cooperation 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, in which amount, at which times is 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.[4]

[4] 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 believe that installing water meters would result in improvements in the system,

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 affinal relations, and form the basic foundation for much of the collaborative energy 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. The lack of trust is most prominent between the Hmong and Karen. The creation of social capital at the watershed level is crucial to the effectiveness of institutions (Uphoff), especially where institutions have been adapted or newly formed. In the Huai Sai Khao valley, it seems that relationships of trust are over-focused on the four elders, and the main manifestation of this trust is seen only in times of crisis.

Finally, the fundamental uncertainty of rainfall underpins these social and technological decision-making processes. Not surprisingly, conflict – and resulting adaptations in technology and institutions – is most acute in dry years. During the 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.

Through the feedback loops of technological and institutional development, farmers adjust the scale of water management in their locality 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.

5. 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. 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.

Indeed, downstream water users, who perceive upstream farmers' development of water management as a step beyond what is acceptable, are increasingly vocal and at times violent in their expression of concern. Figure 5 (ICRAF Chiang Mai GIS data) above shows the location of the Huai Sai Khao valley within the Mae Suk watershed, an upper tributary catchment of in the Mae Chaem River.

The Huai Sai Khao valley is just one small site comprising a larger area of permanent upland fields (shown in orange) that represents successful opium crop replacement. This area of intensive vegetable and fruit cultivation is 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. This area was previously viewed as a threat to downstream society because of a perceived loss of watershed forest that had adverse impacts on the natural hydrological regime (1970s-1990s).

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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.

Recently, pressure on these areas has been compounded by the introduction of irrigation. Although the irrigation is of relatively small scale, its rapid spread has been a major source of concern for lowland farmers and urban areas. Mapping exercises to date have not tried to ascertain the extent of upland irrigation.

Within the socio-cultural and political biases aligned against uplanders in the Thai watershed discourse (Pinkaew, 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 recognize 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 Administration Organization Recent reforms to promote decentralization and democratization have made the TAO the central focal point of local governance. The TAO is seen primarily as an engine of local development, channeling budgetary resources to the most needed projects. However, the mandate of the TAO effectively makes the TAO primary decision-maker on development and environment questions. The TAO has gotten 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 wide-spread 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, TAOs have been hesitant to take an active role in mediating these disputes, as this is still viewed as 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 then began to appear as a platform for dialog between upstream and downstream villages. Most watershed networks focused their efforts on addressing watershed forest loss and its potential impacts on the hydrological system. The networks have been slower to recognize the importance of upland irrigation, and can serve to reinforce the upstream-downstream and ethnic differences that exist (Badenoch, 2006).

River basin organizations 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 a viable mechanism that allows bottom-up processes within a framework to coordinate larger socio-environmental concerns. Discussions under the pilot activities have not recognized upland water users at the higher levels, although local dialogs 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 (David Thomas, pers. comm.). It is clear that the effectiveness of efforts to achieve dialog, 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).

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 centers of energy such as local government, watershed networks or other larger basin-based activities. TAOs watershed networks and river basin organizations 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). While farmers and village leaders are reluctant to address inter-village problems through official channels, there is a widely-held view that the current problems require intervention from a larger source of authority.

Developments in lowland irrigation have focused on devolving management rights and responsibilities from central agencies to local user groups. In the north of Thailand, *muang fai* user groups have been effective in managing the infrastructure 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 fai* experience. However, the upland irrigation system is in a fundamentally different position. These upland systems are not faced with the need to extricate local decision-makers from centralized and bureaucratic administration. They are challenged rather by the need to scale up institutional arrangements and link with other levels of resource governance to achieve water management at higher levels.

Upland irrigation provides an interesting opportunity to explore the subsidiarity principle – that authority over decision-making should be allocated at the level that best represents the relevant stakeholders – from the 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. How levels of governance relate to ecological systems at different scales is a key element of this challenge. However, these upland water management groups still fly below the radar of policy discussion. Nonetheless, the spread of sprinkler irrigation has elevated tensions between between upstream and downstream communities.

6. Conclusions

The evolving upland 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 their water management practices 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 open access resource in the mountains does not hold up to 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. As farmers gradually scale up their technological and institutional arrangements for managing water, important insights emerge on the opportunities and potential difficulties of relating to larger trends in resource governance.

