Agricultural Transformation and the Politics of Hydrology in Northern Thailand

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ABSTRACT

Tensions over water resources in upland areas of northern Thailand are often attributed to reductions in water supply caused by forest clearing. This article argues that the hydrological evidence for such reductions in supply is very weak and that, rather, the key hydrological issue in upland catchments is a significant increase in water demand, especially during the dry season. The arguments are illustrated with a detailed examination of the Mae Uam catchment, located in Chiang Mai province, where the development of dry-season soybean cultivation appears to have tested the hydrological limit of the catchment, and even exceeded this limit in drier years. The author argues that a shift in focus from water supply to water demand has fundamentally important political implications. As long as the focus of public debate is on water supply, the regulatory focus will be on those resident in the forested upland areas that are seen as being crucial in securing downstream flows. But if the water management focus is shifted to water demand, then regulatory attention must shift to the diverse sources of demand that exist throughout the hydrological system.

INTRODUCTION

The recent history of development in the mountainous upland areas of mainland Southeast Asia has been one of increasing resource tension. Population growth, migration, commercialization and infrastructure construction have generated unprecedented pressure on upland resources at the same time that official systems of land regulation have sought to meet both development and conservation objectives. Agricultural transformation and the intensification of linkages between rural and urban sectors have posed new challenges that existing institutional structures are often poorly equipped to meet. In many mountainous upland areas, resource tensions are compounded as they find local and national expression in various forms of ethnic manoeuvre, which seek to define some groups as less legitimate users of highly valued natural resources. Responses to these denials of legitimacy are often framed in similarly ethnic terms as they promote traditions of indigenous resource management as a basis for local identification and political mobilization.

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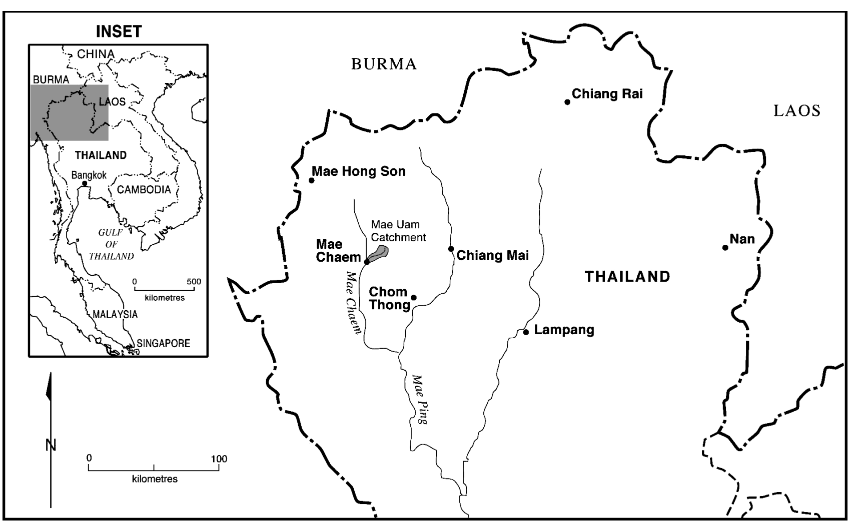
In the mountainous uplands of northern Thailand, water resources have emerged as an important point of tension. In the upland catchments of the Ping River basin (see Figure 1), there have been increasing reports of conflict over agricultural water supplies between upstream and downstream communities. Underlying many of these conflicts is the persistent claim that the shortages experienced by lowland farmers are caused by watershed degradation — forest clearing in particular — by upstream farmers in sensitive watershed areas. It is regularly asserted that forest cover in mountainous areas is crucial for securing downstream water supplies and that population growth and agricultural expansion in these forested zones has resulted in downstream desiccation. Water *supply*, and its relationship with forest cover, has become one of the key issues in national environmental debates.

Much less attention is paid to water *demand*. In fact, with relatively few exceptions, the water demand implications of several decades of agricultural transformation in upland catchments have received little attention. A predominant regulatory and research focus on upland catchment degradation — and an ongoing debate about the best strategies for the preservation of resources — appears to have diverted attention away from the patterns of resource use arising out of transformed production systems. This is somewhat surprising given the available evidence that dry-season agricultural production, in particular, has increased from a very low level some five decades ago, to the point where it now covers much of the paddy land in narrow valley bottoms and, in areas where sprinkler irrigation has been adopted, substantial non-paddy areas as well. Some concerted analysis of the hydrological implications of this expansion is long overdue.

Figure 1. Northern Thailand with the Mae Uam catchment.



This article draws insights from anthropology, economics, agronomy and environmental science to examine these hydrological issues in northern Thailand. It critically assesses the impact of recent agricultural development on both sides of the water management equation — water supply *and* water demand. It is based on a detailed case study of the Mae Uam catchment in Mae Chaem district of Chiang Mai province, a catchment in which some water resource tensions appear to be emerging. These recent tensions are placed in the context of two decades of agricultural transformation and land-use change. In relation to water supply, I examine the widely-held claim that local and regional forest clearing has disrupted the hydrological cycle, resulting in reduced rainfall and dry-season water shortage. I argue that there is very little evidence to support such claims, despite their widespread currency. I then turn to water demand, and examine the hydrological and sociological dimensions of the very substantial increase in dry-season irrigated agriculture in the Mae Uam catchment. My conclusion is that the most likely cause of increased water resource tension in Mae Uam, and elsewhere, is a dramatic and unprecedented increase in the level of demand for water in the dry season in both upstream and downstream areas. This conclusion is not only significant for agronomic and hydrological reasons but it has important implications for the contemporary politics of hydrology in northern Thailand. These political issues are the focus of the following section.

THE POLITICS OF HYDROLOGY

> Forest is the source of water for all people who live on Thai soil... it provides for underground water storage, making the ground moist as a benefit for all people. (Suan Pa Sirikit, n.d.; my translation)

Water resource management in northern Thailand has become highly contentious. State agencies, conservation groups and associations of lowland irrigators vigorously, and sometimes violently, argue that forest clearing undertaken by upland farmers causes water shortages (Pinkaew, 2000). This draws on a long tradition of blame in which upland cultivation, especially shifting cultivation, is portrayed as one of the primary causes of northern Thailand's deforestation and environmental degradation. The fact that many of these upland farmers are members of ethnic minority groups — some of whom are relatively recent arrivals in northern Thailand — provides fertile material for the combination of ethnic prejudice and environmental blame (Lohmann, 1999). These 'others within' (Thongchai, 2000) are all too easily portrayed as undermining the ecological basis of irrigated agriculture, one of the stereotypically core elements of Thai national culture. As such, there is widespread support for an array of watershed regulatory measures put forward by government agencies that seek to preserve and restore forest cover in upland catchments and restrict, or even relocate, the agricultural activities of upland groups. An official system of conservation-based watershed classification has declared vast areas of sloping upland as inappropriate for agricultural activity despite the long-standing presence of farming communities (Pinkaew, 2000).

