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Implications of Yunnan Chinese Land-use Practices for Sustainable Hill Farming in Northern Thailand

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This project is an integral component of the main project, *Building A Sustainable Rural Livelihood in Highland Northern Thailand: Chinese Diasporas and Their Cultural Adaptation*. This study evaluates the impacts of different types of hill farming practices on soil productivity and agro-ecological status; hopefully this will lead to improvements in sustainable crop production on slope land in the future. The sites studied are located in the village of Banmai in Chaiprakarn District, Chiang Mai Province, northern Thailand.

A brief historical narrative describes the Yunnan Chinese diaspora that settled in this region in 1960s after retreating from the Burmese side of the Golden Triangle and their conversion from drug producers and traffickers to hill farmers. Their familiarity with hill farming before settling in Thailand contributed significantly to their selection and construction of hill farms. To further assess the impact of their farming systems on soil sustainability, we identified five patterns of land use: (1) tangerine groves, *Citrus reticulate*; (2) litchi groves, *Litchi chinensis Sonn*; (3) mango orchards, *Mangifera indica Linn.*; (4) maize fields, *Zea mays*; and (5) secondary forest (mainly bamboo, *Arundinaria gigantean*, and mixed deciduous trees). In each of these sites field measurements and soil samples were taken for laboratory analysis. The soil samples were conducted at fixed depths over a period time for comparative purposes.

Keywords: sustainable agriculture, Chinese diaspora, the Golden Triangle, environmental conservation, soil erosion

Background[1]

Northern Thailand is an area of 128,480 km², or approximately 25% of the total land area of Thailand; more than 75% of this region is mountainous. The highlanders here (total population: 1,215,928) are divided into two major groups, the local hill tribes (923,257), and immigrants from lowland areas and neighboring countries (292,671) (Department of Social Welfare Development, Thailand 2003). Most local hill tribes (Karen, Hmong, Lahu, Akha, Lisu, Musur, Thin and Lawa) in this region have for a century been using the slopes for crop production under traditional shifting cultivation. Recently, with land, population, and economic pressures shifting cultivation has been broadened and distributed across a larger hilly area. In addition, some hill slopes formerly used for slash-and-burn have been replaced by intensive cultivation that has directly contributed to severe erosion, poor soil structure, decreased fertility, and degraded productivity. These problems can be seen in the deterioration of the soil's physical and hydrological properties, decreased crop yields and biodiversity across the agro-ecosystem, and finally, increased socio-economic problems (Panomtaranichagul *et al.*, 2001; Rerkasem *et al.*, 1994).

I. History of the Chinese Diaspora in Northern Thailand

In 1949, when the triumphant communist forces swept over Mainland China, several defeated Nationalist army units in Yunnan Province retreated to the south across the international borders and established temporary bases in northeastern Burma (or Myanmar), bordering Laos and Thailand (Chang 2001, 2002; Forbes and Henley 1997; Huang 2005; Maxwell-Hill 1983, 1998; Mote 1967; Young 1962). Taking advantage of the lack of clear state sovereignty in this tri-state border region (*i.e.*, the Golden Triangle) and with active support from the Nationalists in Taiwan, these remnant Yunnan Chinese, approximately 12,000 soldiers, staged several excursions into China as part of the Nationalists' "Recovering the Mainland" campaign.

Under joint diplomatic and military pressures from Burma and the People's Republic of China, the Nationalist government in Taiwan pulled out significant numbers of troops in 1953 and again in 1961, and settled them in

1 This project received funding from the Wenner-Gren Foundation for Anthropological Research under its International Research Collaboration Program in 2002-03 and 2004-05. Funding for 2003-04 came also? from Iowa State University's Bridge Grant. We thank these agencies for their generous support. Our multidisciplinary and multinational research project was carried out by a six-person team composed of three ethnographers, a geographer, a soil scientist, and a photographer.

Taiwan. The remainder of approximately 3,000 soldiers, mostly Yunnan natives, decided to stay and resettle in the hill regions of northern Thailand. In Thailand these Yunnan Chinese found a more receptive host. The Thai government permitted them to purchase privately owned farmland and establish their own communities (Chang 2001, 2002; Forbes and Henley 1997; Hsieh 1997; Huang 2005; Maxwell-Hill 1983, 1998; Mote 1967). To support themselves financially, they initially engaged in drug production and trafficking, providing military escorts to opium couriers in the Golden Triangle. They also provided military assistance to the Thai government when it launched military campaigns against communist forces in northeastern Thailand in 1970 and 1981.

The Yunnan Chinese diaspora community, estimated at around a quarter of a million people today, has experimented with many adaptations to the ecological conditions of northern Thailand since their resettlement. They initially established rice farming as the mainstay of the local economy (Chang 2001, 2002; Forbes and Henley 1997; Huang 2005; Mott 1967). Later on cash crops such as ginger root and tropical fruits were also introduced. Anne Maxwell-Hill, one of the few anthropologists who has direct research experience with them, provides a vivid portrait: "Today these villages are aggregations of several thousand people. Many of the original residents were ex-soldiers and their families, who turned to farming for a living, growing upland crops where land was available and raising pigs and chickens where landholdings were small or (not) contested by local Northern Thai villagers" (1998: 20).

II. Establishing Sustainable Rural Livelihoods in Northern Thailand

Most of the current residents in northern Thailand settled there recently, within living memory, with the exception of small pockets of Mon-Khmer speaking groups, such as Lua and Htin (Geddes 1976, 1983; Kunstadter 1983: 28; Le Bar *et al.* 1964, Young 1962). The slash-and-burn agriculture practiced by tribal groups in the hills primarily addresses subsistence needs. Efforts to improve living conditions initiated by the Tribal Research Centre in Chiang Mai since 1965 have included the introduction of upland rice and vegetables (*i.e.*, cabbage, ginger, tomato and potato) to replace shifting agriculture and the resettlement of the hill tribes to lowland areas (Geddes 1983; Rerkasem 1994).

The arrival of the Yunnanese has introduced an interesting alternative to the hill tribes' farming practices, with the adoption vegetable and tropical fruit cultivation, which has expanded their subsistence-based agriculture. In addition, the Yunnanese are described by Gordon Young to have "demonstrated a type of mountain living which has never before been seen among Thailand's hill tribes. They had brought ploughshares from Yunnan and use these to advantage in their agricultural practices, using oxen to pull them. In addition, they have shown the importance of buckwheat as a staple and as livestock feed. Their vigor in animal husbandry has also been a source of great admiration by the Lahu and Lisu tribesmen living around them" (1962: 83).

