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Indigenous ecological knowledge about the sustainability of tea gardens in the hill evergreen forest of Northern Thailand.

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INDIGENOUS ECOLOGICAL KNOWLEDGE ABOUT THE SUSTAINABILITY OF TEA GARDENS IN THE HILL EVERGREEN FOREST OF NORTHERN THAILAND

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In loving memory of my beloved father, Ai Bug Haing

ABSTRACT

These studies on indigenous ecological knowledge were carried out as a case study of the sustainability of *miang* tea gardens in hill evergreen forest at a remote village setting in the highlands of northern Thailand. The study focused on the *miang* tea farmers' knowledge associated with decision making criteria in managing their gardens as an agroforestry system. Knowledge was investigated relating to how farmers presently manage their garden ecosystems and the underlying biodiversity of the plants and the interactions occurring between tea trees and biotic components. These were forest trees, ground flora and cattle in relation to microclimate and processes of water and nutrient cycling, soil erosion and plant succession. The knowledge acquired from key informants was evaluated in terms of its representativeness of the knowledge of the community as a whole and the extent to which it was complementary or contradictory to scientific knowledge. The extent to which indigenous and scientific knowledge could be usefully combined was investigated.

The indigenous knowledge was collected from interviewing a small number of key informants who were representative of the target population and who were people knowledgeable about the ecology of the gardens. The elicited information was recorded and accessed using knowledge-based system techniques. An indigenous knowledge base was created in terms of diagrams, hierarchies and text statements and stored in a durable, accessible and transparent form.

The research demonstrated that the indigenous ecological knowledge collected from key informants was explanatory, predictive and of technical relevance. It was also representative of most of the farmers in the community. The combination of indigenous and scientific knowledge provided a more powerful resource for improving the sustainability of the tea garden ecosystem than using either knowledge system alone but required further quantification for solid management recommendations to be formulated. The knowledge elicited had a useful role to play in furthering scientific understanding about the ecosystem and suggested new lines of research that may be more appropriate for promoting incremental change to *miang* tea production systems than extending conventional technology packages involving tea monoculture.

CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF ABBREVIATIONS AND ACRONYMS

abh	Diameter at breast height
AID	Agency for International Development
AKT	Agroforestry Knowledge Toolkit
AKT1	Agroforestry Knowledge Toolkit 1
AKT2	Agroforestry Knowledge Toolkit 2
FAO	Food and Agriculture Organisation
GUI	Graphical User Interface
HASD	Thai-Australia Highland Agricultural and Social Development Project, (Thailand)
ICRAF	International Council for Research on Agroforestry.
IDS	Institute of Development Studies, (UK)
ILCA	International Livestock Centre for Africa
NADC	Northern Regional Agricultural Development Centre, (Thailand)
NGO	Non governmental organisation
NRC	National Research Council, (USA)
ODI	Overseas Development Institute, (UK)
R	Rainfall factor
RFD	Royal Forest Department, (Thailand)
RRA	Rapid Rural Appraisal
S.K.1	*Sor Kor Neung*
SEATO	Southeast Asia Treaty Organisation
TAWLD	Thai-Australia World Bank Land Development Project, (Thailand)
Th	Throughfall factor
WWF	World Wide Fund for Nature, (UK)

CHAPTER 1
INTRODUCTION

This chapter outlines the background to the present research and provides the context for the remainder of the thesis. The research was conducted on *miang* tea gardens in hill evergreen forest, in the north of Thailand. The aim of this introduction is to provide a brief description of the general characteristics and the problems of the highlands, and hill evergreen forest (Section 1.1.1). There is an inconsistency between scientifically based recommendations for improving the productivity of tea gardens and traditional practice, which provides a rationale for exploring the indigenous knowledge system that perpetuates the traditional tea gardens as they are (Section 1.1.2). Research objectives for the present study are then outlined in section 1.2. The rest of the chapter gives a brief description of the history of tea cultivation in the region and the specific role of *miang* (fermented) tea gardens located in areas of thinned hill evergreen forest (Section 1.3). Finally the structure of the remainder of the thesis is outlined (Section 1.4).

1.1 Rationale

1.1.1 General characteristics and the problems of highland and hill evergreen forest in the north of Thailand

The northern region of Thailand covers about 170 000 km^2 of which 15 %, 31 % and 54 % are classified as lowland, upland and highland, respectively (TAWLD, 1985). The lowlands have been used for agriculture, industry and living space, while the uplands, where dry dipterocarp forest and mixed deciduous forest predominate, have been utilised for timber. The highlands have recently been designated as a catchment area for supplying water to the plains in the lowlands.

Hill evergreen forest is found in the highlands where most of the area consists of mountain ranges. The forest covers catchment areas that are the source of important rivers in the northern, central and northeastern plains of Thailand. Fortythree tree species with 18 species of undergrowth and 21 phreatophytic species are found in the hill evergreen forest (Aksornkoae *et al.*, 1977). The average percentage of crown cover is approximately 90 %, but this varies with altitude. The main species consist of trees in the family Fagaceae, such as *Castanopsis, Lithocarpus* and *Quercus* species (Ruangpanit, 1971). Stand densities of trees, seedlings and undergrowth were estimated to be 15 491, 179 400 and 964 200 plants ha^{-1} respectively in one representative area north of Chiang Mai (Aksornkoae and Boonyawat, 1977).

Chunkao *et al.*, (1981) summarising 15 years of hydro-ecological research in three small watersheds in Chiang Mai district describe a monsoonal climate, with mean annual rainfall of just over 2 000 mm and typically about 140 rainy days during a rainy season lasting 10 months from March to December. The average water yield in this catchment study was 1 378 000 m^3 km^{-2}, about 71 % of which occurred in the wet season and the rest in the summer (Chunkao and Makarabhirom, 1979). However, Chunkao *et al.* (1981) found that annual pan evaporation from a mountain in the north Thailand was over 1 100 mm. Gross rainfall may be lost from the system as a result of evaporation of water intercepted by vegetation which has been designated 'interception loss' (Ward and Robinson 1990). For mixed evergreen forest in South Island, New Zealand, interception losses averaged 29 % of gross rainfall (Pearce *et al.*, 1982) and variations from 12 to 54 % were quoted for tropical forest in Indonesia, China, Brazil (Franzle, 1979) and Puerto Rico

(Clegg, 1963). It has been found that the interception loss from forest depends on leaf area index, crown structure of the tree species involved and the climate (Rutter, 1975). Preechapanya (1984) found the amount of throughfall under the tree canopy in hill evergreen forest on a mountain near Chiang Mai City to be about 77 % of rainfall in the open. Water is also lost from the system through transpiration which is also related to leaf area index. Chunkao and Tangtham (1974) state that plants may only use 5 % of the total water they absorb from soil for their growth, the rest is lost by transpiration.

Therefore, it is possible, that catchments with thinned hill evergreen forest in *miang* tea gardens will provide more discharge than those catchments with undisturbed hill evergreen forest because forest density is reduced. However, Ruangpanit (1971) and Preechapanya (1984) found that the rate of soil loss and surface run-off from hill evergreen forest near Chiang Mai City was higher when crown cover was lower than 70 %. Therefore, it was recommended that hill evergreen forest on mountainous land in the north of Thailand would have high water yield, if the forest canopy was reduced by 30 % crown cover (Ruangpanit, 1970; Ruangpanit, 1971; Chunkao and Tangtam, 1974; Chunkao *et al.*, 1981; Preechapanya, 1984).

Ruangpanit (1970) found that discharge potential, which is the discharge as a percentage of rainfall, from undisturbed hill evergreen forest was about 65 %. During the investigation period, there had been no surface run-off in the area; that is overland flow, because the soil in the forested area allowed rapid infiltration of water. This suggests that the hill evergreen forest may act as a highly effective vegetation cover for watersheds. These watersheds are important for agriculture, water supply, hydropower, fisheries, industry and transportation (Chunkao *et al.*, 1981).

Most of the population of Thailand relies on rivers for their livelihood. Traditionally, Thai settlements have been on the banks of rivers. Most of the important cities in Thailand are found near rivers including Bangkok, the capital city; Chiang Mai, the second city and Ayuthaya, the old capital city. For these reasons forests and rivers are central in Thai culture. Most Thai people use and depend upon rivers.

There has been a very rapid increase in population through migration of people from the neighbouring countries of China, Myanmar (Burma) and Laos, to the mountainous area in the North (Kunstadter, 1992). Additionally, there has been a very dramatic rise in the birth rate of people in the area over the last 20 years. There are almost 700 000 shifting cultivators in the highlands (Tribal Research Institute, 1995). As a result the hill evergreen forest has been widely destroyed by shifting cultivation. The farmers have cut and burnt the forest with slash and burn systems to grow annual crops without using soil and water conservation methods. In the past some farmers grew poppy for opium as a cash crop, but now most of them grow alternative cash crops, such as cabbage and maize. Most of the farmers have grown upland rice and other vegetables as subsistence crops and maize for fodder. This practice has caused deforestation and destruction of the ecosystem of catchment areas and decreased biodiversity in the hill evergreen forest. The direct consequence has been a very sudden rise in surface run-off and a high amount of sediment transport in the rainy season. This has resulted in a rapid decrease in soil fertility in the cultivated areas of the highland region. It has also caused farmers to move on to cut and burn the forest in other areas. As a result, there is now a large area of wasteland on the mountains and a lack of water in the summer, with floods and land slides ocurring in the rainy season. Preechpanya (1984) working in Doi Suthep watershed west of Chiang Mai, found that there was twice the amount of surface water run-off from areas under shifting cultivation as compared to hill evergreen forest; 14 mm yr^{-1} and 29 mm yr^{-1} for the natural hill evergreen forest and shifting cultivation respectively. Related to this is the increase in toxic loading of pesticides, insecticides, herbicides and heavy metals in stream water where catchments are cultivated as opposed to forested (Chunkao *et al.*, 1981).

1.1.2 The role of traditional *miang* tea gardens

The people living in the highlands of northern Thailand can be categorised as those who are culturally Thai and the indigenous Austro asiatic hilltribe people (Khmu, Lua', Wa and T'in). Thai people who have migrated to the highlands (Keen, 1978) and ethnic minorities in the highlands (Bar, 1967) grow *miang* tea in the hill evergreen forest using an indigenous agroforestry planting system. The system prevents shifting cultivation from spreading into natural forests because farmers conserve forest trees around their crops and the forest cover in these catchment areas provides a high yield of water although it is to some extent disturbed. People also prevent forest fires that would otherwise destroy their crops and the surrounding forest. The villagers seldom practice shifting cultivation in their watershed areas because they need the forest trees to provide shade and to recycle nutrients for growing tea trees. They also value high water yield from their catchment area both as a supply of water for domestic use and turning small hydroelectric generators which are operated in their villages. Further downstream river water is used for irrigation of lowland agriculture. It is quite possible that *miang* tea gardens have acted as a buffer zone between shifting cultivation and the natural forest. In comparison, many areas without *miang* tea gardens are now wasteland.

NADC (1977) describe the importance of traditional tea in the northern Thai economy through first hand evidence gathered by a botanical survey between 1920 and 1922 of the dispersion of '*miang* tea villages' (villages in which most of the inhabitants grow tea for *miang* production). They state that the cultivation of *miang* tea in Thailand is confined to that portion of the country north of latitude 18 ^{o}N, but within that area, *miang* tea cultivation is widespread. They also mention that a map published by the survey group shows clusters of *miang* tea villages scattered throughout the hills along the four major rivers in the area. Past surveys of potential *miang* tea growing areas in the North identify a number of localities in which *miang* tea cultivation continues. Campbell (1963) indicates that a comparison of these sites with those discovered by the 1920-1922 survey shows a high degree of consistency. The tea village clusters of the 1920s, have continued apparently undisturbed into the present time. Major problems faced in the management of *miang* tea gardens are: wood shortage, low production, declining demand for *miang* and hence an over supply of it and the high labour requirement of the system. *Miang* production requires quite large amounts of firewood and it has been estimated that 25 m^3 household^{-1} yr^{-1} of wood, typically from around 16 trees is used in the *miang* steaming process (Castillo, 1990). This has caused the depletion of trees in forest areas (Khemnark *et al.*, 1971; Keen, 1978; HASD, 1988; Castillo, 1990; Sangchai, 1993). Most of the firewood is derived from the dominant forest species, such as *Lithocarpus calathiformis, L. trachycarpus* and *Schima wallichii* (Castillo, 1990). It would seem that extraction of firewood significantly disturbs the ecosystem of the forest because these trees are important in ameliorating the microclimate in the forest understorey, nutrient cycling, protection of soil from erosion and the production of seeds from which natural regeneration occurs. The Thai government through the Ministry of Agriculture and Co-operatives, some non-governmental organisations and some agricultural companies have tried to introduce new crops to replace tea gardens, but people have generally maintained their gardens using traditional methods. However, when *miang* tea gardens are compared to other highland farming systems, they have been less destructive of natural forest and other natural resources. Keen (1978) compared swidden land use systems in this region with the traditional *miang* economy, by looking at the relative population densities that could be supported by each system. Table 1.1 shows the relative population densities, under four different forms of upland land use, in or near the area bounded by the Hill Tribe Settlement Area, which is located to the north west of Chiang Mai. It is apparent from the data that the *miang* tea gardens were capable of supporting much higher densities of population (by a factor of 5 to 10) than forms of swidden agriculture, but only half that of monocultural tea plantations.

Table 1.1 Human carrying capacities of various upland economies in the Chiang Dao hill tribe settlement area, Chiang Dao district, Chiang Mai province, Thailand.

Village	Ethnic group	Total population	Land use type	Fallow period (yr)	Total land area per head (ha)
Huay Tadt	Lahu[1]	200	Upland rice swiddens	10	1.164[2]
Pa Khia	Hmong[3]	303	Upland rice swiddens	10	2.264[2]
			Opium poppy	5	
Pang Kyt and Pang Huay Tadt	Thai(labourers)	258	Tea plantations for producing black tea[4] and green tea[5]	0	0.246[6]
Pang Ma O and Mae Ta Man	Thai	249	Tea gardens for producing *miang*	0	0.451[7]

source: Keen (1978)
Note: [1] Minority group immigrating from Tibet. [2] Including fallow. [3] Minority group immigrating from China. [4], tea produced from leaves that are fully fermented before drying, also known as European tea or black tea. [5] tea produced from steam-dried, not fermented leaves, also known as Chinese tea or green tea. [6] Information by courtesy of the managing director, highland tea Co., Chiang Mai, January 1970; assistance gratefully acknowledged. [7] Not including land required for fuel production.

Keen (1978) described the cropping system of *miang* tea farmers as involving a permanent home with periodic and cyclical exploitation of the *miang* tea gardens rather than as a migratory system.

Low productivity is caused by mixing *miang* tea and forest trees and growing small numbers of tea trees at irregular spacing. Tea farmers typically receive as income from the sale of *miang* about £250 household^{-1} yr^{-1} (Castillo 1990). The average national income of Thai people was quoted as £1 333 yr^{-1} in 1994, which even allowing for inflation at about 4 %, is more than three times what *miang* tea farmers achieve (The Economist, 1994). Therefore, the extension workers have tried to introduce unshaded tea production systems with narrow spacing as practised in Sri Lanka, Japan, China and Kenya in the belief that these systems will provide a higher income, but most tea farmers have not adopted these innovations.

The present trend in the demand for *miang* is declining because it is generally consumed by older people. There is, by contrast, a growing demand for black tea and green tea because the younger generation like to drink these teas. The extension agencies have tried to change product processing from *miang* to black or green tea, but most tea farmers have not changed and still produce *miang*.

Another recognised problem in the forest-tea production system is that of a high labour requirement and the ability of the family to provide their own labour seems to be declining as educational and off-farm employment opportunities have increased (van Roy, 1971; Taisiripech, 1981; HASD, 1988; Castillo, 1990; Sangchai, 1993).

If extension workers are to work constructively with *miang* tea farmers, a number of fundamental questions should be addressed. These include:

- How do the farmers presently manage their forest tea-gardens ecosystems?

- Is there evidence of tea farmers changing their cultivation practices, processing methods and cropping system?

- Are there differences between scientific knowledge and indigenous knowledge that underly the apparent inconsistency between scientifically-based recommendations and farmer behaviour?

- How can extension workers and farmers work together to improve the productivity (productivity is defined after Conway, 1987, see Appendix 1.1) of *miang* tea gardens?

This research aims to investigate these questions and suggest potential solutions to landuse problems.

1.2 Research objectives

The aim of the present research was to explore the reasons for the apparent contradiction between farmer practice and extension advice and comprised the following objectives.

- To acquire indigenous and scientific knowledge about key processes that may affect the sustaininability (sustainability is defined after Conway, 1987, see Appendix 1.1) of *miang* tea gardens in the hill evergreen forest and store it in a durable, accessible and transparent form.

- To investigate this knowledge in order to:

    - analyse the coherence and distribution of knowledge within communities with special reference to gender, age, wealth, altitude, ethnicity and education;

    - establish the extent to which the indigenous knowledge contained information about ecological processes;

    - compare indigenous and scientific knowledge and where appropriate combine both types of knowledge in an encyclopaedic resource.

- To investigate the potential to synthesise information from analysis of the encyclopaedic resource appropriate for use in agroforestry research and extension.

These objectives were achieved by applying a novel, knowledge-based systems approach to agroforestry research and extension (Walker, Sinclair and Kendon, 1995) contemporaneously developed at the University of Wales, Bangor and Edinburgh University in conjunction with the present research and described as appropriate in Chapter 3.

1.3 Background

1.3.1 Tea plantations

The natural geographical distribution of the tea plant covers an extensive area of upland Asia. It is found in the hill areas from the highlands of the south east of the Tibetan plateau (Weatherstone, 1992), Assam, India to the southern hills of eastern China along latitude 29 ^{o}N, while it also has been noted in the mountainous area of northeastern Myanmar at longitude 98 ^{o}E, along the Salween watershed. It has spread southward through the Yunan state of China, Shan state of Myanmar and northern Thailand, down to southern Vietnam (Harler, 1964; Kingdon-Ward, 1950; Weatherstone, 1992). From these origins, tea has been introduced for cultivation in many parts of Asia including southern India, Sri Lanka, Bangladesh, Java, Sumatra, Malaysia, Vietnam, Taiwan, Iran and Turkey (Othieno, 1992; Kingdon-Ward, 1950). Originally the tea plant was brought from China to Japan by Buddhist monks (Takeo, 1992). It has also, more recently, been introduced into commercial plantations in many parts of Africa, such as Kenya, Malawi and Tanzania (Othieno, 1992; Kingdon-Ward, 1950) and in parts of South America, such as Argentina and Brazil (Weatherstone, 1992). In Russia, tea has been grown in Georgia (Weatherstone, 1992). Carr (1972) stated that commercially viable tea industries have been established as far north (42 ^{o}N) as Georgia (USSR) and as far south as Argentina (27 ^{o}S) and at altitudes from sea level to 2200 m. Table 1.2 shows the estimated production and value of black tea in 1990 and green tea in 1989 from the main producing countries.

Table 1.2 Estimated production and value of black tea in 1990 and green tea in 1989 in main producing countries.

Country	Black tea		Green tea
	Amount (1 000 Mt)	Estimated value (£1 000 000)	Amount (1 000 Mt)
India	722	1 306.82	8.0
Sri Lanka	230	416.30	1.0
Kenya	195	352.95	
Turkey	140	253.40	
Indonesia	125	226.25	37.0
China	117	211.77	314.3
USSR	90	162.90	22.0
Bangladesh	56	101.36	0.9
Malawi	43	77.83	
Argentina	33	59.73	
Japan			90.5
Vietnam			28.0

Source: International tea committee (1989) and (1990a) in van de Meeberg (1992).
Note: The value of the black tea product was calculated using the mean price of quality and medium tea at auction in London in 1990 of £1.81 kg^{-1} (van de Meeberg 1992). Prices for green tea were not available and, therefore, it's value could not be calculated, but the unit price of green tea is generally lower than that for black tea.

The first tea to reach Europe came by way of the Dutch who, being active eastern traders, brought the first consignments to Holland in the early part of the 17th century. All the early supplies of tea entering England were brought over from Holland (Weatherstone, 1992). Tea is now one of the most important beverages in many countries including the United Kingdom. Table 1.3 shows estimated consumption and value of black tea and green tea in 1989 by major importing countries.

Harler (1964), states that there are three original tea types: the China variety, small leaved and bushy, the Assam variety with large glossy leaves, and the Cambodian variety with long, narrow turned-up leaves. Commercial strains of tea are hybrids of these plants.

Table 1.3 Estimated consumption and value of black tea and green tea in 1989 by country.

Country	Black tea		Green tea
	Amount (1 000 Mt)	Estimated value (£1 000 000)	Amount (1 000 Mt)
India	462	762.30	22.0
Pakistan	275	453.75	
USSR	263		
UK	163	326.00	
Egypt	156	257.40	
Turkey	140	231.00	
USA (Incl. Central America)	88	176.00	
Indonesia	37	61.05	37.0
Argentina	30	60.00	
Iran	30	49.50	
China			314.3
Japan			89.0
Vietnam			18.0

Source: International tea committee (1988) and (1989) in van de Meeberg (1992).
Note: van de Meeberg (1992) suggested that industrialised countries consume high quality tea, so the value of black tea consumed in the UK, USA and Argentina was calculated using the mean price of quality tea at auction in London in 1989 of £2.00 kg^{-1}. van de Meeberg (1992) also suggested that lower quality tea usually finds its way to the Middle East, so black tea consumed in Iran Egypt and Turkey was calculated using the mean of price of medium quality tea in 1989 of £1.65kg^{-1}. The value of black tea consumed in India, Pakistan and Indonesia was calculated from the mean price of plain tea at auction in London in 1989 of £1.28 kg^{-1}. Prices for black tea consumed in the USSR was not available and, therefore, values could not be calculated. Prices for green tea were also not available and, therefore, values also could not be calculated, but the unit price of green tea is generally lower than that for black tea.

1.3.2 Fermented tea *(miang)* plantations

Bar (1967) suggests that four Austro asiatic hill tribes occupying highland areas in northern Thailand, produced and consumed *miang*. Bar (1967) also infers that *miang* production may well have originated among these tribes. Weatherstone (1992) elucidated that the people in the Shan state of Myanmar and northern Thailand have been using tea leaves, at first for medicinal purposes, and then as a beverage for as long as the Chinese; that is more than 2 000 years.

The practice of fermenting tea leaves by steaming them and then storing them anaerobically, such as in pits or sealed baskets, is widespread throughout the original homeland of the tea plant. The people of the Shan State of Myanmar (Aung San, 1995) and the northern Thai people make fermented tea for consumption within their own countries. In Myanmar the product is called *leppet-so. Miang* tea leaves are steamed for two hours or so, and fermented in sealed bamboo containers in which it is then sold (Keen, 1978). *Miang* is consumed by both men and women as a social custom. When visitors come or when the family is seated together in the evening, the *miang* is passed around from one to the other for chewing (Keen, 1978).

Tea grows freely and apparently wild in these areas, although it is unclear to what extent human activity has influenced its current distribution (Keen, 1978). The tea plant used is generally described as quite small, rarely more than 5 m tall, with large, smooth, shiny and slightly serrated leaves, bearing characteristics of both Assam and Cambodian strains (Eden, 1976). However, Weatherstone (1992) contests this commenting that the indigenous tea in the forests of south east Asia grows to a height of between 12-15 m in its natural state. Both soil and climate in north Thailand are suited to the needs of tea, as the growing pattern induced by the wet and dry monsoons and the somewhat acid soils contribute to the flavour (Harler, 1964).

The lowland Thai population may have long acquired the finished product for their own consumption through a widespread pattern of quasi politicoeconomic exploitation of their tribal neighbours. Inter-marriage has led to cultural assimilation of tribal groups, while the Thai peasants themselves have recently turned to production of *miang* as population pressures have mounted in the valleys. The indigenous tea and the seeds from it have been used to develop *miang* tea gardens in thinned hill evergreen forest. The farmers occupied areas in the forest where tea trees were abundant. Keen (1978) explains that the farmers cut through the forest for several hundred meters, leaving only a footpath about twenty feet wide, to wherever the tea was growing.

Kunstadter (1978) studied the land use system of forest dwellers in northern Thailand (Figure 1.1), identifying four types of forest and six land use patterns. The ecological characteristics of the forest types are shown in Table 1.4. The cultivation and fallow duration, kinds of crop and land used patterns are shown in Table 1.5. Kunstadter (1978) found that *miang* tea gardens were generally established at an altitude of about 900-1 400 m above sea level. They were usually mixed in with the hill evergreen forest, although they were also occasionally found in coniferous forest.

1.3.3 The forest-tea production system as indigenous agroforestry

There have been and are many kinds of agroforestry systems in the highlands of northern Thailand. Preechapanya *et al.* (1985), found that there were: 30 distinct agroforestry practices including indigenous ones such as: patterns of short cultivation and long fallow by the minority Lua' and Karen people; raising cattle in forest areas; home gardens and the forest-tea production system (Table 1.6). Research carried out by Preechapanya *et al.* (1985) determined the degree of suitability of 30 agroforestry practices for the different biophysical and social conditions existing at high altitudes in the northern region. The classification was based on three factors: durability, income and adoptability.

The practices which have overall scores from 0 to 3 are not considered a suitable form of land use in highland areas, scores from 4 to 6 suggests the practice requires adjustment to be suitable and scores from 7 to 9 suggest the practice is suitable for use in highland.

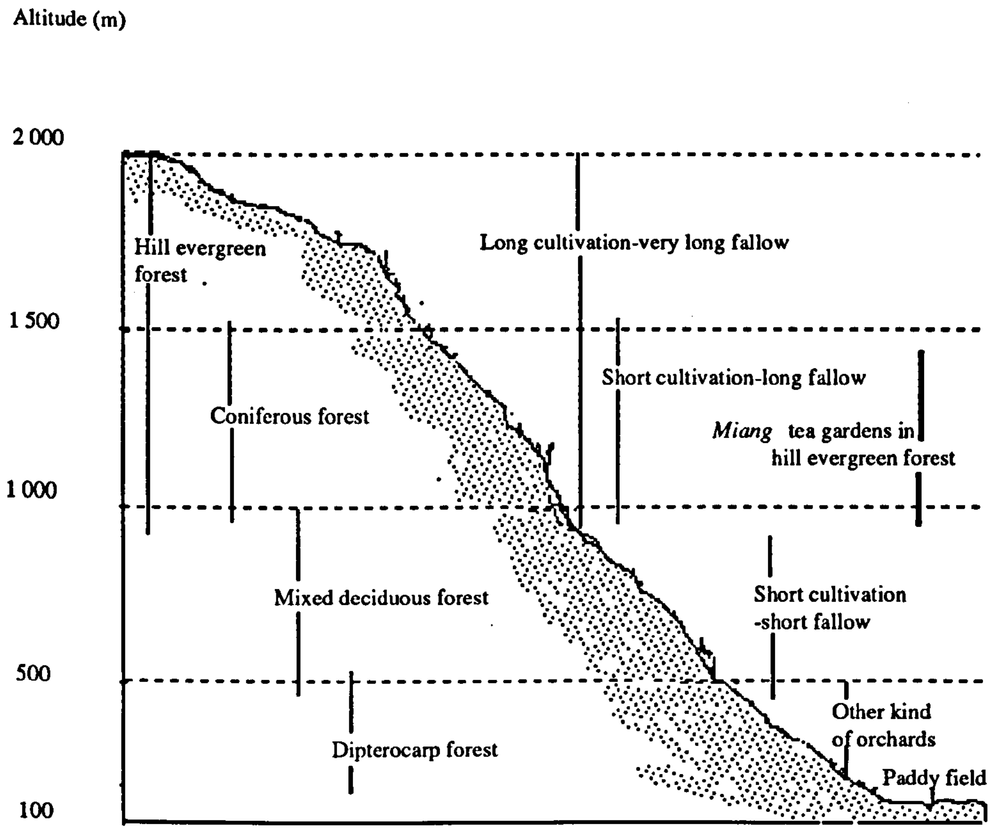


Figure 1.1 General land use pattern in relation to altitude.
Adapted from Kunstadter, 1978

The study found *miang* tea gardens in the hill evergreen forest to be one of the practices most suitable for the highlands not least because it has been capable of utilisation over a long period of time.

Castillo (1990) assessed the sustainability of a forest-tea production system through a case study in one village in the north west of Chiang Mai Province.

Table 1.4 Ecological characteristic of forest types.

Ecological characteristic	Hill evergreen forest	Coniferous forest[3]	Mixed deciduous forest[4]	Dipterocarp forest[5]
Climatic conditions				
Mean annual rainfall (mm)	2 000[1]	1 100-2000	1 750	1 000-1 250
Rainfall period (months)	10[1]	6-10	7	5-7
Temperature				
Maximum 30 °C	24[1]	38	42	30
Minimum 20 °C	17[1]	18	12	20
Soil conditions				
soil texture	Sandy clay loam[1]	Loamy sand, sandy loam, sandy clay loam	Sand and clay	Fine sandy loam, sandy loam, clay loam and clay
Vegetation characteristics				
Tree density	dense[2]	light	dense	light
Canopy height(m)	38[2]	40	26	9-24
Canopy layers	2-3[2]	1	3	2-3
Dominant trees	*Castanopsis spp. Lithocarpus spp.* and *Quercus spp.*[1]	*Pinus kesiya* and *P. merkusii*	*Tectona grandis, Pterocarpus macrocarpus, Xylia xylocarpa, Gmelina arborea, Terminalia alata, Lagerstroemia calyculata, Dalbergia cultrata, D. dengnaiensis, Vitex pinnata* and *Haldina cordifolia*	*Dipterocarpus obtusifolius, D. tuberculatus, Shorea siamensis* and *S. obtusa*

Source: [1] Chunkao *et al.* (1981), [2] Bhumibhamon and Wasuwanich (1970), [3] Tawumasawan (1981), [4] Kuldilok (1981) and 5 Kanzaki *et al.* (1991).