The responses to the charges of forest destruction and water source depletion have been vigorous. In northern Thailand, as in many other parts of the world, activist academics and NGOs argue that upland minority communities have well-established traditions of forest management and sustainable land use that provide a basis for sustainable community presence in forested watershed areas. Attention is drawn to forest-friendly cultivation techniques; ritual forms and belief systems that prioritize forest protection; indigenous systems of watershed protection; and local knowledge systems that reflect local understanding of the crucial links between upper-catchment forest cover and healthy stream flow (Walker, 2001). To challenge negative stereotypes of the impact of upland cultivation on hydrological health, NGOs have worked with upland villagers to form 'watershed networks' that promote the capabilities of local institutions in protecting forest cover and maintaining water supply (for example, Northern Development Foundation, 2000). As one report notes, 'the lowland people receive water because their brothers and sisters in the upland areas work together for conservation' (Saengdaaw, 2000: 67, my translation).

Despite the contention of this debate there is an underlying agreement that forests are the key to sustainable water resource management. The debate is about the appropriate way of protecting forest cover — essentially, the internationally familiar debate between state regulation and local management — but it is not a debate about the relationship between forest cover and water supply. There is a widely-shared consensus that forest cover maintains water supply and that deforestation causes water shortage. In the large and contentious literature on environmental management in northern Thailand this persistent focus on forest protection and water supply has drawn attention away from the important issue of water demand. Very little attention is given to the greatly increased quantities of water that new agricultural systems consume. Water shortages are regularly and consistently attributed to a reduction in supply caused by deforestation and the debate is framed by a preoccupation with water resource *preservation* (which is seen as equating with forest protection) rather than focusing on contemporary patterns of water resource *use*.

This ongoing focus on water supply has important political implications. As long as the focus of public debate is on maintaining and protecting water supply, the regulatory focus will be on those resident in the forested upstream areas that are seen as crucial in securing downstream flows. Accordingly, upland hill-slope cultivation has come to be the key site of claim, counter-claim, regulatory intervention and institutional mobilization. If the water management focus is shifted to water demand, however, then attention must shift to the diverse sources of demand that exist throughout the hydrological system. Suddenly upper-catchment farmers are not the only focus, but lowland irrigators are also brought into the picture along with industrialists, tourist resort operators and urban water consumers. This broader regulatory focus may well be unwelcome and it should come as no surprise if supply-based arguments continue to be mounted in order to maintain the geographically and socially restricted focus on upstream forested catchment areas.

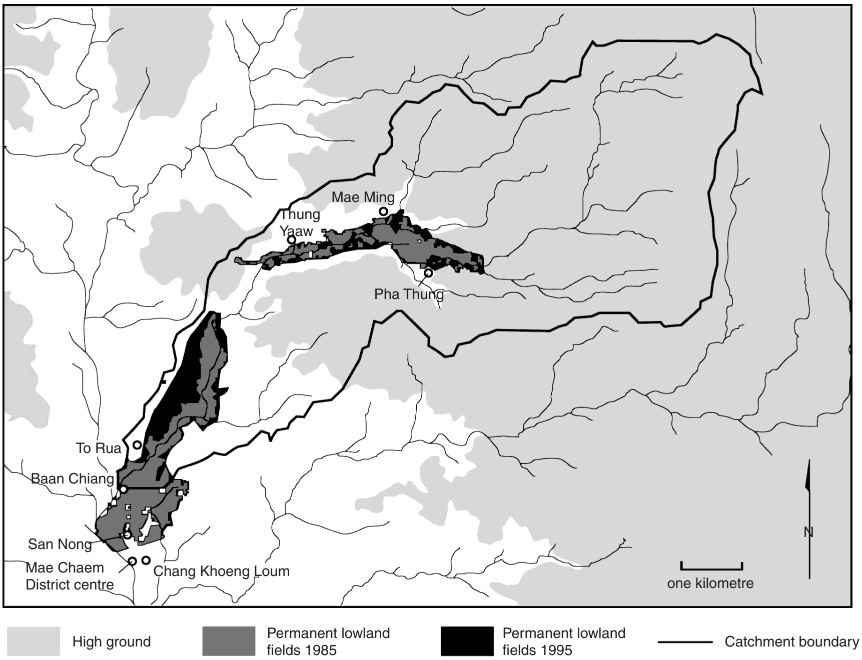
A shift in emphasis to water demand should also prompt some rethinking of the current strategies used to defend the rights of upland farmers. At present, this defence is framed largely in terms of their ability to protect forests and maintain water supply. This defence has been mounted in very particular terms with considerable emphasis placed on subsistence-oriented, low-input forms of forest-friendly cultivation (Walker, 2001). But, as the case-study below demonstrates, many of these upland minority farmers are now becoming heavily engaged in commercially-oriented production, especially in the dry season where the use of irrigation water is essential. There is a real danger that images of subsistence-oriented, forest-friendly and low-resource-use agriculture will be used by lowland farmers to undermine the resource claims of their upstream rivals. It would, after all, be in the interests of downstream water users if upstream farmers were pressured to exercise ecological restraint and to adhere to agricultural practices that make minimal claims on catchment resources. In short, in presenting upstream farmers as guardians of catchment resources and as protectors of water supply, the legitimacy of their position as consumers of resources — as water users — is potentially undermined.

THE MAE UAM: A MOUNTAINOUS CATCHMENT IN NORTHERN THAILAND

The Mae Uam has its sources on the western slopes of Doi Inthanon, the highest mountain in Thailand. From this high mountain source, it runs in a south-westerly direction to its junction with the Mae Chaem, dropping about 2000 metres in the process (see Figure 2). The total area of the Mae Uam catchment is 43 km^2 with elevation ranging from a low point of 480 metres (near the district centre of Mae Chaem) to a high point of almost 2,400 metres (near the peak of Doi Inthanon). The average slope is 18 degrees and flat land suitable for intensive irrigated agriculture is confined to narrow strips along the valley floor.

The population of the Mae Uam catchment is approximately 3500, distributed among seven villages. In the two most upstream villages (Pha Thung and Mae Ming in Figure 2), almost 85 per cent of household heads surveyed identify themselves as Karen. The Karen are the largest 'hill-tribe' group in northern Thailand who, in response to official charges of hill-tribe natural resource degradation, have developed a reputation in academic and activist literature for their conservationist, forest-friendly and non-commercial orientation (Walker, 2001). In the other five villages of the Mae Uam catchment almost all households identify themselves as northern Thai, the majority lowland population in Chiang Mai province.

Figure 2. Mae Uam Catchment.



Note: Paddy fields lying outside the catchment boundary are irrigated by water from the Mae Uam catchment.

Even though the downstream villages form part of the district township of Mae Chaem, the Mae Uam catchment is overwhelmingly agricultural, with 93 per cent of household heads surveyed indicating that their main occupation is agriculture.[1] Until about twenty years ago, the agricultural focus of both Karen and northern Thai households was the production of rice for subsistence purposes. Rice was grown both in irrigated paddy fields and in rain-fed hill-slope fields. Rice production was, and still is, supplemented by vegetables grown on the edges of rice fields and in home gardens and by the collection of bamboo shoots, mushrooms and wild vegetables from surrounding forests. Prior to the mid-twentieth century it appears that Mae Uam formed part of a relatively open land frontier, with 'satellite'

1. A detailed resource, production and marketing household survey was conducted in Mae Uam during December 1998. The survey covered six of the seven villages in the catchment, and a total of 138 samples were collected, representing approximately 20 per cent of the population in each village. Detailed information was obtained on all sources of subsistence and income including cropping, livestock production, non-timber forest harvesting and off-farm employment.

communities experiencing little difficulty in opening up new areas of agricultural land. In some cases, villages were established in degraded forest areas that had been opened up by logging operations. Based on experience in other districts of northern Thailand, it seems likely that population growth in the past was accompanied by the gradual expansion of paddy land and the shortening of fallow cycles on upland fields (Walker, 2001). With the incorporation of the upper reaches of the catchment in Doi Inthanon National Park in the late 1970s, shifting cultivation systems in the upstream Karen villages came under increasing pressure.