III. Development of Agro-Industry and the Socio-Economic Systems of Yunnanese Community

Besides their skills with crop varieties and animal domestication, Yunnanese financial management skills (Young 1962:32) and their ability to build ethnic marketing networks (Maxwell-Hill 1998:98; Pannee Auansakul 1995:33) have enhanced the viability of cash cropping in the hills. In recent years, the production of litchi and tangerines has become the most successful economic activity in the region and has brought a measure of prosperity. Capital has also been invested in local canning factories to process these tropical fruits, further expanding the area's economic activities.

From an environmental point of view, however, we may ask how sustainable are the new hill farming systems as a long-term development? Just what constitutes sustainable agriculture has been discussed extensively by various scholars (Dryzek 1997; Gold 1999; Heller and Keoleian 2000; Huang 2005; Roling and Wagemakers 2000). A synopsis of their viewpoints, which can be described as emphasizing the human versus nature dialectic, must highlight the following three characteristics: a sustainable agricultural regime is friendly towards the environment, economically profitable for farmers, and provides a rural livelihood that is self-generating socio-culturally. Another recent approach proposed by Lindsey Falvey (2005), envisages the spirituality of sustainable agriculture and further expands the notion to "... include(s) beliefs of responsible approaches and actions to forestall change that share some characteristics with religion—such as immortality and stewardship" (Falvey 2005:2). It is in this context that Falvey believes the artificial boundaries which separate major world religions such as Buddhism and Christianity evaporate, and we may regain the core values of both.

When applying these criteria to the Chinese hill farms, we may ask: What technologies are used to maintain soil fertility and protect long-term productivity in ways that shifting cultivation cannot? Will the expansion of tropical fruit production in lowland rice paddies deplete nutrients and degrade the topsoil and hence the self-regeneration capacity of irrigated paddy fields? Are there viable indigenous measures developed locally, based on shifting agriculture, that can cope with problems such as soil erosion, water pollution, and a changing biosphere structure? How are agricultural residues and wastes to be managed? This kind of practical knowledge will be essential for development projects not only in highland northern Thailand but also in other Southeast Asian countries.

The hill farming systems in Chiang Mai and Chiang Rai provinces include both perennial fruit trees and annual crop production. Fruit trees have been promoted in recent years by the government and development agencies because they are believed to function in the same way as forests with respect to land surface coverage and soil conservation; their cultivation is also more likely to increase local incomes than subsistence farming (Rerkasem *et al.* 1994; Rojanasoonthon and Kheoruenromne 2002). Empirical data and information on the dynamics of soil properties and hydrological status are important to evaluate soil water availability for sustainable rain-fed cropping system management. Studies of seasonal variations in the physical and hydrological properties of soil under different types of land use may help improve soil and water management for sustainable crop production in sloping highland country.

Objectives of the Study[2]

This study is a sub-project of a multi-year, multidisciplinary project titled, *Building Sustainable Rural Livelihood in Highland Northern Thailand: Chinese Diasporas and Their Cultural Adaptation* that was based in Banmai village from January, 2003 to July 2005. The project was conceived to discover and understand the complex relationships between the hill-farming regime established by the Yunnan Chinese and its impacts on soil and water quality, soil fertility, changes to the physical and chemical composition of the soil and the socio-economic development of the studied areas. Two practical technologies adopted by the Yunnan Chinese clearly indicate their concern about topsoil erosion and fertility preservation. The first involved the building of terraces across the slopes with ditches for runoff water. The second was digging shallow basins or pits, about half meter in diameter, around the plants—ostensibly for purposes of water and fertilizer conservation (Huang 2005). We are certainly interested in finding out whether either one (or both) of these practices has had any direct and tangible effect in the agricultural sustainability of the hill orchards. But the specific objectives of this sub-project, carried out

2 Several research articles resulting from this project have already been published; these provide further contextual information for the current project. Please see Huang 2005a, 2005b, 2006, and 2007.

from August 2003 to July 2004, were to evaluate the impact of different types of agricultural land use (fruit trees versus annual crop production) on the dynamics of soil quality and agro-ecological problems. Longitudinal data can identify the changes in the physical, chemical and hydrological properties of the soils, including the kinds and amounts of toxic substances accumulated in both soil and water. This data was expected to lead to better guidelines for appropriate soil and water management strategies for hilly areas and for broader environment protection in the future. Needless to say, the present article will not address the issues of spirituality in sustainable agriculture raised by Falvey (2005).

Locations, Site Selections and Land-use Types

The village of Banmai is located 9 km northwest of the Chaiprakarn district center in Chiang Mai Province in upper-northern Thailand (Figure 1).

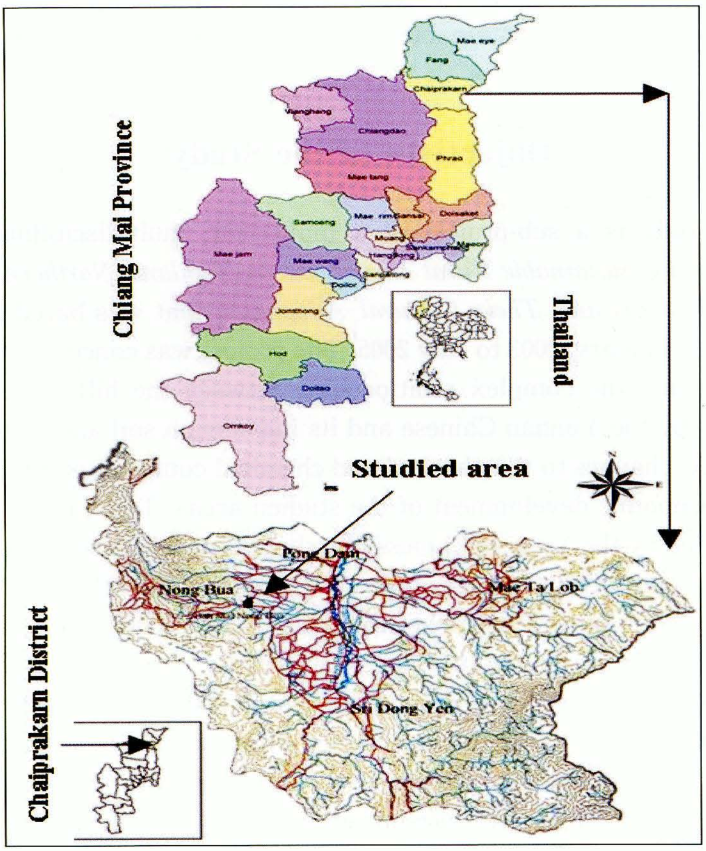

Figure 1 Map of Chiang Mai Province and Chaiprakarn District showing Banmai

The water used for irrigation and in households is supplied by two major streams entering the village, one from the southwest and the other from the northwest.