The cropping system consisted of forest trees, bamboos, fruit trees and vegetable crops (Table 1.7). He found that no inputs such as fertilisers and pesticides were applied to the crops, and that, in spite of this, there had been no problems concerning pests and diseases.

Table 1.5 Cultivation, fallow, crop varieties and land use patterns.

Land use patterns	Cultivation and fallow	Cropping
Paddy	Cultivated 2-3 times a year on irrigated areas	Rice, garlic, onion and soy beans
Orchards		
Miang tea gardens	Permanent cover, continuous cultivation under the forest	Tea trees and hill evergreen forest
Other orchards	Permanent cover, continuos cultivation in the open	Mangoes, Litchi and longans
Shifting cultivation[1]		
Short cultivation-short fallow	Cultivation for one year and followed by two or more years of fallow, during which time the vegetation recovers to low-growing bushes.	Maize, onions, peanuts and sweet potato
Short cultivation-long fallow	Cultivation is for one year followed by seven or more years of fallow, during which the secondary vegetation, composed largely of trees, restores itself	Rice, tomato and onions
Long cultivation-very long fallow	Cultivation is continued until fertility declines or grassy secondary vegetation makes further cropping impractical in terms of labour requirements and then the field is abandoned.	Cabbage, rice and maize

Source: [1] adapted from Kunstadter (1992)

Cattle play an important role in the traditional forest-tea agroforestry practices. They are used for ploughing, weeding and transport. The cattle are allowed to graze, among the tea trees and in the forest, on the native grasses which thrive in the sunlight available in areas of thinned forest. The animals help to keep the land clear of weeds, feed themselves and they are permitted to roam freely on all people's land. Their presence reduces the weeding required to be done by farmers during the tea leaf picking season (Castillo, 1990).

Table 1.6 Durability, income and adoptability ranking of highland agroforestry practices.

n	Agroforestry practice	Durability	Income	Adoptability	Total
1	*Miang* tea gardens in the hill evergreen forest	3	2	3	8
2	Short cultivation-long fallow	1	3	3	7
3	Raising cattle in forest area	1	3	3	7
4	Home gardens	3	1	3	7
5	Coffee with *Acacia sp.*	3	1	3	7
6	Coffee with *Betula sp.*	3	1	3	7
7	Coffee with *Erythina sp.*	3	1	3	7
8	Coffee with *Toona sp.*	3	1	3	7
9	Coffee and castor bean with *Calliandra callothyrsus*	3	1	3	7
10	Coffee gardens in the hill evergreen forest	3	1	3	7
11	*Leucaena leucocephala* for fodder	3	3	1	7
12	Medicinal plants with mixed deciduous forest	3	2	2	7
13	Coffee with *Dracontomelon sp.*	2	1	3	6
14	Coffee with *Gmelina sp.*	2	1	3	6
15	Coffee with *Leucaena leucocephala*	2	1	3	6
16	Passion fruit with mixed deciduous forest	3	1	2	6
17	Rice and maize with fencing trees	2	2	2	6
18	Maize with *Eucalyptus sp.*	0	3	2	5
19	Maize with *Leucaena leucocephala*	0	2	3	5
20	Lemon with *Acacia sp.*	3	0	2	5
21	Rice with *Erythrina sp.*	0	2	3	5
22	Castor bean with *Pinus sp.*	0	2	2	4
23	Coffee with *Pinus sp.*	1	1	2	4
24	Maize with *Pinus sp.*	0	2	2	4
25	*Chrysanthemum sp.* with *Acacia sp.*	0	0	3	3
26	Range under dipterocarp forest	2	0	1	3
27	Range under mixed deciduous forest	2	0	1	3
28	Rice with *Acacia sp.*	0	2	1	3
29	Rice with *Melia sp.*	0	3	0	3
30	Range under hill evergreen forest	1	0	1	2

Source: Preechapanya *et al.* (1985)
Note: If durability of agroforestry practices was 1-3, 4-6, 7-9 and >10 years, these agroforestry practices were graded 0, 1, 2, and 3, respectively. If income from agroforestry practices was <78.13, 78.13-546.88, 546.89-1 015.63 and >1 015.63 £ ha^{-1} yr^{-1}, these agroforestry practices were graded 0, 1, 2 and 3 respectively. In case of adoptability, if farmers did not adopt agroforestry practices, they were graded 0. If farmers adopted upon receipt of financial support, they were graded 1. If farmers adopted when encouraged to do so, these agroforestry practices were graded 2. If farmers adopted the practice on their own initiative, these agroforestry practices were graded 3.

Preechapanya *et al.* (1985) found that *miang* tea garden shade reduced heat stress in cattle and consequently led to a faster growth rate than when cattle were kept in unshaded conditions. Where cattle graze in the gardens, they provide manure. Ismail (1994) found that animals rapidly recycle nutrients through the production of faeces and so increase soil fertility. At the same time, control of weeds by cattle reduces fire hazard and competition amongst young forest trees and tea trees. The reduced costs of clearing the bush and the saving in labour through the introduction of cattle can offset some of the costs of planting and managing the gardens (Preechapanya *et al.,* 1985).

Table 1.7 Components of *miang* tea gardens of Chiang Mai Province case study.

Forest trees	Bamboos	Fruits trees	Vegetable crops
Lithocarpus calathiformis	*Bambusa arundinaeca*	Apricot	Cabbage
L. trachycarpus	*B. tulda*	Coffee	Chillies
Schima wallichii	*Gyantoehloa albeiliata*	Jack fruits	Garlic
		Lemons	Onion
		Litchi	Pumpkins
		Mangoes	Taro
		Peaches	Ginger
		Pomeloes	Maize

Source: Castillo (1990)

Planting and growing tea trees among the forest trees with irregular spacing, planting other crops and raising cattle in tea gardens, results in a variable tea tree density. Preechapanya *et al.* (1985), found that there were typically about 600 tea trees ha^{-1} in a wide-ranging study north of Chiang Mai, whereas Sangchai (1993), found a range of 300 to 3 000 tea trees ha^{-1} with a mean of about 635 trees ha^{-1} in a detailed study of one village in the north west of Chiang Mai province.

1.4 Thesis structure

This remaining structure of the thesis is presented as follows:

Chapter 2 describes the general background of the study site: location, soil, climate, land use pattern and vegetation (Section 2.4.1-.5). The socio-economic status and demographic profile of the villagers is also described (Section 2.4.6).

Chapter 3 describes the process of acquisition indigenous ecological knowledge from the *miang* tea farmers (Section 3.3). It also characterises the unitary statements acquired (Section 3.4). The process of assessing the knowledge (Section 3.5) and formalisation of the knowledge base (Section 3.6) are presented.

Chapter 4: in this chapter, firstly, the subject themes contained in the knowledge base are described (Section 4.2), secondly, the content of knowledge on each topic is presented (Section 4.3) and then finally an analysis of the contents of the knowledge base is presented (Section 4.4).

Chapter 5 evaluates the indigenous knowledge base. Methodological approaches to evaluate the representativeness are implemented and are discussed (Section 5.2). Sampling and the socio-economic and demographic status of respondents are presented (Section 5.3). The results of this research are presented and discussed (Section 5.4).

In Chapter 6, the differences and the similarities in the indigenous and scientific knowledge are presented (Section 6.2). Secondly, acquisition of scientific knowledge is described (Section 6.3). The merging of scientific and indigenous knowledge bases is then presented (Section 6.4) and then a comparison made of scientific and indigenous knowledge is identified and analysed (Sections 6.5 and 6.6). Finally, formation of recommendations combining indigenous and scientific knowledge are discussed (Section 6.7).

In the concluding chapter (Chapter 7), the principal findings and conclusions of the research are reviewed and their implications for forest policy discussed. Improvement of the methods and techniques and further research are identified.

CHAPTER 2
STUDY SITE

2.1 Introduction

There are many *miang* tea gardens surrounding the Pee Pan Num mountain range, which is situated at the inter section of Chiang Mai, Chiang Rai and Lumpang Provinces. The mountain range is also a catchment area of many small rivers whose water supply supports the livelihood of the people in these three provinces, including irrigated agriculture which is the main occupation of people in these regions. The Thai Government, through the Royal Forest Department and the National Environmental Committee Office, have designated that the highland in this mountain range is to be a protected area for the supply of water and not to be used for other activities. The large number of *miang* tea gardens in the area can, therefore, be seen as a buffer zone of semi-natural forest around the protected catchments. The villagers have generally used and protected the natural forest and wildlife through their own understanding and knowledge.

The study site is a *miang* tea village; that is a village whose occupants mainly derive their living from *miang* tea gardens. It is a typical *miang* tea village in which most of the villagers are *miang* tea farmers and it is far from the influence of main roads and thus representative of most of the *miang* growing areas and a place where traditional knowledge is likely to still be in use. Documenting the farmers' ecological knowledge in one case study village is intended to facilitate an assessment of the potential for knowledge-based approaches which might be extended to cover a wider area if the results merit this. A deeper study in one village was considered more useful than attempting a necessarily more superficial study over a wider area, because detailed knowledge was being sought that requires an extended and committed interaction with people to obtain (Thomas and Suphanchaimat, 1987; Bruce, 1989; Okali, Sumberg and Farrington, 1994, Thapa, 1994). A detailed case study was, therefore, a sensible first step in exploring the potential for using indigenous ecological knowledge to explain current land use patterns and to effect development in conjunction with scientific knowledge.

2.2 Objectives

This chapter reports on three research objectives required to understand the study site sufficiently to set up a knowledge acquisition strategy and interpret the knowledge then acquired. These objectives were:

- to describe the general background of the site including its history, culture, administration, education, infrastructure and communications;
- to describe the ecology of the *miang* tea gardens and the natural forest;
- to describe the socio-economic and demographic profile of the village.

2.3 Methodology

The research study employed two main survey methods: RRA (McCracken, Pretty and Conway, 1988) and a formal questionnaire survey. Five broad techniques were used during the RRA in order to achieve a comprehensive understanding of the complex issues and relationships under study. These were collection of secondary data, direct observation, mapping the study area, physical measurement and semi-structured interviewing. There is a strong tradition of RRA in north eastern Thailand evidenced, for example, by the international conference in 1985 held at Khon Kaen University (Khon Kaen University, 1987). RRA techniques, particularly with an agro-ecosystems analysis perspective (Conway, 1987; Conway, 1990) have been developed and applied in the region and were familiar to the researcher. Not only was RRA employed to characterise the study area but the findings from it were also used to revise the questionnaire so that the survey questions became increasingly concise and formulated so that they elicited consistent responses from consultants. On the other hand, the formal questionnaire survey was used primarily to collect quantitative data on selected descriptive variables that characterised the socio-economic status of informants and might be expected to affect the knowledge they possess.

The RRA work was carried out in three consecutive weeks before the formal questionnaire survey. The information from the RRA was used to organise important topics and subtopics on socio-economic and demographic aspects of the village and refine questions for the formal questionnaire survey.

RRA is defined as a study used as the starting point for understanding a local situation, based on information collected in advance, direct observation and interviews where it is assumed that all relevant questions can not be identified in advance (Beebe, 1987). One of the characteristics of RRA is that it is carried out by a multidisciplinary team (Khon Kaen University, 1987; Okali, Sumberg and Farrington, 1994). In the present research, the team composed the author (a watershed management scientist), Mr J. F. Maxwell, a plant taxonomist, (from the

Department of Biology, Chiang Mai University) and Mr S. Keawpoosri, an economist (from the Co-operative Office, Doi Sa Kade District, Chiang Mai Province). Mr J.F. Maxwell identified the plant species in the area and considered the biodiversity of the flora in the *miang* tea gardens, the natural forest and homegardens. Mr S Keawpoosri had been involved in introducing cooperative activities to the village and had worked as an agricultural extension officer in the village for five years. He was thus able to provide general information on the background of the study site, the agricultural activity of *miang* tea farmers and the villagers' tree cutting practices.

2.3.1 Site selection

As explained in the introduction (see Section 2.1), a case study approach in one village community was adopted rather than an attempt to make a representative sample across the region. The use of a case study approach not only has a distinguished tradition in ethnoscience (Conklin, 1954; Werner and Schoepfle, 1987a) but has been used successfully in the study of the sustainability of tree use by farmers elsewhere (Carter, 1991). In the present context the primary objective was to find out whether the farmers in the case study village had an ecological rationality for their actions, requiring acquisition of detailed knowledge that could be related to a scientific understanding of the ecology of the system. This was only feasible, in the first instance, by working in detail with one community. While this rules out subsequent generalisation of the results, it is reasonable to expect that if the case study village was selected as typical of the *miang* tea villages in the region that a similar level of knowledge might be found in other villages. The results from the case study would also provide a basis for testing the representativeness of what was found across a wider area. On a global scale, the accumulation of farmers' knowledge from various agroecological and cultural settings provides a basis for subsequent comparative analysis. The present research can also, therefore, be seen to contribute to what is known about local ecological knowledge in a broader context. Complementary knowledge-based systems case studies have been carried out in the terraced farmering systems of the mid-hills of eastern Nepal (Thapa, 1994), the multilayered tree gardens in Kandy district, Sri Lanka (Southern, 1994; Jinadasa, 1995 and Hitinayake, 1996) and the dry rangelands of northern Tanzania (Kilahama, 1995).

In identifying a typical *miang* tea village in the present context, two factors were considered important. First, that the majority of people in the village derived a large proportion of their income from *miang* tea gardens, to ensure that people had experience and hence knowledge relating to the production system. Secondly, it was considered desirable that the village was far enough away from major roads that might distort both the socio-economic context within which the *miang* tea gardens were operated and the traditional knowledge on which they were based. The village chosen, Ban Mae Ton Luang, based on reconnaissance in the region, met these criteria and clearly exhibited *miang* tea gardens predominantly managed using traditional methods.

2.3.2 Collecting secondary data

Secondary data and information were collected from published and unpublished work by extension workers and researchers and from reports, texts books or theses, in order to get an initial understanding of the *miang* tea plantation systems and the climate, soil types and topography on the site. These data were found in the Department of Soil Science and Conservation, Faculty of Agriculture, Chiang Mai

University. Preliminary data, particularly on the history, culture and the livelihood of the northern Thai people, was acquired from the Department of Anthropology and Sociology, the Faculty of Social Science and the Social Research Institute, Chiang Mai University and Doi Sa Kate District Office, Chiang Mai Province.

2.3.3 Compiling the village profile

The village profile which includes the history, topography, communication, infrastructure, water resources, administration, education, religion, culture, land use and resettlement pattern was arrived at by interviewing a group of leaders in the village comprising, old people, teachers at Ban Mae Ton Laung school, officers of the local co-operative and district officials, of Doi Sa Kate District.

2.3.4 Mapping the study site

The *miang* tea gardens, home gardens, natural forest and residential areas within the study site were mapped. The maps were produced by ground truthing government maps by surveying and identifying the actual land uses occurring at the time of study. They were also useful as a communication tool because few farmers had seen their holdings in this way so that creating a sketch map generated considerable interest and provided a basis for discussion of ecological knowledge and land use in the field interview (Bruce, 1989; Simaraks, 1990).

2.3.5 Vegetation inventory

Two sets of transects at different scales and levels of detail were used to characterise the vegetation in the area. At a low level of resolution four linear transects of about 2 km were walked during which the floral species encountered along the transect were recorded. The transects were selected from the land use map and their rough positions are indicated in Figure 2.3. The first was from the hill evergreen forest on one side of the valley to a similar altitude on the other side of the valley. The other three low resolution transects were oriented horizontally through part of the hillside occupied by homegardens, *miang* tea gardens and natural forest, respectively. The vegetation encountered in the areas of principal interest; that is, the *miang* tea gardens and natural forest was reasonably homogeneous throughout the study area. To obtain a more detailed characterisation of each of these vegetation types, two belt transects of 100 m x 6 m were set up, one in each vegetation type, their approximate locations are shown on Figures 2.4 and 2.5. The stem diameter at breast height of 1.3 m (dbh), tree height, height of the base of the crown line, crown diameter and crown projection of every tree with a dbh larger than 10 cm were recorded.

Plant nomenclature follows that of Smitinand (1980). Tree volume of each tree was calculated by assuming that the stem was conical. The percentage of crown cover of the forest trees was calculated by drawing the crown cover on paper at a scale of 1:100 and estimating the covered area using a dot grid with 16 dots cm^{-2}. Number of trees, mean total height, mean height of the crown line, mean dbh, mean crown diameter, total number of tree species and mean number of trees species were calculated. Areas covered by each kind of ground flora in the tea garden transect were drawn to overlap on the paper and also were estimated by the dot grid. Tea tree and forest tree density on the areas covered by each ground flora were calculated.

2.3.6 Socio-economic and demographic information

A draft model of the formal questionnaire, concerning socio-economic and demographic aspects was designed. It consisted of household characteristics, social and population status. A copy is included in Appendix 2.1. It was tested by interviewing 10 % of the total households in the village (30 households) and was discussed with the members of the Multiple Cropping Centre, of the Faculty of Agriculture, Chiang Mai University. Subsequently a final version of the questionnaire was enumerated. The sample included a third of the households in the study area (100 households) selected randomly. The questionnaires were enumerated by interview with the researcher filling in a proforma questionnaire based on responses from informants to each question.

2.4 Results and discussion

2.4.1 Location

The study area lies in the highland region of Ban Mae Ton Luang, Tape Sa Daje Subdistrict, Doi Sa Kade District, Chiang Mai Province, and is in the Pee Pun Num mountain range (Figure 2.1). The study site is a small watershed. The main streams are the Mae Ton and Mae Wang. The study site lies approximately 45 km, by paved provincial highway number 1 019, from Chiang Mai on the way to Chiang Rai City and lies approximately 20 km, by unpaved highway, from Ban Yong Kog Noi to Chae Hom District, Lampang Province.

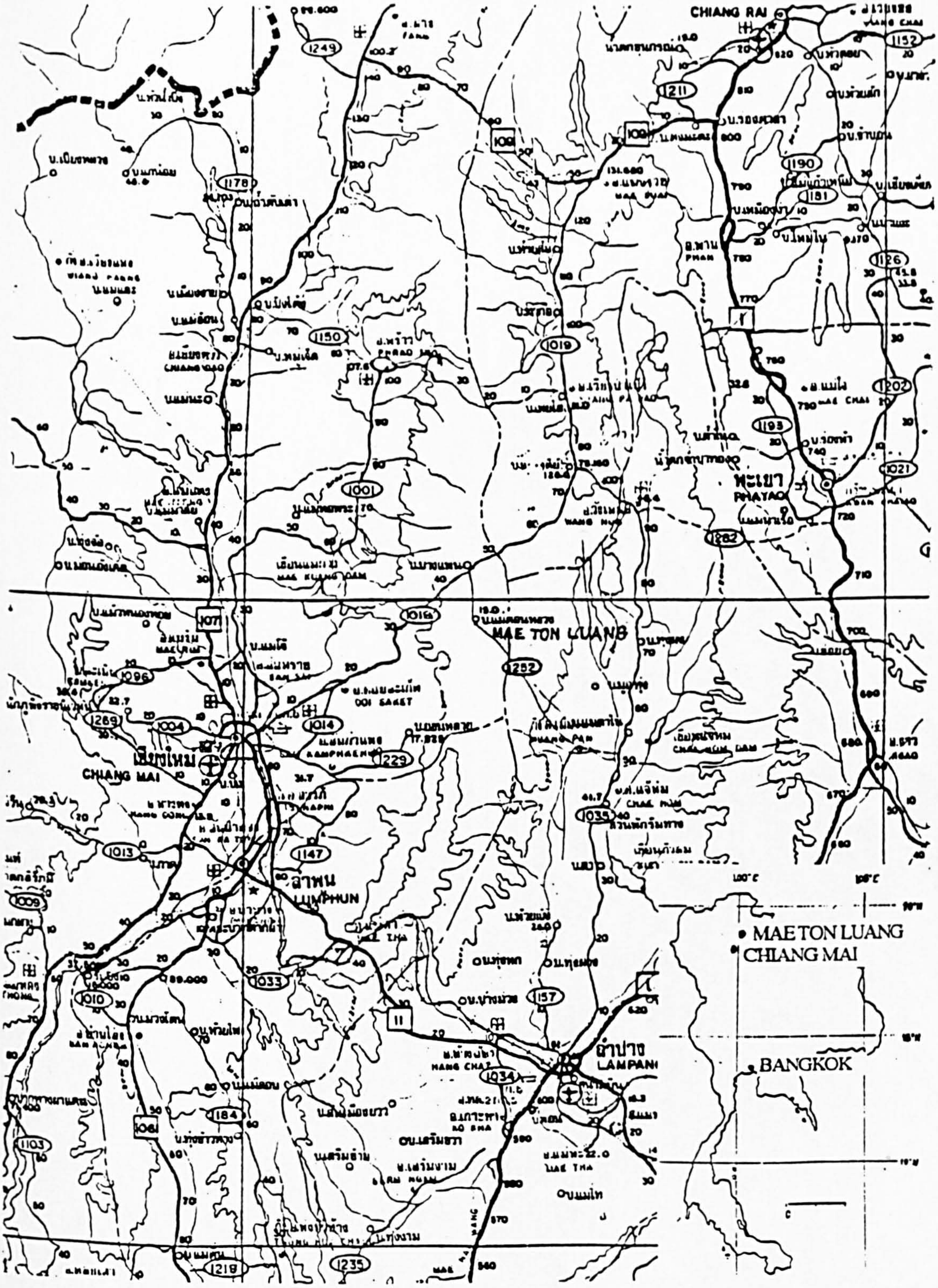


Figure 2.1 The study site area at Ban Mae Ton Luang, Tape Sa Daje Subdistrict, Doi Sa Kade District, Chiang Mai Province, Thailand. Scale 1: 1 000 000.

The boundary of the study area was located according to the watershed, which covers a total area of 17.17 km^2, between latitude 18° 56'-18° 59' north and longitude 99° 20'-99° 23' east, and lies at an altitude of from 900 to 1 800 m.

The name of the village Ban Mae Ton Luang signifies the importance of harvesting tea from gardens in the hill evergreen forest. Literally, *ban* means village; *mae* means mother and is a common part of village nomenclature in northern Thailand; *ton* means to cut, and in this instance refers to harvesting tea and is modified by the final part of the name *luang* which means big, signifying that a lot of tea harvesting occurs.

2.4.2 Soil

The soil in the small watershed belongs to the family Tropohumults of the Great Group ULTISOLS which go to a depth deeper than 150 cm. All soil horizons are sandy clay loam with a pH value ranging from 5.3 to 5.7. Bulk density of the topsoil (0-45 cm) was less than 1.0 g cm^{-3}. The maximum water holding capacity, field capacity and the permanent wilting point averaged 67 %, 30 % and 18 % respectively. All the soil horizons have a high total porosity with a constant rate of infiltration capacity of 280 cm h^{-1} (Department of Soil and Science and Conservation, 1988).

2.4.3 Climate

There is no climatic data in Ban Mae Ton Luang. This research employed the data (Table 2.1) from the Highland Agriculture Research Station, Doi Chang Khian, Mae Rim District, Chaing Mai Province, which is at the same altitude as the study site (about 1 400 m). The Research Station is owned by the Faculty of Agriculture, Chiang Mai University.

The average annual rainfall was 2 036 mm, with the maximum (436 mm) falling in August and the minimum between January and March. The rainy season usually starts in April and lasts until November and the summer season occurs in December to March. Mean annual atmospheric temperature was 19 °C, reaching a maximum of 28.2 °C in April and a minimum of 10.2 °C in December. Daily differences between maximum and minimum atmospheric temperature range from 6.0 °C to 11.8 °C.

Table 2.1 Mean 1986-1992 monthly rainfall, atmospheric temperature, relative humidity, wind velocity and pan evaporation at the Highland Agriculture Research Station, Doi Chiang Khian, Mae Rim District, Chiang Mai Province, Thailand.

Month	Air Temperature			Humidity	Rain	Wind speed	Sunshine hours	Pan evaporation
	Maximun (°C)	Minimum (°C)	Mean (°C)	(%)	(mm)	(km day^{-1})	(h)	(mm)
Jan.	22.0	10.9	15.6	68.9	4.4	89.5	11.0	74.4
Feb	24.0	12.2	17.3	61.5	5.7	94.8	11.4	78.4
Mar	26.6	15.0	20.0	61.5	11.4	104.6	11.9	111.6
Apr	28.2	17.1	21.9	67.9	86.9	103.1	12.4	123.0
May	26.5	18.2	21.8	76.9	195.5	90.8	12.9	114.7
Jun	24.6	18.3	21.0	85.2	269.8	100.8	13.1	96.0
Jul	24.1	18.1	20.6	85.8	295.6	100.6	13.0	93.0
Aug	24.1	17.7	20.5	85.6	436.4	83.8	12.7	86.8
Sep	24.2	17.4	20.3	85.1	325.9	60.8	12.1	84.0
Oct	23.2	16.5	19.4	84.3	249.9	58.3	11.6	77.5
Nov	21.9	13.7	17.3	78.1	115.8	56.8	11.1	63.0
Dec	20.3	10.2	14.5	72.3	38.2	54.0	10.9	55.8
Total					2 035.5			1 032.4
Mean			19.2	76.1		83.2	12.0	

Source: Department of Soil and Conservation, Faculty of Agriculture, Chiang Mai University, Thailand (1992).

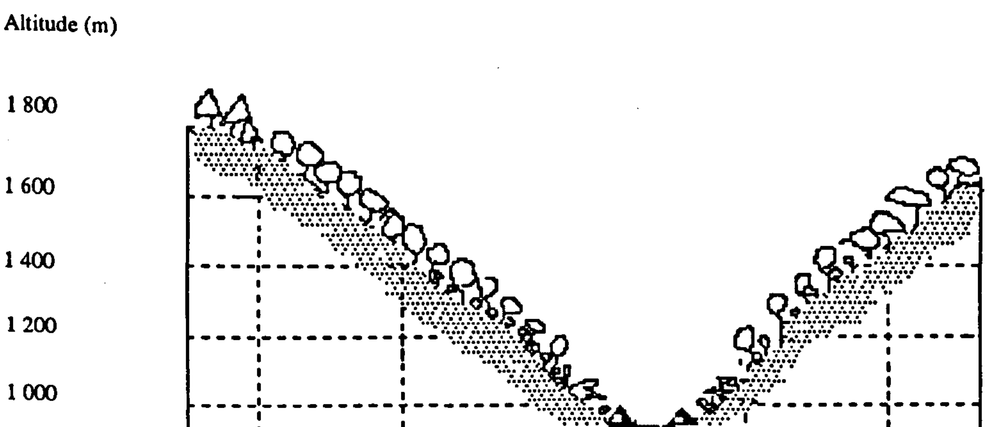
It can be said that the climate is characterised by three seasons, namely the summer, March to April, the rainy season, May to November and the winter, December to

February. The rainy season is influenced by the west and east winds and the winter by the north wind.

The average humidity of 76.1 % had a maximum in September of 98.1 % and a minimum in February of 43 %. The mean annual wind velocity was 83.2 km day^{-1} with a maximum in March of 104.6 km day^{-1} and minimum in November of 54 km day^{-1}. The mean annual day length was 12 h with a maximum in June of 13.1 h and a minimum in December of 10.9 h. The average annual pan evaporation was 1 032 mm, roughly half the annual rainfall, with a maximum of 123 mm occurring in April and a minimum of 56 mm in December. Mean daily evaporation was approximately 2.9 mm.

2.4.4 Land use pattern

The study found four major kinds of land use in the study area: natural forest, *miang* tea gardens, homegardens and settlement areas. The natural forest was restricted to the upper slopes of the mountains. The *miang* tea gardens were next, located along a mid-altitude belt between the natural forest on the upper slopes and the homegardens and settlement areas on the lower slopes. Homegardens are small, intensively cultivated areas close to the house. The farmers allow forest trees to grow in their homegardens and plant fruit trees, herbs and vegetables for home consumption. The settlement areas are located on a narrow plain in the valley near to streams. It is very difficult to clearly distinguish a boundary between the natural forest and *miang* tea gardens because farmers plant their tea trees within the natural forest. There is a shortfall of labour to manage *miang* tea gardens because of rural-urban migration, so that some *miang* tea gardens are reverting to natural forest vegetation. Figure 2.2 shows the basic vertical profile of the land use pattern, with the natural forest comprising coniferous forest at the highest elevations giving way to hill evergreen forest which is undisturbed above an attitude of 1 800 m but thinned below this to accommodate *miang* tea gardens. The schematic profile view also indicates a rough percentage slope of the *miang* tea gardens varying from 20-60 %. The birdseye view of the land use pattern (Figure 2.3) gives some indication of the relative importance of land areas under different land uses and the layout of the study area and transects. The natural coniferous forest occurred on 4 % of the study area; the natural hill evergreen forest on 42 %; the *miang* tea gardens on 38%, home gardens on 4 % and settlements on the remaining 12 %.



Land use	Cf	Hf	Tg	Hg	Sm	St	Sm	Hg	Tg	Hf
Slope (%)	20-40	20-50	20-60	30	20	0	20	30	30-40	20-30

Figure 2.2 Schematic profile view of the general land use pattern at the study site. Note: Cf=Natural coniferous forest, Hf=Natural hill evergreen forest, Tg=*miang* tea gardens, Hg=Homegardens, Sm=Settlement, St=Stream.