Over the past twenty years there has been substantial agricultural change in the Mae Uam catchment, in part as a result of the activities of agricultural development agencies. During the 1980s, Mae Chaem district was a priority area for development given its relative isolation, poverty and reputation for opium production and communist insurgency. Government and non-government development activities in the Karen and northern Thai villages along the Mae Uam included infrastructure support (roads, irrigation systems and fish ponds); promotion of new crops and farming techniques; construction of terraced paddy fields; marketing initiatives; and distribution of fruit-tree seedlings (Hufschmidt, 1991; Ministry of Agriculture and Co-operatives, 1984). Irrigation development was a priority activity and, in the upper reaches of the catchment, a series of concrete weirs were constructed from the late 1970s onward, while in the lower reaches two major irrigation weirs were built in the late 1980s. An aqueduct which draws supplementary — but expensive, given the need for pumping — irrigation water from the main stream of the Mae Chaem was also constructed to service farmers in the lower reaches of the catchment in the mid-1980s. Agricultural development was greatly facilitated by the construction of a road linking Mae Chaem with the major northern Thai marketing centres during the 1970s and by the gradual improvement of the road along the Mae Uam catchment itself in the 1980s and 1990s. These development initiatives appear to have contributed to a significant increase in the production of cash crops, especially soybeans.

Land-cover data for the Mae Uam catchment from the period 1985 to 1995 provide some interesting perspectives on this recent period of agricultural transformation.[2] First, these data suggest that — contrary to popular

2. The land-cover data were derived from Landsat satellite imagery acquired in 1985 (August), 1990 (February) and 1995 (February) (NRCT, 1997: 43). The National Research Council of Thailand study (NRCT, 1997: 45–6) classified land-cover into five main categories: forest, agriculture, urban, bareland/openland and grass/regrowth. The forest category includes permanent natural forest and reforestation. The agricultural category is said to include 'permanent or temporary agricultural areas that are mostly. . . in flat plain or lowland'. From analysis of the spatial distribution of this category, and limited ground truthing, it is clear that in the majority of cases this refers to paddy fields and some permanently cultivated fields on the fringes of paddy. Bareland/openland is defined in the study as 'the area of new cleared area or prepared highland agricultural area'. In this article, I refer to this category as 'rain-fed hill-slope fields'.

images of rampant hill-slope expansion, and associated deforestation, in northern Thailand — there has been a modest decline in rain-fed hill-slope cultivation over this period, from 425 ha in 1985 to 393 ha in 1995. Importantly, these data suggest that most rain-fed hill-slope fields are now permanently cropped, rather than being left fallow or abandoned. Of the 393 ha cultivated in 1995, over 336 ha had also been cultivated in 1990 and almost 240 ha had been cultivated in both 1985 and 1990. Discussions with village leaders and household surveys have indicated that all upland fields are now permanently cropped, even in Karen villages where, from recent literature (see, for example, Waraalak, 1998), one may expect significant levels of rotational shifting cultivation. There is an ongoing debate in northern Thailand about the impacts of shifting cultivation on the environment of upland catchments, but in the Mae Uam catchment this now appears to be a non-issue.

The second, and most important, trend in land-use in the Mae Uam catchment is the expansion in permanent agricultural fields in the relatively low slope and low elevation areas along the valley floor. This expansion has taken the form both of irrigated paddy fields (assisted by improvements in irrigation infrastructure) and the establishment of orchards and permanent gardens on the sloping land immediately adjacent to paddy fields. As can be seen in Figure 2, this expansion has been most significant in the downstream zone of the catchment, though there is also evidence of paddy field consolidation in the upstream agricultural zone. Land-cover data indicate that in 1985 these areas of permanent valley bottom cultivation covered 203 ha (4.4 per cent of the catchment area). By 1990 this had increased to 256 ha (5.6 per cent) and by 1995 had reached 350 ha (7.6 per cent). This expansion has been facilitated by the construction of irrigation infrastructure and the construction of paddy fields as part of local development initiatives.

Water Resources

The climatic pattern in Mae Chaem district is typical of that in northern Thailand, with a distinct wet season from about May to September. Outside the wet season, rainfall is limited and in some years no rain falls for three months or more. According to data collected by the Royal Irrigation Department for the town of Mae Chaem, average annual rainfall during the 1980s was 910 mm. During this period the driest month was January (average of zero) and the wettest month was September (average of 155 mm). Rainfall is much higher in the more elevated parts of the catchment: the peak of Doi Inthanon has an average annual rainfall of about 2200 mm.[3]

As can be expected from the seasonal pattern of rainfall, stream flow in the Mae Uam peaks during July and August and declines steadily from

3. Rainfall data were obtained from the website of the Royal Irrigation Department at www.rid.go.th.

October to April. Total stream flow during the dry-season months is only about 20 per cent of annual stream flow (Walker, 2002: 7), although this low flow is a crucial source of irrigation water for dry-season cropping. Dry-season stream flow is 'harvested' by an extensive network of irrigation weirs and canals. There are approximately forty wooden and ten concrete weirs distributed between the two Karen and five northern Thai settlements and numerous village-based institutions exist to maintain the irrigation infrastructure and to manage the distribution of water to farmers' fields.

During field surveys undertaken by the author and collaborators in December 1998, farmers in the downstream northern Thai villages expressed concerns about dry-season water shortages and the high cost of pumping supplementary water supplies from the main stream of the Mae Chaem River. These concerns are typical of those expressed by downstream farmers in mountain catchments in many areas of northern Thailand. In the Mae Uam catchment, water resource concerns are encouraged somewhat by a high profile forest protection and reafforestation project that continually emphasizes the link between upper-watershed forest degradation and water shortages: 'the result of cutting forest is the destruction of the water source of the Thai people' (Suan Pa Sirikit, n.d.; my translation). Concerns about dry-season water supply have even prompted locally contentious proposals for dams in the middle and upper reaches of the Mae Uam to store 'surplus' wet season flow. In the early 1990s, activists in the upstream Karen villages campaigned vigorously, and successfully, against a proposed reservoir that would have inundated some of their valuable paddy fields. By the late 1990s more modest plans were being developed, with army engineering teams reportedly planning the construction of a number of small 'check-dams' on minor sub-tributaries within the catchment. In nearby areas of Mae Chaem district, upstream Karen farmers are said to fear relocation due to complaints of lowland farmers about the impact of water shortages on agricultural production (Ukrit, 2001: 18), and in the neighbouring district of Chom Thong there have been violent protests against upland Hmong villagers who are accused of forest clearing and destruction of water sources (Pinkaew, 2000; Renard, 1994). These well-publicized events contribute to a climate of uncertainty in minority communities in upland areas.