Most cultivated catchments in the village are located on sloping land with a gradient that varies from <50% to> 100%, at a latitude of 19° 42' N, longitude 99° 04' E and altitude of approximately 600-1,000m. The dominant land use is fruit production. Secondary forest (mainly bamboo, *Arundinaria gigantean*, and mixed deciduous trees) is found approximately 2-5 km west of the village and next to the village itself. Five small catchments with similar slope gradients of about 50%-100%, covering an area of approximately 2-3ha each, and located around 2 km southwest and northwest of the village, were selected as the study sites. Five types of land use were selected for study: (1) Tangerine, *Citrus reticulata*; (2) Litchi, *Litchi chinensis Sonn*; (3) Mango, *Mangifera indica Linn*; (4) Maize, *Zea mays* and (5) Secondary forest. These sites are shown in the aerial photo of Nongbua village (Figure 2). Some of the study sites were located near each other (Figure 3) and the five types of land use are shown in Figure 4.

Figure 2 The aerial photo showing the five catchments: (1) Tangerine orchard at 972.1 m asl, (2) Litchi orchard, 627.9 m asl, (3) Mango orchard, 619 m asl, (4) Maize field (upland crops), 634.3 asl, and (5) Secondary forest, 928.3 m asl.

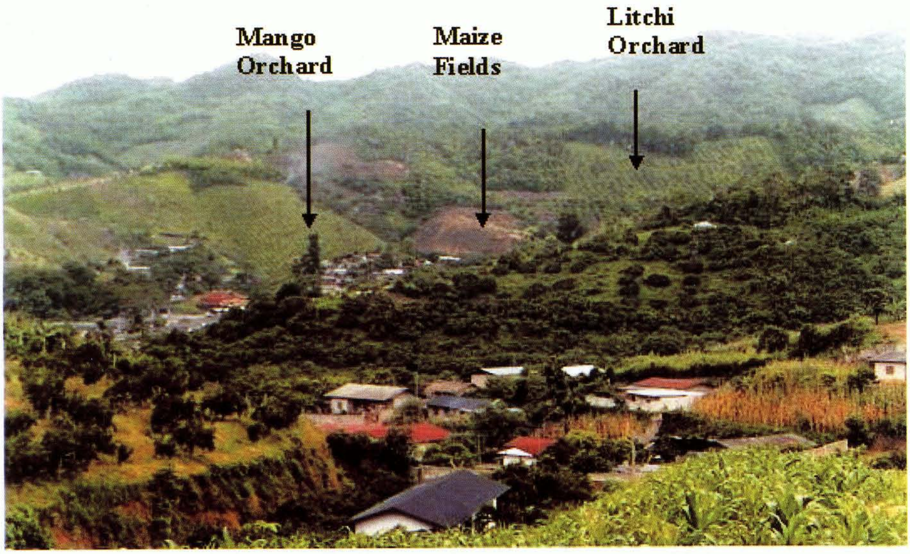

Figure 3 Three of the study sites are located next to each other. Each catchment has similar soil parent material and soil formation processes and the same geological structure.

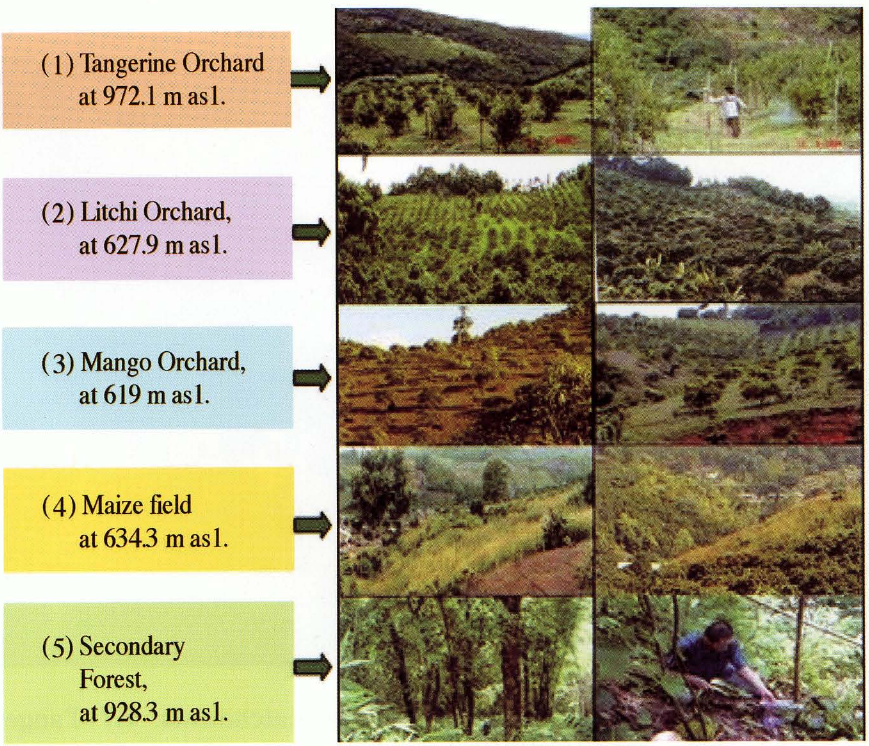

Figure 4 Different agricultural practices and crop management for each type of land use could have a different impact on the environment.

Soil Sampling and Measurements

Preliminary soil sampling for profile characteristics and morphology, a general survey and information gathering were carried out at the beginning of the project. Samples of soil, weeds, stream sediment and water along the stream lines (Figure 5) were taken and tested for toxic substances and toxic elements (heavy metals) as an indicator of pesticide contamination.

Figure 5 Samples of weeds, soil, stream sediment and water were taken from the water ways (surface drain from the orchard) and along the stream lines for toxic substance analysis, to asses pesticide contamination to the environment and ecological problems.

The soil profile characteristics revealed similar soil formation processes, geological structure, and parent materials. Soil profile characteristics under different types of land use differed depending on management practices and the degree of slope gradient. The measurements of physical properties of the sampled soil were carried out several times from the mid rainy season, August 2003, to the early-to-mid rainy season, July 2004. Soil samples and *in situ* measurements were taken from 8-11 August 2003, 22 October-24 November 2003, 21-24 February 2004 and 10-14 June 2004. Soil samples and *in situ* measurements are shown in Table 1.

I. Physical Properties of the Soil

The physical properties of local soils were measured at 0–20 and 20–40 cm depths by consistent methods for every sampling period. Soil textures (sand-silt-clay) were measured along the soil profiles for every 20 cm increment within 0–100 cm depth, from 22 October to 24 November 2003. The monitored properties were bulk density (BD), particle density (PD), total porosity (TP), field capacity (FC), air capacity (AC), aggregate stability based on total soil mass (%SAT), and mean weight diameter (MWD), including steady infiltration rate (IR). The physical property values were used to indicate quality development under different types of land use for sustainable land use management evaluation. The methods of physical analysis followed standard methods (Page *et al.* 1992).