Legally, the watershed area belongs to the government. However, the farmers have been allowed to live in this area. Some farmers obtain documents showing temporary ownership of the land from the Ministry of the Interior (see Section 2.4.6.8). According to the law, this area is a National Forest Reserve, but not a National Park, Wildlife Sanctuary or Non-hunting Area. However, there are proposals from the Royal Forest Department to designate the natural forest within Ban Mae Ton Luang as a National Park which would exclude cultivation and effectively prevent any expansion of the area under tea gardens. At present as the area is a forest reserve, cultivation is permitted under the control (via a permit system) of the Royal Forest Department.

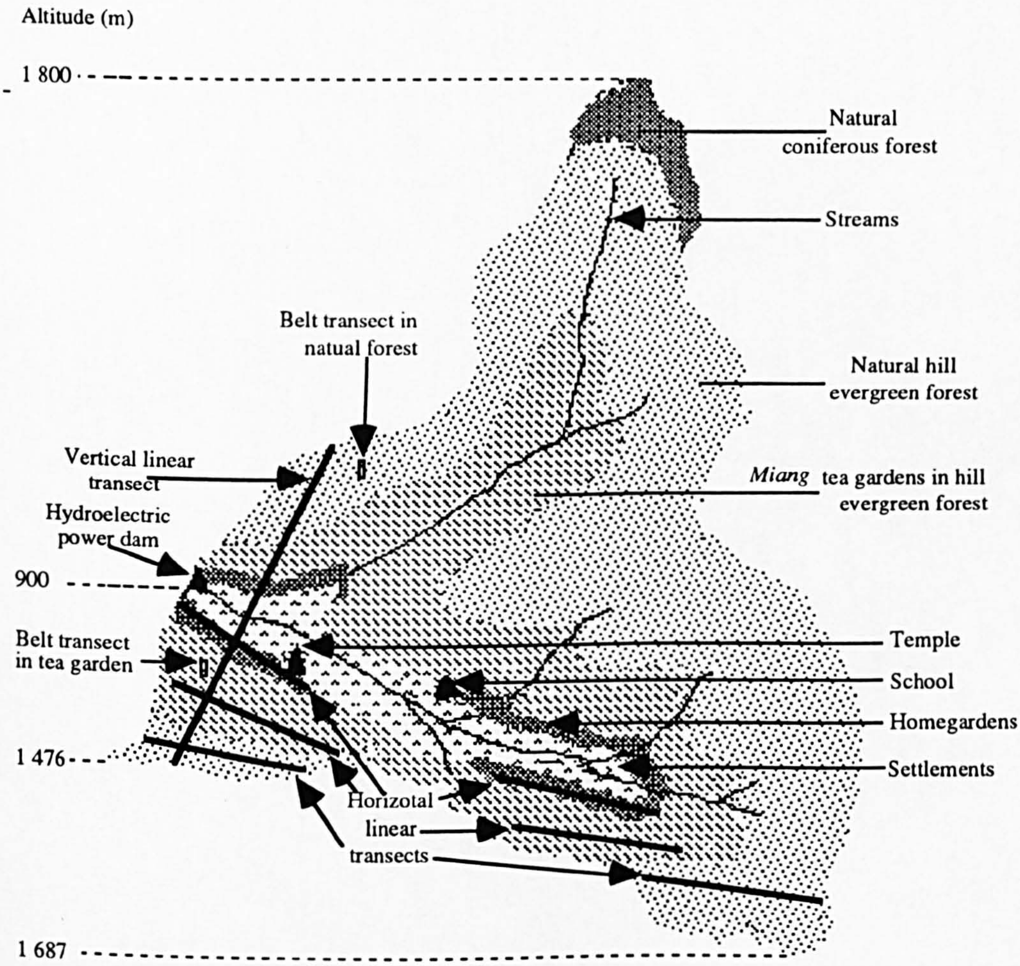


Figure 2.3 Schematic birdseye view of the general land use pattern at the study site. Note: scale approximate 1: 50 000.

2.4.5 Vegetation

The results of the four low level resolution linear transacts are summarised in Table 2.2 and show that there were 149 plant species from 71 families in study site.

Table 2.2 Plant species found in low resolution linear transects in the study site. Abbreviations: Nf=Natural hill evergreen forest, Tg=*miang* tea gardens, Gf=Ground flora, Sd=Seedlings and Hg=Homegardens.

Scientific name	Families	Habits	Uses	Nf	Tg	Gf	Sd	Hg
Dracaena fragrans	Acanthaceae	tree	insecticide/ ornamental/ religious ceremonies					+
Cordyline fruticosa	Agavaceae	shrub	ornamental/ religious ceremonies					+
Alangium kurzii	Alangiaceae	tree	firewood/ shade	+	+			
Choerospondias axillaris	Anacardiaceae	tree	firewood/ shade	+	+			
Gluta obovata	Anacardiaceae	tree	firewood/ shade	+	+			
Mangifera indica	Anacardiaceae	tree	fruit/ timber/ firewood					+
Mangifera longipetiolate	Anacardiaceae	tree	fruit for cattle/ timber/ firewood/ shade	+	+	+	+	
Semecarpus cochinchinensis	Anacardiaceae	tree	firewood/ shade/ timber	+	+			
Toxicodendron rhetzoides	Anacardiaceae	trree	firewood/ shade/ timber	+	+	+		
Ilex umbellulata	Aquifoliaceae	tree	firewood/ shade	+	+	+		
Alocasia cucullata	Araceae	herb						+
Colocasia esculenta	Araceae	herb	tuber					+
Acanthopanax trifoliatus .	Araliaceae	shrub						+
Schefflera clarkeana	Araliaceae	epiphyte		+	+			
Trevesia palmata	Araliaceae	tree	vegatation					+
Hoya lacunosa	Asclepiadaceae	climber			+			
Averrhoa carambola	Avaerrhoaceae	tree	fruit					+
Betula alnoides	Betulaceae	tree	firewood/ medicine/ poles	+				
Markhamia stipulata	Bignoniaceae	tree	shade/ nitrogen fixing	+	+	+		
Ananas bracteatus	Bromeliaceae	herb	fruit					+
Ananas comosus	Bromeliaceae	herb	fruit					+
Protium serratum	Burseraceae	tree	firewood/ shade/ timber	+	+			
Acrocarpus fraxininifolius	Caesalpiniaceae	tree	firewood/ timber/ shade	+	+	+	+	+
Tamarindus indica	Caesalpiniaceae	tree	shade/ timber/ nitrogenogen fixation/ fruit					+
Cannabis sativa	Cannabidaceae	herb	medicine/ drug					+
Crateva magna	Capparidaceae	tree	vegetable					+
Euonymus similis	Celastraceae	tree	firewood/ shade	+				
Combretum procursum	Combretaceae	climber			+			
Commelina diffusa	Commelinaceae	herb		+	+	+		
Eupatorium adenophorum	Compositae	herb	medicine/ soil conservation/ bee forage	+	+	+		+
Eupatorium odoratum	Compositae	herb	medicine/ soil conservation/ bee forage	+	+	+		
Momordica charantia	Cucurbitaceae	climber	fruit/ vegetable					+
Cyathea lateborosa	Cyatheaceae	fern		+	+	+		
Cycas micholitzii	Cycadaceae	tree			+	+		
Scleria terrestris	Cyperaceae	herb		+	+	+		
Davallia lobbiana	Davalliaceae	epiphyte		+	+			
Microlepia platyphylla	Dennstaedtiaceae	fern		+	+	+		
Pteridium aquilinium	Dennstaedtiaceae	fern	soil conservation	+	+	+		
Dillenia parviflora	Dilleniaceae	tree	firewood/ shade	+			+	
Diospyros glandulosa	Dioscoreaceae	tree	dye/ shade		+	+	+	+
Diospyros kaki	Dioscoreaceae	tree	fruit					+
Elaeocarpus floribundus	Elaeocarpaceae	tree	firewood/ shade/ fruit for cattle/ timber	+	+			
Elaeocarpus nitidus	Elaeocarpaceae	tree	firewood/ shade/ timber	+	+			
Elaeocarpus stipularis	Elaeocarpaceae	tree	nut/ firewood/ shade/ fruit for cattle/ timber	+	+			
Manihot esculenta	Eugnoliaceae	shrub	tuber					+
Acalypha kerrii	Euphorbiaceae	shrub			+			
Breynia retusa	Euphorbiaceae	shrub	dye	+	+	+		
Codiaeum variegatum	Euphorbiaceae	shrub	ornamental/ religious ceremonies					+
Glochidion sphaerogynum	Euphorbiaceae	tree	firewood/ shade		+		+	+
Jatropha curcas	Euphorbiaceae	shrub	fence/ oil/ soil conservation					+
Ostodes paniculata	Euphorbiaceae	tree	firewood/ shade					+
Phyllanthus sootepensis	Euphorbiaceae	shurb		+	+	+		
Sapium baccatum	Euphorbiaceae	tree	firewood/ shade/ timber	+	+			
Trewia nudiflora	Euphorbiaceae	tree	firewood/ shade/ timber	+	+			
Castanopsis acuminatissima	Fagaceae	tree	nut/ firewood/ pole/ timber/ shade	+	+			+
Castanopsis argyrophyll	Fagaceae	tree	firwood/ shade	+				
Castanopsis armata	Fagaceae	tree	nut/ firewood/ shade	+	+			+
Castanopsis brevispinula	Fagaceae	tree	firewood/ shade	+				
Castanopsis calathiformis	Fagaceae	tree	firwood/ shade	+	+			
Castanopsis cerebrina	Fagaceae	tree	firewood/ shade	+	+			
Castanopsis crassifolia	Fagaceae	tree	firewood/ shade	+				
Castanopsis diversiflolia	Fagaceae	tree	nut/ firewood/ timber/ shade	+	+			+

Castanopsis fissa	Fagaceae	tree	firewood/ shade	+				
Castanopsis indica	Fagaceae	tree	nut/ firewood/ shade	+				
Castanopsis lancaefolia	Fagaceae	tree	firewood/ shade	+				
Castanopsis pierrei	Fagaceae	tree	firewood/ shade	+				
Castanopsis puspurea	Fagaceae	tree	firewood/ shade	+				
Castanopsis tribuloides	Fagaceae	tree	firewood/ shade	+				
Lithocarpus elegans	Fagaceae	tree	firewood/ shade/ timber	+	+			
Lithocarpus trachcarpus	Fagaceae	tree	firewood/ shade/ timbe	+	+			
Quercus kingiana	Fagaceae	tree	firewood/ shade/ timber	+	+			
Aeschynanthus longicaulis	Gesneriaceae	epiphyte			+			
Dicranopteris linearis	Gleicheniaceae	fern	soil conservation/ soil fertiliser	+	+	+		+
Bambusa arundinacea	Gramineae	bamboo	shoot/ fenec/ poles/ strips/ building material	+				
Bambusa natans	Gramineae	bamboo	shoot/ fenec/ poles/ strips/ building material	+				+
Bambusa vulgaris	Gramineae	bamboo	shoot/ fence/ poles	+				+
Gigantochloa albociliata	Gramineae	bamboo	shoot/ fenec/ poles/ strips/ building material	+				+
Saccharum officinarum	Gramineae	grass	sugar					+
Gigantochloa apus	Gramineae	bamboo	fence/ poles/ building material			+		+
Imperata cylindrica	Gramineae	grass	foliage for roofing/ medicine /grazing		+	+		
Thysanolaena maxima	Gramineae	grass	fodder/ grazing/ flower for making broom		+	+		
Apodytes dimidiata	Icacinaceae	shurb			+			
Salvia splendens	Labiatae	herb	ornamental					+
Actinodaphine henryi	Lauraceae	tree	firewood/ shade					+
Litsea monopetala	Lauraceae	tree	firewood/ shade/ timbe	+	+			
Leea indica	Leeaceae	shurb		+	+	+		
Ophiopogon malayanum	Liliaceae	herb		+	+	+		
Tupistra albiflora	Liliaceae	herb	vegetation					+
Turpinia montana	Liliaceae	tree	firwood/ shade		+			
Helixanthera parasitica	Loranthaceae	parasite			+			
Macrosolen cochinchinnsis	Loranthaceae	parasite			+			
Scurrula gracilifolia	Loranthaceae	parasite			+			
Magnolia craibiana	Magnoliaceae	tree	firewood/ shade/ timber	+				
Hibiscus rosa-sinensis	Malvaceae	shrub	ornamental/ religious ceremonies					+
Melastoma normale	Melastomataceae	shrub		+	+	+	+	
Dysoxylum andamanicum	Meliaceae	tree	firewood/ shade/ timber	+	+			
Melia toosendan	Meliaceae	tree	firewood/ shade/ timber/ fruit for cattles	+	+	+	+	
Acacia megaladena	Mimosaceae	climber		+	+	+		
Albizia odoratissima	Mimosaceae	tree	firewood/ shade/ nitrogen fixing	+	+	+	+	
Artocarpus heterophyllus	Moraceae	tree	timber/ fruit/building material					+
Ficus altissima	Moraceae	tree	vegetable/ firewood/ shade					+
Ficus fistulosa	Moraceae	tree	vegetable/ firewood/ shade		+	+	+	
Ficus hirta	Moraceae	tree	vegetable/ firewood/ shade		+	+	+	+
Ficus pubigera	Moraceae	climber		+	+	+		
Musa acuminata	Musaceae	herb	fruit/ vegetable					+
Psidium guajava	Myetaceae	tree	fruit/ firewood					+
Ardisia vestita	Myrsinaceae	shrub	medicine		+			
Maesa montana	Myrsinaceae	shrub			+	+	+	
Eugenia albiflora	Myrtaceae	tree	firewood/ shade/ timber	+	+			+
Eugenia malaccensis	Myrtaceae	tree	fruit/ shade/					+
Jasminum sambac	Oleaceae	climber	ornamental/ religious ceremonies					+
Ludwigia parviflora	Onagraceae	herb			+			
Dendrobium sp.	Orchidaceae	orchid		+	+			+
Malaxis calophylla	Orchidaceae	orchid		+	+	+		
Vanda denisoniana	Orchidaceae	orchid			+			
Cocos nucifera	Palmae	palm	fiber/ nut/ shade/ beverage/ timber/ pulp					+
Pueraria candollei	Papilionaceae	climber		+	+			
Dalbergia abbreviata	Papilionaceae	climber	insecticide/ nitrogen fixing	+	+	+		
Adiantum capillus-veneris	Parkeriaceae	fern		+	+	+		+
Piper nigrum	Piperaceae	climber	spice					+
Zizyiphus oenoplia .	Rhamnaceae	climber			+	+		
Zizyphus attopoensis	Rhamnaceae	tree	firewood/ shade/ medicine/ ornamental	+	+	+	+	
Prunus persica	Rosaceae	tree	fruit/ firewood					+
Coffea arabica	Rubiaceae	shrub	beverage		+	+		+
Hedyotis captitellata	Rubiaceae	climber		+	+	+		
Mussaenda sanderiana .	Rubiaceae	climber		+	+	+		
Psychotria monticola	Rubiaceae	shrub	vegetation	+	+			
Wendlandia paniculata	Rubiaceae	tree	firewood/ shade	+	+	+	+	
Citrus limon	Rutaceae	tree	fruit					+
Citrus maxima	Rutaceae	tree	fruit					+
Euodia glomerata	Rutaceae	tree	firewood/ shade/ timber	+	+	+		
Sambucus javanica	Sambucaceae	shrub		+	+	+		
Litchi chinensis	Sapindaceae	tree	fruit					+
Mischocarpus pentapetalus	Sapindaceae	tree	firewood/ shade	+	+	+	+	
Selaginella roxburghii	Selaginellaceae	fern		+	+	+		
Capsicum frutescens	Solanaceae	shurb	spice					+
Solanum spirale	Solanaceae	shrub	medicine					+
Solanum torvum	Solanaceae	shrub	vegetation					+
Antidesma bunius	Stilaginaceae	tree	firewood		+	+	+	
Adinandra integerrima	Theaceae	tree	firewood/ shade		+			
Camellia oleifera	Theaceae	shurb	beverage/ oil/ medicine	+	+			
Camellia sinensis	Theaceae	tree	beverage/ oil/ medicine	+	+	+	+	+
Eurya acuminata	Theaceae	tree	firewood/ shade	+	+	+		
Schima wallichii	Theaceae	tree	firewood/ shade/ timber	+	+	+	+	
Callicarpa arborea	Verbenaceae	tree	firewood	+	+	+		
Callicarpa rubella	Verbenaceae	shrub			+			
Cissus discolor	Vitadaceae	climber		+	+	+		
Catimbium malaccense	Zingiberaceae	herb		+	+	+		
Hedychium coronarium	Zingiberaceae	herb	tuber/ spice					+

Only thirteen plant species were found in the hill evergreen forest, most of them belonging to the Fagaceae family. The seeds of forest trees in this family cannot readily germinate in other areas because they need high moisture levels and shade (Ngampongsai, 1969). In the low resolution survey, however, half of the forest trees were found in both hill evergreen forest and *miang* tea gardens, often in the form of coppice. One third of all plants found occurred in both hill evergreen forest and *miang* tea gardens. Almost a quarter of them were forest trees, many from the families Anacardiaceae and Theaceae, because seeds of these trees do not need high moisture levels for germination and their seedlings can tolerate both high and low degrees of shade. Few forest trees species were found only in low shade areas in *miang* tea gardens or homegardens; these were mainly from the families Euphorbiaceae and Moraceae, because their seedlings are light demanding (Ngampongsai, 1969). Bamboos were found in the hill evergreen forest and the homegardens, but not in the *miang* tea gardens. Farmers do not allow bamboos to grow in the *miang* tea gardens because of allelopathic effect of their root systems which suppress the growth of other plants (McClure, 1966), especially, tea. However, in the homegardens most bamboo species were recorded, being planted to prevent bank erosion and for home consumption. Most grass species, such as *Imperata cylindrica* and *Thysanolaena maxima* were found only in some parts of the *miang* tea gardens, especially in the dry areas because of their intolerance of high moisture and high shade. Farmers do not weed them out because these grasses produce fodder for cattle and are useful as building material for houses, making domestic tools such as brooms and baskets, and in the preparation of traditional herbal medicine. Almost a third of the plants from the low resolution survey were found only in the homegardens because the farmers grew them for home consumption. Half were for food, such as fruits or vegetables, the rest were for ornamental purposes, traditional medicine, religious ceremonies or as a source of insecticide. The details of each area are discussed below.

2.4.5.1 Natural forest

The most prevalent natural forest in this area is hill evergreen forest. The low resolution transects found that there were 83 species from 40 families including trees, shrubs, bamboos, epiphytes, climbers, parasitic plants, ferns, herbs, grasses and orchids. The high resolution transect enumerated nine tree species from eight families (Figure 2.4). The dominant species were *Lithocarpus elegans* and *Euonymus similis* (Table 2.3). Tree volume was estimated from the belt transect as 231 m^3 ha^{-1}. At the top of some areas was coniferous forest, the dominant species being *Pinus kesiya* and *P. merkusii*, family Pinaceae.

Table 2.3 List of trees and lianas of girth at breast height of 10 cm or more occurring on a transect 100 m long and 6 m wide of natural forest enumerated in 1993.

Species	Abbreviation used in Figure 2.4	Family	Number	Mean height (m)	Mean dbh (cm)
Lithocarpus elegans	Le	Fagaceae	9	14.21	41.02
Euonymus similis	Es	Celastraceae	9	13.08	19.55
Protium serratum	Ps	Burseraceae	4	6.20	29.74
Dillenia parviflora	Dp	Dilleniaceae	2	7.95	16.06
Ficus fistulosa	Ff	Moraceae	2	4.15	25.59
Mallotus philippensis	Ma	Euphorbiaceae	1	12.00	11.32
Castanopsis armata	Ca	Fagaceae	1	14.60	36.78
Aporusa villosa	Av	Euphorbiaceae	1	9.00	15.55
Styrax benzoides	Sb	Styracaceae	1	8.20	13.55
			30		

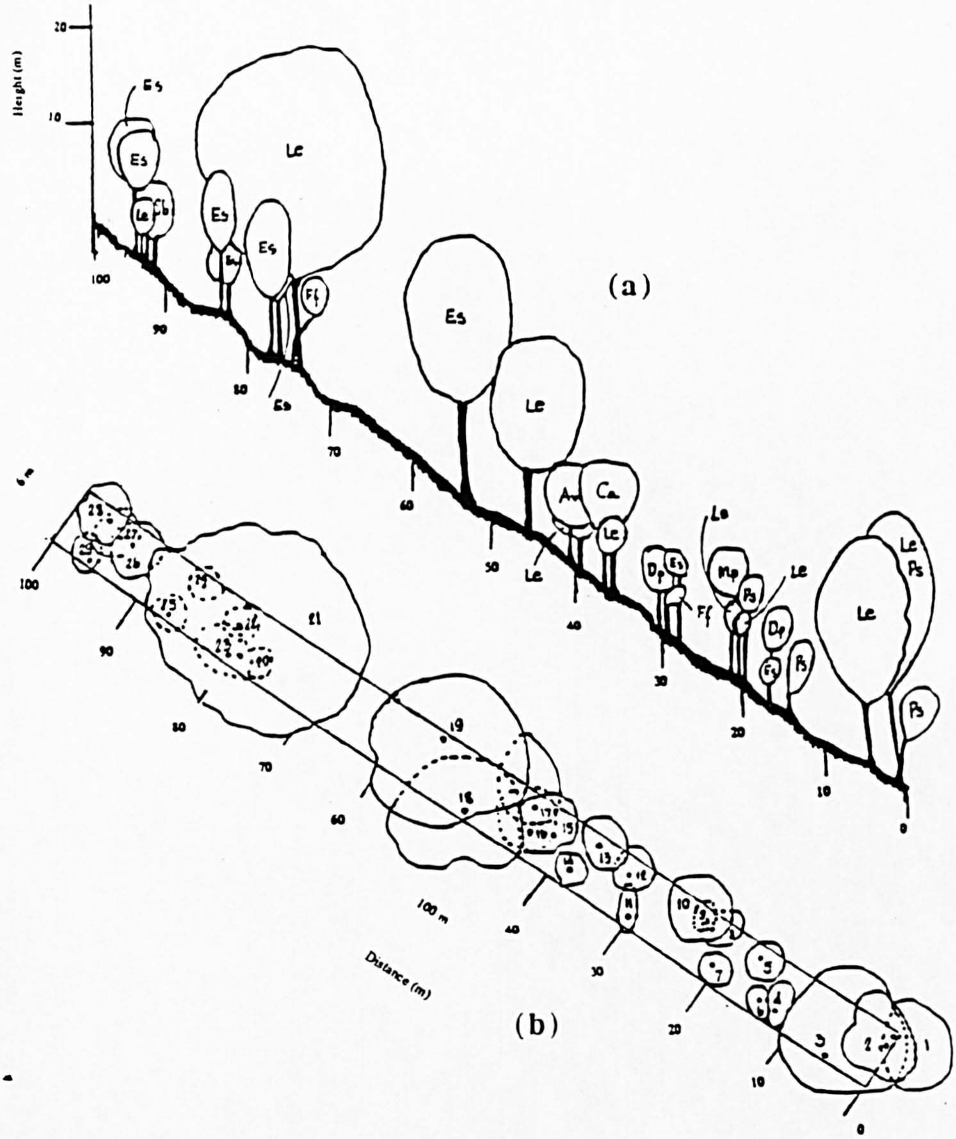


Figure 2.4 Stand profile (a) and crown cover (b) of natural forest from the belt transect (Section 2.4.5.1). Note: Letters in tree crowns in (a) refer to species name abbreviations as listed in Table 2.3. Numbers in (b) refer to individual plants sampled as listed in Appendix 2.2

2.4.5.2 *Miang* tea gardens

The *miang* tea gardens (Plate 2.1) represent the major vegetation type in the area situated in the valley and on slopes typically to halfway up the hill side and, in some places, to the top of the slope. The low resolution transect found that there were 91 species from 48 families including trees, shrubs, epiphytes, climbers, parasitic plants, ferns, herbs, grasses and orchids. The high resolution transect enumerated 14 tree species from 11 families (Figure 2.5).

Theaceae was the dominant family (Table 2.4). The dominant species were *Camellia sinensis* var. *assamica*, *Schima wallichii*, *Adinandra integerrima*, and *Eurya acuminata*. Tree volume was estimated as 71 $m^3 ha^{-1}$.

Plant 2.1 *Miang* tea garden vegetation in hill evergreen forest at the study site.

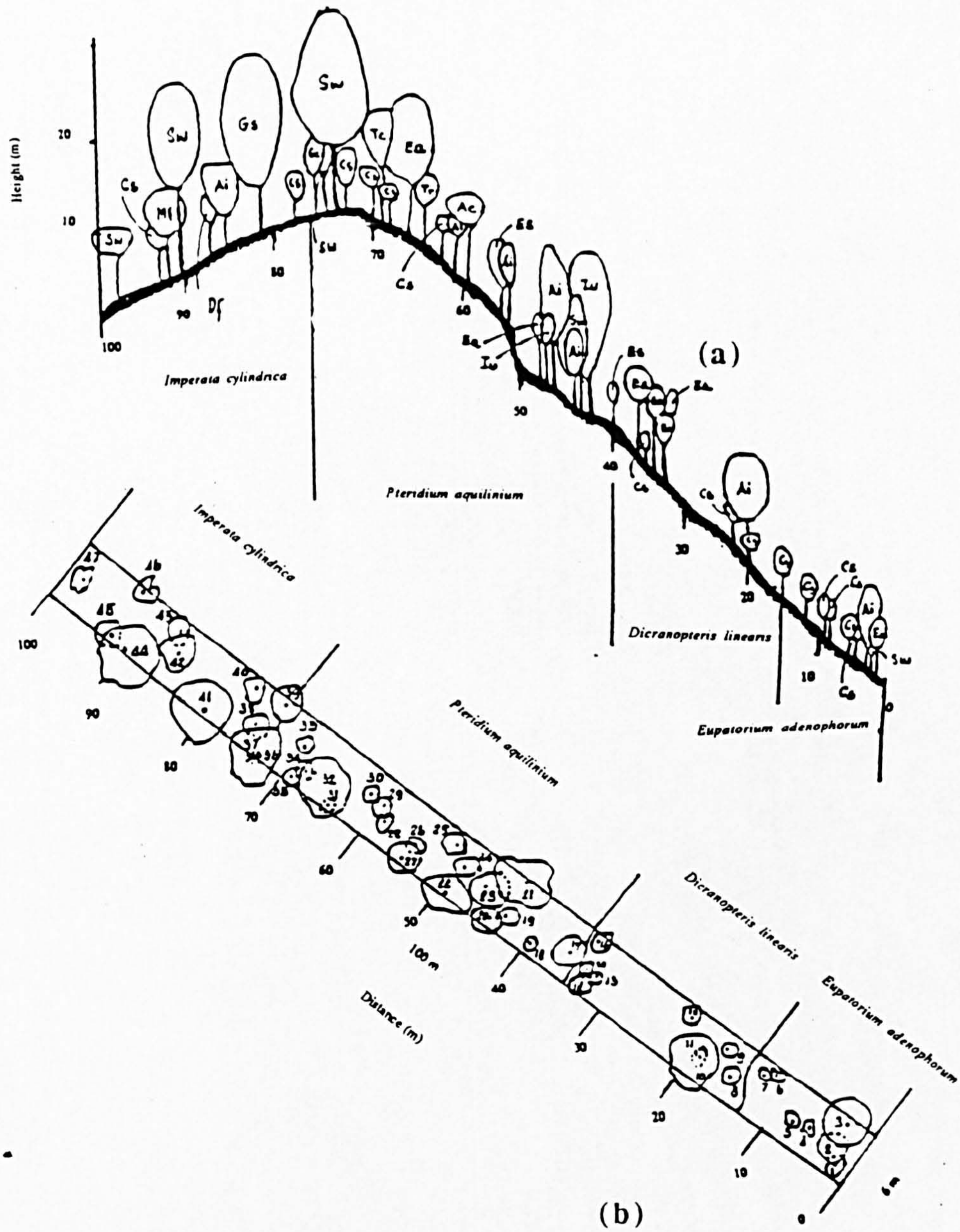


Figure 2.5 Stand profile (a) and crown cover (b) of *miang* tea gardens in the hill evergreen forest from the belt transects (Section 2.4.5.2).Note: the letters in tree crowns in (a) refer to species name abbreviations as listed in Table 2.4. Dominant ground flora are indicated in (a) where: Ic=*Imperata cylindrica*, Pa=*Pteridium aquilinium*, Dl=*Dicranopteris linearis*, Ea=*Eupatorium adenophorum*. Numbers in (b) refer to individual plants sampled as listed in Appendix 2.3.

Table 2.4 List of trees and lianas of girth at breast height of 10 cm or more occurring on a transect 100 m long and 6 m wide in the *miang* tea gardens in hill evergreen forest enumerated in 1993.