FOREST LOSS AND WATER SUPPLY[4]

The first hydrological issue I will address is whether or not there is any evidence to support the widely expressed claim that forest loss has reduced water supply. There is no doubt that there has been a reduction in forest cover in Mae Uam and in many other mountainous catchments of northern Thailand. Land-cover data indicate that in 1985 approximately 78 per cent

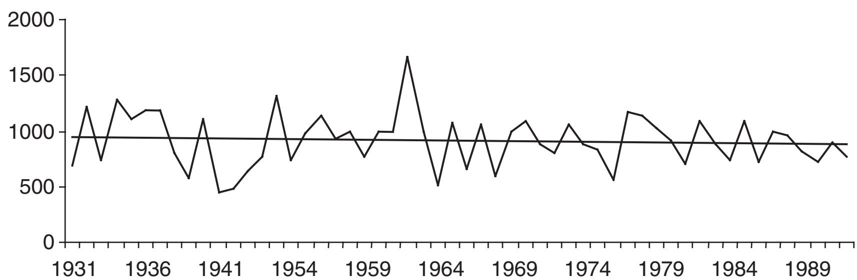
4. This section is a brief summary of relevant sections of Walker (2002).

of the Mae Uam catchment was covered with forest but by 1995 this had declined to 72 per cent, a loss of over 250 ha. There is also some evidence of considerable forest degradation, especially in areas of the catchment outside the national park. This local reduction in forest cover is one small part of a much more significant regional trend that has seen the level of forest cover in northern Thailand decline from, presumably, close to 100 per cent in the early 1900s to about 44 per cent in the mid-1990s (Walker, 2002: 11).

Has Forest Clearing Reduced Rainfall?

Long-term rainfall data are available for the district centre of Mae Chaem, which is located very close to the lower reaches of the Mae Uam catchment. The data must, however, be interpreted with considerable caution, as there are numerous years for which the data are clearly incomplete or erroneous. When the most obviously incorrect years are excluded from the analysis the data suggest a very modest long-term decline in rainfall combined with significant short-term variation (see Figure 3). Analysis from some other locations in northern Thailand where the data-set is somewhat more complete suggests a similar pattern of long-term decline, but there are also other locations where there have been long-term increases. Taken as a whole, the regional rainfall data suggest that there has been no long-term reduction in levels of precipitation despite substantial reductions in forest cover (Walker, 2002: 11). It is interesting to note that the data from Mae Chaem (where forest loss has been relatively modest) suggest a slight decline, while data from the neighbouring district of Chom Thong (where forest loss has been much more significant and water resource conflicts are much more intense) suggest a long-term increase (see Figure 4). Only a very selective reading of the regional data could support the claim that deforestation has lead to reductions in levels of rainfall.

Figure 3. Annual precipitation (millimetres) with long-term trend in Mae Chaem.



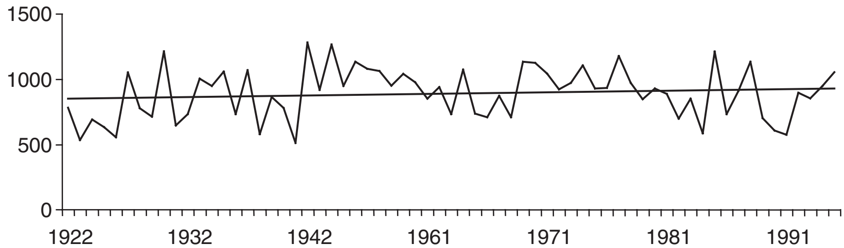
Source: Royal Irrigation Department (*www.rid.go.th*).
Note: Years where data are missing or clearly erroneous have been omitted.

Regional rainfall data do, however, suggest that a relatively drier period occurred during the 1980s and early 1990s and that this followed a relatively wetter period during the 1970s (Walker, 2002). Importantly, the drier period during the 1980s and 1990s coincided with a dramatic increase of interest in forest policy in Thailand and it is not surprising that these two key environmental issues — water supply and forest loss — have become linked in public debate and policy discourse. But it must be emphasized that the recent drier period is by no means unprecedented, with the longer-term data showing a long-standing oscillation between relatively wetter and relatively drier periods, seemingly independent of the progressive decline in forest cover (Walker, 2002: Figure 8).

Do Forests Act as Catchment 'Sponges'?

In Thai public discussion of environmental issues it is regularly argued that upland forests serve as catchment 'sponges' — storing wet season rainfall and releasing it during the dry season. However, despite the level of public certainty, the role of forests in modifying stream flow in catchments is one of the more complex issues confronting hydrologists. On the one hand, there is some evidence that during rainfall events forests are relatively effective 'sponges' in that they absorb more water than other land-surfaces, largely as a result of the layer of forest humus and relatively good soil condition (see, for example, Takahashi et al., 1983; Vincent et al., 1995: 8–9). However, the ability of forests to absorb water during rainfall events is only part of the story. While it is popular to refer to forests as sponges it would also be appropriate to refer to them, metaphorically, as 'pumps'. Rates of evapotranspiration from forests in northern Thailand are such that fully-forested landscapes can return up to 80 per cent of rainfall to the atmosphere leaving only 20 per cent as stream flow, the source of water supply for irrigators

Figure 4. Annual precipitation (millimetres) with long-term trend in Chomtong.



Source: Royal Irrigation Department (*www.rid.go.th*).
Note: Years where data are missing or clearly erroneous have been omitted.

(Walker, 2002: 13–14). It is this high water use of forest that leads Alford (1992: 267) to conclude that 'the mountain catchments of northern Thailand are among the most "arid" on earth'.

The fact that forests are relatively high water users means that clearing forests typically increases annual stream flow and this increase can be very significant. However, with some loss of the 'sponge effect' there may be an increase in the proportion of annual flow that takes place in the wet season shortly after rainfall events. Will this mean that there is less water for the dry season? A careful and detailed answer to this question has been provided by Bruijnzeel (1989) who, after reviewing numerous international catchment studies, argues that if *a reasonable amount of care* is taken to maintain the infiltration capacities of cleared land, the effect of reduced forest water use will outweigh the effect of reduced infiltration, *resulting in an increase in dry-season base flow*.

So, what conclusions can be drawn from the hydrological evidence in relation to Mae Uam? Overall, it seems clear that a modest reduction in forest cover is unlikely to have had a substantial impact on stream flow and, if anything, the impact on dry-season stream flow may have been marginally positive. It is relevant to note that almost half of the forest loss in the Mae Uam catchment between 1985 and 1995 has resulted in the development of permanent agricultural fields in the lower-lying and lower-slope areas of the catchment. The substantial presence of terraced paddy in these areas — which slows and filters the passage of water through the landscape — means that opportunities for soil infiltration are relatively abundant (Hamilton, 1987: 257). In other words, the negative impact of forest loss on the so-called 'sponge' effect in these areas is likely to be very modest. It is also important to remember that any minor (positive or negative) effects of human-induced land-cover change on water supply are likely to be relatively insignificant when compared to the naturally occurring short-term variation in rainfall.