A. **Bulk density (BD)** is the ratio of mass per unit total volume. It indicates degree of soil compaction and root penetration resistance. The critical value for root growth limitation is 1.60 m^3 m^{-3}.

B. **Total porosity (TP)** is the ratio of total pore volume per unit total volume. It can be used to calculate aeration porosity if a soil's water holding capacity is specified. TP value of cultivated soils varies from 0.30 to 0.50 m3 m-3, depending on the texture and structure of each soil type.

C. **Moisture content in actual field conditions (MC)** is measured as the ratio of water volume per unit total volume. It is used to indicate the quantity and availability of water in the soil at the specific time of measurement.

D. **Field capacity (FC)** or *water holding capacity* is the maximum amount of retained water after free water is drained under gravitational force. It indicates the highest level of water availability for each soil type.

E. **Aeration porosity or air capacity (AP)** is the ratio of macro pore (or non-capillary pore) volume per unit total volume. This non-capillary porosity is an index of soil aeration. Normal root development in all cultivated soil requires an AP-value of at least 0.10 m^3 m^{-3}.

F. **Aggregate stability (SAT)** is the amount of stable soil aggregate which is not slaking or eroded or disrupted under the impact of rain drops or water interaction. It is calculated as the dry mass of stable aggregate per unit total dry soil mass.

G. **Steady infiltration rate (IR)** is calculated as the depth of water infiltrated into the soil surface per unit of time (cm hr^{-1}). It indicates the accession of rainfall into the soil surface and the movement of water with in the sub-soil layers. If the infiltration rate is lower than rainfall intensity, with poor soil aeration surface runoff or surface waterlog may occur on sloping or level cultivated land, respectively.

Table I Dates of soil sampling for chemical and physical analysis, including *in situ* measurements.

Date of soil sampling	Activities Soil sampling and measurement
8-11 August 2003	—Site selection and preliminary soil sampling (to decide the depth and number of samples for each site. General survey and information gathering.
22 October–24 November 2003	—Undisturbed soil sampling for 5-8 individual samples each site (depending the studied area), at 2 depth ranges (0-20 and 20-40 cm), carried out for the upper and lower part of each slope. Soil samples were taken from both inside and outside (between) the planting pits. —Disturbed soil sampling for 2 composite samples at 2 depth ranges (0-20 and 20-40 cm), taken from 5-8 locations for the upper and lower part of each slope, from both inside and outside (between) the planting pits. —Surface soil aggregate sampling (0-5 cm) for composite samples, taken from 5-8 locations for the upper and lower part of each slope, from both inside and outside (between) the planting pits. —Field measurements of the Steady Infiltration Rate conducted at 3-4 locations both inside and outside (between) the planting pits for each catchment. —Disturbed soil sampling for water content measurement, 5-8 composite samples at 5 depth ranges (20 cm increments from 0 to 100 cm depth), taken from both inside and outside (between) the planting pits for each catchment. —Samples of soil, weeds, stream sediment, and water along the stream-line, taken for toxic substances and toxic element (heavy metals) analysis.
21-24 February 2004	—the same activities as carried out during 22 October—24 November 2003 were repeated
11-14 June 2004	—the same activities as carried out during 22 October—24 November 2003 were repeated

II. Soil Water Regimes

The soil water content was measured four times during the studied year. Disturbed soil samples were taken from five to eight locations for each site using the soil auger for five depth ranges (0-20 cm interval from -100 cm depth). The soil water content of each sample was measured by gravimetric method and calculated as volumetric water content ($m^3\ m^{-3}$). The amount of total stored soil water was calculated as the equivalent depth (mm) per 100 cm soil depth. Water content in forest soils was measured only twice during February and June of 2004.

III. Soil Chemical Properties, Water Quality and Accumulations of Toxic Substances and Toxic Elements in Weeds and Sediments along the Stream Lines

Measured chemical properties included acidity (pH), salinity (electric conductivity, EC), organic matter (OM), phosphorus (P), potassium (K), copper (Cu), toxic elements such as arsenic (As), lead (Pb), and mercury (Hg), including toxic substances such as Organophosphate (OP), Organochlorine (OC) and Pyretroid groups. Our soil chemical analysis followed standard methods (Page, *et al.* 1992).

Samples of water, weeds and stream sediments along the stream line were taken for toxic substances (OP and OC and Pyretroid) and toxic elements (Hg, Pb, As and Cu) three times from November 2003 to June 2004. The results were expected to indicate the impact of agricultural management practices (intensive uses of pesticides and fertilizers) on the soil, water, and ecological environment quality. The analysis of water samples (for quality evaluation) was conducted only twice between August and November of 2003. The measured qualities were nitrogen (NO_3^{-1}, NO_2^{-1}), phosphorus ($H_2PO_3^{-1}$), water hardness (CaCO3), bio-chemical oxygen demand (BOD), acidity (pH) and salinity (electrical conductivity, EC).

Results and Discussion

The properties of samples obtained from the upper and lower parts of the slope land fields were not significantly different. Therefore, the values of each soil property are an average of those from both the upper and lower slope, calculated as the mean values for both outside and inside the growing pit under each type of land use. The average values of each of the physical properties are presented graphically to minimize the complications of the technical data. Seasonal variations and the mean values of some measured physical properties—soil texture (sand-silt-clay), field capacity (FC), total porosity (TP), air capacity (AC), bulk density (BD), stable aggregate (SAT) and steady infiltration rate (IR) are presented in Figures 6 to 9. The seasonal variations in water storage or total stored soil water (TSW) at a 1 meter depth are presented in Table 2. and Figure 10.

The results of soil chemical analysis are presented in Table 3 and analysis results of water quality and toxicity in weeds, stream sediment, and water along the stream line are presented in Tables 4 and 5, respectively.

I. Physical Properties of the Soil

A. Texture Analysis (sand-silt-clay)

Clay content increased with increased depth under every type of land use. The topsoil (0–20 cm) texture under tangerine, mango and maize fields was classified as clay loam while under litchi the texture was largely clay. Most subsoil (20–100 cm) was clayey in texture, but particularly under litchi orchards (Figure 6). These soil texture results might suggested that litchi cultivation produces the best soil with the deepest profile and the highest fertility compared to tangerine, mango and maize. It could also be that the history of land use differed in these areas: the litchi orchard had been established for almost 20 years while the tangerine and mango orchards had replaced annual crop land only 3 to 5 years before. The soil profile under maize cultivation was very shallow, suggesting that soil loss from erosion was more serious there than with other types of land use (Figure 6).