Species	Abbreviation used in Figure 2.5	Family	Number	Mean height (m)	Mean dbh (cm)
Camellia sinensis	Cs	Theaceae	15	3.54	12.26
Schima wallichii	Sw	Theaceae	7	11.75	24.15
Adinandra integerrima	Ai	Theaceae	7	8.74	16.58
Eurya acuminata	Ea	Theaceae	5	6.65	7.41
Eugenia albiflora	El	Myrtaceae	2	10.60	15.05
Amoora cucullata	Ac	Meliaceae	2	9.05	12.39
Eugenia subviridis	Es	Myrtaceae	2	3.00	6.10
Glochidion sphaerogynum	Gs	Euphorbiaceae	1	16.50	38.21
Ilex umbellulata	Iu	Aquifoliaceae	1	15.00	19.56
Macaspermum fruitcosum	Mc	Euphorbiaceae	1	7.60	8.14
Stereospermum colais	Sc	Bignoniaceae	1	7.40	13.84
Toxicodendron rhetzoides	Tc	Anacardiaceae	1	5.50	4.93
Archidendron clypearia	Ac	Mimosoideae	1	5.10	7.41
Decaspermum fruticosum	Df	Myrtaceae	1	4.20	9.03
Total			47		

The farmers allowed forest trees to grow tall because they have to use forest trees for firewood. An extensive amount of firewood is used for steaming tea leaves. At the same time, forest trees provide important shade for the tea trees. Soil moisture and atmospheric humidity in the gardens are maintained at higher levels than they otherwise would be by the shade of the forest trees which reduces the amount of solar radiation reaching the understorey. If tea leaves receive high solar radiation, it causes them to age quickly. Tea production is believed to be higher with the higher moisture and lower solar radiation levels pertaining in shade than it would be in the open. Most of the farmers let *S. wallichii, A. integerrima* and the other native forest trees in Table 2.2 grow because they produce firewood with a high calorific value. One consequence of the demand for firewood to process the *miang* tea is that farmers retain forest trees in *miang* tea gardens.

2.4.5.2.1 Comparison of tree cover in *miang* tea gardens and natural hill evergreen forest

The characteristics of trees in the belt transects from *miang* tea gardens and natural hill evergreen forest are summarised in Table 2.5. There were a smaller number of larger trees in the natural hill evergreen forest than in the *miang* tea gardens. Tree density was thus higher in the *miang* tea gardens than in the natural forest, but the mean number of tree species and crown cover of trees was higher in the natural forest than in the tea gardens. There would be intense competition between the large number of small trees growing in *miang* tea gardens while competition could be expected to be low in the natural forest, where there were only a small number of large trees. Large trees may suppress the germination and growth of other trees, so that the annual increment of the natural forests would be small. This suggests that the ecology of *miang* tea gardens are maintained in the competition stage by human activity, while the ecology of natural forest has reached the climax stage (Tangtham and Suntadgarn, 1973; Dhammanonda, Chunkao and Boonyawat, 1974; Elliott, Maxwell and Prakobvitayakit, 1989).

Table 2.5 Characteristics of the *miang* tea gardens and natural hill evergreen forest.

Forest	Tea gardens	Natural hill evergreen forest
Number of trees	47	30
Mean diameter of tree crowns (cm)	45.10	86.29
Mean total height (m)	7.27	12.36
Mean height at lower branch (m)	2.50	5.41
Mean dbh (cm)	14.83	27.49
Total number of tree species	15	8
Mean number of trees species	3.13	3.75
Forest tree density (trees ha^{-1})	784	500
Tea tree density (trees ha^{-1})	1983	-
Crown cover (%)	28.39	44.67

2.4.5.2.2 Ground flora

From the results of the low resolution transect in *miang* tea gardens, it was found that there were 50 ground flora species from 34 families including grasses, ferns, herbs, ochids, climbers, tree seedlings and shrub seedlings (see Table 2.2).

The ground flora in tea gardens could be recognised as areas where *Imperata cylindrica*, *Pteridium aquilinium*, *Dicranopteris linearis* or *Eupatorium adenophorum* predominated (see Figure 2.5). *P. aquilinium*, *D. linearis* and *E. adenophorum* generally grow in moist shaded conditions whereas *I. cylindrica* is found in more open conditions. *I. cylindrica* is known to grow in conditions of dry soil, low fertility and high light and to have high root densities that may suppress the germination of seeds of other plants (Tangtham and Suntadgran, 1973; Dhammanonda, Chunkao and Boonyawat, 1974). The tips of the roots have also been reported to contain a toxin which stops the growth of other plants (Dhammanonda, 1972; Dhammanonda, 1973). Less competitive ground flora may conversely conserve soil moisture because their roots increase soil porosity and their leaves cover the soil surface, reducing evaporation, water and nutrients are not so heavily exploited. They may, therefore, allow high germination of the tea and other plants.

Tea and forest tree density and their crown cover were similar in the area dominated by *E. adenophorum* and *D. linearis*, together accounting for 43 % of the belt transect (Table 2.6). About a third of the transect had ground cover dominated by *P. aquilinium*, that was associated with markedly higher densities of both tea and forest trees and a higher total crown cover. Tea tree density was almost ten times lower in the area dominated by *I. cylindrica* and, while forest tree density was also lower than with other ground flora, the total crown cover was similar. The *I.cylindrica* was thus associated with an area with fewer larger forest trees with a higher crown base and hence higher solar radiation levels at ground level, and much lower tea tree densities, consistent with the very competitive nature of *I. cylindrica*.

Table 2.6 Crown cover, number of tea and number of forest trees in the *miang* tea garden belt transect.

Ground flora	Tea tree density (trees ha^{-1})	Forest trees density (trees ha^{-1})	Crown cover (%)	Area of ground flora cover (%)
P. aquilinium	3150	867	32	36.5
E. adenophorum	2152	793	23	14.7
D. linearis,	1866	746	20	22.3
I. cylindrica,	377	692	25	26.5
Mean	1983	783	28.39	

2.4.5.2.3 Seedlings

According to Table 2.2, there was a high density of tree seedlings in the *miang* tea gardens including 17 tree species from 16 families. The farmers have allowed them to establish and grow to provide future firewood. The process of *miang* tea steaming requires a large amount of firewood. On the other hand, there are many forest trees in the *miang* tea gardens because the farmers allow their gardens to have a suitable density and shading for the growth and production of the *miang* tea trees.

2.4.5.2.4 Parasitic and epiphytic plants and lichen

There were two kinds of parasitic plants on the tea trees; *Scurrula gracilifolia* and *Helixanthera parasitica*. The farmers may pick *S. gracilifolia* to mix with low quality green tea since they look similar and this is a means of bulking up their harvest. Fruit of both parasitic plants are eaten by birds and hence seeds are dispersed. They both cause tea tree mortality, if they are allowed to grow unchecked. Because of high humidity in the tea gardens, there were also epiphytic orchids (*Dendrobium sp* and *Vanda denisoniana*) in the crowns and lichens on the stems of tea trees.

2.4.5.2.5 Plant disease

During the low resolution transect it was found that there were small spots (diameter about 0.1 to 0.2 cm) on tea leaves. Identification by the Department of Plant Pathology, Faculty of Agriculture, Chiang Mai University suggested that they were caused by Grey blight and Brown blight disease associated with *Pestalotia theae* and *Collectotrichum camilliae* respectively. Both are relatively benign disease organisms that can gain entrance through a wound or into tissues that in some way have been weakened (Rattan, 1992). These two diseases do not pose significant problems as they generally affect old or damaged tea leaves.

2.4.5.3 Homegardens

Normally, the farmer plants vegetables, herbs and fruit trees together with bamboos amongst the tea trees and forest trees but only in the narrow areas behind the homes. The low resolution transect found that there were 58 plant species from 41 families in homegardens. Half of them were introduced species.

From the interview by questionnaire it was found that about a quarter of those farmers interviewed had planted other fruit trees as a commercial crop, for example; mango, jack fruit, pummelo, persimmon, prunes, apricot and litchi. However, they had not met with any success. The information shows that the farmers also grow vegetables such as ginger, taro, chilli, pumpkin, cabbage, garlic, onion, squash, and fruit such as pineapple and tomato as well as maize for home consumption. From observation and discussion with farmers it was found that few of them tried to developed native species for commercial use, such as *Tupistra albiflora* and *Ficus hirta* . The production of both plants were in response to demands of the market in the cities. Moreover, from observation around the homegardens, it was found that temporary nurseries were created near the houses of some farmers for keeping pot plants, the pots being constructed from small pieces of wood. These pots were used for growing orchids (*Cymbidium insigne*). The farmers said that they collected these orchid plants from the mountain, north of the watershed. From discussion with the farmers, it was found that this kind of orchid was also in demand from the market. The farmers would like to develop their orchid business on a commercial scale. Enquiries with some lecturers in the Laboratory of Flowers and Ornamental Plants, Department of Horticulture, Chiang Mai University revealed that the orchid is native to the Pee Pan Nam mountain range above 1 000 m elevation, and that it would be possible to develop it for the cut flower or the pot plant market. Their roots could also be propagated by the process of tissue culture.

Unlike the production from homegardens in this *miang* tea village, which was primarily for home consumption, production from homegardens surrounding

Bangkok, Uttradit (a province approximately 200 km south of Chiang Mai) and Chumporn (a province in Southern Thailand) was mainly for commercial purposes (FAO, 1989). This was because the *miang* tea farmers received sufficient income from their *miang* tea sale. The number of plant species recorded in the *miang* tea farmer homegardens surveyed was six to fourteen times greater than that observed in other homegardens. However, this diversity was similar to that reported the multistoreyed agroforestry garden system of Western Sumatra, Indonesia (Michon, Mary and Bompard, 1994), but less than half that found in homegardens in Kandy, Sri Lanka (Southern, 1994).

2.4.6 Socio-economic and demographic profile

2.4.6.1 History

Ban Mae Ton Laung was established approximately 150 years ago. From interviews, it was learnt that the Khmu tribe, a subgroup of the Cambodian or Khmer (Khom in Thai) had lived in Bo Keaw Province in the north of Laos and migrated to this area. They settled in the village and cleared the forest to grow upland rice for home consumption. At the same time, they established tea gardens for commercial reasons. Kunstradter (1988) reports that the Khmu in north Laos including other related groups such as the Lamet and T'in, and Lua' in Thailand, Wa in Myanmar and Korwa in India, speak languages distantly related to the language of the majority population of Cambodia. Their ancestors lived in the area long before the ancestors of the now dominant majority ethnic groups in Myanmar, Laos, Thailand, Malaysia and Vietnam. The Khmer empire reached the peak of its power in the 11th century when it ruled over the entire Mekong valley from the capital at Angkor and was destroyed by Thai conquests in the 12th and 14th centuries. The Tribal Research Institute (1995) stated that most of the Khmu in Thailand come from Vietiante, Luang Prabang and Xieng Khoung in Laos. They are concentrated and still make their living in the mountains in Nan Province, that is to the east of Chiang Mai Province. The first Khmu migrated into the country as labourers and worked either in the teak forest or in similarly isolated places. At the end of their contracts, they decided to settle rather than return to their native villages in Laos. Besides Nan, they are also found in Lampang, the province to the south of Chiang Mai and Kanchanaburi, the province to the west of Bangkok. The Tribal Research Institute reports also that the Khumu' trace their descent patrilineally and traditionally adhere to the custom of patrilocal residence. They live in small villages located on mountain slopes and survive on subsistence agriculture supplemented by hunting, fishing and trading. The Khmu practise an animistic religion. In Laos, Khmu shamans are considered to be excellent magic-religious practitioners and often invited to participate in Laotian ceremonies.

When the pioneer farmers received more income from selling tea leaves, they expanded their gardens, but also needed a larger work force, especially for picking the tea leaves. This resulted in the Thai people migrating to the village to work in the *miang* tea gardens. Thai people work as seasonal tea pickers. Most of the initial labourers were men. Some of them married with women in the village and settled permanently to live as *miang* tea farmers. Some of them bought *miang* tea gardens from the traditional farmers or occupied forest areas and developed *miang* tea gardens.

In the 45 families in the village interviewed who had migrated (45 % of household sampled), it was found that 70 people (41 % of the people from 45 families) were migrants. Roughly equal numbers of migrants stated their reason was because of marriage, or the prospect of better economic opportunity (encompassing roughly 80% of requirements), whilst land availability was cited by the remaining 20 % or so (Table 2.7).

Table 2.7 Number of respondents migrating to Ban Mae Ton Luang within each 10 year period and their reason for doing so between 1953 and 1992, n=70
Abbreviation: land=greater land availability, economy=greater economic opportunity.

Year	Number of villagers	Reason for migrating			Total
		land	economy	marriage	
1953-1962	5	3	0	4	7
1963-1972	23	7	12	14	33
1973-1982	26	6	19	13	37
1983-1992	16	5	8	9	23
Total	70	21	39	40	100

By interviewing the 70 migrants, it was found that almost all of them were from the north (Table 2.8). These people came from different districts of Chiang Mai, Chiang Rai and Lumpang Provinces. Most of them were from Wiang Pa Pao (about 40 %), Doi Sa Kade (33 %) and San Kam Pang (about 15 %) which is consistent with these three districts being near to the village. The districts have long been in contact with each other dealing in *miang* tea and other goods. People from these districts have then migrated to the village, where there is more economic opportunity than in their own villages. Few people had migrated during the 1950s and 70% of those sampled had migrated during the 1960s and 1970s with an indication of a declining trend more recently.

Table 2.8 Region, province and district from where migrating villagers have originated.

Region Province District	People
North	69
Chiang Mai	36
Doi Sa Kade	23
San Kam Pang	10
Phrao	1
San Sai	1
Muang	1
Chiang Rai	27
Wiang Pa Pao	27
Lumpang	6
Muang Pang	4
Wiang Nern	1
Chae Hom	1
Northeast	1
Roi Ad	1
Su Wan Na Khate	1
Total	70

2.4.6.2 Social structure and religion

Most of the villagers were descendants of Khmu and migrant Thai people. They are of Thai nationality. From observation, it appears that no people in the village talk Khmer in the same way as the Cambodians. The Khmu have, therefore, became culturally assimilated. They use *Kuam Muang* (the northern Thai language) for communicating and practice their lifestyle according to the *Khon Muang* (northern Thai) people. The Tribal Research Institute (1980) also found that many Khmu have been assimilated into the Thai culture and way of life. Only a few of them still maintain their mountain livelihood and they are concentrated in Nan Province. Some Khmu were found to live with other tribes such as Karen, Meo and Thai in the highlands.

All of the people interviewed were Buddhist in the Hinayana tradition, as are the majority of Thai people. There are two temples in the village, namely: Mae Ton Temple and Pang Kam Pang Hin Temple. These are important meeting places for the community for non-religious as well as religious functions.

2.4.6.3 Population structure

There were about 1 100 people from 301 households in the village in 1992. In the survey, 51 % (1.96 people family^{-1}) of the people were male and 49 % (1.87 people family^{-1}) were female, with mean household size of 3.83 people. The population structure is shown in Figure 2.6.

People within *miang* tea farming households accounted for 90 % of the total population. The population birth rate was 1.74 % in 1992 in accordance with the national rate of population growth that was 1.70 % in 1992 (Institute of Population, 1994).

It is evident from Figure 2.6 that the female population is largest amongst adults between the ages of 26 and 40 with a jagged, but clearly declining trend in younger age groups. The male population structure is consistent with a similar underlying trend of a reducing birth rate, affected by out-migration of young men between the ages of 16 and 30.

The labour force can be roughly defined as those people between 15 and 54 years old and comprised 60 % of the total population (2.3 people family^{-1}) with roughly equal numbers of men and women.

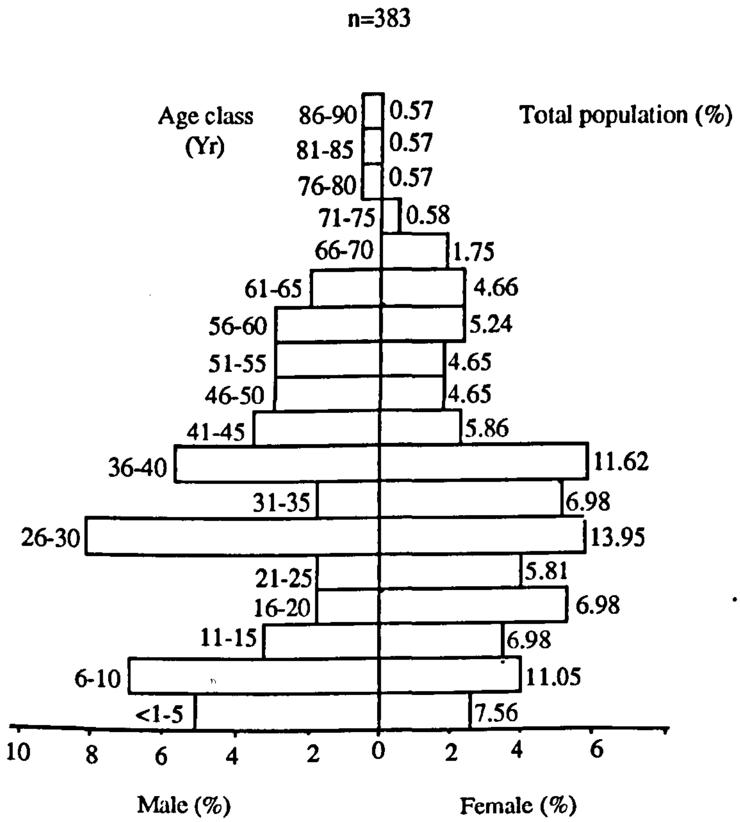


Figure 2.6 Population structure of Ban Mae Ton Luang, 1993.

In the sample surveyed, 26 % of the population were under 16 years old and there was only a small dependent group of retired people over 55 years old who comprised 14 % of the total sample, two thirds of whom were men.

At present, there is a downward trend in family size because people in the North have become concerned with family planning and because some farmers have migrated to work in cities. The result is reduced pressure on the natural resources and a reduction in the size of *miang* tea gardens as less labour is available to cultivate them. Some gardens have been abandoned, especially on steep land or higher lands that were difficult to maintain. They have been left to revert to natural forest.

2.4.6.4 Employment

The major occupation of people interviewed who classified themselves as working was tea farming, although there were significant numbers of *miang* tea merchants and labourers who didn't cultivate their own gardens, but lived permanently in the village and worked in other people's tea gardens. Two percent of household members at the time of survey were said to be working away from the village as temporary labourers in the city (Figure 2.7)

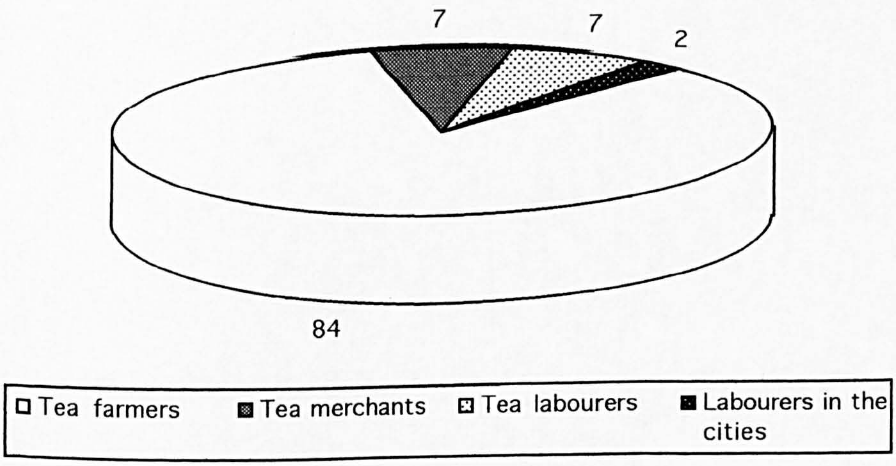


Figure 2.7 Percentage of major occupation of adults in the villagers, 1992. n=221.

2.4.6.5 Marriage

In the survey, most of the adults (>95 %) were married. The society of tea farmers is an agricultural society in which many activities were labour intensive. The people also have a low education standard and can not depend on their own income to survive. They have to get married to stay within the family structure.

2.4.6.6 Education

The village has a government primary school. This school has six classes, with children progressing from level 1 to level 6 in annual steps. Almost half of the people consulted had finished primary school at level 4. There was, however, an upward trend in the number of people finishing primary school at level 6, currently 23 % of those consulted had reached this level in keeping with new government policy. Less than 10 % of the population had received no education at all and a similar percentage were below education age. Only 5 % of people consulted had reached secondary school level 3, and only one half of a percent a higher education certificate and no respondents had received university education.

2.4.6.7 Administration

Ban Mae Tong Luang is *Moo 4* (Number 4 in the village group), which belongs to the Tape Sa Daje Subdistrict, Doi Sa Kade District, Chiang Mai Province. It is governed by *Pu Yai Ban,* a head-man who is based in the village. There is a village committee that consists of 15 members. The head-man is the committee chairman. The head-man and the committee are elected by the villagers every four years.

2.4.6.8 Land ownership and tenure

It is very difficult to accurately determine the extent of individual holdings. In most cases, the information given by villagers was only the area currently being cropped.

Nobody in the village has legal title to the land, be it a *miang* tea garden, house or other. However, certain forms of land use rights were enjoyed by the villagers. The Sor Kor Neung (S.K.1) is a formal certificate of land occupancy, which states an area of land occupied but does not specify clearly its boundary. These were issued before the promulgation of the 1954 Land Code, and although they cannot be sold, they can be inherited. These certificates were given by the office of Doi Sa Kade District which belongs to the Ministry of the Interior. A person holding such a certificate is obliged to pay tax on any land he occupies.

The distribution of land area used by households in a convenient division of 0.8 ha (which corresponds approximately to 5 rai, the local unit of land area) is shown in Figure 2.8. It is evident that there was a preponderance of smaller farm holdings. The mean land holding per household was 1.08 ha with 65% of households having 1.6 ha or less. About 13 % of households rented some of the land that they occupied to other people.

2.4.6.9 *Miang* tea production

The seasonal activities of the forest-tea production system in Ban Mae Ton Luang are shown in Figure 2.9. The collection of firewood is the first and one of the main activities in *miang* production. It is an operation wherein the villagers collect firewood for many uses, especially the steaming of *miang* tea.

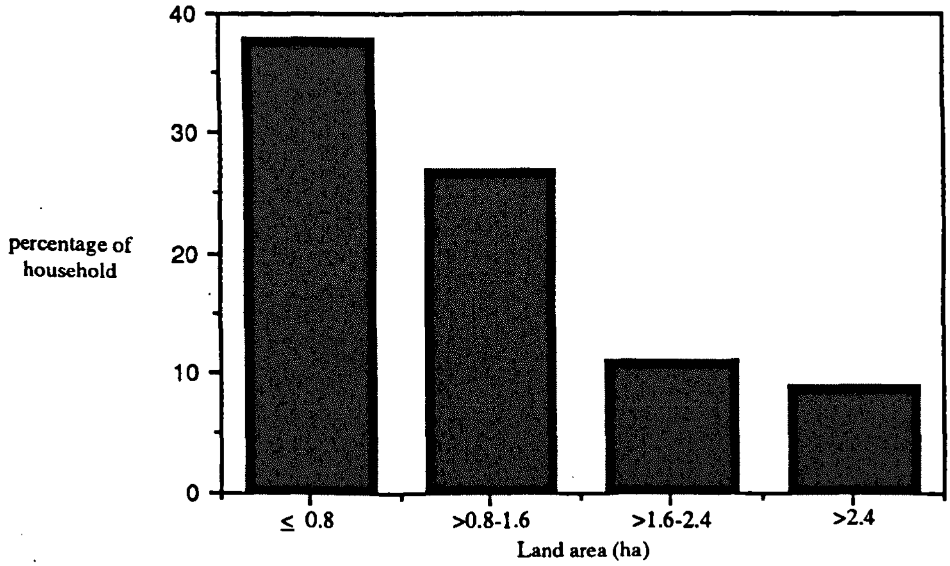


Figure 2.8 Total land area used by households (n=85 households) including areas with tea gardens and homegardens.

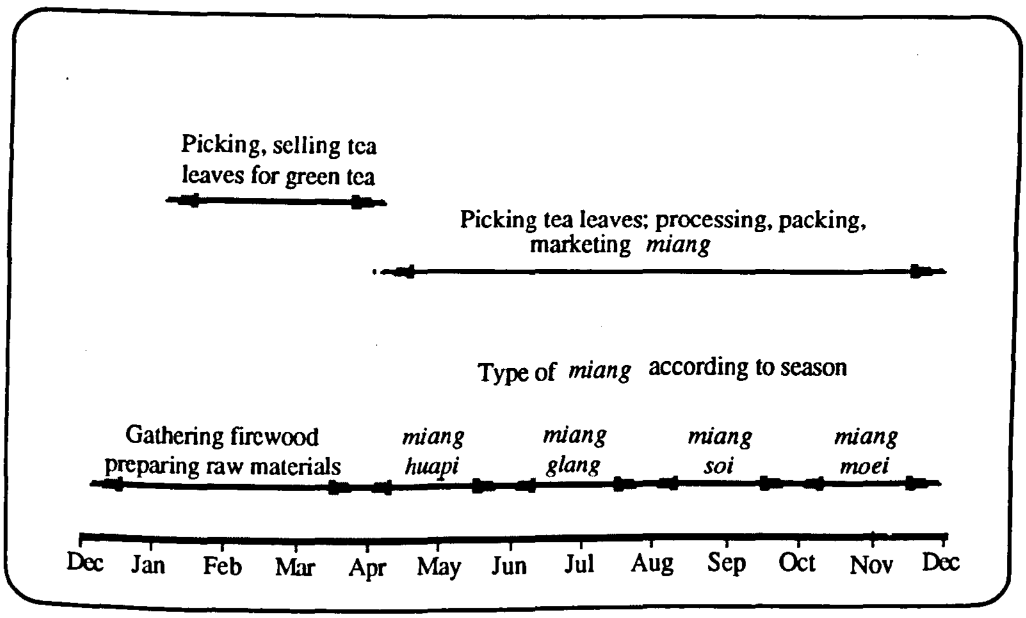


Figure 2.9 Seasonal activities of the forest-tea production system.

Tea for *miang* is picked four times a year according to the four seasons (from April-November), with the second picking being the largest. As can be seen in Figure 2.9, there are four types of *miang* tea according to the four seasons in which they are picked, namely: *miang huapi, miang glang, miang soi and miang moei. Miang huapi* is harvested during the months of April and May when there is little rain. *Miang glang* is then harvested during June and July and usually has the largest crop. *Miang soi* is harvested before the end of the rainy season during August and September. The last type, *miang moie* is harvested before the end of the rainy season, when conditions are particularly humid. In between each of the four harvests, the pickers rest for one to two weeks to allow the regeneration of new leaves for the next harvest.

Only two thirds of each tea leaf are picked at any harvest, one third is left. People said this maintained nutrients and ensured the survival of the tea trees. The pickers used make-shift ladders if the tea trees were tall. The pickers go to their work carrying a large basket and a small bundle of bamboo laths *(Tok),* about 1 cm width, used to tie the leaves into small, fist-sized bundles called a *Kam*. An average skilled picker can collect about 30 to 50 *Kam* in a day.

The total harvest of *miang* leaves of Ban Mae Ton Luang in 1992 was 307 400 *Kam*. Distributed amongst *miang huapi, miang glang, miang soi* and *miang moei* as 39 %, 34 %, 23 % and 4 % respectively.

The mean annual household production was 7 498 *Kam*. The first harvest *miang huapi,* unusually had the highest number of *Kam* harvested because there was a large rainfall received during the beginning of the rainy season, this was matched by the small harvest in the fourth season, at the end of the rainy season.

2.4.6.10 Other crop production in *miang* tea gardens

Some farmers produced green tea rather than *miang* tea, including the head-man who has a small factory in this village. The process of producing green tea does not involve fermentation, only steaming and drying. However, few *miang* tea farmers produce green tea because the process of drying requires charcoal and is labour intensive. Some farmers produced sun-dried tea leaves, which buyers mix with low quality green tea. Some farmers also gather tea seeds and germinate tea seedlings which were then sold to other farmers.

About a quarter of the farmers interviewed had planted coffee bushes amongst their tea trees. In 1987-1988, coffee prices were high. As a result, the village committee voted not to allow cattle to stray in to *miang* tea gardens because cattle eat coffee leaves and trample on coffee seedlings. Farmers said that this had changed the ecological system because, in the absence of cattle, there was no weed control. The farmers naturally had, therefore, to control the weeds themselves or pay for the labour to do so. There was no significant use of chemical weed control in *miang* tea gardens. Farmers complained that weeds suppressed the growth of tea, made harvesting difficult and were also a fire hazard. Tea cannot be harvested for three to five years after a fire. The price of coffee has since declined and most tea farmers have abandoned coffee. During interviewing and farm observation in tea gardens, it was found that most coffee trees had died. The farmers said that coffee merchants no longer came to the village and farmers had, therefore, to take the produce to the cities to sell, which was a major disincentive.

Black mushroom (*Lentinus edodes*), call *shitake* in Japan, is a commercial crop extended to the farmer by the Royal Project which is a non governmental organisation initiated by his Majesty King Bhumipol, the King of Thailand. Black mushroom is grown on logs of *Castanopsis diversifolia*. The wood is derived from *miang* tea gardens or natural forest trees that are cut. The mushrooms are then cultured on stacks of logs kept in huts close to the home. On a small scale, some farmers derive an income from this activity.

2.4.6.11 Animal husbandry

The animals raised by villagers include cattle, ducks and chickens. Cattle were once raised especially for transporting the *miang* harvest to markets as there were no roads or motor vehicles available. In the past, caravans of cattle were used by the *miang* tea villagers to transport goods to and from lowland markets. Now a feeder road has been built, connecting the village to a trunk road, so that motorised transport is used. However, the farmers still raise cattle to provide meat to eat and to sell in the village. After the village committee excluded cattle from *miang* tea gardens, the farmers who raised cattle had to confine cattle within their own gardens or graze them in the forest. Only five farmers in the sample kept cattle, however, during interview most of the farmers said they would like to return to raising cattle because they had problems with weeds and greater fire risk and have experienced a decline in soil fertility in tea their gardens. The mean number of animals kept by the five who had cattle was about four.

Ducks and chickens were raised for home consumption. They were fed on maize, rice husks and food scraps and ranged freely eating plants and seeds around the village and gardens. They also eat worms and insects, such as termites, crickets, cockroaches and ants. Thereby the poultry were thought by farmers to contribute to pest control.