AGRICULTURAL INTENSIFICATION AND WATER DEMAND

Dry-season water resource constraints are emerging in the Mae Uam catchment in an environment of modest reductions in forest cover, relatively stable hill-slope cultivation but significant increase in the area of paddy and paddy-fringe cultivation in the low-slope areas of the catchment. The trend away from land-extensive shifting cultivation to land-intensive paddy production has been documented in a number of studies of agricultural systems in northern Thailand (Cooper, 1984; Kanok and Benjavan, 1994; Michaud, 1997) but has not been given much serious consideration in recent discussions of water resource management in mountainous upland catchments. Instead, public discussion of water resource management has been dominated by the politics of blame whereby water shortages are all too readily attributed to a reduction in supply caused by the forest clearing undertaken by minority groups in upland areas. In the following sections I will argue that water resource tensions are much more likely to have emerged as a result of substantial increases in water demand. While my focus is on dry-season agricultural activity, it is informative to compare this with trends in wet-season cultivation.

Wet-Season Agricultural Change

Agricultural modernization has had a relatively limited impact on wet-season agricultural activity in the Mae Uam catchment. In both Karen and northern Thai villages, the predominant agricultural activity during the wet season is the production of rice in irrigated rice fields for subsistence purposes. During the wet season in 1997, rice was grown on 83 per cent of the cultivated paddy area. The balance was made up of soybeans and maize (about 5 per cent each) and small plots of shallots and turnips. Over 80 per cent of these non-rice crops were grown on rain-fed paddy fields with irrigated paddy devoted almost exclusively to rice production. It is clear that subsistence-oriented production is by far the highest priority on the relatively high-yielding irrigated fields (over 3000 kg of rice per ha). During the wet season there is also some cultivation of hill-slope rain-fed fields, which in 1997 amounted to about 45 per cent of the area of paddy cultivation. During 1997 these fields were cropped with upland rice (71 per cent), soybeans (19 per cent) and maize (10 per cent). Upland rice features prominently — despite relatively low productivity (around 1200 kg per ha) — largely because there is a significant group (about 17 per cent of farmers) who are entirely dependent on hill-slope, rain-fed fields for their agricultural livelihoods.

Dry-Season Agricultural Change

By contrast, there have been very important changes in the patterns of dry-season cultivation. While further ethno-historical research is needed, it appears that until about twenty years ago dry-season cropping in the small upland catchments surrounding Mae Chaem was limited to small areas of vegetable gardens on the banks of streams. The absence of dry-season cropping does not appear to have been a reflection of rice-based self-sufficiency — given local reports of regular rice deficiency — but reflected the dry-season economic focus on off-farm labour and trading activities as a supplement to under-producing rice production systems. Local accounts suggest that cattle trading was an important feature of these economic systems, with dry-season paddy fields used as a staging point for cattle in the trade between upland villagers, and perhaps even villages across the border in Burma, and the larger trading centres close to Chiang Mai. Given the rudimentary state of transport connections, farmers working as dry-season ox-traders also played an important part in the basic commodity trade (Congmu, 1997: 152; cf. Chusit, 1989; Moerman, 1975).

While non-agricultural pursuits are still an important component of dry-season activity, the widespread adoption of soybean cultivation represents a very substantial change. Data from the household survey in Mae Uam indicate that soybeans were cultivated on almost 70 per cent of the irrigated paddy area during 1997–98. Soybeans have been widely promoted in northern Thailand, largely as an import substitution initiative, and they now constitute, by area, one of the main non-rice crops in the region (Abamo, 1992: 15, 26). In the Mae Uam catchment, local varieties have been grown for local consumption over a long period but commercial production of soybeans was only introduced in about 1984 when demonstration plots of improved varieties were established in numerous villages in the district as part of the Mae Chaem Watershed Development Project (Ministry of Agriculture and Co-operatives, 1984: 21). Good yields were recorded and, despite the fact that limited input support was offered to farmers, adoption was rapid, perhaps due to uncharacteristically high prices in the latter half of the 1980s (TDRI, 1994: 74). Soybeans remain attractive given relatively stable prices, low input costs and relatively modest labour requirements. Of course, adoption has not been completely unproblematic with low yields in some areas — possibly associated with declining soil fertility — prompting adoption of other dry-season crops. Maize, which can be readily sold in Mae Chaem, is a popular alternative, though its relatively high water consumption is a major disadvantage in dry years. Other farmers have experimented with higher value vegetable crops such as sweet corn, carrots, potatoes and shallots, but none of these alternatives have become as popular as soybeans.

The Hydrology of Dry-Season Cultivation

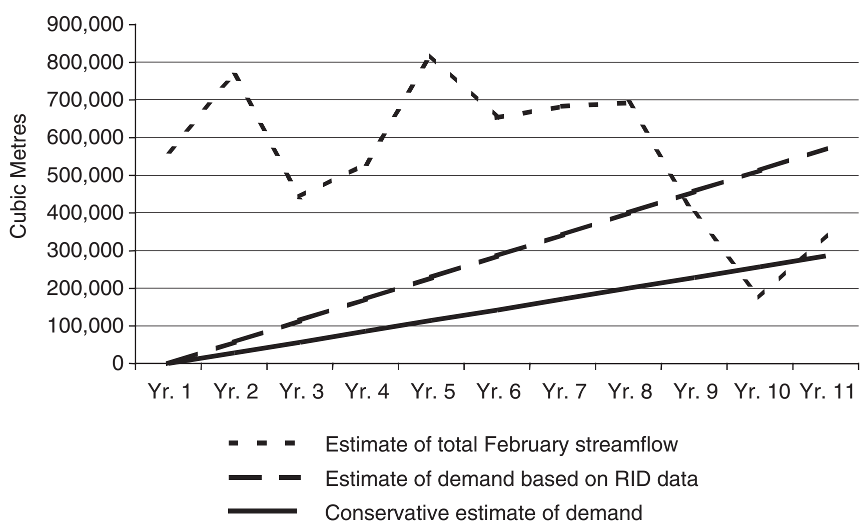
How hydrologically significant may this increase in dry-season agriculture be? Some relatively simple calculations suggest that it may be very significant indeed. First, it is necessary to provide some data on dry-season water *supply*. Given that there is no stream gauge in Mae Uam I have estimated supply by taking eleven years of stream flow data from a nearby catchment with roughly similar aspect, elevation and morphology and scaling the data according to the specific characteristics of the Mae Uam.[5] My intention is merely to provide an indication of the likely magnitude of water supply in Mae Uam. Figure 5 provides one of the key results of these calculations: the top dotted line represents *total* stream flow during the month of February

5. These data are then scaled by two factors: catchment size and average elevation. The source catchment has minimal agricultural activity, so the stream flow (supply) data are not affected by irrigation extractions (demand).

for each of the eleven years. These data represent the total amount of water available, measured in cubic metres, for irrigators in the catchment during the month of February. This month has been chosen because it is usually a month of high irrigation demand given the stage of development of the soybean crop. The very significant year-to-year variation in dry-season water supply — independent of longer-term land-cover trends — is clearly evident. In February of Year 5 (a year of particularly high rainfall) the catchment is estimated to have yielded over 800,000 cubic metres while in Year 10 (a drought year) the amount is less than 200,000 cubic metres.