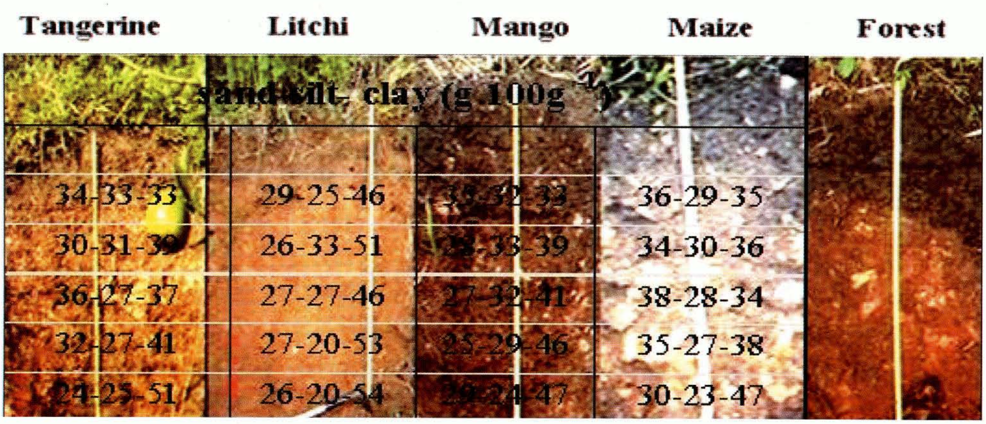

Figure 6 Profile structure and texture or particle size distributions (sand-silt-clay) with different types of land use. The ratio of clay particles increased with increased depth regardless of land use.

B. Bulk Density (BD), Field Capacity (FC), Moisture Content (MC), Total Porosity (TP) and Air Capacity (AC)

In general, the soil outside the growing pits of the fruit trees was looser and had better aeration, shown by lower values of BD, FC and higher values of TP and AC, than the soil inside the growing pits (Figure 7). The highest bulk density (BD=1.331 Mg m^{-3}) with the lowest soil aeration porosity or air capacity (AC=0.092 m^3 m^{-3}) was found inside the growing pits of the tangerine orchards. Forest soil tended to have the best physical properties, wiht the lowest BD (1.014 Mg m^{-3}), the highest TP (0.533 m^3 m^{-3}) and AC (0.171 m^3 m^{-3}) compared to the soils of all types of agricultural use.

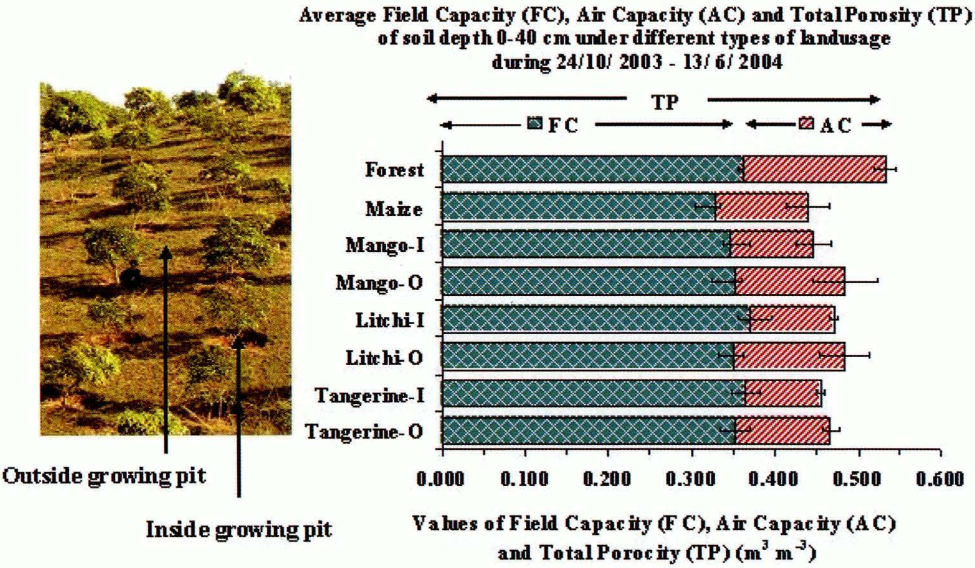

Figure 7 The average values of Total Porosity (TP), Field Capacity (FC) and Air Capacity (AC) within 0-40 cm soil depth as influenced by different types of land use during the late rainy season, October 2003 to the mid rainy season, June 2004.

C. Aggregate Stability (%SAT) and Steady Infiltration Rate (IR)

The seasonal variations of stable aggregate amounts (SAT), mean weight diameter (MWD) of the stable aggregate, and the steady infiltration rate (IR) under different types of land use from October 2003 to February 2004 are presented in Figures 8 (a), (b) and Figure 9, respectively.

Figure 8 shows that the higher amount of stable aggregate (SAT) were found outside the fruit tree growing pits (Tangerine-O, Litchi-O and Mango-O), while inside the growing pits (Tangerine-I, Litchi-I and Mango-I) had smaller aggregate size and a lower amount of stable aggregate. The amount of SAT decreased under all types of land use, but tended to increase in the forest as shown in Figure 8(a). Forest gave the best soil aggregate stability (SAT=52.24 g/100g) while the second best stable soil aggregate was found outside the growing pits of the litchi tree, Litchi-O (SAT=41.54 g/100g). The poorest soil aggregate stability was found in the maize field (SAT=24.23 g/100g) as well as inside the pits of the mangos, Mango-I (SAT=24.68 g/100g) and tangerines,