Two families interviewed kept bees on a small scale. A native bee, the Indian honey bee (*Aphids indica*) was used. Bees collect pollen in the forest and from tea gardens, especially from the flowers of the tea bush, forest trees in the family Fagaceae and herbs in the family Compositae. Bees are domesticated by putting artificial hives, made from bamboo and *Castanopsis spp*., in the *miang* tea gardens and relocating them to the home compound when colonised by bees.

2.4.6.12 Gathering of non-wood products

Non-wood products gathered, but not deliberately cultivated, included mushrooms, chestnuts, wild flowers, young wild leaves used as a green vegetable, bamboo shoots, herbs and insects. These products, gathered from the surrounding gardens and forest, were for home consumption (Table 2.9).

2.4.6.13 Income

The main source of income in the village was from *miang* tea and other tea production. Other sources of income were from selling other crops and home craft products, *miang* dealing, waged labour, leasing *miang* tea gardens and interest an capital (Table 2.10).

Table 2.9 Non-wood products collected from tea gardens and forest.

Name	Comments	Examples of species
Mushrooms	Several species, usually in wet season.	*Cantharelus cibarius, Clavaria corolloides, Lactarius piperatus, Ispholiota lucifera* and *Boletus edulis.*
Chestnut	From *Castanopsis spp.* available around October.	*Castanopsis acuminatissima, C. armata, C. diversifolia, C. tribuloides* and *C. wallichii*
Bamboo shoots	Usually available in wet season.	*Bambusa arundinacea, B. natans, B. vulgaris, Dendrocalamus hamiltonii* and *Gigantochloa apus.*
Wild flower	Some wild flowers are eaten. Usually available in wet season.	*Fernandoa adenophylla* and *Musa acuminata*
Wild fruit or pod	Some wild fruits and pods are edible.	*Cynanchum corymbosum, Fernandoa adenophylla* and *Schium edule.*
Young leaves	Young leaves of plant are eaten.	*Camelia sinensis, Canarium subulatum, Cleome gynandra, C. chelidonii, Cynanchum corymbosum* and *Ficus hirta.*
Leaf, bark and root	Tradition plant medicines are commonly collected.	Leaves of *Camellia sinensis, Eupotorium adenophorum, E. odoratum, Rhinacanthus communis* and *Sloanea corbularia* Bark of *Betula alnoides* and *Cinnamomum bejolghota,* Roots of *Alphonsea siamensis, Catimbium melaccense* and *Imperata cylindrica*
Insect	Some types of egg and worm and young insects are use in cooking.	wasp, termite, cricket, ant lion, and tussock.

The mean annual household income was about 39000 Baht (£975), of which two thirds was from tea production. Figure 2.10 shows the mean proportion of each *miang* tea product contributing to the mean income from tea production in 1992. Although the amount of *miang huapi* harvested in 1992 was more than *miang glang,* the income from *miang glang* was higher because the price of *miang glang* was higher than that for *miang huapi.* The quality of *miang glang* is generally higher than *miang huapi* because younger leaves are picked.

Table 2.10 Source of income. All income for households sampled were combined and that from each source expressed as a percentage of the total.

Production	%
Miang and other tea production	61.0
Miang dealing	25.0
Labour in the village	3.0
Labour in the cities	3.0
Coffee production	3.0
Leasing land	2.0
Home crafts (e.g. bamboo baskets)	1.0
Interest from bank and cooperative deposits	1.0
Mushroom production	0.5
Bee production	0.5
Total	100.0

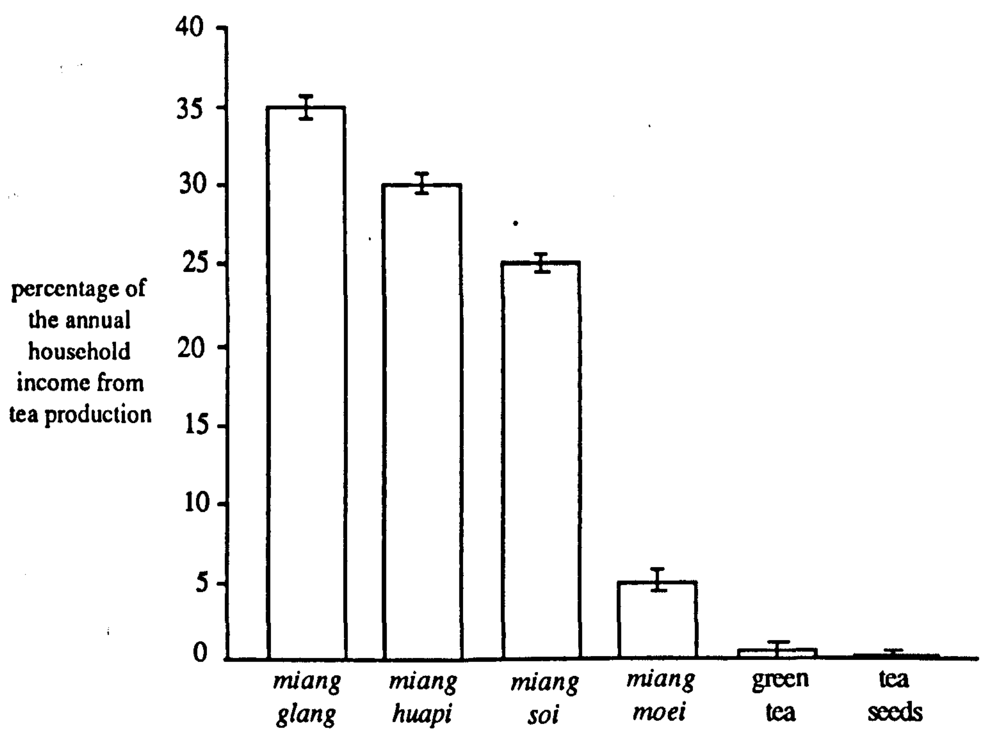


Figure 2.10 Composition of the annual household income from tea production in 1992 n=98 *miang* tea farmer, households, frequency of responses (%) ± standard error, data from all *miang* tea farmers involved.

2.4.6.14 Production costs

The mean total household production costs for the *miang* tea gardens was 8 000 Baht (£200) family^{-1} yr^{-1} which is around 20 % of the mean annual income. The main cost (49 % of the total) was in the form of wages and sustenance of labourers who work in the tea gardens (Table 2.11). There were two kinds of labourers: villagers and seasonal labourers from elsewhere who required accommodation and subsistence as well as wages. Most *miang* tea farmers have two houses. One house for them and their family, another house for labourers and packing and steaming tea leaves. Seasonal labourers come to the village during the picking season when a large amount of labour is required for picking, steaming and packing *miang* tea leaves and for weeding *miang* tea gardens.

Table 2.11 Annual investment of tea farmers in 1992 (n=98 tea farmers households, frequency of response (%) ± standard error) data from all *miang* tea farmers involved).

Kind of investments	%
Wages for picking, packing, steaming *miang* tea leaves, weeding *miang* tea gardens and food for labourers	47.18±2.35
Material for harvesting the tea leaves	20.01±1.47
Transportation	17.62±1.10
Firewood and gathering fire wood (Labour or purchase price from other farmers)	5.10±0.48
Renting lands	3.10±0.10
Fertilisers	3.09±0.75
Pesticides	2.45±0.50
Interest on loans	1.45±0.10

Most of the labourers were rice farmers who work in other areas, once their rice seedlings have become well established and require less labour for adequate maintenance. However, during interview it was found that it was very difficult for *miang* tea farmers to find sufficient labour because most people preferred industrial employment in cities rather than agricultural work because wages were higher. Therefore, *miang* tea farmers were having to pay higher wages to attract labourers. Material for harvesting the tea leaves accounted for about a fifth of the annual investment including baskets, plastic bags, bamboo laths and plastic shoes used when picking the tea and plastic bags used for fermenting it. A similar proportion was required for transportation. Where *miang* tea gardens were far from farmers' houses the farmers had to pay for vehicles or labour to transport tea leaves to their house. Some farmers hired cars to carry *miang* tea to sell in the cities where they achieved a higher price than selling their produce to local merchants. A few farmers purchased chemical fertiliser and pesticides because they still maintain coffee trees.

2.4.6.15 Other household expenditure

As only 20 % of annual income was spent on production costs with respect to *miang,* 80 % was available for other expenditure (31 000 Baht or £775). Most of this (60 %) was spent on food including rice that was not grown in the area. Other significant expenditure was on healthcare, education, alcohol (and commercial soft drink) and cigarettes. Most families were able to save some money and the mean amount was about 7 000 Baht (£170). Most of the *miang* tea farmers kept their savings in their home, although some deposited them in banks or co-operative societies in the cities.

2.4.6.16 Infrastructure

There was a small hydroelectric dam using water from the Mae Ton stream in the village. This dam and electricity system were built by the Chiang Mai Development Energy Station. The electricity was distributed by a village co-operative. If the dam or electricity supply required maintenance, then repairs were done by members of the cooperative. The electricity was very useful to villagers because it provided light, energy for cooking and powered televisions. The villagers expressed an awareness that natural resources, especially the forest, need to be conserved in order to serve the water supply for hydro-electricity and clean drinking water. There were two water storage units supplying clean water for the villagers. These units and the water supply system were maintained by a local user group.

2.4.6.17 Communications

Most (>90 %) of the villagers had television and radio equipment. Radios were used by farmers during the long working hours, when they were picking *miang* tea leaves. Television was watched at night, when the *miang* tea was being processed. They listened and viewed local news, information and entertainment transmitted from Chiang Mai City including information about agriculture. Other television programs including the national news, information and entertainment transmitted from Bangkok. The villagers outlook and knowledge are likely to have been influenced by both these sources of mass communication.

2.5 Conclusion

The purpose of building up a picture of the general background of the study site, the ecological characteristics of the *miang* tea gardens and the natural forest and the socioeconomic and demographic profile of the people in the village was to select research topics germane to acquiring indigenous ecological knowledge from *miang* tea farmers. The description has shown that there was extensive biodiversity in the *miang* tea gardens and that *miang* tea farmers had knowledge about combining natural forest trees, ground flora and cattle in their tea gardens. These preliminary findings suggest that knowledge acquisition about interactions between forest trees, ground flora, cattle and tea trees together with the management of erosion, fire control and plant succession in the gardens would be productive and perhaps explain the traditional production system. The natural forest trees are the dominant component in *miang* tea gardens by virtue of their controlling influence over the growth of other species, the microclimate and the cycling of nutrients. The ground flora appears important in the control of soil erosion and surface runoff. Cattle used to play an indirect but important role in the control of weeds and in protecting the growth of forest tree seedlings by reducing fire hazard. Labour is the major production cost and cattle may reduce labour requirements as well as contributing to tea production via fertility enhancement and the control of competing weeds. Knowledge acquisition on these aspects is pursued in the next chapter.

CHAPTER 3

ACQUISITION OF INDIGENOUS ECOLOGICAL KNOWLEDGE

3.1 Introduction

During the fieldwork described in Chapter 2, it was observed that the pioneer *miang* tea farmers on the study site had learnt how to cultivate *miang* tea from their own experiences and from exchanging knowledge with their neighbours and people in other *miang* tea villages. There appeared to have been little influence of the techniques used on modern tea plantations on the indigenous tea farming system. Most of the *miang* tea farmers still cultivated *miang* tea gardens using traditional techniques handed down from one generation to the next. Sangchai (1993), interested in farmers attitudes to natural resource conservation in ten tea villages north west of Chiang Mai, found that over 80 % of their knowledge was passed down from their ancestors, while only about 10 %, 7 % and 2 % was derived from their neighbours, from training and from others sources, respectively, confirming the importance of the oral tradition and experiential learning from working within the family context.

The research described in this chapter aimed to acquire *miang* tea farmers' traditional ecological knowledge and store it in an accessible form, so that it could be rigorously analysed and then, if appropriate, used to understand current farmer practice and formulate relevant research and extension activities.

3.2 Objectives

The information on the study site described in Chapter 2 was used to formulate a specific knowledge acquisition strategy in terms of defining the knowledge domain, deciding how to collect knowledge in that domain from people at the study site and deciding how to represent the knowledge in a durable and accessible format. The process can be summarised in terms of three overall objectives.

(1) To formulate specific research hypotheses about the knowledge held by farmers on defined topics through consideration of the information derived from the study site in Chapter 2.

(2) To use the structured hypotheses in (1) to facilitate the collection of detailed indigenous ecological knowledge from a purposive sample of key informants.

(3) To create an indigenous ecological knowledge base, about *miang* tea gardens by representing the knowledge elicited in (2) using proprietary knowledge-based systems software.

The *miang* tea gardens in the hill evergreen forest are a form of agroforestry that combines the management of many elements of an agroecosystem. The research in Chapter 2 shows that the combination of biotic elements in *miang* tea gardens (see Table 2.2) includes 91 plant species including four dominant species: *Eupatorium adenophorum, Pteridium aquilinium, Dicranopteris Linearis* and *Imperata cylindrica* (see Section 2.4.5.2.2) two species of parasitic plant, and two species of epiphytic orchids (see Section 2.4.5.2.4). Some *miang* tea farmers also incorporate domestic animals in their gardens, particularly cattle. It is a reasonable starting point to assume that knowledge about *miang* tea gardens may be derived from many sources and it may, therefore, be sparsely distributed amongst people in the community and structured differently to scientific knowledge covering the same domain. Existing texts by authors who have observed or interviewed *miang* tea farmers have not been collected in such a way that they are available for use for purposes other than the analysis for which it was collected. Essentially, previous authors have presented their view of the *miang* tea farmers' knowledge system rather than make the system available for subsequent analysis and use (Keen, 1978; Preechapanya *et al.*, 1985; the Royal Forest Department, 1989; Watanabe, Takeda and Kamyong, 1990; Sangchai, 1993). In the present study, *miang* tea farmer's knowledge was collected in order to understand the concepts, ideas and practices used by the *miang* tea farmers and to establish the extent to which local knowledge contained useful information about ecological process. To achieve this, knowledge-based systems software and methodology were contemporaneously developed by collaborating scientists and knowledge engineers (Walker *et al.*, 1995a). The use of a knowledge-based systems approach for acquiring local knowledge has been reviewed and justified by Walker *et al.* (1995b). The stages of the collection process are summarised in Figure 3.1. There were essentially three key stages within an iterative cycle each of which is described below: knowledge elicitation (Section 3.3), continuous assessment of the knowledge that was collected (Section 3.4) and formal representation (Section 3.5).

The indigenous ecological knowledge resulting from this research was represented using the AKT (Agroforestry Knowledge Toolkit) software, so that it was stored and accessible through the use of a knowledge-based system (Walker *et al.*, 1994). A knowledge base in the present context is, therefore, defined as an articulated and defined set of knowledge stored in a computer (Sinclair *et al.*, 1993). The knowledge is stored in such a way that it can be accessed, evaluated and used for a variety of purposes in a research and development context.

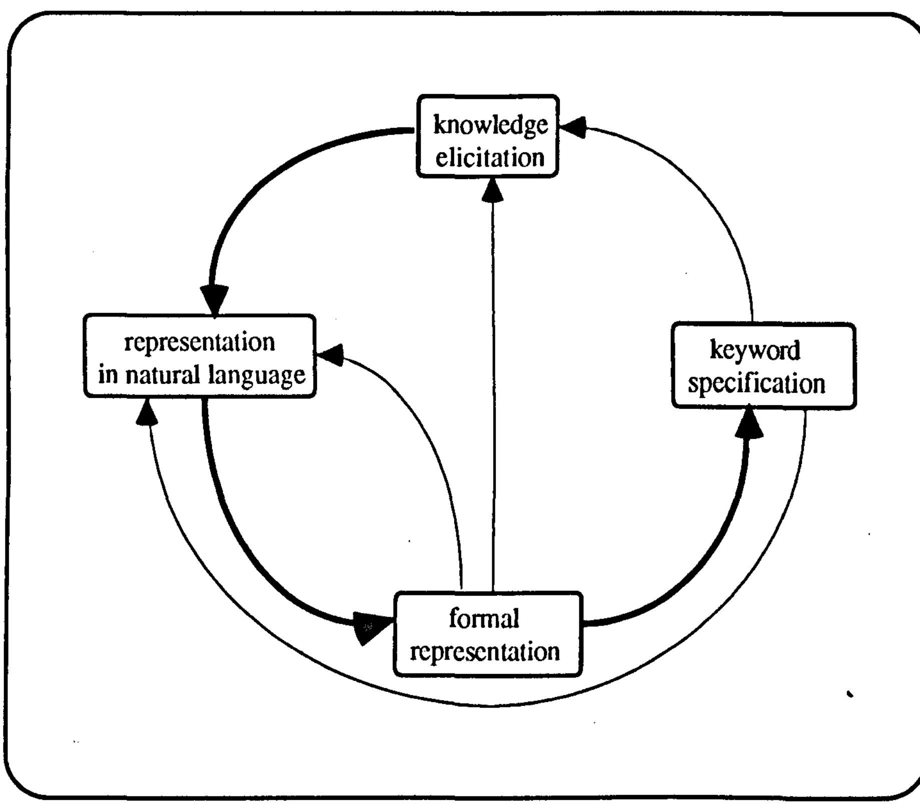


Figure 3.1 The collection of knowledge. There were four principal activities in the creation of the knowledge base, as shown in the diagram, but it is convenient to discuss elicitation and representation of knowledge in natural language as a single stage in the present context, since the product of the elicitation process is a set of statements in natural language (Section 3.3). These stages occur in sequence (bold arrows), but evaluation during the creation of the knowledge base and consequent return to previous activities (fine arrows) mean that the process was in fact a series of cycles.

Adapted from Walker *et al.*, 1994.

3.3 Knowledge elicitation

Knowledge elicitation is the process whereby selected informants were encouraged to articulate their knowledge. Knowledge elicitation thus involved: the selection of topics for interviewing (Section 3.3.1), the sampling strategy and selection of key informants (Section 3.3.2), development of a semi-structured questionnaire (Section 3.3.3), development of a fieldwork plan (Section 3.3.4), the interview techniques used (Section 3.3.5), and finally the recording of information as natural language statements (Section 3.3.6)

3.3.1 Selection of research topics

Knowledge elicitation focused on what people knew about the ecology of the *miang* tea garden system, particularly:

- the role of forest trees in controlling microclimate and nutrient cycling;
- the comparative role of the four dominant ground flora in the control of soil erosion; and
- the role of cattle in the cycling of nutrients and the germination of forest tree seeds.

There are four reasons why these topics were selected. Firstly, the forest, ground flora and cattle interact as important elements in the garden ecosystem. The results of previous research in Chapter 2 have shown that these elements are an important influence in controlling energy flows and the balance of nutrients in the garden ecosystem. Secondly, it was shown previously (see Section 2.4.5.2) that forest trees control the microclimate of the understorey by, for example, providing shade and it is thought that tea trees require high moisture and low radiation levels. Furthermore, Preechapanya *et al.* (1985) found that the *miang* tea farmers planted tea in the forest without using fertiliser because the fertility provided by forest cover was sufficient to maintain acceptable tea yield because the tea trees derived nutrients from rain, animal faeces and tree and ground flora litter. Tiasiripech (1981) similarly constructed a cost-benefit analysis of the tea gardens in north Thailand and in agreement with the results in Section 2.4.6.14 from the present study site, found that there was no investment for buying chemical fertilisers for tea trees. The third reason was that it appeared from transects of vegetation at the study site (see Section 2.4.5.2) that tea grew well at high density in association with some ground flora (*P. aquilinium, D. linearis* and *E. adenophorum*), but that it did not germinate or grow well in association with *I. cylindrica.* These ground flora were also said by farmers to have an influence on soil erosion. The fourth reason was that it was evident that cattle may enhance nutrient cycling. Some farmers suggested that cattle also reduce the risk of fires and increase the survival rate of tea and forest tree seedlings by controlling the growth of weeds. It was also indicated that cattle may play a role in seed germination of some forest trees species by eating their fruit and breaking the dormancy of the seed. These three areas, therefore, formed the framework for the study of farmers' knowledge.

3.3.2 Sampling strategy and selection of key informants

To elicit detailed ecological knowledge from farmers, Thapa (1994) found that it was effective to focus upon a limited number of carefully selected individuals referred to as key informants and to generalise the results obtained from this purposive sample in a second phase of research (Knight, 1980). Walker *et al.* (1994) also maintain that it has proved more productive to speak to fewer people on more occasions to obtain an internally consistent set of knowledge rather than to speak to a larger number of people since it is generally known that much knowledge is shared within close-knit communities (Werner and Schoepfle,1987b), and it is not, therefore, necessary to talk to a large sample to acquire what knowledge is available. Bruce (1989) has also pointed out that consulting a larger number of people did not necessarily improve the reliability of information obtained. Kumar (1987a), however, stresses that key informants should be representative of the target population and that an acceptable degree of representativeness can be achieved by classifying the target population on the basis of criteria relevant to the study objectives and by including key informants from each category. Kumar (1987b) thus defines key informants as a selected group of individuals who provide information, ideas and insights on a particular subject.

The key informants who were interviewed in this research were divided into two groups. Firstly, ten key informants were selected on the basis of interest, articulation, depth of knowledge and willingness to participate (Brokensha and Riley, 1980). They were thus purposively, (non-randomly) selected from the source community to develop an overall understanding of the domain in question, defining boundaries and identifying terminology (Walker *et al.*, 1994). On the basis of the knowledge obtained from the first informants, 24 further key informants were selected on the basis of an indication of the variability of knowledge over the community as a whole (Walker *et al.*, 1994). The socio-economic and demographic profiles in Chapter 2 suggest that variation between tea farmers in the study site, according to land holding (Section 3.3.2.1), gender (Section 3.3.2.2) and age (Section 3.3.2.3), may be expected to influence the knowledge held by people. A stratified purposive sample of 24 informants was, therefore, used based on these selection criteria (Figure 3.2).

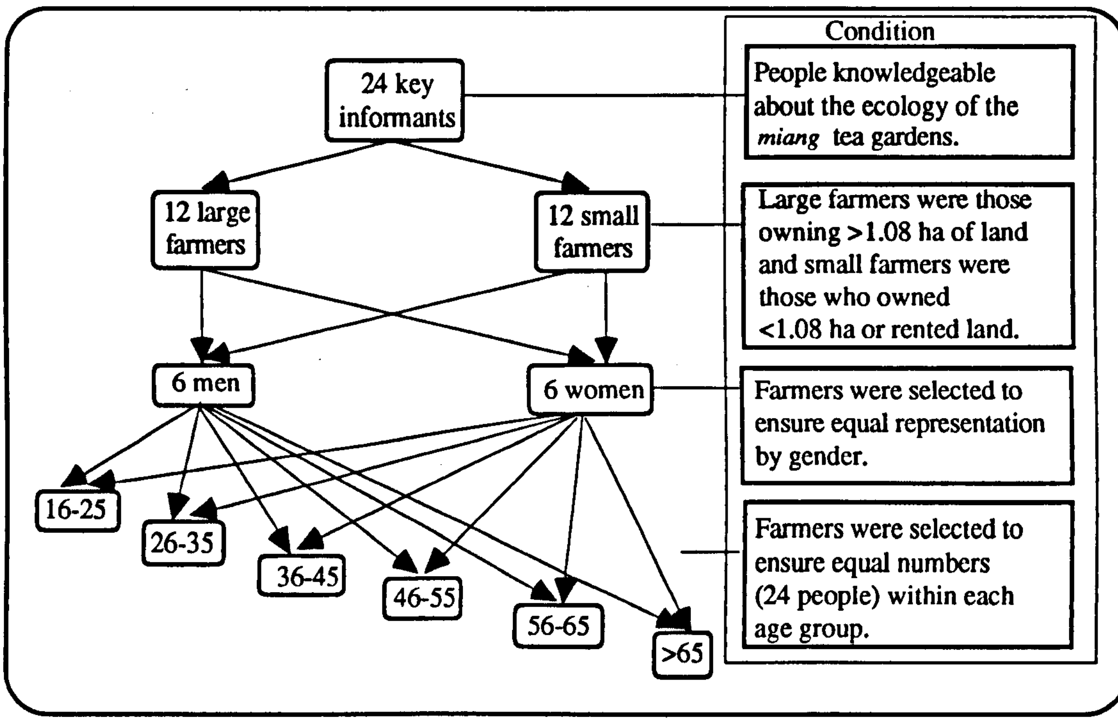


Figure 3.2 Stratified sampling of key informants by land holding size, gender and age.

3.3.2.1 Land holding

Castilo (1990) suggested that the forest-tea production system involves three groups of people based on the size of land holdings. These were large *miang* tea farmers (farmers who owned > 1.76 ha), small *miang* tea farmers (farmers who owned <1.76 ha) and landless farmers who rented land from other people. There was also considerable evidence from the rural appraisal at the study site that *miang* tea gardens were managed according to the size of the *miang* tea farmers' land holding. *Miang* tea farmers with larger holdings were able to conserve more natural forest trees within their gardens. An impression gained during initial fieldwork was that most of the large *miang* tea farmers had been in the village for longer than the *miang* tea farmers with smaller holdings, who were often recent migrants. It may be, therefore, that having observed degradative processes for longer, they were more aware of the need to conserve the environment. It may also be that farmers with larger holdings can tolerate more forest trees in the garden since their overall yield from tea trees across their large land holding is sufficient, whereas, farmers with smaller holdings require more intensive production per unit of land. The mean land holding size per household was 1.08 ha and, therefore, equal numbers of *miang* tea farmers with farms larger than this and with farms smaller than this were selected.

3.3.2.2 Gender

Male and female *miang* tea farmers perform different activities in the *miang* tea gardens. Mostly, it is the men who work in the gardens; planting forest tree seedlings, cutting the trees for firewood and weeding. The women spend more time boiling the tea leaves, processing the *miang* tea product, cooking food and looking after their family. These factors may influence the knowledge held, in that male farmers may be expected to have more understanding of the ecological processes in the gardens and women more knowledge about product quality. For this reason key informants were divided by gender and an equal numbers of men and women were interviewed.

3.3.2.3 Age

It was observed during the initial data collection phase that as farmers increased in age, so too did their recognition of the need for conservation. Gardens maintained by older farmers had a higher density of forest trees and ground flora than those maintained by younger farmers. Earlier interviews indicated that older farmers were more concerned about the sustainability of the ecosystem in their gardens rather than the production of tea leaves. They were not in favour of adopting new cropping systems which they felt disturbed the sustainability of their gardens and the ecosystem of the watershed. For example, ten years ago, most of the younger farmers introduced coffee *(Coffea arabica)* into their tea gardens, whilst the older farmers maintained their gardens in the traditional way. Coffee differs from tea in its requirements for light, fertiliser and pesticides and so the younger farmers have acquired new knowledge relevant to coffee and have different ideas about ecological sustainability within their *miang* tea gardens. D'Andrade (1970) cited in Werner and Schoepfle (1978b) showed that if three or more consultants agreed on some ethnographic detail (in a relatively homogeneous culture), then all or most consultants would also agree. The amount of sharing between any two consultants, however, rarely, exceeds 60 % and in less homogeneous societies may be well below 50 %. Lack of homogeneity may involve different age groups in a small community (Huff, 1969). For these reasons, people over 15 years old were selected, and a range of age ensured by selecting equal numbers of people from each of six age cohorts (see Figure 3.2).

It was not anticipated that the influence of factors such as altitude, ethnicity and education, would vary greatly amongst the target population or significantly affect knowledge acquisition. *Miang* tea gardens only occur in hill evergreen forest in high mountainous land at an elevation of 900-1 400 m above sea level. Species composition did not vary much with altitude within this range. Ethnicity and religion (see Sections 2.4.6.1 and 2.4.6.2) and occupation (see Section 2.4.6.4) of the people in the study site did not vary and educational backgrounds (see Section 2.4.6.6) did not vary independently of age.

3.3.3 Semi-structured interviews

The purpose of the interviews was to elicit the basic concepts and terminology used in the tea culture system. The key informants were interviewed using a set of guideline questions (Table 3.1). The nine questions were designed to encourage informants to articulate their knowledge on a topic of interest without asking leading questions.

Table 3.1 Semi-structured questionnaire checklist used in knowledge elicitation.

1	Which forest trees do you have in your *miang* tea gardens?
2	Why do you retain these forest trees in the gardens?
3	[1]Probe for information on the role of trees in controlling microclimate and nutrient cycling. Generally, by asking people how the trees performed the role for which they were retained as articulated in (2).
4	What types of ground flora occur in your tea gardens?
5	[2]What influences does the ground flora in (4) have in the garden and why?
6	For the types of ground flora mentioned in (4); how do they compare with respect to role mentioned in (5).
7	Have you raised cattle in your gardens?
8	What influences do cattle have on the gardens and why?
9	[1]Probe for information on the role of cattle in nutrient cycling and seed germination by asking people how the cattle perform the roles articulated in (8)?

note: [1] Suggested by initial interviews with ten informants. [2] The aim here was to probe for information on the role of ground flora in controlling soil erosion and surface run-off as was articulated in initial discussions with ten informants.

3.3.4 Field work plan

After the research objectives and the interview guidelines were established, a first round of interviews was conducted. The information was then entered into a knowledge base on computer (Walker, Sinclair and Kendon, 1995). Any information that was unclear was further investigated by reinterviewing the informants individually or in groups. Furthermore, interview guidelines were developed to cover areas for which the information already elicited was not complete or required further justification or explanation. This cycle was repeated until a comprehensive understanding of the topic had been gained and further questioning did not elicit new knowledge about it. In using this work plan, the researcher had to be careful to introduce limits into the questioning and not ask the key informants to discuss topics on which they clearly had no knowledge. The field work plan is shown in Figure 3.3.