My estimate of water *demand* is based on the water consumption (evapo-transpiration) of the soybean crop. My calculation uses the standard method of combining an estimate of evapo-transpiration from a 'reference crop' (for Chiang Mai) with a crop coefficient for soybeans (which varies according to the stage of growth of the crop). Using the Royal Irrigation Department's (RID) reference crop data and their crop-coefficients for soybeans, the total water consumption of one hectare of soybeans during February (assuming a planting date of mid-November) is 1340 cubic metres. However, this represents crop water consumption under ideal and well-fertilized conditions and, if achieved, would result in levels of yield significantly beyond those typically achieved by farmers in Mae Uam. A much more conservative estimate of 670 cubic metres is provided by Perez et al. (2002) based on an estimate of likely agronomic conditions in Mae Uam.

Figure 5. Estimate of water supply and water demand in February, given hypothetical 11-year increase in dry-season soybean cultivation.



Given the significant difference, I have used both estimates of water consumption — the RID estimate and the Perez et al. 'conservative' estimate. These estimates of water demand for the month of February have been added to Figure 5. In Year 1, I have assumed that none of the paddy area is cropped with soybeans, with the percentage steadily increasing to 80 per cent in Year 11.[6] I am not suggesting that this is an accurate reflection of the history of soybean cultivation in Mae Uam. Rather, my intention is to provide a broad indication of the hydrological magnitude of past, and possible future, dry-season agricultural trends within the catchment. (In the survey year, 1997–98, approximately 70 per cent of the paddy area was cropped with soybeans.)

At the higher levels of soybean cultivation the potential for water deficit in dry years is clearly evident, even if the more modest levels of crop evapo-transpiration are used. Furthermore, there are a number of additional factors that highlight just how critical this water constraint may have become. First, given irrigation inefficiencies, significantly more water has to be extracted from the stream to meet crop evapo-transpiration. Considerable amounts of water are 'lost' through canal seepage and evaporation, deep-percolation and drainage back into the stream (Molle, 2001). While much of this additional water can be re-used within the catchment, the relative inefficiency of conveyance and delivery systems compounds timing and co-ordination problems. Second, technological constraints place limits on the percentage of water that can be extracted from the stream — some estimates I have heard are as low as 50 per cent — given that pumps are not used to extract water from streams or canals during low flow periods. Moreover, irrigation weirs have no capacity to store water to meet water demand in peak periods. For all these reasons it is very likely that substantial water resource constraints and tensions are likely to emerge well before the supply and demand lines intersect. The complaints of downstream soybean cultivators about water shortages in drier years are certainly unsurprising.

My aim in presenting this brief hydrological analysis is to demonstrate that the potential exists for the hydrological limits of catchments to be reached — and exceeded in drier years — as a result of relatively unremarkable processes of agricultural intensification and in cases where the irrigated land comprises a modest percentage of the total catchment area. It is simply not necessary to explain water resource tensions in terms of the dubious effects of forest cover reduction on water supply. The data suggest that water demand needs to be targeted as the key driver of resource tensions in upland catchment systems. Accordingly, a deeper understanding of the nature and distribution of this demand is required.

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6. The total area of irrigated paddy is estimated on the basis of land-cover data, village mapping and household survey data.

THE SOCIOLOGY OF DRY-SEASON AGRICULTURE

Dry-season cultivation of soybeans is a widespread phenomenon in both upstream and downstream areas of the Mae Uam catchment, and in both Karen and northern Thai villages. Among all the households surveyed in the Mae Uam catchment almost 60 per cent cultivated soybeans in the previous dry season devoting, on average, almost 80 per cent of their household paddy fields to this pursuit. What are the key sociological dimensions of this very substantial agricultural change?

Access to Irrigated Paddy Land

In the debates about forest cover and water supply it has become very easy for government officials and lowland irrigators to point the finger of environmental blame at upland cultivation. However, if the focus of the debate is shifted to water demand, it becomes evident that irrigated paddy fields are, in fact, the key driver of resource tension. In the Mae Uam catchment, all dry-season soybean cultivation takes place on irrigated paddy fields. Upland fields simply lack the irrigation infrastructure that is essential for any dry-season cultivation. Within the Mae Uam catchment, development project support for irrigated agriculture has contributed to a high level of paddy ownership, with about 80 per cent of households in the catchment owning irrigated paddy fields. Among dry-season soybean cultivators, the average size of irrigated fields owned is about 0.7 ha. The fact that all dry-season soybean cultivators are irrigated paddy owners may seem obvious, but it is a point worth reinforcing given the ongoing preoccupation with hill-slope farmers as the key agents of catchment transformation.

A few simple statistics illustrate the key role of irrigated fields in supporting agricultural intensification. Irrigated fields result in higher and more stable yields during the main rice-growing season. Survey data indicate that those who cultivate soybeans in the dry-season are relatively successful wet-season rice cultivators with average production of about 2200 kg of rice per household. This generously covers subsistence requirements and permits the sale of about 15 per cent of irrigated rice production. Revenue from wet-season rice sales facilitates investment in dry-season agricultural inputs and, in turn, fertilizer residue and nitrogen benefits[7] from dry-season cultivation have a beneficial effect on wet-season rice yields. For some farmers (about 15 per cent of dry-season soybean cultivators) cash incomes and investment potential are further supplemented by the ownership of rain-fed, hill-slope fields on which they can grow wet-season cash crops (soybeans and maize) given the subsistence security afforded by their irrigated paddy fields.

7. Soybeans are nitrogen fixing.

The contrast with the 17 per cent of households totally dependent on rain-fed hill-slope fields is striking. Contrary to widely-held stereotypes, this is not just an upper-catchment 'hill-tribe' phenomenon. The Karen village of Mae Ming does have the highest incidence of complete dependence on upland fields (44 per cent of households) but the second highest incidence occurs in the downstream northern Thai village of Ban Chiang (24 per cent). In the highest elevation Karen village of Pha Thung, the incidence is relatively low (only 14 per cent). These households, of course, have no impact at all on dry-season irrigation demand and none indicated that they had been able to rent irrigated paddy fields during the dry season (unsurprisingly, given their high level of use). A brief consideration of the comparatively precarious position of these households casts important light on their relative inability to benefit from processes of agricultural intensification within the catchment. During the wet season they farm, on average, 0.6 hectares of hill-slope fields on which cultivation of rain-fed rice is the predominant activity (almost 90 per cent of the cultivated area). This is a strongly subsistence-oriented system with all households indicating that they consume (or keep for seed) all the rice they produce. Given that average rice production is only about 650 kg per household — and average household size is five — it is not surprising that 75 per cent of these households cannot meet their subsistence needs from rice production and an estimated 40 per cent have difficulty meeting their subsistence needs even when income from non-agricultural sources is taken into consideration.[8] By a range of other indicators these households emerge as the most disadvantaged: they have by far the lowest level of spending on agricultural inputs; the lowest household labour input; the lowest use of hired labour and the lowest ownership of consumer durables. Given the precarious position of many households in this category, their inability to invest in hill-slope irrigation systems (such as sprinklers) is unsurprising and it seems unlikely that many will be in a position to purchase or construct more productive irrigated paddy fields.