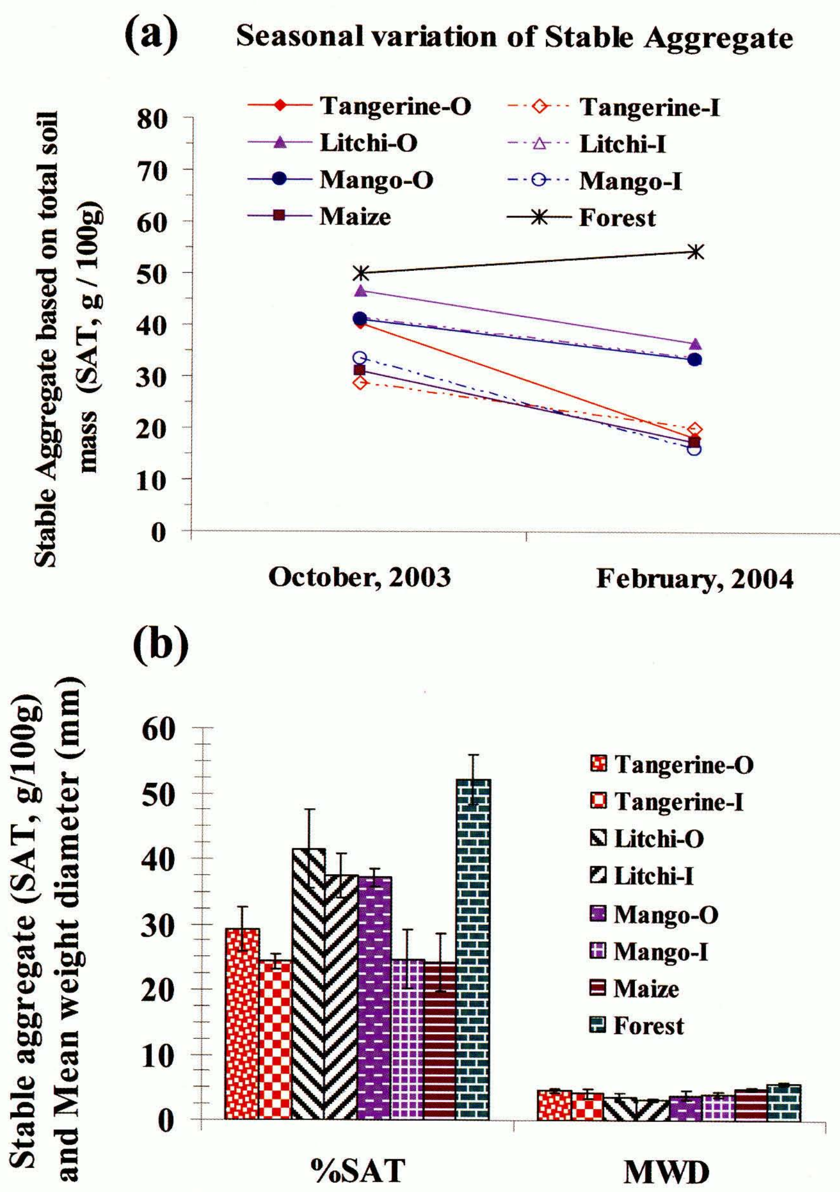

Figure 8 The seasonal variations (a), and the average amounts (SAT) and mean weight diameter (MWD) (b) of stable aggregate based on total surface soil mass under different types of land use from October 2003 to February 2004.

Tangerine-I (24.35 g/100g). Mean weight diameters of stable aggregates (MWD) were not different under the different types of land use (Figure 8(b)).

The results of the steady infiltration measurement were compared to the results of aggregate stability (Figure 9). The highest value of the steady infil-

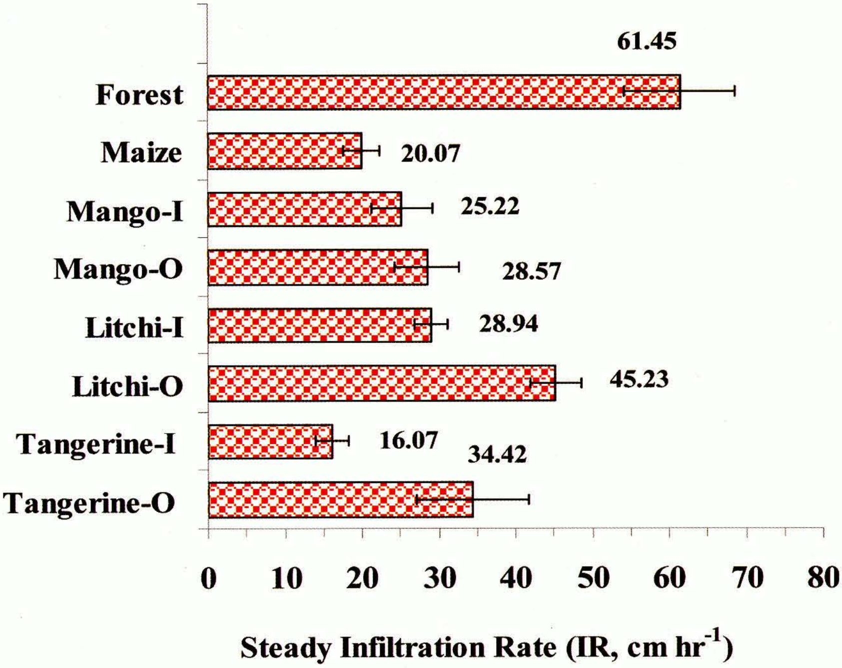

Figure 9 The average values of steady infiltration rate (IR) under different types of land use during the early rainy season (June 2004) Banmai.

tration rate (IR) was found in forest soil (IR=61.45 cm hr^{-1}) while the second highest IR value was obtained outside the growing pits of the litchi trees, Litchi-O (IR=45.23 cm hr^{-1}). The lowest IR value was found inside the growing pits of tangerine trees, Tangerine-I (IR=16.07 cm hr^{-1}).

These results suggest that forest soil should have the highest stored soil water and the lowest runoff with the lowest erosion rate under high-intensity rainfall compared to soils under all types of the studied land uses.

The results of all the studied soil properties suggests that the intensive care given the 3 to 4-year-old tangerine orchard has produced poorer soil properties than the litchi orchard, which was weeded only rarely and had been used for perennial fruit trees for more than ten years. In general, the soil outside the growing pits of tangerine, litchi, mango and maize had similar values in every category. However, the mango orchard and the maize field had rather shallow soil due to higher the runoff and soil erosion rates under the previous annual cropping regimes. The land had been used for growing annual crops (vegetables, upland rice, and maize) for several years before being replanted with to mango orchard (5 years before). The maize field had the shallowest top soil with the poorest soil structure. The topsoil of the maize field contained high amounts of gravel and a generally course texture with a high accumulation of organic matter at the lower part of the slope (Figure 6). This indicated substantial movement of the surface soil layer carrying high levels of organic matter from the upper to the lower parts of the slope due to considerable runoff; this resulted in soil loss and low soil productivity.

II. The Total Stored Soil Water and Soil Water Content Profile

The seasonal variations of the average amounts of the stored soil water (TSW) within 1 m soil depth under different types of land usage are presented in Table 2 and Figure 10. Distribution of the soil water content along the soil profile (soil water content profile) during each period of measurement is not presented here.

Table 2 and Figure 10 show that during early rainy season (11-15/06/2004), forest soil had the highest soil water storage (426 mm) while the second highest was found inside the litchi growing pits (415 mm). The lowest water storage was obtained inside the mango tree pits (317 mm) (Table 2). However, the total stored soil water (TSW) inside the fruit tree pits was always higher than the outside pits under every type of land use (Figure 10). This indicates that irrigation water was applied mainly inside the fruit tree pits. In general, the total stored soil water (TSW, Figure 10) and the soil water contents along the soil profile under rainfed conditions increased during the early rainy season (June 2004), and decreased sharply during the late rainy season to the mid

Table 2 Soil water storage rates as impacted by different types of land use during the late rainy season 2003 to the early rainy season 2004 (October 2003 to June 2004) in Banmai. (I and O represent inside and outside the pits of the growing trees respectively)

Land Use	Mean values of total stored soil water (mm)			
	Late Rainy season 22-24/10/2003	Early Dry season 22-24/11/2003	Mid Dry season 21-24/2/2004	Early Rainy season 11-15/6/2004
Tangerine-O	346	310	224	379
Tangerine-I	383	330	352	370
Linchi-O	362	254	243	401
Litchi-I	390	245	321	415
Mango-O	244	281	202	345
Mango-I	269	311	231	317
Maize	321		217	349
Forest			224	426

dry season (October 2003 to February 2004), particularly outside the growing pits as shown in Figures 10.