3.3.5 Interviewing technique

The most important ingredient of a successful informal interview is to have a clear set of objectives, stating exactly what the fieldwork is intended to achieve. The informal interview strategy may be summarised as a set of semi-structured, flexible and open-ended conversations with the farmers. The interviews were guided by a checklist which was primarily used to ensure that the same issues and key points of interest were discussed with each key informant (Grandstaff and Grandstaff, 1987). The interview was started by introducing a few topics which the informants were encouraged to expand upon and the conversation would then be allowed to flow naturally.

Interviews were conducted during the rainy season in the tea harvesting period. Most of the interviews were conducted in the *miang* tea farmers' gardens. Here they were able to talk more extensively about garden ecology and provide examples. For example, farmers could demonstrate how forest trees controlled microclimate by indicating how a dense canopy of a particular tree reduced the solar intensity beneath and increased the soil moisture.

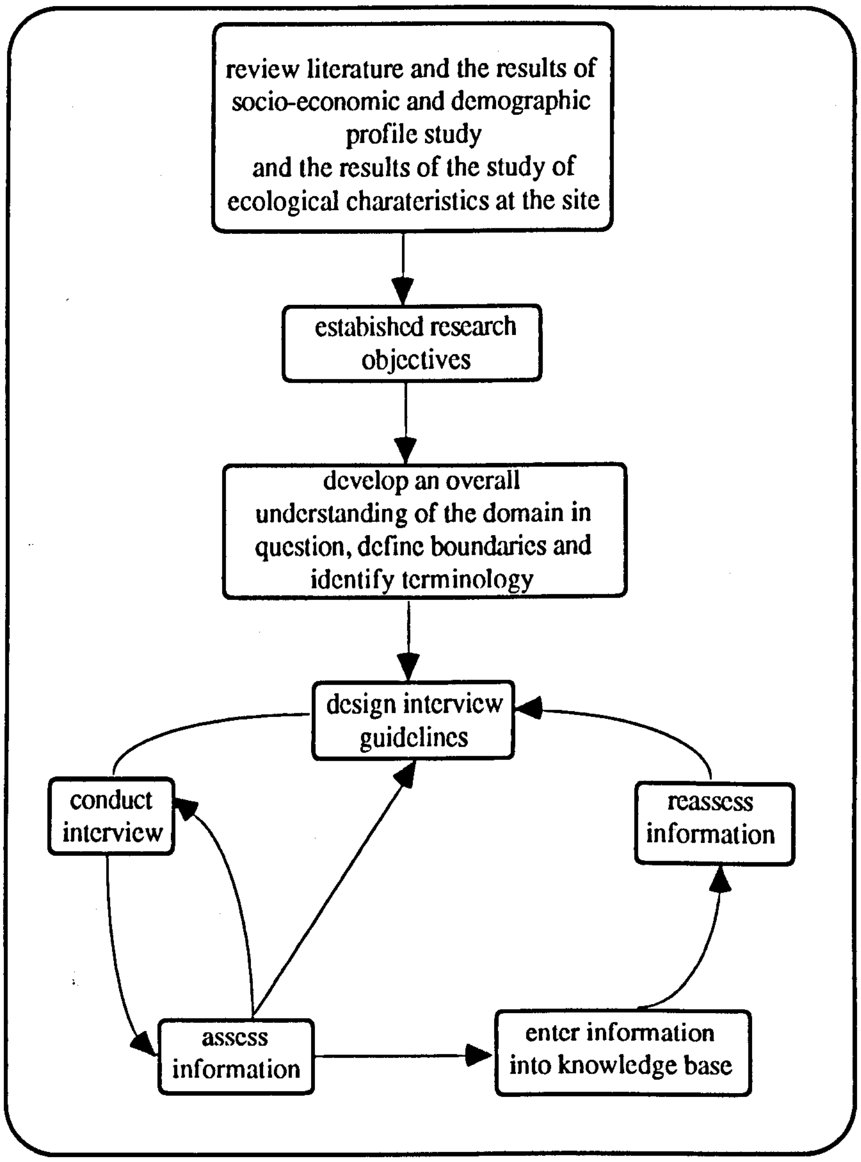


Figure 3.3 Iterative planning of knowledge elicitation based on assessment of knowledge as it was collected.

Maps of the land use of the study site (see Figures 2.2 and 2.3) and a picture of the stand profile of the gardens (see Figure 2.5) were used as tools for focusing the discussion. Chambers (1992) has attempted to draw a distinction between techniques and tools which are more verbal or observational and others which are visual. Visual techniques are described as creative, facilitating and empowering, especially for interviewing those people who are marginalised in their society rather than empowered, for example, the poor, the weak and often the women.

Any contradictions amongst information elicited at different times from the same interviewee or from different people were investigated in subsequent interviews with the informants or with a subgroup of informants who had given conflicting information. The group discussions provided information that was felt to be correct by all informants. Any problems mentioned by key informants were written down on large sheets of paper in the order that they arose in the meeting. Farrington and Martin (1990) argued that there is a tendency for groups to bias their responses in order to present a consensus which may arise from the dominance of a particular section of the community. Observation in the present study suggested that a large group meeting could not provide reliable information because of such bias. For example, subsequent discussion in subgroups, such as a group of poor farmers or a group of women, actually changed the information they had given when in a larger mixed group. Bruce (1989) suggested that small group interviews are the most productive, usually as informal discussions. Small meetings were, therefore, held in huts where *miang* tea farmers sheltered from heavy rain in the tea gardens, with the farmers when they were taking a break, in temples, in the local bar or in farmers' houses. Most of the knowledge about the ecosystem which needed to be extracted through brainstorming, such as the role of forest trees in energy flow and the role of cattle in the nutrient cycle were discussed in such opportunistic small group interviews.

3.3.6 Recording information and extracting statements

Interviews were conducted in Thai and recorded using a voice-activated tape recorder, supplementary written notes were also made. These were subsequently combined to create a structured set of field notes which were then translated into English. Table 3.2 shows an example of a typical extract from an interview with a key informant.

Table 3.2 An extract from structured notes resulting from an interview with a *miang* tea farmer in his tea garden. The responses are an English translation of what the farmer said, explanatory notes are enclosed in square brackets.

Question: Which forest trees do you have in your tea garden?

Response: There are many forest trees in my garden such as *Kaang kheemot, Ko duei, Ma faen* and *Ko daeng.* [farmer pointed out examples of each species].

Question: Why do you retain these forest trees in the garden?

Response: Because they provide shade from the sun and tea trees grow well under forest trees. Tea trees cannot grow without shade. If there is no shade, the tea trees will die. Bright sunlight will burn young tea leaves.

Question: Can you explain more about how forest trees shade the tea trees?

Response: The forest canopy reduces and reflects sunlight. It causes cool air and wet soil. Tea trees also grow well in cool air. Cool air under dense shade reduces soil drying and so the soil is wetter. In these conditions [of wet soil] there are more leaves on the tea trees.

3.3.6.1 Translation

Translation was carefully carried out. The principal concern was to gather ecological knowledge and, therefore, attempting to maintain a faithful representation of the local idiom in recorded statements was overridden by the need to confirm the underlying meaning of the statements farmer's made and ensure that any conditions, including those implicit in the context of the discussion, were noted (Southern, 1994). The author was accompanied by Mr Nirun Chaikan who is a *miang* tea farmer and graduate from the Chiang Mai Agricultural College to clarify the meaning of Thai words. Thus, the informative parts of interviews were translated into English and then the key ecological information was abstracted from this text as a set of statements using standard scientific terminology where possible. Care was taken to ensure that the terminology used sensibly reflected the farmers understanding. For example, sunlight, sunshine and other variants were all synonymous and well summed up by the catch-all scientific term solar radiation. Similarly the Thai word *ra hoei* which farmers used to refer to soil drying as a result of high ambient temperature, was sensibly represented by the term 'evaporation'. Other examples of translations are shown in Table 3.3.

The local names of plants given by key informants were checked and translated to scientific names (Smitinand, 1980) together with the results of the resolution survey in Chapter 2. An example of the key ecological information abstracted from the interview extract in Table 3.2 is shown in Table 3.4.

Table 3.3 Local words, their literal translation and the meaning interpreted and used in developing the knowledge base.

Local words	Literal translation	Interpreted meaning
din dee	good soil	fertile soil
din jued	tasteless soil	unfertile soil
din chum	wet soil	moist soil
din ron	hot soil	dry soil, polluted or toxins in soil from the roots of plants (such as roots of *Imperata cylindrica)* or fallen leaves (such as fallen leaves of *Pinus spp.)* or by chemical fertiliser.
din pang	broken soil	river bank eroded by discharge.
lom yen	cool air	low temperature
lom ron	hot air	high temperature
pui	fertiliser	sometimes, the *miang* tea farmers mean plant nutrients, but sometimes, they mean fertiliser. However, the farmers understand that plants nutrients and fertiliser are the same thing.
yaa	grass	small ground flora including grasses, such as *I. cylindrica, (yaa khaa)* and non grasses, such as *Eupatorium adenophorum (yaa pee wang).*
liang	to take care of or contribute to	transfer; such as, roots of forest trees contributing nutrients to roots of tea trees.
nag	heavy	high intensity, such as high intensity of rainfall.
bao	light	low intensity such as low intensity of rainfall.
jad	strong	high intensity such as high intensity of sun light.
on	soft	low intensity such as low intensity of sun light.

Table 3.4 The key ecological information abstracted from the interview extract in Table 3.2.

Albizia odoratissima (kaang kheemot) is a forest tree.
Castanopsis acuminatissima (ko duei) is a forest tree
Protium serratum (ma faen) is a forest tree
Quercus kingiana (ko daeng) is a forest tree.
Forest trees reduce solar radiation.
Forest trees reflect solar radiation.
Tea trees require shade.
Unobstructed solar radiation damages young tea leaves.
Reduction in solar radiation causes a reduction in air temperature.
Reduction in air temperature causes reduction in evaporation of water from soil (soil drying).
Reduction in evaporation of water from soil (soil drying) causes an increase soil moisture.
Increase in soil moisture causes an increase in the number of leaves on tea bushes.

3.3.6.2 Conditional information

If it was thought that the key informants were not supplying correct information, they were asked again to ensure that it was correct information. For example, farmers said that the root systems of forest trees are connected to and transfer water and nutrients to the root systems of tea trees. This, the key informants maintained, was their view. However, this *miang* tea farmers' knowledge was contradicted by general scientific knowledge. Therefore, this issue was discussed with more informants and in a group meeting. Some information needed more detail than was initially forthcoming , for example, one key informant suggested that cattle do not eat tea leaves. On further questioning, the informant explained that this was because the tea leaves were bitter. Many statements needed to be expressed in a conditional manner and the key informants were asked in which conditions statements were valid. For example, at one stage the statement 'an increase in shading intensity causes a decrease in growth rate of ground flora' was abstracted. However, the growth rate of some ground flora was found not to reduce with an increase in shading intensity. This statement clearly needed to be conditional and so informants were asked what kind of ground flora it referred to from which it was possible to ascertain that this only applied to *Imperata cylindrica*. Thus appending if the ground flora is *I. cylindrica* to the statement clarifies the statement.

3.3.6.3 Causal diagrams

Causal knowledge was recorded in a diagrammatic form. Firstly, the diagrams were built from individual interviews and drafted on paper (Figure 3.4). They were useful in identifying comprehensive sets of explanatory knowledge by suggesting further lines of enquiry.

If it was found that a diagram could not be developed from a single interview because there was not enough information, more than one interview was used. The draft diagrams were shown to informants in group interviews designed to enable people to combine, improve and correct the knowledge represented. The diagrams were particularly effective in considering linkages between individual statements and almost all of the useful knowledge articulated by farmers could be represented in only a few diagrams.

Recording information in a diagrammatic form assisted in reducing repetition and conflict in the resulting knowledge base. Lightfoot *et al.*, (1989) have previously commented that the knowledge synthesis inherent in diagramming can provide a useful vehicle for knowledge elicitation.

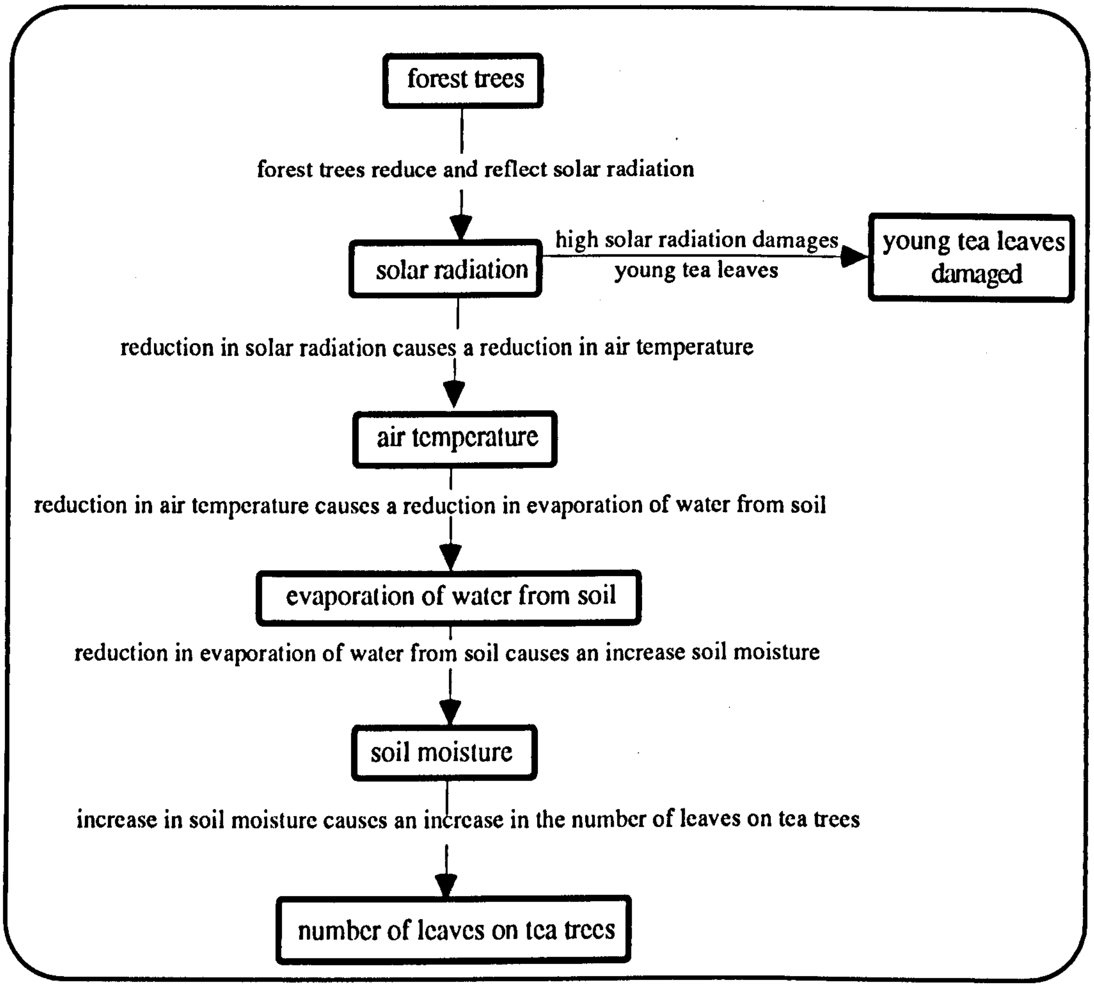


Figure 3.4 Diagram showing information from Table 3.4 drawn as a simple cause and effect diagram.

3.3.6.4 Unitary statements

The resulting knowledge base consisted of a set of unitary statements that were the smallest useful units of knowledge abstracted from the dialogues described. A unitary statement thus contained knowledge that was useful without reference to other statements, but could not be broken down into two or more statements. Unitary statements were in the form of natural language abstracted from text or interview material. This form is more restricted than natural dialogue, and provides an intermediate stage between articulation and formal representation. The objective of creating an intermediate knowledge base was to produce a succinct and explicit record of current knowledge which could then be formally represented.

Each statement was tagged with its source (s), and interview details, and as stated previously, the conditions under which it was valid. The knowledge-based systems software allows selection of statements and organisation of statements by source and/or keywords that occurred in them.

3.4 Assessing the knowledge

Information from the interviews was assessed as it was recorded. An objective of assessing knowledge was to eliminate any distortions caused by the partial or incorrect interpretation of what had been articulated and to resolve any conflicts in the knowledge base where possible. The process of assessing knowledge included assessing chains of reasoning (Section 3.4.1) and assessing their information content (Section 3.4.2).

3.4.1 Assessing chains of reasoning

This assessment was to ensure that the causal links captured between events provided a detailed explanation of the relationships involved. Thapa (1994) created diagrams from his interviews, and then assessed the diagram and identified possible gaps in the information recorded by logical inference. These gaps were used to formulate new questions to be asked at the next interview. As new information filled the gaps and improved the diagram, so it was reassessed. This process continued until the information was complete in as much as further elicitation did not augment the diagram. The *miang* tea farmers' knowledge was collected in this manner and an example is given concerning the farmers knowledge about the effects of cattle on the growth rate of tea trees in which it is seen that an increasingly detailed explanation is arrived at (Figure 3.5).

3.4.2 Assessing the information content

The content of the knowledge base was also assessed as a whole. For example, it was found that there was little information about the characteristics of the forest trees and ground flora recognised by the tea farmers as causing shade and nutrient recycling; and the characteristics of four dominant ground flora species recognised as having an effect on soil erosion and moisture content. As such information would be useful for recommending the kind of plants that would be useful, new questions were designed to inquire about the characteristics of each plant species in this manner. Questions were asked about ethno plant taxonomy to elicit the general background understanding of the farmers about plant classification and for linking the characteristics of these plants. Most of the information gained about plant taxonomy was recorded in the form of individual statements and then organised hierarchically to compact the knowledge base during formalisation (see Section 3.6.3).

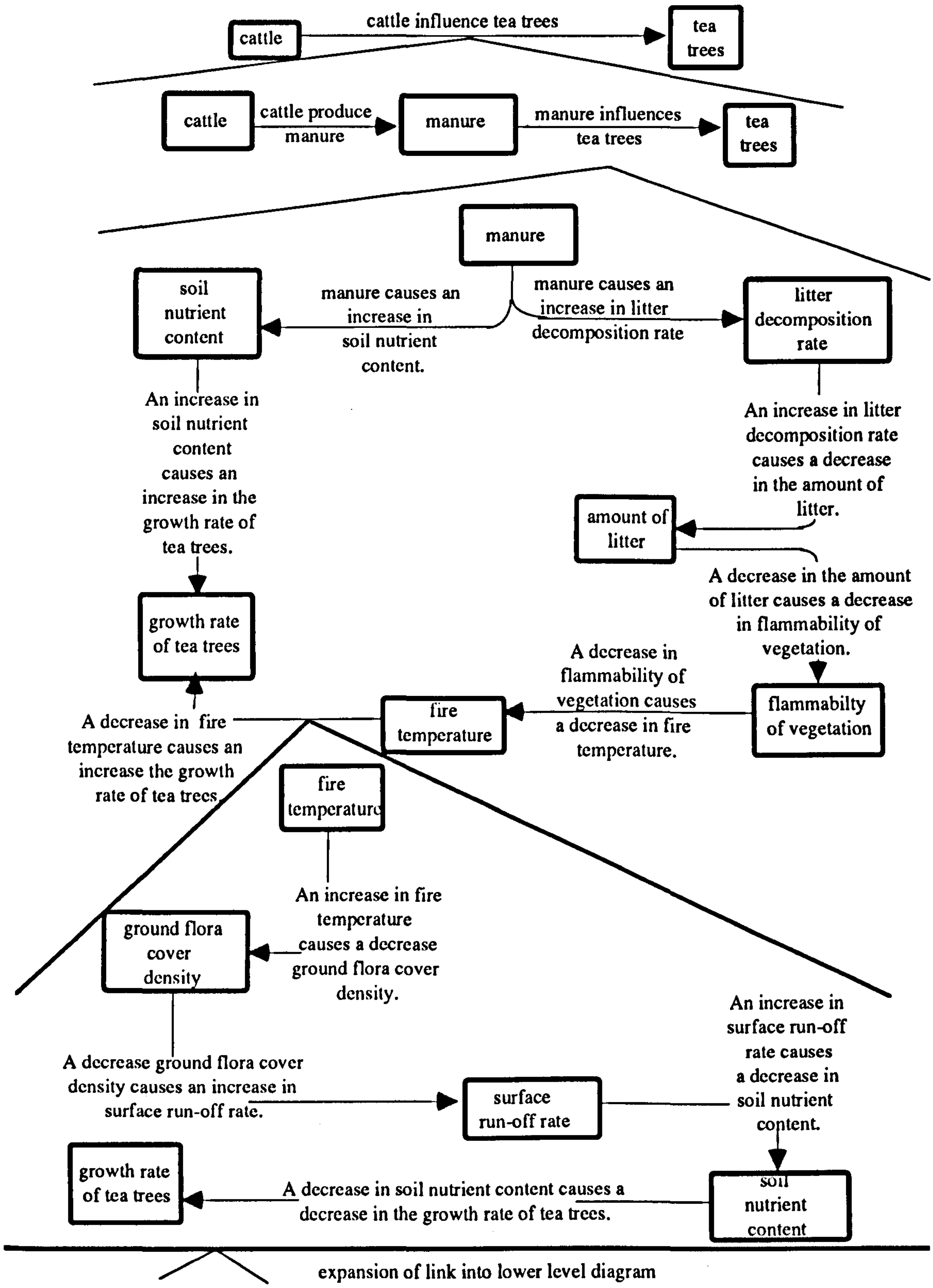


Figure 3.5 A section of the knowledge base about the effects of cattle on the tea trees growth rate constructed into a set of hierarchical link diagrams.

Key informants classified forest trees by using leaf characteristics into two kinds: forest trees with small leaves and large leaves (Table 3.5). However, the interviewer was not sure what the key informant meant by 'small' and 'large' leaves. The key informants provided more detail, when we went to see each forest tree. After the key informants showed the kind of forest trees, it was discovered that forest trees with 'small leaves' actually have compound leaves and forest trees with 'large leaves' had simple leaves. When key informants were asked about the size of leaf of the forest trees, most of the simple-leaved forest trees that were mentioned also had a small leaf size. Key informants also subclassified forest trees with simple leaves into chestnut trees and non-chestnut trees. They recognised that forest trees which provide nuts were chestnut trees and gave names to most of these trees. The first part of the local name being *ko,* such as *ko duie, ko muu doi* and *ko taamuu.* Only with *ma ko* was *ko* used as the last part of the tree name. However, the key informants did not subdivide forest trees with compound leaves.

Key informants also classified dominant ground flora in terms of prevention of soil erosion and surface run-off using leaf shape and size (see Figure 4.1). However, tea trees were divided by using colour of their leaf rather than leaf shape, orientation or size. *Miang rerng* were tea trees that had yellowy green leaves. *Rerng* is the Thai word for yellow. *Miang ee aam* are tea trees that have dark green leaves. However, key informants could not provide a direct translation of *ee aam* because it is an old name and none of the farmers knew its meaning. Key informants said that it might originale from the Khmu language. Farmers also suggested that the crowns of *miang rerng* were bigger than crowns of *miang ee aam* Key informants also classified small plants that grow on tea trees into two kinds orchids and parasitic plants. They did not subclassify the orchids because physical characteristics of the various orchids were similar and the features too small to be reliably observed with the naked eye. The people in the north call all kinds of orchids '*ueang*'.

Table 3.5 Some individual statements recorded about plant classification.

Forest tree is a type of plant.
Forest trees were classified by their leaf characteristics: compound and simple.
Kaang khemot (Albizia odoratissima) is a type of compound leaf tree.
Ma faen (Protium serratum) is a type of compound leaf tree.
Hian (Melia toosendan) is a type of compound leaf tree.
Forest trees with simple leaf structure were classified by their fruit characteristics: chestnut trees and non-chestnut trees.
Ko (chestnut) is a type of simple leaf tree.
Ko duie (Castanopsis acuminatissima) is a type of *ko* (chestnut).
Ko mon (Lithocarpus elegan) is a type of *ko* (chestnut)
Ko daeng (Quercus kingiana) is a type of *ko* (chestnut)
Tha lo (*Schima wallichii*) is a type of non-chestnut tree.
Chom phuu paa (*Eugenia albiflora*) is a type of non-chestnut tree.
Haat (*Ficus hirta*) is a type of non-chestnut tree.
Ground flora is a type of plant.
Dominant ground flora was classified by leaf inclination angle: vertical or horizontal.
Kuut pit (Dicranopteris linearis) is a type of ground flora with vertical leaf inclination.
Kuut kia (Pteridium aquilinium) is a type of ground flora with vertical leaf inclination.
Yaa khaa (Imperata cylindrica) is a type of ground flora with vertical leaf inclination.
Yaa pee wan (Eupatorium adenophorum) is a type of ground flora with horizontal leaf inclination.
Tea is a type of plant.
Miang rerng (Camellia sinensis) is a type of tea tree.
Miang ee aam (Camellia oleiferra) is a type of tea tree.
Orchid is a type of plant.
Parasitic plant is a type of plant.
Scurrula gracilifolia is a type of parasitic plant.
Helixanthera parasitica. is a type of parasitic plant.

The key informants were aware that there were two types of parasitic plant, but did not give specific names to these types. They called all kinds of parasitic plants '*kaafaak*' which refers to the behaviour of a cuckoo which lays it's eggs in nests of other bird species.

This iterative process of interviewing and assessing tea farmers knowledge resulted in two draft diagrams about the role of forest trees in controlling microclimate and nutrient cycling and about the role of cattle in controlling nutrients and facilitating germination of forest tree seeds. These together comprised 89 unitary statements. A further 286 statements were recorded in text format only.

3.5 Process of formalisation

The formalisation of knowledge in this research used the Agroforestry Knowledge Toolkit (AKT) software. This comprised two integrated programs; for knowledge acquisition (AKT1) (Walker, Sinclair and Kendon, 1995) and for reasoning with the acquired knowledge (AKT2) (Kendon *et al.*, 1995). The use of knowledge-based systems approaches and the development of the AKT is described in detail in the software manual (Walker *et al.*, 1994).

The process of formalisation involved computer coding the knowledge by creation of statements written in the restricted syntax of a formal grammar (Section 3.6.2). Because of the ambiguity and complexity inherent in language, accurate interpretation of unitary statements in unrestricted natural language may often be difficult. Natural language is extremely flexible in its use and interpretation; it can contain a great deal of ambiguity and imprecision. The meaning of natural language statements were often specific to the context in which articulation occurred, it cannot be clearly assumed that the contextual meaning of a unitary statement will still be understood by the user once it has been included in a knowledge base, if it remains implicit. Furthermore, automated reasoning techniques cannot cope with flexibility of meaning according to context. As a result, the next stage in the creation of knowledge base was to create a version of the natural language statements that conformed to a formal syntax (Walker *et al.*, 1995). The formal syntax was developed to be able to represent the knowledge collected from farmers in agroforestry research programmes in Nepal, Sri Lanka, Tanzania and Thailand. Formalisation could be done using the AKT package via either a diagrammatic or a textual interface. With the diagrammatic interface the computer generated formal statements in prolog corresponding to the diagrammatic structure created, step by step, by the user on the screen. With the text interface the user had to rewrite the natural language statement in the formal grammar; the system then parsed the statement and, if it conformed to the syntax of the grammar, accepted it. The key elements of statements (that is, the names of objects, attributes, values, processes and management actions, further described in Section 3.5.2) were automatically stored in glossaries within the knowledge-based system. Terms in glossaries could be organised in hierarchies, and definitions of terms and synonyms stored. In the present research formalisation proceeded according to the scheme shown in Figure 3.6. Casual knowledge was first formalised using the diagrammatic interface (Section 3.5.1) and then the remaining natural language statements were formalised using the text interface, the meaning of some statements being captured through the creation of formal statements (Section 3.5.2) others by the development of object hierarchies (Section 3.5.3).

3.5.1 Diagram interface

Formal methods had already been used to construct diagrams on paper (see Section 3.3.6). The major utility of the diagram approach was in organising knowledge and ensuring that comprehensive causal knowledge was elicited.