While research, policy and dialogue efforts should not assume a complete vacuum in local institutions governing upland irrigation, one should not over-estimate the strength of collective norms embodied in the institutional arrangement observed. The observed cycles of competition and cooperation caution against a static understanding of institutions. 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 resource governance landscape will require a shift in the popular thinking from 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. For example, locally administered water fees linked to operation and maintenance costs of upland irrigation may in the future emerge as a mechanism for more equitable allocation. Although local rights systems that could support such 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, and across the local scales of management, are needed before larger policies can begin to provide legal recognition of water rights.

Meanwhile, the watershed remains a politically ambiguous concept. But 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 is 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, are examined in light of larger resource relations.

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Figure 1: Huai Sai Khao valley

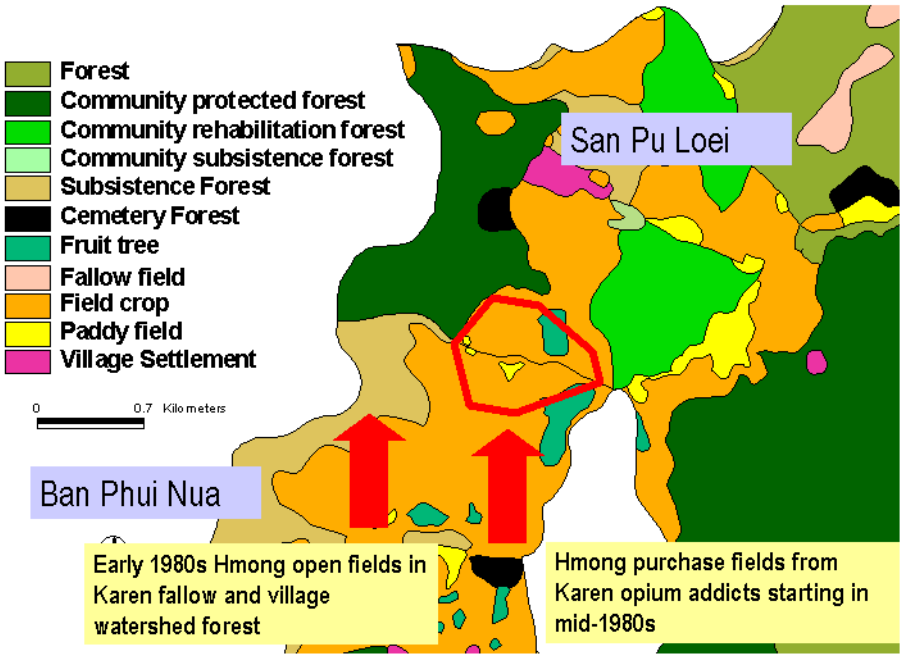

Figure 2: Shallot fields in the Huai Sai Khao valley, 2004-2005 dry season

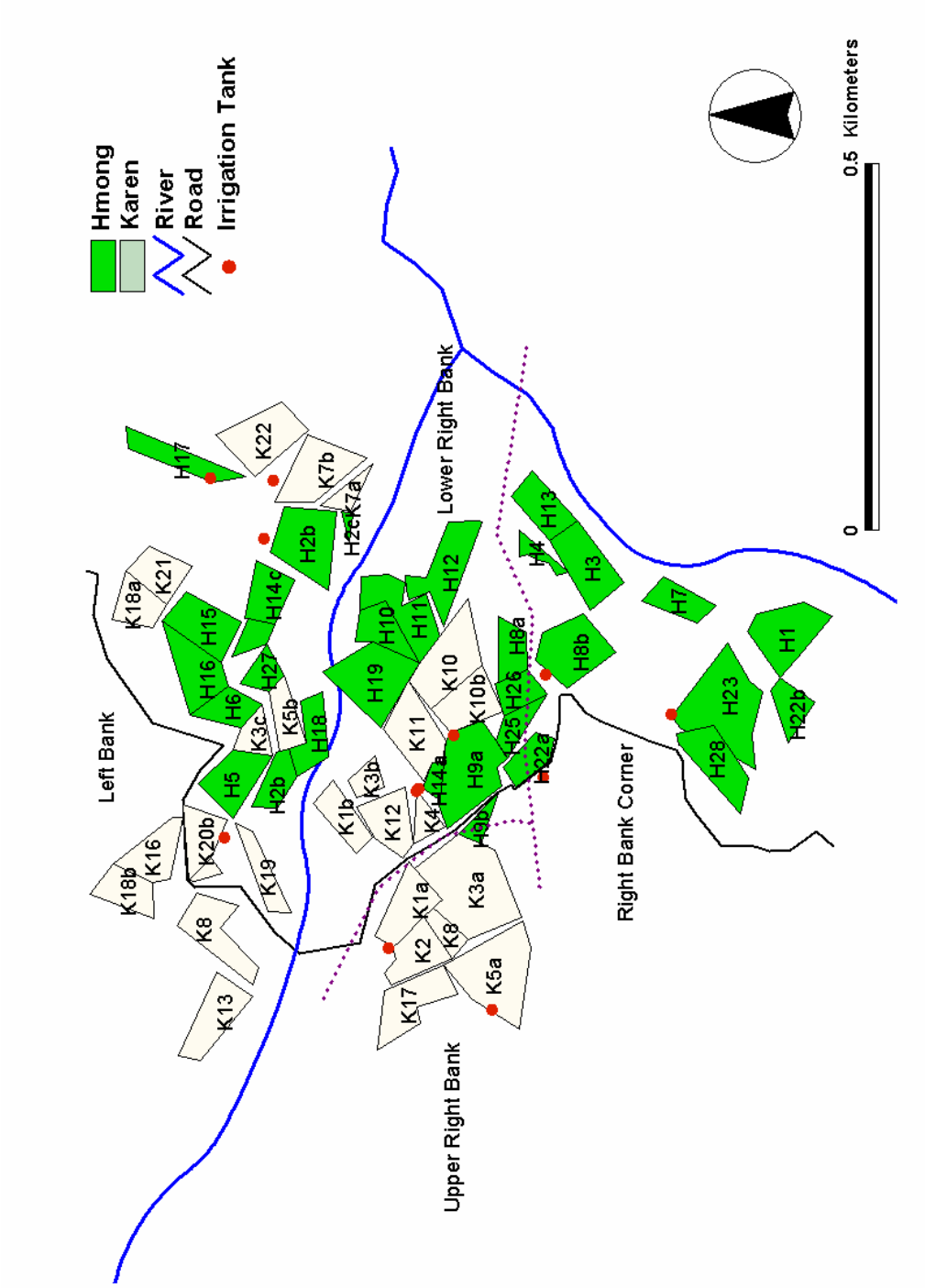

Figure 3: Huai Sai Khao PVC pipe irrigation

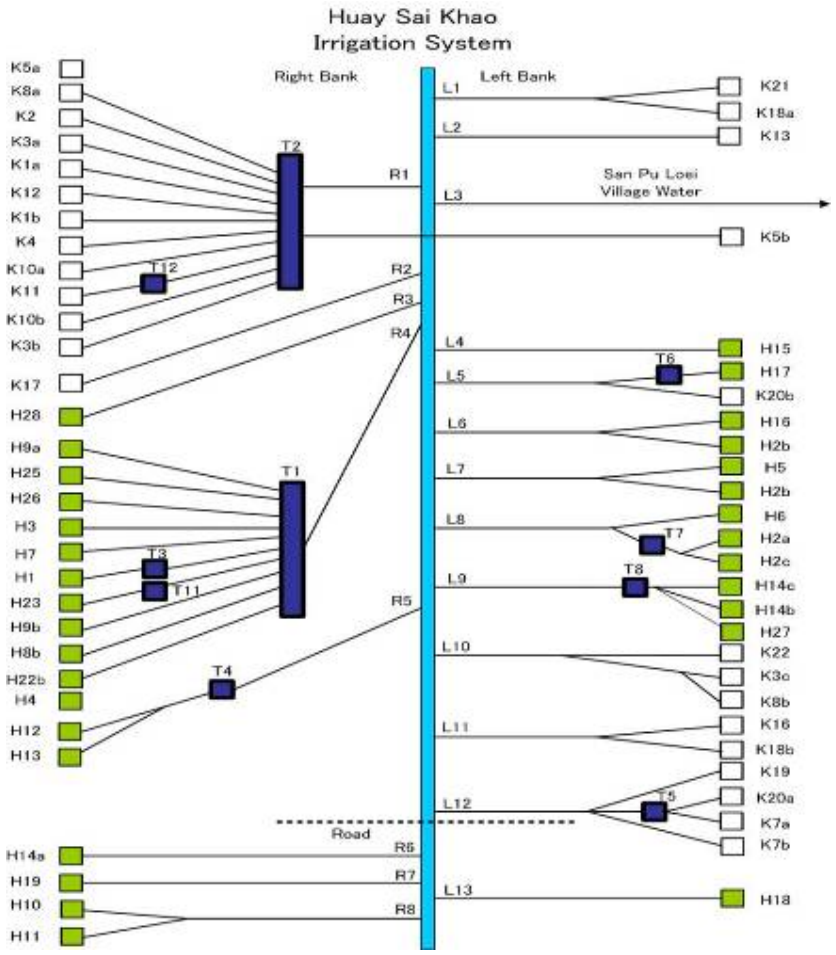

Figure 4: Cyclical processes of adaptive management

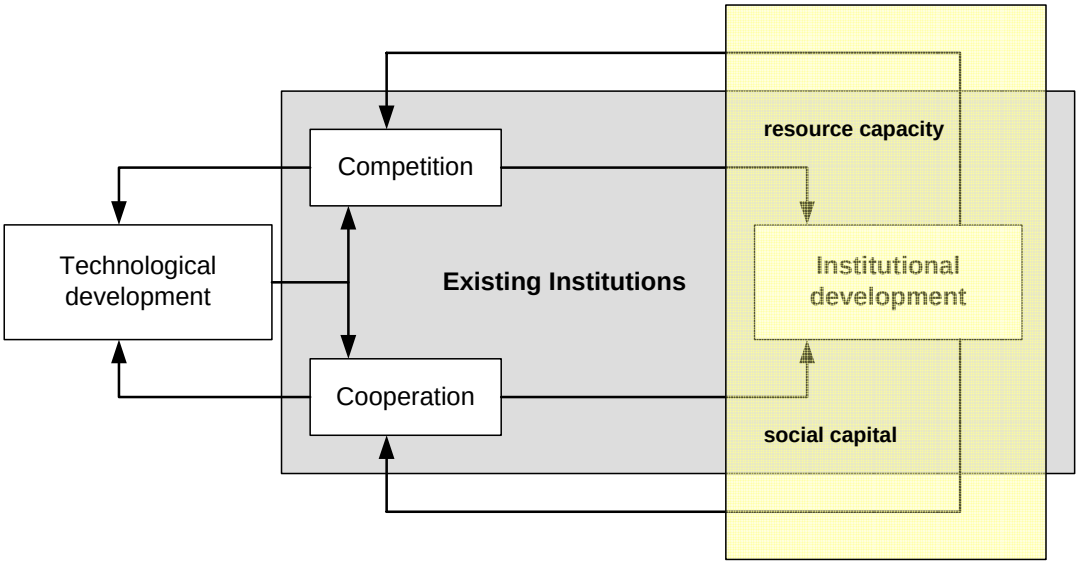

Figure 5: Huai Sai Khao within Mae Suk Watershed

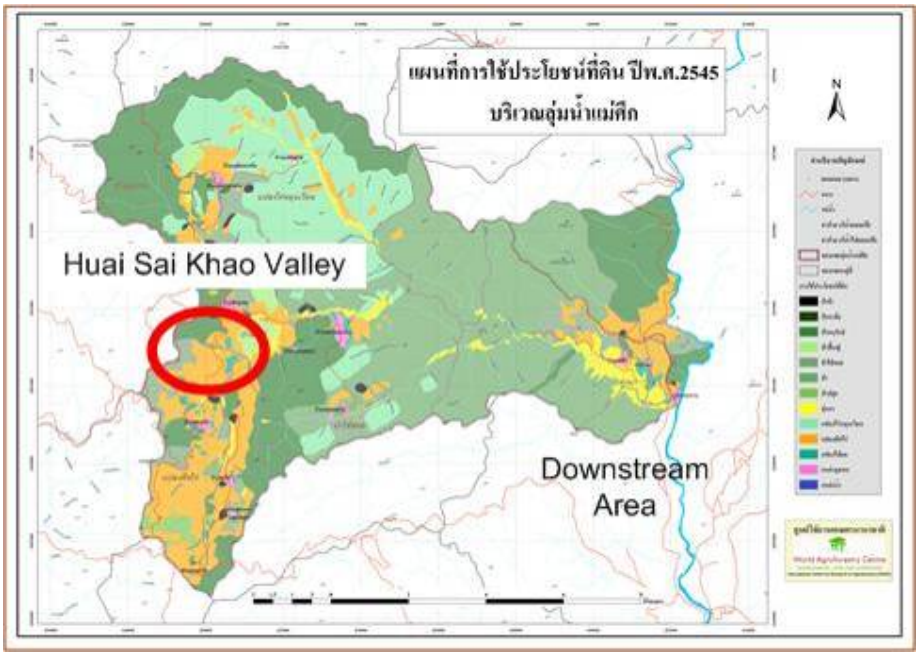

Table 1: Chronological development of PVC irrigation pipes

Chronology of Pipes					
	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