Ethnicity, Catchment Location and Soybean Cultivation

What can the data tell us about the relationship between ethnicity and dry-season cash crop cultivation? Overall, the data from the Mae Uam catchment do not support any clear distinction between commercially-oriented lowland villagers and subsistence-oriented uplanders. While it has become popular to portray Karen communities in other-worldly and forest-focused terms (Walker, 2001) in this case it is clear that Karen farmers are actively engaged in commodity production. In Mae Ming almost 80 per cent of Karen households that own paddy fields grew soybeans in the dry season. In

8. Tanabe (1994: 66) estimates annual per capita consumption of rice in northern Thailand at 300 kg.

the other Karen village, Pha Thung, the percentage is lower, but still very significant, at 53 per cent. Indeed, the lowest rate of soybean cultivation (38 per cent of households surveyed) was not found in the more isolated Karen villages but in the downstream northern Thai village of Chang Khoeng Loum (see Figure 2) that is, in many other respects, the most commercialized village in the catchment.

However, while it is important to acknowledge that the upstream Karen farmers are heavily involved in soybean cultivation, it is also important to emphasize that there are a number of factors that facilitate even higher levels of soybean cultivation in some of the northern Thai downstream villages. First, some of the downstream villages have particularly high rates of irrigated paddy ownership, which, as noted above, is the key to dry-season soybean cultivation. In the northern Thai village of To Rua (see Figure 2), for example, 94 per cent of farmers own irrigated paddy land (and almost all of them grow soybeans). This is substantially higher than the rate of paddy ownership in the Karen village of Mae Ming (56 per cent). Second, the soil in the downstream areas, particularly near the village of To Rua, is said to be particularly suitable for soybean cultivation, requiring minimal fertilizer input. During the survey, farmers in other villages often spoke enviously about the quality of the soil in the lower reaches of the catchment. Third, it appears that as a result of good planning or topological good fortune, the two weirs built in the lower reaches of the catchment in the 1980s have provided the opportunity for a substantial increase in permanent cultivation around the northern Thai villages of To Rua and Ban Jiang. Analysis of the land-cover data indicates that the largest area of expansion of permanent lowland cultivation in the catchment occurred on the northern fringes of these villages' paddy fields (see Figure 2). Fourth, the downstream villages have very good access to marketing infrastructure in the town of Mae Chaem. The upstream Karen villages are not particularly inaccessible, but fewer regular visits by traders and higher transport costs mean that 'farm-gate' soybean prices in these villages are about 10 per cent lower. Finally, downstream farmers appear to have more secure tenure than their upstream counterparts. In To Rua, for example, only 20 per cent of agricultural plots have no formal title while in the Karen village of Pha Thung 72 per cent of plots fall into this category. Although there is no unambiguous relationship between tenure security and agricultural strategy, it is likely that more secure tenure gives the downstream farmers access to cheaper, formal sources of agricultural credit.

In brief, it appears that the superior resource endowments of some of the northern Thai villages mean that they can achieve particularly high rates of dry-season soybean cultivation. Their complaints about the (in)adequacy of dry-season water need to be placed alongside the fact that they are the highest water users in the catchment. This is not to suggest that the water use by the upstream Karen farmers is hydrologically insignificant: they are also growing substantial areas of soybeans and there is no doubt that if they were not using this water the situation for the downstream farmers would be much alleviated. But the Karen farmers would see little reason why they should forgo their water-use for the benefit of more favourably located farmers living in downstream villages.

CONCLUSION

Analysis of secondary literature suggests that the dry-season trends in Mae Uam are broadly typical of those occurring in other mountain catchments especially in some of the areas where the most intense water resource conflicts have emerged (Pinkaew, 2000; Renard, 1994: 663; Ukrit, 2001; Ukrit and Isager, 2001). This unprecedented increase in *demand* for water should prompt some reassessment of the widespread preoccupation with water *supply* and its relationship with forest cover. Too often, it seems, catchment conflicts have been reduced to unproductive debates about the appropriate strategies for protecting the forest cover that is said to ensure adequate water supplies. Lowland farmers, uniting under the environmental banner of 'watershed protection', advocate relocation of upstream 'forest destroyers' while the defenders of these upstream farmers point to long-standing traditions of sustainable forest management in sensitive water supply areas. Despite the vigour of the debate,[9] there is little questioning of the role of forest cover in maintaining water supply. Two vital aspects are ignored in this debate: firstly, the growing body of hydrological evidence that forest clearing has had no significant impact on long-term rainfall trends and a very modest impact, if any, on stream flow in the dry season; and secondly, the fact that there is very substantial natural short-term variation in water supply, and that this variation is unrelated to medium-term or long-term changes in forest cover.

The ongoing focus on water supply and forest protection frames catchment management debates in partial and highly selective terms. In particular, it contributes to the maintenance of a regulatory focus on farmers located in areas where the level of forest cover is still significant, precisely the farmers who, by various measures, are often the most socio-economically disadvantaged. The inequity of this regulatory focus on forest is evident at various spatial scales. At a local level — within villages — the impacts of forest protection measures fall most heavily on farmers who are completely dependent on the cultivation of rain-fed, hill-slope fields. The material from Mae Uam demonstrates that these farmers are the most disadvantaged and vulnerable and — underlining the injustice — these are the farmers whose agricultural activities have the least hydrological impact. There is increasing anecdotal evidence from other areas suggesting that these farmers are

9. For one of the most recent contributions to this ongoing debate see Delang (2002).

particularly vulnerable when local forestry initiatives aimed at demonstrating conservationist credentials are put in place. On a broader scale, the material from Mae Uam demonstrates that hydrological pressures in terms of water demand are emerging from agricultural activities throughout the catchment and that, in fact, the demand pressures are likely to be most intense in downstream lowland areas. This study suggests that there is no reason at all for regulatory mechanisms targeting hydrological issues to be focused on relatively forested upstream areas. This selective application of the principles of catchment management — a point highlighted by Pinkaew (2000) — clearly serves the interests of the relatively more developed and socio-politically influential communities in downstream areas.

Socially and environmentally sustainable initiatives in catchment management must surely involve attention to the water demands of upstream *and* downstream farmers. In some recent cases of water resource conflict, defenders of upstream communities have drawn attention to the increasing demands for water by lowland farmers (Pinkaew, 2000). This is important but not sufficient. The material from Mae Uam shows that sharp dichotomies between high-water-using downstream farmers and subsistence-oriented upstream farmers are simply not tenable and they are even less tenable in some areas where highland intensification has been more marked. Some may consider it politically risky to draw attention to increasing water use by upstream farmers, especially when these farmers are members of minority ethnic groups who tend to be denied a legitimate presence in northern Thai landscapes. But, as I have suggested throughout this paper, it is important to assert the rights of these relatively marginal farmers as legitimate users of catchment resources not just as guardians of resources for those in downstream areas. In future processes of water resource negotiation it would be unfortunate indeed if upstream irrigators found their resource claims constrained or even undermined by normative images of catchment guardianship, forest protection and subsistence orientation. It is surely relevant to note that those most virulently targeted in recent catchment disputes are upland farmers whose intensively commercial practices are inconsistent with official and alternative images of appropriate upland livelihoods (Pinkaew, 2000; Renard, 1994). A defence of their rights may best be framed in terms of their legitimate claim to a fair share of scarce and valuable resources, a claim that needs to be liberated from the normative imagery of the hydrological importance of upland forest guardianship.