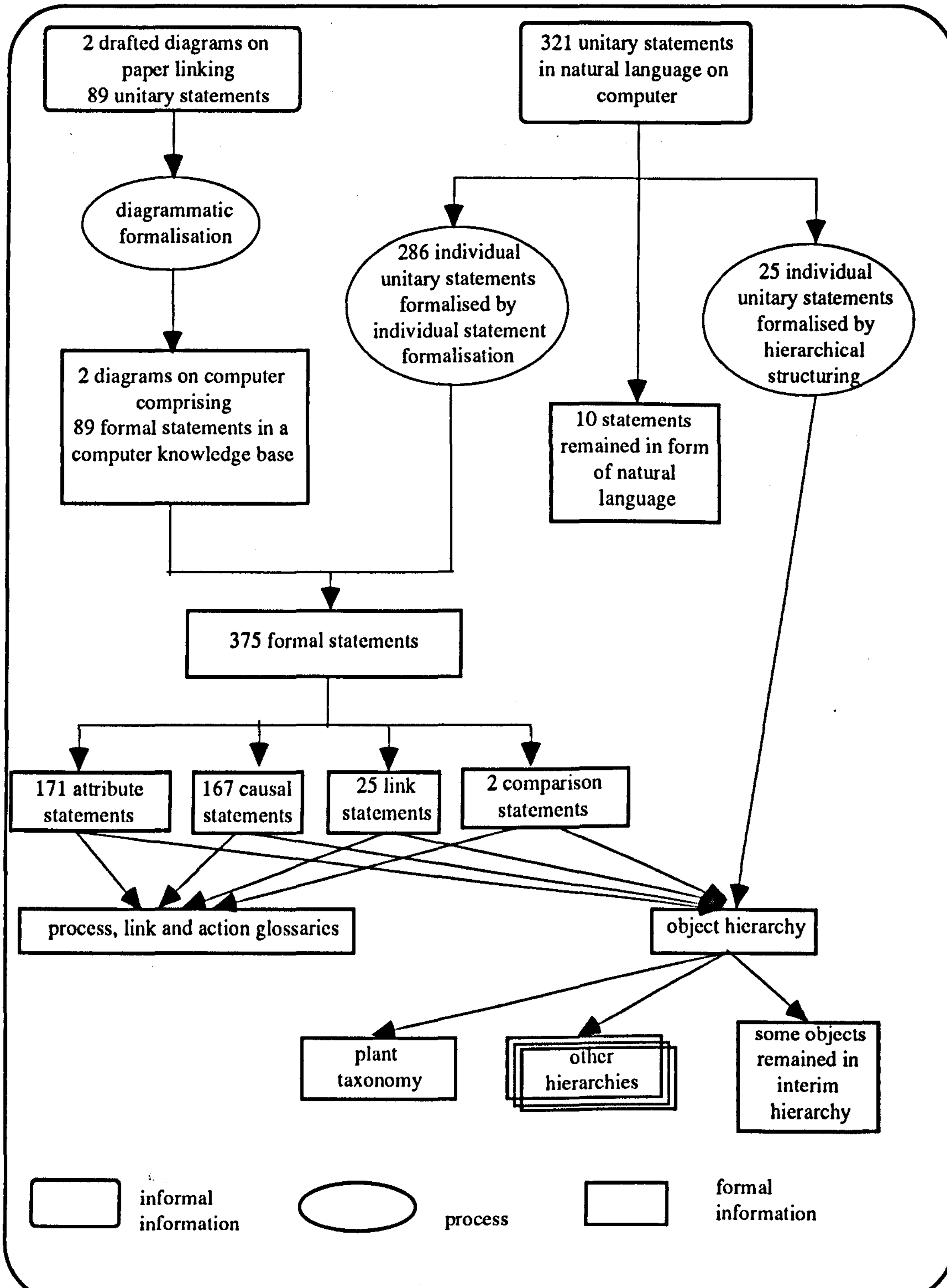


Figure 3.6 Summary of the process.

In particular, the diagrams provided a useful medium for reaching consensus amongst informants and between the researcher and informants, because, they were based on a defined set of symbols and conventions and, therefore, represented an unambiguous explanation of the domain in question. Since AKT1 had the formal diagramming syntax that had been used to create the draft diagrams on paper, implemented on computer, it was possible to simply re-construct the drafted diagrams using the diagramming interface. This resulted in the same diagram as on paper in a computerised from with a corresponding set of formal statements (conforming to the grammar) automatically generated by the computer. The resulting diagrams (Figures 4.3 and 4.4) comprised a set of knowledge that is significantly more coherent than a list of disaggregated text statements.

3.5.2 Text interface

In the process of formalisation with the text interface, the natural language statements were re-written according to the definite clause grammar provided in AKT1 and fully specified in Appendix 3.1. The formal representation both forces an unambiguous interpretation of the meaning of the statement and enables automated reasoning with the statement on computer. The formal statements, which may be conditional, include five fundamental elements; i) objects, which are physical items e.g. forest trees, tea bushes, rain; ii) processes (or events), that are natural changes or fluxes, e.g. germination, eating, burning; iii) actions, which are human induced changes or fluxes, e.g. pruning, weeding, picking; iv) attributes, which are properties of objects or processes; e.g. height of forest trees, rate of erosion or intensity of solar radiation; v) values, which are the measurable state of an attribute may be qualitative (e.g. low) as well as quantitative 5 t ha a^{-1} and may refer to a range (e.g. 5 to 10 t ha^{-1} a^{-1}) or may employ one of four special value terms in the grammar that indicate change (increase, decrease, change, or no change). The elements may be combined in four ways that involve i) associating attributes and values to objects or processes; ii) representing causal linkages; iii) representing other, user-specified linkages; and iv) making comparisons. A part construct is available to identify component parts of an object (e.g. leaf is a part of a tree) and causation may be two-way, in which case an increase in x causing an increase in y is automatically equivalent to a decrease in x causing a decrease in y; or one-way, in which case this equivalence does not necessarily hold. The way in which formalisation was done, was first to identify the key elements in a natural language statement (Table 3.6) and then select a statement type that most usefully captured the meaning of the whole natural language statement.

Table 3.6 Example of identification of elements of intermediate statements.

Natural language statement	Elements	Explanation
an increase in the rate of litter decomposition causes an increase in soil fertility.	'litter' and 'soil' are objects, 'decomposition' is a process, rate and fertility are both attributes, increase is a special value.	'rate' is an attribute of the process (decomposition) and 'fertility' is an attribute of the object. Both attributes take the special value 'increase'.
Eupatorium adenophorum has soft stems, if it is mature.	'Eupatorium adenophorum' and 'stem'are both objects, and 'soft' and 'mature' are values, although their attributes are implicit.	The statement can reasonably be supposed to be referring to an attribute of the object stem called 'hardness' and 'soft' is value of hardness. Similarly, 'maturity' can reasonably be supposed to be an attribute of the object *Eupatorium adenophorum* which takes the value 'mature'. Stem is a part of *Eupatorium adenophorum.*
Camellia sinensis crowns are bigger than *Camellia oleifera* crowns.	'*Camellia sinensis*'and '*Camellia oleifera*' are both objects, crowns are parts of objects. size is an attribute of the crowns, and bigger can be captured by the 'greater_than' comparison type.	'Size' can reasonably be supposed to be an attribute of crowns.
cattle graze on young leaves of *Imperata cylindrica*	'cattle', and '*Imperata cylindrica*' are objects, leaves are part of *I. cylindrica*', 'eat' is a link and 'young' is a value of the attribute maturity of the leaf .	In this case, 'maturity' can reasonably be supposed to be an attribute.

In general, since causal representation allowed more flexible reasoning with knowledge and diagrammatic representation, it was the most useful way to capture knowledge. Similarly comparison statements were more useful than link statements. All types of statements could have conditions appended to them. The outcome of the formalisation with the textual interface was a set of formal statements, examples of which are shown in Table 3.7.

Table 3.7 Examples of natural language statements and their corresponding formal equivalents.

Statement types	Natural language statements	Formal statements
Causal statement	an increase in tea stem height causes an increase in tea leaf quantity	att_value(part(tea, stem), height, increase) causes2way att_value(part(tea, leaf), quantity., increase)
Causal statement	Ingestion by cattle causes a decrease in seed dormancy rate of *Mangifera longipetiolat*	process(cattle,ingestion)causes1way att_value(process(part('Mangifera longipetiolate', seed), dormancy), rate, decrease)
Causal statement	weeding tea gardens causes no change in soil moisture content IF season is rainy	action(weeding, garden)causes1way att_value(soil, 'moisture content', no_change)if att_value(time, season, rainy)
Comparison statement	*Camellia sinensis* crowns are bigger than *Camellia oleifera* crowns	comparison(size,('Camellia oleifera', crown), greater_than, ('Camellia sinensis',crown)
Link statement	cattle eat young leaves of *Imperata cylindrica*	link(eat,cattle,part('Imperata cylindrica',leaf),if att_value(leaf, maturity,young)
Link statement	Cattle do not eat tea leaves	link(not_eat, cattle, part('tea tree', leaf))
Attribute-value statement	Quercus kingiana has small leaves	att_value(part('Quercus kingiana', leaf), size, small)
Attribute-value statement	rate of nutrient transfer of roots of castanopsis calathiformis is high IF roots of castanopsis calathiformis entwine tea root system	att_value_value(process(part('Castanopsis calathiformis',root) 'nutreint transfer'),rate,high)if link(entwine, part ('Castanopsis calathiformis',root), part (tea, root system')

3.5.3 Hierarchical structuring

The remaining knowledge was captured through the hierarchical structuring of objects. Walker (1994) suggested that hierarchies provide a means of increasing the parsimony of the knowledge base because they allow knowledge to be recorded at its most general level of application, but to be used to consider more specific instances, through consideration of the hierarchical relationship between terms. Berlin (1973) argues that the naming of plants and animals in folk systematics is essentially the same in all languages and can be described by a small number of principles. Most taxa in natural folk taxonomies are members of one of five ethno-biological classes: the unique beginner (e.g. all living things); life forms (e.g. forest tree, ground flora, herb), generic (e.g. chestnut, tea, grass), specific (e.g.white oak, *miang rerng)* and varietal (e.g baby lima bean, jasmine rice).

Information about the *miang* tea farmers' knowledge of plant classification in *miang* tea gardens in Section 3.5.2 could be compacted by utilizing a mechanism for recognising the hierarchical nature of the taxonomic statements as occurs when object hierarchies are created in AKT. For example, all statements about chestnut trees automatically apply to *Castanopsis acuminatissima, Lithocarpus elegan* and *Quercus kingiama.* Knowledge not explicitly stated can be deduced by applying the general rules to lower orders of the hierarchy. Hierarchical information is captured by identifying a parent-daughter relationship between two terms. In principle, it is not necessary to specify the nature of this relationship. So hierarchical ordering can simply provide a mechanism for indexing the keywords in a set of statements. In practice it has proved more productive to explicitly state the meaning of a hierarchical relationship by doing so the hierarchy produced becomes a more meaningful representation of source knowledge and provides a resource that can be more flexibly used in automatic reasoning (Walker, 1994). In AKT only one form of hierarchical linkage is supported in which the link captures the sense that 'A is a type of B' when A is the 'daughter' and B the 'parent'. Objects may be in any number of different hierarchics. Hierarchical classification is widely used in ethnographic research (Werner and Schoepfle, 1987a; Werner and Schoepfle, 1987b) for example, in deriving species taxonomies (Berlin, 1973; Thapa, 1994) and soil taxonomies (Benfer and Furbee, 1990). Rajasekaran and Warren (1995) also used this method to identify rice varieties in South India. Using the key word interface in AKT such information was captured in a hierarchical tree structure (Figure 3.7) and the separate statements made redundant since they were deducible from the hierarchy. The outcome of hierarchical structuring was a significant compaction of the knowledge base and an end result that could be more flexibly accessed and explored.

There were few unitary statements that could not be formalised. They remained in the form of natural language and could not be automatically reasoned with.

3.6 Discussion

An iterative cycle of knowledge elicitation and representation of *miang* tea farmers' ecological knowledge facilitated assessment of knowledge in respect of ambiguity, consistency in the use of terms and completeness of the knowledge base as a whole. Thus the knowledge base provides structured information in a form in which it can be tested, stored, accessed and used. This knowledge is encyclopaedic collecting knowledge within the community in relation to gender, age, class and wealth. The methodology comprised a set of increasingly restrictive forms of recording knowledge that led to coherent, consistent and comprehensive statements that are, therefore, useful for subsequent analysis and use rather than just for the descriptive presentation of the *miang* tea farmers' knowledge system.

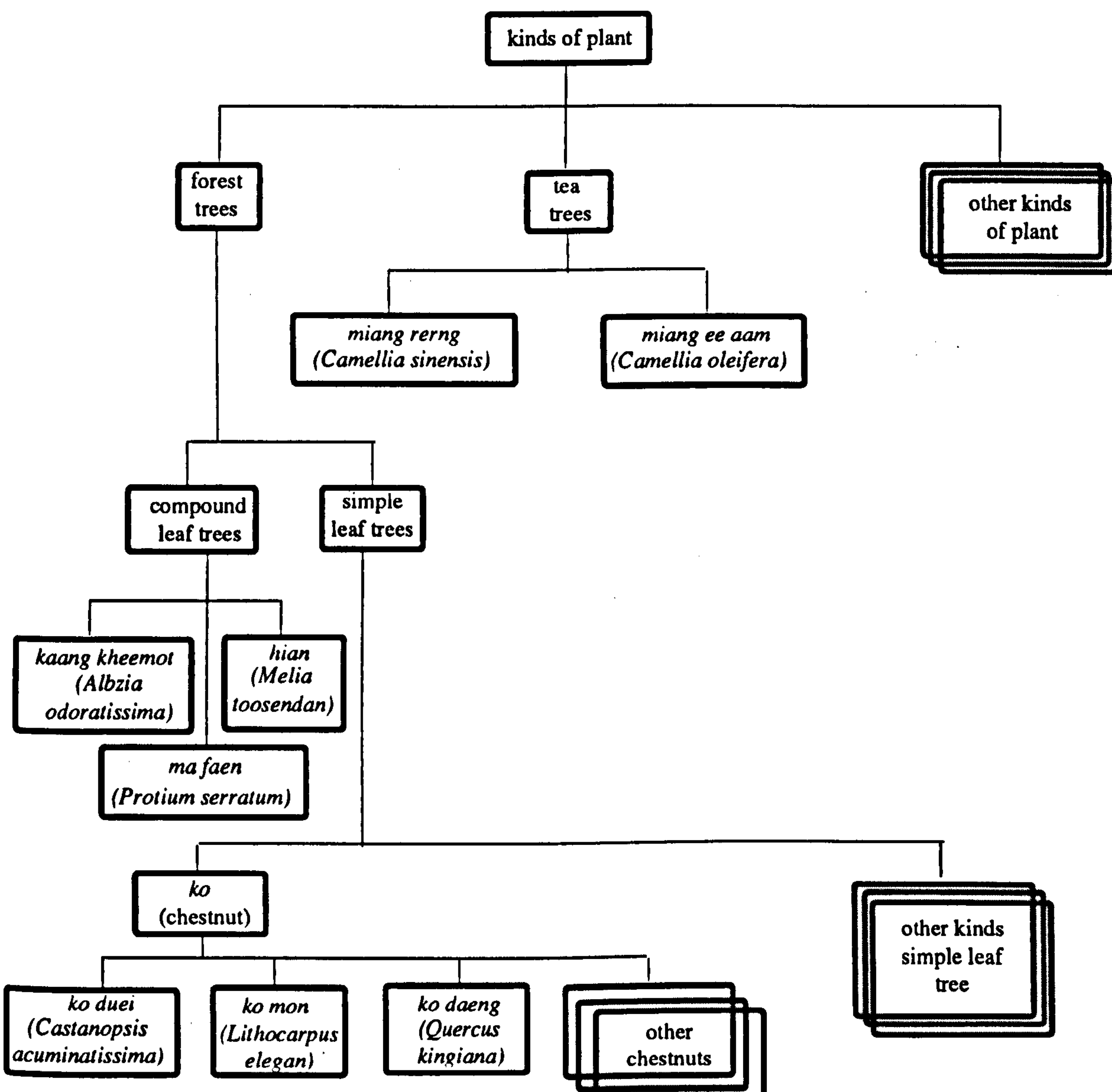


Figure 3.7 An example of part of the indigenous plant taxonomy used by *miang* tea farmers.

This study has elucidated *miang* tea farmers' ecological knowledge about the relationship between the main elements in the *miang* tea gardens, such as; tea trees, forest trees and ground flora, cattle, and environment processes, such as, solar radiation, rainfall, soil erosion and nutrient cycling including the farmers' activities. The knowledge was fully recorded as two diagrams, a hierarchy and a set of unitary statements. The set of unitary statements was recorded in natural language and represented in a computer coded form amenable to automatic reasoning defined by the restricted syntax of a formal grammar.

The process of acquisition used, especially, the formalisation, was useful because the information stored in the knowledge base could be presented in the form of diagrams, hierarchies and as sets of unitary statements, restricted to an unambiguous meaning by the nature of the formal grammar that encouraged precise representation of the knowledge. Therefore, it can be concluded that the information in the knowledge base is stored in a durable, accessible and transparent form. The contents of the knowledge base are analysed in the next chapter.

CHAPTER 4
THE KNOWLEDGE CONTENT

4.1 Introduction

The detailed process involved in the acquisition of indigenous ecological knowledge of *miang* tea farmers, including the structure of the resulting farmers' knowledge base were presented in Chapter 3. In this chapter, a range of systems and analytical approaches were used to evaluate the contents of the indigenous ecological knowledge base. Firstly, the subject themes contained in the knowledge base are described (Section 4.2), secondly, searching the contents of knowledge on each topic is presented (Section 4.3) and then the results of the analysis of the contents of the knowledge base are described (Section 4.4).

4.2 Subject themes contained in the knowledge base

The research topics in Chapter 3 (see Section 3.3.1) form the major subject areas covered in the knowledge base, although the need to understand the local classification of plants was identified through interviewing and knowledge representation during the acquisition phase (see section 3.5.2). Further assessment of the formalised knowledge using automatic reasoning procedures in AKT2 led to coherent sets of statements being abstracted on a number of management themes (Figure 4.1).

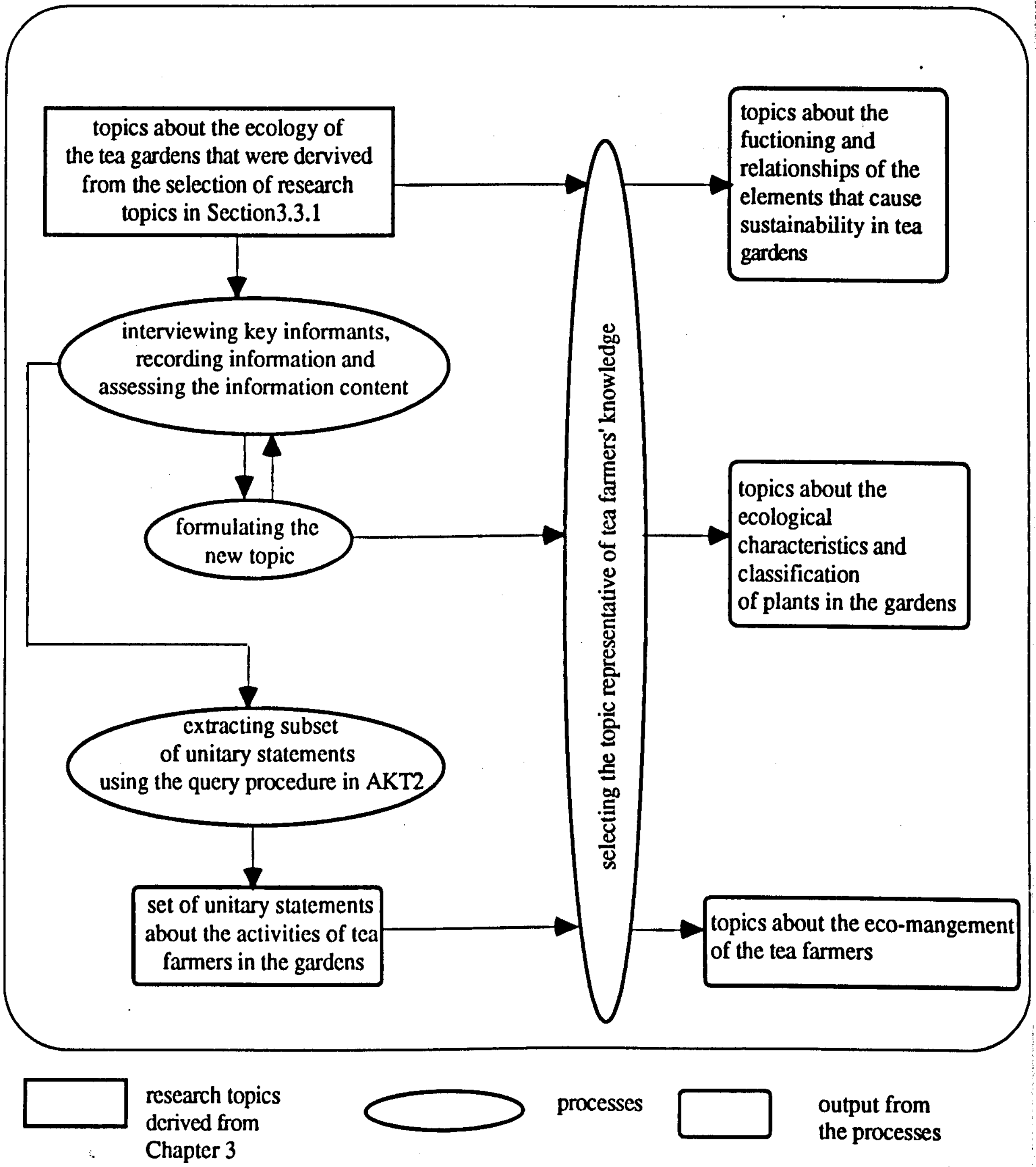


Figure 4.1 The process of selecting the topics that are representative of the content of the tea farmers knowledge base.

AKT2 is comprised of a basic graphical user interface (GUI) which is linked to a set of pre-defined reasoning tools. These tools were written in a task language, rather like a macro language in a spread sheet package that acts as an interface to the Prolog interpreter (Kendon *et al.,* 1995). The AKT2 task language has a number of pre-defined tools comprising a set of primatives and control structures which the user can employ to modify existing tools or define new tools. The searching procedures enabled the abstraction of subsets of knowledge on specific topics which could then be used as a basis for automated reasoning with the query primatives. The searches involved using appopriate combinations of keywords from the glossaries and/or object keyword hierarchies and the selection of subsets of unitary statements that contained these words to create a focussed 'extract' of the knowledge base. Prolog-type queries (Walker *et al.* 1994) were used to investigate whether the knowledge base contained certain specific items of knowledge. They basically returned a set of statements selected on the basis of the query, which could be formulated in relation to statement types (e.g. all the attribute value statements in an extract) or subjects (e.g. all the statements about chestnut trees in an extract).

4.3 Assessment of the content of the knowledge on each topic

From the reserch topics in Section 3.3.1, the tea farmers' knowledge about the fuctioning of and relationships between elements that ensure sustainability in the tea gardens, such as the role of forest trees in controlling microclimate and nutrient cycling and the role of cattle in the nutrient cycle, was presented in two diagrams with sets of statements linking between nodes in each diagram (see Figures 4.3 and 4.4). These had been formalised through the diagram interface (see Section 3.5.1). The diagrams and sets of statements can be searched using the 'Diagram' menu in AKT1. The knowledge about the classification of plants in tea gardens was therefore captured through the hierarchical structuring of objects. This hierarchy can be found using the 'Key word' menu in AKT1.

Further knowledge in other subtopics can be searched for using the query tool implemented in AKT2, this was used to investigate whether the knowledge was in the form of attribute-value statements, link statements, process statements or action statements.

Queries were made in the form of attribute-value statements and were used to identify statements in the knowledge base containing attributes and values of particular parts of an object or processes, for which the query procedures were:

att_value (X, Y, Z)

or

att_value (part(X, W), Y, Z)

or

and att_value(process (part (X,W),V),Y,Z).

Where X can be varied by the kind of tea species, such as, *Camellia oleifera, C. sinensis,* forest tree species, such as *Adinandra integerrima, Albziz odoratissima* or *Castanopsis cerebrina,* dominant ground flora, such as: *Dicranopteris linearis, Eupatorium adenophorum, Imperata cylindrica* or any other species of other kinds of plants in the *miang* tea gardens and Y, Z, W and U are variables. This query procedure returns a set of all the statements in the knowledge base containing attributes, values of each species of plant, part of plant and process, respectively. The example responses generated by this query are presented in Table 4.1.

The information generated by the query was then used to examine what attributes and values farmers had articulated about the ecological characteristics of tea, forest trees and the four dominant ground flora in the tea gardens and the comparative role of the four dominant ground flora in controlling soil erosion. Examples of conclusions possible from the information in Table 4.1 are summarised in Table 4.2.

Further queries were used to identify link statements in the knowledge base, for example, the set of knowledge about the effect of cattle in the *miang* tea gardens ecosystem and the role of cattle in facilitating the germination of forest tree seeds. The query procedure used was:

```
Link(X,cattle,Y)
```

where X and Y are variables, this returned a set of statements from the knowledge base containing all the link types and other objects involved with cattle in the definition of link types, relating to cattle. Some statements generated by this query are presented in Table 4.3.

The query tool was also used to investigate the process statements containing *miang* tea farmers' knowledge about the effect of cattle on forest tree seed dormancy, in this example, the query procedure was:

Table 4.1 An example of information extraction about attributes of *Adinandra integerrima* and *Dicranopteris linearis* using the query procedure. The set of natural language statements returned by the query and their formal equivalents are shown. The queries used to generate this information were att_value(X,Y,Z); att_value(part(X,W),Y,Z) and att_value(process (part (X,W),V),Y,Z); X was set to *Adinandra integerrima* and *Dicranopteris linearis*, respectively and the other variables (V,W, Y, Z) were returned by the procedure as shown.

Adinandra integerrima has dense canopies, if *Adinandra integerrima* is mature. att_value(part('*Adinandra integerrima*', canopy), density, dense)if att_value('*Adinandra integerrima*', maturity, mature) *Adinandra integerrima* has heavy shade, if *Adinandra integerrima* is mature. att_value(process('*Adinandra integerrima*', shade), intensity, heavy)if att_value('*Adinandra integerrima*', maturity, mature) *Adinandra integerrima* has medium stems, if *Adinandra integerrima* is mature. att_value(part('*Adinandra integerrima*', stem), height, tall)if att_value('*Adinandra integerrima*', maturity, mature) *Adinandra integerrima* has small leaves. att_value(part('*Adinandra integerrima*', leaf), size, small) rate of nutrient transfer to tea roots of *Adinandra integerrima* is high, if roots of *Adinandra integerrima* entwine tea roots. att_value(process(part('*Adinandra integerrima*', root), 'nutrient transfer to tea root'), rate, high)if link(entwine, part('*Adinandra integerrima*', root), part(tea, root)) rate of water transfer to tea roots of *Adinandra integerima* is high, if roots of *Adinandra integerrima* entwine tea roots. att_value(process(part('*Adinandra integerrima*', root), 'water transfer to tea root'), rate, high)if link(entwine, part('*Adinandra integerrima*', root), part(tea, root)). *Dicranopteris linearis* has light canopies, if *Dicranopteris linearis* is mature. att_value(part('*Dicranopteris linearis*', canopy), density, light)if att_value('*Dicranopteris linearis*', maturity, mature) *Dicranopteris linearis* has light roots, if *Dicranopteris linearis* is mature. att_value(part('*Dicranopteris linearis*', root), density, light)if att_value('*Dicranopteris linearis*', maturity, mature) rate of filtering out of solar radiation of canopy of *Dicranopteris linearis* is medium, if *Dicranopteris linearis* is mature. att_value(process(part('*Dicranopteris linearis*', canopy), 'filtering out of solar radiation'), rate, medium)if att_value('*Dicranopteris linearis*', maturity, mature) rate of increasing water infiltration is medium, if *Dicranopteris linearis* roots grow into soil. att_value(process('increasing water infiltration'), rate, medium)if link('grow into', part('*Dicranopteris linearis*', root), soil)

Table 4.2 Terms recognised by *miang* tea farmers in keyword glossaries formulated by the using the query tool to investigate the attribute statements about the ecological characterics of tea, forest trees and gound flora and their influence on the ecosystem.

Object	Part of object	Process	Attribute	Attribute-value
Tea	Bush		Size	Small, large
	Leaf		Size	Small, large
			Colour	Dark green, yellow green
Forest trees	Stem		Height	Short, medium, tall
	Leaf		Size	Small, large
	Crown		Density	Light, dense
		Growth	Rate	Low, medium, tall
		Shade effect	Intensity	Light, heavy
	Root	Water transfer to tea root	Rate	Low, medium, high
		Nutrient transfer to tea root	Rate	Low, medium, high
Ground flora	Stem		Hardness	Soft, hard
	Crown		Density	Light, dense
	Root		Density	Light, dense
	Crown	Filtering out of solar radiation	Rate	Low, medium, high
		Providing litter	Rate	Low, medium, high
		Reducing throughfall energy	Rate	Low, medium, high
	Leaf	Water transpiration	Rate	Low, high
		Decreasing surface run-off	Rate	Low, medium, high
		Increasing surface run-off	Rate	Low, medium, high
		Decreasing soil erosion	Rate	Low, medium, high
		Decreasing water infiltration	Rate	Low, medium, high
		Increasing water infiltration	Rate	Low, medium, high

Table 4.3 An example of information extracted about the effect of cattle in the *miang* tea garden ecosystem and the role of cattle in facilitating the germination of forest tree seeds. The query used to generate this information was: procedure: Link(X,cattle,Y).

cattle do not eat tea leaves.
link(not_eat, cattle, part(tea, leaf))

cattle eat *Andropogon micranthus* leaves.
link(eat, cattle, part('*Andropogon micranthus*', leaf))

cattle eat *Artocarpus heterophyllus* leaves.
link(eat, cattle, part('*Artocarpus heterophyllus*', leaf))

cattle eat bamboo leaves.
link(eat, cattle, part(bamboo, leaf))

cattle eat *Choerospondias axillaris* fruits.
link(eat, cattle, part('*Choerospondias axillaris*', fruit))

cattle eat *Coffea arabica* cherries.
link(eat, cattle, part('*Coffea arabica*', cherry))

cattle eat *Coffea arabica* leaves.
link(eat, cattle, part('*Coffea arabica*', leaf)).

cattle eat *Diospyros kaki* leaves.
link(eat, cattle, part('*Diospyros kaki*', leaf))

cattle eat *Elaeocarpus stipularis* fruits.
link(eat, cattle, part('*Elaeocarpus stipularis*', fruit))

cattle eat *Imperata cylindrica* young leaves.
link(eat, cattle, part('*Imperata cylindrica*', leaf)) if att_value(leaf, maturity, young)

cattle eat *Mangifera longipetiolate* fruits.
link(eat, cattle, part('*Mangifera longipetiolate*', fruit))

cattle eat *Nephelium litchi* leaves.
link(eat, cattle, part('*Nephelium litchi*', leaf))

cattle eat *Thysanolaena latifolia* young leaves.
link(eat, cattle, part('*Thysanolaena latifolia*', leaf)) if att_value(leaf, maturity, young)

cattle trample on annual crop.
link('trample on', cattle, 'annual crop')

cattle trample on seedlings.
link('trample on', cattle, seedlings)

process(cattle,X) causes att_value(A,B,C)

in which X, A, B and C are variables, this returned a set of all process statements that have an effect on attribute statements in the knowledge base. The responses generated by this query are presented in Table 4.4.