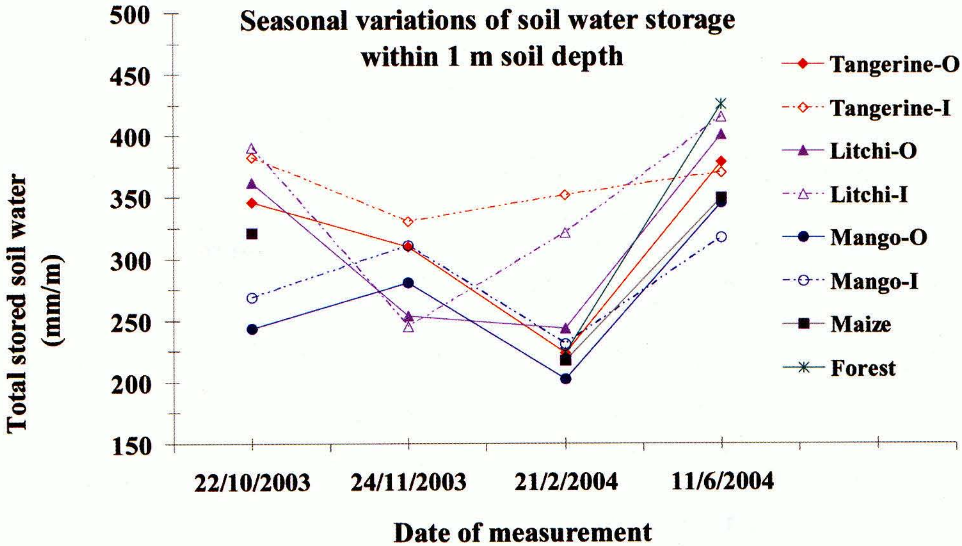

Figure 10 The seasonal variations of total stored soil water (TSW) at 1 m soil depth under different types of land use during the late rainy season (October 2003) to the early rainy season (June 2004) in Banmai.

The actual field capacity (FC) or the maximum water-holding capacity of the soil profile is also shown in Figures 10 during the early to mid rainy season (June 2004). The highest amount of stored water at 1 meter soil depth in June 2004 indicated that all the profiles under different types of land use were nearly saturated with the rain water. The soil water content profile confirmed that the mango orchard had the lowest storage capacity while the forest had the highest. Furthermore, soil water at deeper soil layers was used by plants during the dry periods (data not shown). This result indicated that the subsoil water was available to plants under all types of land use. However, the amount of available soil water might not be sufficient for maintaining high water use efficiency and high quality crop production without supplementary irrigation during the dry period. Litchi-growing soil had a better water-holding capacity than the other cultivated soils. The amount of stored soil water inside tangerine growing pits was higher than the others during the dry periods. It did not vary significantly between seasons (Figure 10) because of the adequate application of water by irrigation during the dry period.

III. Chemical Properties and Water and Stream Sediment Contamination

Table 3 shows the average values of each chemical property at a 0-40 cm soil depth obtained from all periods of soil sampling. The seasonal variation in each chemical property value is not presented. The standard critical values and optimal range of each soil and water chemical property are presented in Table 4.

A. Soil Chemical Properties

Table 3 shows that all types of agricultural land use result in lower soil pH and organic matter content than the forest, which had the highest pH values (5.27) and organic matter content (8.128 g/100g). The soil inside the planting pits (I), under all types of growing fruit trees, showed higher seasonal variations and higher amounts of soluble salt (salinity indicated by electric conductivity, EC), available phosphorus (P), potassium (K) and copper (Cu) than the soil outside the pits (O) (Tables 3).

The annual maize growing resulted in the lowest seasonal variations of each measured soil chemical property, with the lowest average values of EC, P and Cu compared to the inside-pit soils of the perennial fruit trees (data are not presented). The highest values of EC, OM, P, and K content (73.4 μS cm^{-1}, 4.844 g/100g, 472.5 mg/kg, 570 mg/kg) of soil (0-40 cm depth) were found inside the growing pits of the litchi trees.

Table 3 Average values of measured chemical properties within a 0-40 cm depth, as influenced by different types of land use during the late rainy season, October 2003 to the early rainy season, June 2004, in Banmai. (I and O represent inside and outside the tree pits)

Land Use*	Soil acidty pH	Electric Cond. Ec(μ S/cm)	Organic matter OM, (g/100g)	Ext. Phosphorus P (mg/Kg)	Ext. Potassium K (mg/Kg)	Ext. Copper Cu (mg/Kg)
	Soil Depth (cm)					
	0-40	0-40 cm	0-40 cm	0-40 cm	0-40 cm	0-40
	MEAN					
Tangerine-O	4.99	48.8	3.916	30.6	203	1.944
Tangerine-I	4.91	62.4	3.513	90.7	338	1.851
Litchi-O	4.71	45.6	2.950	14.0	308	1.781
Litchi-I	4.49	73.4	4.844	472.5	570	1.681
Mango-O	4.11	25.6	3.678	5.6	138	2.046
Mango-I	4.33	50.5	3.720	18.4	160	2.783
Maize	4.65	36.2	4.210	4.6	186	1.923
Forest	5.27	43.4	8.128	8.4	326	2.760

The high values of OM, P and K contents inside the growing pits of fruit trees suggest the over-application of chemical and organic fertilizer (farm manure, cow dung) for several years. Intensive management of the litchi and tangerine orchards has caused an imbalance in plant nutrients and degradation of the soil's chemical properties.

B. Water and Stream Sediment Contamination.

The analysis of water samples was conducted only twice between August and November of 2003. The measured water quality indices were nitrate and nitrite (NO_3^{-1}, NO_2^{-1}), phosphate ($H_2PO_3^{-1}$), water hardness ($CaCO_3$), biochemical oxygen demand (BOD), acidity (pH) and salinity (electrical conductivity). The average values of these water quality indices are presented in Table 4. The values of toxic substances and toxic elements (heavy metals) accumulated in weed samples and sediment along the stream line are shown in Table 5.