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REFERENCES

Abamo, Antonio Pajo (1992) 'Credit Utilization and its Impact on Farm Productivity in Chiang Mai Province'. Masters dissertation, Chiang Mai University.

Alford, D. (1992) 'Streamflow and Sediment Transport from Mountain Watersheds of the Chao Phraya Basin, Northern Thailand: A Reconnaissance Study', *Mountain Research and Development* 12(3): 237–68.

Bruijnzeel, L. A. (1989) '(De)forestation and Dry Season Flow in the Tropics: A Closer Look', *Journal of Tropical Forest Science* 1(3): 229–43.

Chusit Chuchart (1989) 'From Peasant to Rural Trader: The Ox-Train Traders of Northern Thailand, 1855–1955', *Thai-Yunnan Project Newsletter* 7: 2–8.

Congmu Carupa (1997) 'Mae Jaem: Hope for the Future' (in Thai), in S. Sutchaya (ed.) *Chiang Mai*, pp. 146–73. Bangkok: Sarakadee Press.

Cooper, Robert (1984) *Resource Scarcity and the Hmong Response: Patterns of Settlement and Economy in Transition*. Singapore: Singapore University Press.

Delang, Claudio O. (2002) 'Deforestation in Northern Thailand: The Result of Hmong Farming Practices or Thai Development Strategies?', *Society and Natural Resources* 15: 483–501.

Hamilton, L. S. (1987) 'What are the Impacts of Deforestation in the Himalayas on the Ganges-Brahmaputra Lowlands and Delta? Relations Between Assumptions and Facts', *Mountain Research and Development* 7: 256–63.

Hufschmidt, Maynard M. (1991) 'A Conceptual Framework for Watershed Management', in K. W. Easter, J. A. Dixon and M. M. Hufschmidt (eds) *Watershed Resources Management: Studies from Asia and the Pacific*, pp. 17–31. Singapore: Institute of Southeast Asian Studies; Honolulu: East-West Center.

Kanok Rerkasem and Benjavan Rerkasem (1994) *Shifting Cultivation in Thailand: Its Current Situation and Dynamics in the Context of Highland Development*. London: International Institute for Environment and Development.

Lohmann, Larry (1999) 'Forest Cleansing: Racial Oppression in Scientific Nature Conservation'. Dorset: The Corner House. Available online at: http://cornerhouse.icaap.org/briefings/13.html

Michaud, Jean (1997) 'Economic Transformation in a Hmong Village of Thailand', *Human Organisation* 56(2): 222–32.

Ministry of Agriculture and Co-operatives (1984) *Mae Chaem Watershed Development Project: Annual Report 1984*. Bangkok: Ministry of Agriculture and Co-operatives.

Moerman, Michael (1975) 'Chiangkham's Trade in the "Old Days"', in G. W. Skinner and A. T. Kirsch (eds) *Change and Persistence in Thai Society: Essays in Honor of Lauriston Sharp*, pp. 151–71. Ithaca, NY: Cornell University Press.

Molle, François (2001) 'Economic Tools for Water Demand Management in Thailand: Conventional Wisdom and the Real World', in D. Brennan (ed.) *Water Policy and Reform: Lessons from Asia and Australia*, pp. 209–23. Canberra: Australian Centre for International Agricultural Research.

National Research Council of Thailand (NRCT) (1997) 'Thailand Landuse and Land Cover Change Case Study'. Bangkok: National Research Council of Thailand.

Northern Development Foundation (2000) 'Villagers' Network: Community-based Management of Watershed Resources through Involving the People' (in Thai). Chiang Mai: Northern Development Foundation.

Perez, P., N. Ardlie, P. Kuneepong, C. Dietrich and W. S. Merritt (2002) 'CATCHCROP: Modelling Crop Yield and Water Demand for Integrated Catchment Assessment in Northern Thailand', *Environmental Modelling and Software* 17: 251–9.

Pinkaew Laungaramsri (2000) 'The Ambiguity of "Watershed": The Politics of People and Conservation in Northern Thailand', *Sojourn* 15(1): 52–75.

Renard, Ronald D. (1994) 'The Monk, the Hmong, the Forest, the Cabbage, Fire and Water: Incongruities in Northern Thailand Opium Replacement', *Law and Society Review* 28(3): 657–64.

Saengdaaw Srattaman (2000) 'The "luu pakaa" Ceremony . . . Remembering Punu Dokjimu' (in Thai), in Saengdaaw Srattaman, Mala Khamjan and Paithun Phromvijit (eds) *Journey to the Water Source* (in Thai), pp. 61–79. Chiang Mai: Source of Water–Source of Life Project.

Suan Pa Sirikit (n.d.) 'People Living with Forests: By Helping Each Other' (in Thai). Chiang Mai: Royal Forest Department.

Takahashi, Tsuyoshi, Kinzo Nagahori, Charat Mongkolsawat and Manas Losirikul (1983) 'Run-Off and Soil Loss', in K. Kyuma and C. Pairintra (eds) *Shifting Cultivation: An Experiment at Nam Phrom, Northeast Thailand, and its Implications for Upland Farming in the Monsoon Tropics*, pp. 84–109. Bangkok: Ministry of Science, Technology and Energy.

Tanabe, Shigeharu (1994) *Ecology and Practical Technology: Peasant Farming Systems in Thailand*. Bangkok: White Lotus.

Thailand Development Research Institute (TDRI) (1994) *Assessment of Sustainable Highland Agricultural Systems*. Bangkok: TDRI.

Thongchai, Winichakul (2000) 'The Others Within: Travel and Ethno-Spatial Differentiation of Siamese Subjects 1885–1910', in A. Turton (ed.) *Civility and Savagery: Social Identity in Tai States*, pp. 38–62. Richmond, Surrey: Curzon.

Ukrit Aparasit (2001) 'A Case Study of Doi Inthanon National Park Area: Socio-Economic Characteristics of the Case Study Villages'. Project report, Research Centre on Forest and People in Thailand, University of Aarhus, Denmark.

Ukrit Uparasit and Lotte Isager (2001) 'Survey Report of Mae Chaem/Doi Inthanon including a Presentation of Selected Villages for Further Studies'. Project report, Research Centre on Forest and People in Thailand, University of Aarhus, Denmark.

Vincent, Jeffrey R., Mingsarn Kaosa-ard, Laxmi Worachai, Eric Y. Azumi, Nipon Tangtham and Arnel B. Rala (1995) *The Economics of Watershed Management: A Case Study of Mae Taeng*. Bangkok: Natural Resources and Environmental Program, Thailand Development Research Institute and Harvard Institute for International Development.

Walker, Andrew (2001) 'The "Karen Consensus", Ethnic Politics and Resource-Use Legitimacy in Northern Thailand', *Asian Ethnicity* 2(2): 145–62.

Walker, Andrew (2002) 'Forests and Water in Northern Thailand'. RMAP Working Paper no 37. Canberra: Resource Management in Asia Pacific Programme, The Australian National University. Available online at: http://rspas.anu.edu.au/rmap/Wpapers/rmap_wp37.pdf

Waraalak Ithiphonorlan (1998) *Rotational Shifting Cultivation: Mother of Plant Varieties* (in Thai). Chiang Mai: Project for the Development of Northern Watersheds by Community Organisations.

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