Table 4 shows that almost all the measured parameters of water quality (NO_3^{-1}, NO_2^{-1}, $H_2PO_3^{-1}$, BOD, and pH and EC) were lower than the acceptable standard values for drinking water. Moreover, the water sample taken from the upper stream line (site 1) had a higher $CaCO_3$ concentration (421.1 mg l^{-1}) than the standard value (<300 mg l^{-1}) and the other studied sites. The upper stream line also had a higher value of nitrate (NO_3^{-1}) and nitrite (NO_2^{-1}) concentration than the other parts of the stream because this part of the stream received direct runoff from the litchi orchard.

Table 5 shows that the concentration of toxic substances (Organophosphate, OP, Organochlorine, OC, and Pyrethroid) in the weed samples taken from the three studied sites were very low and virtually un-detectable. Only a small amount of organophosphate was found in weed tissue taken from the

Table 4 The average values of the water quality taken from three sites along stream lines. Starting at the foot of litchi orchard, from August to November 2003, in Banmai.

Sampling Date	Sampling Location	Nitrogen NO_3^{-1}, NO_2^{-1} (mg l^{-1})	Phosphate $H_2PO_4^{-1}$ (mg l^{-1})	Hardness $CaCO_3$ (mg l^{-1})	BOD (mg l^{-1})	pH	Elect. EC μmho cm^{-1}
	Litchi orchard -						
10/8/2003	—Upper stream line (site 1)	0.29	0.13	421.1	1.23	7.55	2.84
10/8/2003	—Lover stream line (site 2)	0.04	0.12	181.8	1.72	7.76	2.87
22/11/2003	—Near Reservoir (site 3)	0.06	0.13	194.9	0.08	7.62	3.3
	Standard values for drinking water	**<10.00**	**0.70-0.80**	**<300.0**	**<12.00**	**6.0-8.0**	**<72**

Table 5 The average amounts of toxic substances and toxic elements accumulated in weeds and stream sediments along the stream lines, starting at the foot of the litchi orchard, from August to November 2003.

Sampling Date	Sampling Location	Toxic substance in weeds*			Toxic heavy element in sediment**		
		Organo-Phosphate mg Kg^{-1}	Organo-Chlorine mg Kg^{-1}	Pyrethroid mg Kg^{-1}	Arsenic, As $\mu g\ Kg^{-1}$	Lead, Pb mg Kg^{-1}	Mercury, Hg $\mu g\ Kg^{-1}$
24/11/2003	Water drains at Lower slope (site 1)	0.000	0.000	0.000			
21/2/2004	Stream sideway (site 1)	0.000	0.000	0.000			
11/6/2004	Water ways in Litchee orchard (1)	0.000	0.000	0.000			
	Stream sideway (site 2)	0.000	0.000	0.000			
	Lower stream line (site 3)	0.000	0.000	0.000			
	Stream bottom and sideway (site 1)	0.000	0.000	0.000	0.65	16.16	0
	Standard values for food and drinking water	**0.050-0.100**	**0.05-0.10**	**<0.050**	**0.05**	**0.01**	**0.005**

* Plant samples were taken from the stream side-wall and water drain channel.
* * Sediment samples were taken from the bottom of stream line and water drain channel.

stream-side (site 2). This means that toxic substances had accumulated in soil and water and was being absorbed by the weeds.

Conclusions

I. The Yunnan Chinese diaspora of Banmai village in Chiang Mai Province established new hill farming systems in the form of fruit orchards when they were granted citizenship by the Thai government in the early 1980s. In an effort to ameliorate their association with opium production, its refinement into heroin, and its distribution, they devoted substantial amounts of time and capital into building a sustainable rural living in the hills. Their orchards (litchi, tangerine and mango) appear to have had some negative impact on soil quality, but the degree of impact seems manageable. Our study lends support to the notion that this approach may be considered a viable and reasonable option for addressing problems that continue to devastate the region: opium production, poverty, and soil erosion.

II. The survey indicates that among the five types of land use studied, forest soil had the best soil properties with the highest values of organic matter content, stable aggregate, infiltration rate, water storage, etc, when compared to all types of agricultural land use. All four hill-farming regimes have caused some degradation of both the physical and chemical fertility of the soil since the land was converted from forest to shifting then intensive cultivation. Litchi orchards tended to be the most sustainable land-use type, resulting in the deepest soil profile with the best physical and chemical properties, the highest values of aggregate stability (SAT), infiltration rate (IR), and water storage, compared to tangerine, mango orchards and maize field. Maize cultivation proved the worst agricultural practice, producing the shallowest soil profile with the poorest quality.

III. The construction of individual small basins or pits at the base of the fruit trees is a practical soil and water conservation strategy. However, the removal of topsoil from the growing pits, over-weeding, over-fertilizing and over-watering led to poor physical characteristics (BD, FC, AC, SAT, IR and TSW) and chemical properties (pH, EC, OM, Ext. P, Ext. K and Ext. Cu), consequently decreasing sustainable soil productivity.

IV. There were signs of negative impacts on water and the agro-ecological environment from overuse of chemical fertilizers and pesticides. Contaminations of nitrogen, phosphorus, organophosphate, arsenic and lead were found in water, weeds and stream sediments taken from the studied area. A particularly high concentration of lead ($Pb=16$ mg Kg^{-1}) was detected in the stream sediment. Almost all the measured parameters of water qualities (NO_3^{-1}, NO_2^{-1}, $H_2PO_3^{-1}$, BOD, pH and EC) were found to be lower than the marginal residual limit for drinking water, except CaCO3, which was over the acceptable limit.

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泰北雲南華人土地利用模式對永續性山坡農業的影響

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本計畫是「建立泰北高地永續性鄉村生計：離散華人及其文化適應」整合型研究計畫中的一環。研究的目標是藉由評估不同類型的坡地農耕操作，瞭解其對土壤生產力和農業生態系運作有何具體的影響，進而改善坡地作物的永續性生產。研究地點位於泰北清邁省 Chaiprakarn 區的 Banmai Nongbua 村。

文中首先簡述雲南離散華人在 1960 年代後，從金三角的緬甸境內退居此地，以及其後他們從毒品生產與運銷，轉為從事坡地農耕的歷史。由於他們在移居泰國前，已極為熟悉坡地農作方法，這直接影響到他們對梯田的選擇與建構。為了進一步評估其農作系統對土壤永續性的影響，我們選擇下列五種土地利用模式，以定期、固定土壤深度實地測量並採取土壤樣本，於實驗室分析土壤成分做比較：(1)橘科（*Citrus reticulate*），(2)荔枝（*Litchi chinensis Sonn.*），(3)芒果（*Mangifera indica Linn.*），(4)玉蜀黍（*Zea mays*），(5)再生林（主要是竹子 *Arundinaria gigantean*，和混合的落葉喬木）。

關鍵詞：永續性農業，離散華人，金三角，環境保護，土壤沖蝕