Table 4.4 Information about processes of management used by *miang* tea farmers generated using the query procedure. The query used to generate this information was: process(cattle,X) causes att_value(A,B,C).

cattle ingestion causes a decrease in seed dormancy rate of *Choerospondias axillaris*.
process(cattle, ingestion)causes1way att_value(process(part('*Choerospondias axillaris*', seed), dormancy), rate, decrease)

cattle ingestion causes a decrease in seed dormancy rate of *Elaeocarpus stipularis*.
process(cattle, ingestion)causes1way att_value(process(part('*Elaeocarpus stipularis*', seed), dormancy), rate, decrease)

cattle ingestion causes a decrease in seed dormancy rate of *Mangifera longipetiolate*.
process(cattle, ingestion)causes1way att_value(process(part('*Mangifera longipetiolate*', seed), dormancy), rate, decrease)

cattle ingestion causes a decrease in seed dormancy rate of *Melia toosendan*.
process(cattle, ingestion)causes1way att_value(process(part('*Melia toosendan*', seed), dormancy), rate, decrease)

Finally, the query tool was used to generate action statements, as a set of statements about *miang* tea garden mangement. This was achieved through the use of query procedure:

action(X,Y) causes att_value(A,B,C)

in which X, Y, A, B and C are variables, it returned the set of all action statements which have an effect on attribute statements. The responses generated by this query are presented in Table 4.5.

Table 4.5 Information about the management of *miang* tea farmers generated using the query procedure. The query used to generate this information was: action(X,Y) causes att_value(A,B,C).

growing tea with irregular spacing causes an increase in tea leaf size.
action(growing, 'tea with irregular spacing')causes1way att_value(part(tea, leaf), size, increase)

growing tea with narrow spacing causes a decrease in tea leaf size.
action(growing, 'tea with narrow spacing')causes att_value(part(tea, leaf), size, decrease)

making a fire barrier causes a decrease in fire frequency, if season is summer.
action(making, 'a fire barrier')causes1way att_value(process(fire), frequency, decrease) if att_value(time, season, summer).

making a fire barrier causes a decrease in fire temperature, if season is summer.
action(making, 'a fire barrier')causes1way att_value(process(fire), temperature, decrease)if att_value(time, season, summer)

supplying fertiliser causes no change in tea tree growth rate.
action(supplying, fertiliser)causes1way att_value(process(tea, growth), rate, no_change)

picking tea leaves causes an increase in tea leaf initiation rate.
action(picking, part(tea, leaf))causes1way att_value(process(part(tea, leaf), initiation), rate, increase).

ploughing gardens causes an increase soil erosion rate, if season is rainy.
action(ploughing, garden)causes1way att_value(process('soil erosion', rate, increase) if att_value(time,season, rainy)

ploughing gardens causes a decrease soil moisture content, if season is rainy.
action(ploughing, garden)causes1way att_value(process(soil, 'moisture content', decrease) if att_value(time,season, summer)

pruning tea causes a decrease in tea leaf size.
action('tea pruning')causes1way att_value(tea, leaf, size)

pruning tea causes a decrease in tea leave quantity.
action('tea pruning')causes1way att_value(tea, leaf, quantity)

terracing gardens causes no change soil moisture.
action(terracing, garden)causes1way att_value(soil, 'moisture content', no_increase)

weeding gardens causes a decrease soil moisture, if season is summer.
action(weeding, garden)causes1way att_value(soil, 'moisture content', decrease) if att_value(time, season, summer)

weeding gardens causes an increase nutrient cycling rate, if season is rainy.
action(weeding, weed)causes1way att_value(process(nutrient, cycling), rate, increase) if att_value(time, season, rainy).

weeding gardens causes no change in nutrient cycling rate, if season is summer.
action(weeding, garden)causes1way att_value(process(nutrient, cycling), rate, no_change) if att_value(time, season, summer).

4.4 The contents of the knowledge base

The contents of the information of farmers' knowledge consists of: knowledge about the kinds of flora and some of their ecological characteristics that have an effect on the ecosystem in *miang* tea gardens (Section 4.4.1); knowledge about the role of forest trees in the *miang* tea gardens (Section 4.4.2); knowledge to be able to compare four dominant ground flora in their erosion control (Section 4.4.3); knowledge of the role of cattle in the *miang* tea gardens (Section 4.4.4); and knowledge about *miang* tea garden management (Section 4.4.5).

4.4.1 Farmers' knowledge about garden flora and their ecological characteristics

The *miang* tea farmers recognised four kinds of plants in the gardens (Figure 4.2). The farmers also recognised that there are two kinds of tea. Most of the farmers pick tea leaves for *miang* from *miang rerng* because of the large size of its leaves and the yellow colour of steamed leaves which is desirable for the consumer. *Miang ee aam* has small leaves which have a dark green colour. Most of the farmers have stopped picking this kind of tea leaf because of the steamed leaves being dark green, for which there is no longer a market. Previously, before the introduction of *miang rerng* to the area *miang ee aam* was harvested and a market for it existed. *Miang rerng* is *Camellia sinensis* var. *assamica* whereas *miang ee aam* is *Camellia oleifera* Abel. var. *confusa* (Smitinand,1980). Wight (1962) classified *C. sinensis* var *assamica* as an Assam tea variety, while Kingdon-Ward, (1950) described *C. oleifera* Abel. var. *confusa* as a Combod race. However, *C. oleifera* Abel. var. *confusa* was considered by Wight (1962) to be a sub-species of *C. assamica* and named *C. assamica* ssp. lasiocalyx (planchon ex Watt).

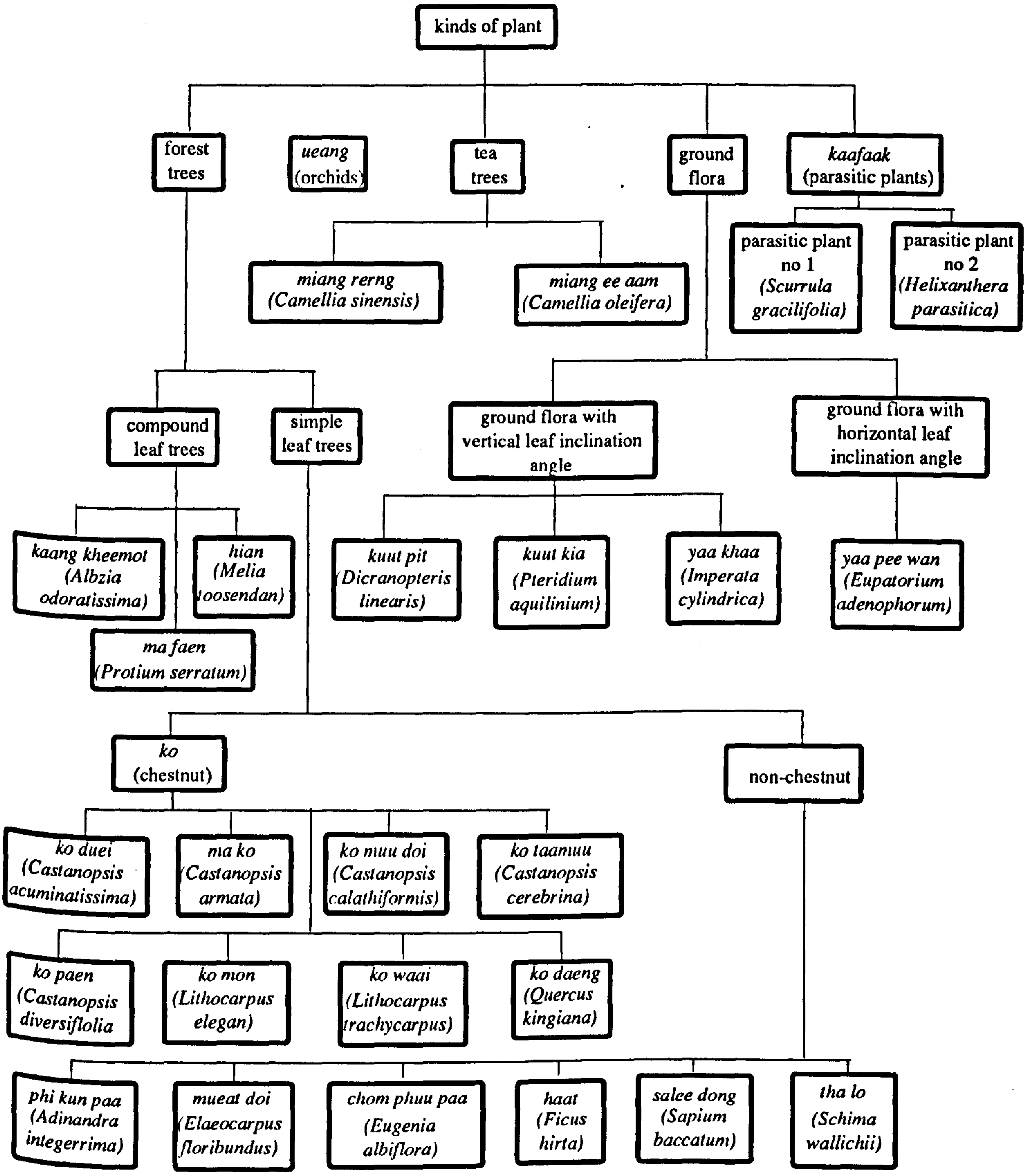


Figure 4.2 Indigenous plant taxonomy of tea garden plants.

From the interviews with *miang* tea farmers it was found that, in the past, the farmers grew *miang ee aam* until *miang rerng* was introduced by tea farmers from another *miang* tea village. Since tea from *miang rerng* is less bitter than that tea from *miang ee aam*, it was preferred. Therefore, *miang* tea farmers changed to grow *miang rerng* instead of *miang ee aam*. The survey in this study found that most of tea trees in the study site were *miang rerng* .

The farmers recognised that at least 17 forest tree species in the tea gardens fell into one of two groups; trees having simple leaves and trees having compound leaves. The farmers mentioned only three species that have compound leaves, but 14 species that have simple leaves. Eight species of simple leaf trees were recognised as varieties of chestnut species. The farmers suggested that most of forest tree species are tall when they are mature and most have a slow growth rate. Fourteen forest tree species provide heavy shade (Table 4.6) because of having a small leaf size and a dense crown. The farmers said that there was a relationship between leaf size, tree height and shade effect. The farmers cut down some forest trees, if they considered that the intensity of shading was too high. The wood from trees felled in this way was used for fire wood.

The farmers recognised that four dominant types of ground flora grow underneath the canopy of the forest trees, having two kinds of leaf inclination angle: vertical and horizontal. All species of ground flora were said to have soft stems. (Table 4.7). Two of the four gound flora species had a dense canopy and a dense root system.

Table 4.6 The characteristics of some forest tree species recognised by *miang* tea farmers as influencing shade, recycling of nutrients and the moisture and nutrient status of intercropped tea.

Forest tree species	Attributes				Intensity of interaction effect		
	Tree Height	Leaf size	Crown density	Growth rate	Shade effect	Water transfer to tea	Nutrient transfer to tea
Adinandra integerrima	Medium	Small	Dense	Slow	Heavy	High	Medium
Albzia odoratissima	Tall	Small	Light	Fast	Light	Low	High
Castanopsis cerebrina	Tall	Small	Dense	Slow	Heavy	High	High
Castanopsis acuminatissima	Tall	Small	Dense	Slow	Heavy	High	High
Castanopsis . armata	Tall	Small	Dense	Slow	Heavy	High	High
Castanopsis calathiformis	Tall	Small	Dense	Slow	Heavy	High	High
Castanopsis diversiflolia	Tall	Small	Dense	Slow	Heavy	High	High
Elaeocarpus floribundus	Medium	Small	Dense	Slow	Heavy	Medium	High
Eugenia albiflora	Medium	Small	Dense	Slow	Heavy	Medium	High
Ficus hirta	Short	Large	Dense	Fast	Heavy	Low	Low
Lithocarpus elegan	Tall	Small	Dense	Slow	Heavy	High	High
Lithocarpus trachcarpus	Tall	Small	Dense	Slow	Heavy	High	High
Melia toosendan	Medium	Small	Light	Fast	Light	Low	Medium
Protium serratum	Tall	Small	Light	Fast	Light	Low	Medium
Quercus kingiana	Tall	Small	Dense	Slow	Heavy	High	High
Sapium baccatum	Medium	Small	Dense	Slow	Heavy	High	Medium
Schima wallichii	Tall	Small	Dense	Slow	Heavy	High	High

Table 4.7 Characteristics of four dominant ground flora species recognised by *miang* tea farmers as having an effect on erosion and soil moisture in *miang* tea gardens and recycling nutrients.

Dominant ground flora species	Attribute			Intensity of interaction effect			
	Hardness of stem	Canopy density	Root density	Efficiency in prevent -ing soil moisture loss	Efficiency in prevent -ing solar radiation	Trans- piration rate	Efficiency providing litter
Dicranopteris linearis	Soft	Light	Light	Medium	Medium	Low	High
Eupatorium adenophorum	Soft	Dense	Dense	High	High	Low	Medium
Imperata cylindrica	Soft	Dense	Dense	Low	Low	High	Low
Pteridium aquilinium	Soft	Light	Light	Medium	Medium	Low	High

4.4.2 Farmers' knowledge about forest trees in *miang* tea gardens

Tea trees are one element in the natural forest ecosystem. Most people in the extreme north of Thailand call the *miang* tea gardens *'Pa miang'*. *Pa* means natural forest, *miang* means tea trees (another meaning of *miang* is fermented tea leaves). The farmers' indigenous knowledge about forest trees in tea gardens consists of knowledge about the role of forest trees in controlling microclimate (section 4.4.2.1) and; in the water cycle (Section 4.4.2.2) and nutrient cycle (section 4.4.2.3).

4.4.2.1 The role of forest trees in controlling microclimate

Miang tea farmers grow tea trees in the forest (as opposed to a monoculture), because it is widely believed that the forest ecosystem, including the ground flora and litter (fallen leaves and branches), increases the quality and quantity of tea leaves by controlling the microclimate (Figure 4.3).

An analysis of the collected knowledge showed that three reported factors contributed to the quality and quantity of the tea leaves.

4.4.2.1.1 Solar radiation

The farmers believed that the shade, created by the thick forest canopy, decreases the high solar radiation that could burn the tea leaves. The shading also increases the yellowness and softness of tea leaves, which are then accepted as having high quality.

4.4.2.1.2 Atmospheric temperature

The shade of the forest canopy regulates the atmospheric temperature. The forest canopy maintains a mass of cold air beneath it, which the farmers state improves the quality and quantity of the tea leaves. It also allows them to comfortably work for longer, maintaining and picking the tea crop. During the winter months, the atmospheric temperature is also buffered by the forest canopy. The farmers said that this prevents frost, which causes wounds on the tea leaves, making them susceptible to tea leaf spot disease.

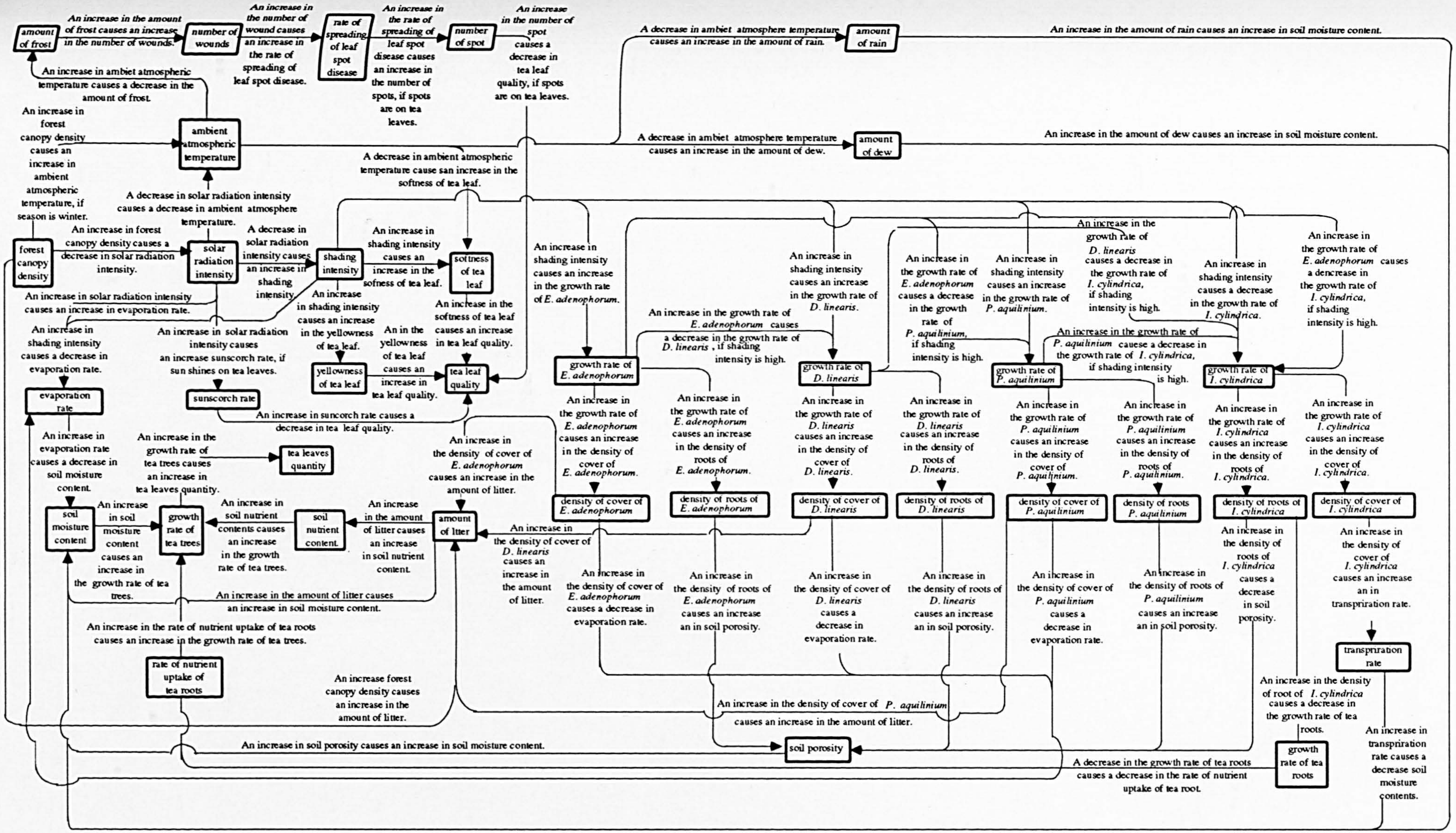


Figure 4.3 Indigenous ecological knowledge of the role of forest trees in controlling microclimate and recycling nutrients.

4.4.2.1.3 Soil moisture

The shade of the forest trees influences the level of moisture in the soil. The farmers state that a high level of moisture in the soil increases the number of tea leaves and three different mechanisms were proposed for the way in which the shade of the forest trees achieved this as detailed below.

(1) Decreasing the evaporation rate

The forest tree canopy reduces the solar radiation receipt below the canopy and solar radiation evaporates the water from the soil and reduces the moisture present in the atmosphere. The farmers state that the level of moisture in the soil and the atmospheric humidity is greater under a dense forest canopy than in areas of low cover.

(2) Increasing the amount of precipitation (rain and dew)

The amount of precipitation is affected by the forest canopy as the farmers believe that the dense forest canopy indirectly increases precipitation by reducing the atmospheric temperature. Both the soil moisture and reduced atmospheric temperature improve growing conditions for the tea trees.

(3) Controlling ground flora

Finally, the forest shade provides suitable growing conditions for some species of ground flora, namely *Dicranopteris linearis, Eupatorium adenophorum* and *Pteridium aquilinium*. The farmers detailed how these plants grow well under heavy shade and, again, by protecting the soil against solar radiation, the plants themselves maintain the soil moisture level. Furthermore, the forest shade restricts the growth of *Imperata cylindrica,* which is said to reduce the level of moisture in the soil due to its high transpiration rate.

The farmers also suggest that soil moisture is conserved by the presence of leaf litter, so the farmers leave the litter in the gardens, even though it presents a fire hazard. They make fire lines by clearing the ground flora and litter around the gardens and help other farmers if their tea gardens catch fire.

4.4.2.2 The role of forest trees in the water cycle

As well as influencing the soil moisture level, a further benefit that the farmers said was derived from the forest trees is that they serve as a water source for the tea trees. Their root system is believed to be connected to the tea tree root system, supplying it with water. For this reason the farmers will plant tea tree seeds and seedlings near to forest trees or saplings. If there are no forest trees in the area that the farmers propose to plant tea, the farmers transfer forest seedlings from another place and replant them near to the tea. This causes the spacing of trees in the gardens to be irregular.

4.4.2.3 The role of forest trees in the nutrient cycle

Farmers said that forest trees play an important role in the cycling of nutrients in the *miang* tea gardens. They take up nutrients from the soil and then, it is believed, supply these nutrients to the tea trees and other plants in one of two different ways.

Firstly, the farmers believe that root systems of forest trees directly supply not only water but also nutrients to the root system of tea trees. The farmers also advocate that the litter from forest trees enriches the soil for the tea trees. The farmers suggest that tree species with small leaves are the most efficient in the nutrient cycle as the small leaves decompose at a faster rate. As a result, the farmers do not even produce a compost from the leaves, but they have learnt to leave them as they fall naturally.

Secondly, the farmers believe that the forest trees shade and suppress the growth of *I. cylindrica* which is believed to stunt tea tree growth. The root system of *I. cylindrica*, which is dense as the roots weave together closely, is felt to disturb and compact the soil. Such compact roots make it difficult for water to infiltrate into the soil as well as it being difficult for the roots of other plants to grow into the soil. It was also suggested that the root system of *I. cylindrica* competes with the root system of other plants, absorbing water and nutrients at their expense. Therefore, it was believed that seedlings that germinate near *I. cylindrica* cannot grow to a normal size.

In contrast, it was believed that the shade of forest trees increases the growth of *E. adenophorum, D. linearis* and *P. aquilinium*. Under dense shade, *E. adenophorum, D. linearis* and *P. aquilinium* will replace *I. cylindrica*. An increase in flora produces more ground litter which, as it decomposes, will provide nutrients to the top soil and ultimately to the tea trees and other plants.

The tea farmers' knowledge about the sustainability of the tea garden ecosystem appears to be based on ecological concepts. The farmers believe that forest trees are the dominant component in the *miang* tea garden ecosystem. Forest trees can be used to control the tea garden ecosystem if there are sufficient trees and canopy. Forest trees are used to naturally select the undergrowth that grows underneath the canopy. The farmers also believe that the forest trees control the water cycle; increasing rainfall, soil moisture and dew, reducing evaporation, preventing frost and supplying water. Furthermore, the forest trees control tea growth and the growth of other plants by the recycling and supply of nutrients.

4.4.3 Farmers' comparison of the erosion control of four dominant types of ground flora

There are four dominant ground flora species in the tea gardens; *Eupatorium adenophorum, Dicranopteris linearis, Pteridium aquilinium* and *Imperata cylindrica.*

The farmers call the plant *E. adenophorum 'yaa pee wan' Yaa* means grass or small plant, *Pee* means ghosts or spirits and *Wan* means to scatter. Thus a '*yaa pee wan*' is a plant dispersed by forest spirits. *E. adenophorum* is in the family of *Chrysanthemum* and normally grows on the banks of a stream. The farmers believe that *E. adenophorum* retains soil moisture because it provides a dense ground cover, however, this also decreases the growth of tea and forest seedlings in the gardens. It also makes it difficult for tea pickers to walk in the gardens in the tea picking season, so the farmers simultaneously weed *E. adenophorum* as they pick the tea leaves. The farmers say that it is easy to remove this species because of its soft stems. The farmers prefer *E. adenophorum* to cover the gardens because they believe that it keeps the soil cold or '*din yen*'. The farmers attribute to this plant not only a reduced soil temperature but also decreased solar radiation, increased soil fertility and soil moisture retention. The farmers suggest its dense roots increase soil porosity and its dense ground canopy reduces the throughfall energy of rain (Preechapanya, 1984) so minimising soil erosion.

D. linearis (*kuut pit*) and *P. aquilinium* (*kuut kia)* are both ferns. Farmers call them *'phug kuut'; Phug* means vegetable, but they are not a vegetable and *kuut* is the name of these ferns. People in upper north Thailand sometimes call small plants with soft leaves vegetables, whether or not they are edible. Table 4.4 shows how it was felt that an increased canopy of *D. linearis* and *P. aquilinium* reduces throughfall energy. Some farmers suggest that *D. linearis* and *P. aquilinium* are less effective in decreasing the throughfall energy than *E. adenophorum* because the ground canopy of both ferns is less dense, implying that they are also less effective in minimising soil erosion (Table 4.8).

Table 4.8 Indigenous knowledge comparing the ecological effects of four dominant ground flora in erosion control.

Ground flora species	Throughfall energy	Surface run-off	Soil erosion	Water infiltration
E. adenophorum	- -	-	- -	+
D. linearis	-	- -	-	+ +
P.aquiliunium	-	- -	-	+ +
I. cylindrica	- -	+	- - -	-

Note: + causes an increase, - causes a decrease; the greater the number of symbols the greater the effect.

It was believed that *D. linearis* and *P. aquilinium* improve soil porosity due to their copious litter-fall and a root system which penetrates well into the top soil. *E.*

adenophorum produces less litter and has a less extensive root system, leading to less infitration of water into the soil and so more surface run-off.

I. cylindrica is a dominant ground flora species in the *miang* tea gardens, especially in drier areas and on poor soils. Its local name is '*yaa khaa*'. *Khaa* means roof. Some people use its leaves to make temporary roofs. The villagers believe that it produces a hot soil '*din ron*'. This may be because it does not protect the soil from solar radiation. As the soil temperature rises, so the moisture evaporates, producing a very dry soil. *I. cylindrica* has a compact root system, which, whilst reducing water infiltration also controls the amount of soil erosion. It is difficult for surface run-off to erode a compact soil.

I. cylindrica was said to be more effective in controlling soil erosion than *E. adenophorum, D. linearis* and *P. aquilinium.* Furthermore, the foliage reduces throughfall energy, which also reduces the level of erosion. However, *I. cylindrica* competes heavily for the available nutrients and water in the tea gardens. Its presence was felt to indicate poor soil fertility, a disturbed soil structure and a very dry soil.

Therefore *E. adenophorum* , *D. linearis* and *P. aquilinium* are favoured for the conservation of soil and water. They are considered so effective that the building of terraces is unnecessary.

4.4.4 Farmers' knowledge about the role of cattle in the *miang* tea gardens

In the past, most farmers raised cattle to transport *miang* tea leaves to the town market and then carry goods from the town to the village. These cattle caravans returned not only with goods but also with cultural ideas and knowledge. They also encouraged people from the lowlands to migrate and become *miang* tea farmers, with some townsfolk eventually marrying *miang* tea farmers.

Nowadays, cars are used for transport, with the consequence that *miang* tea farmers have either reduced their herds or stopped raising cattle altogether. Some cattle are kept for weeding the *miang* tea gardens, for food or for selling. The village committee of Ban Mae Ton Luang are against farmers raising cattle because cattle eat the fruit and leaves of fruit trees and trample on the fruit and especially coffee seedlings. Many *miang* tea farmers have been encouraged to grow coffee due to the high price obtainable for coffee beans.

Tea farmers' knowledge about the role of cattle in *miang* tea gardens consists of the role of cattle in nutrient recycling (Section 4.4.4.1) and facilitating the germination of tree seeds (Section 4.4.4.2).

4.4.4.1 The role of cattle in the nutrient cycle

Although cattle feed on the young leaves of *I. cylindrica* and *Thysanolaena maxima*, forest tree fruits and bamboo, it is believed that they do not eat tea leaves. The cattle appear to benefit the forest tea gardens in a variety of ways described below.

(a) Forest fire control

With the reduction of cattle, it is believed that the amount and intensity of garden fires has increased. The farmers who still raise cattle in their own gardens explain that in summer, shifting cultivators, who live near the village, prepare the land for cropping by burning the dry grass. These fires then spread into the *miang* tea gardens. Cattle kept in the gardens reduce the biomass and canopy of the ground flora, especially *I. cylindrica,* which serves as a fuel to the fires. These fires all contribute to the loss of nutrients and soil erosion in the *miang* tea gardens. This knowledge is detailed in Figure 4.4.

(b) Leaf-litter dispersal

The farmers also said that as the cattle walked around in the gardens, they scattered leaf-litter. Better spread litter decomposes more quickly and is less likely to catch fire. If fire occurs when litter is scattered the farmers believe that the intensity of the fire is not enough to damage the tea trees.

(c) Nutrients

Cattle excrement and urine increased the nutrient level in the top soil. These waste products also speed up the decomposition of the litter. As cattle cease to be raised, the farmers said that the growth rate of tea trees decreased and their *miang* tea gardens became less productive.

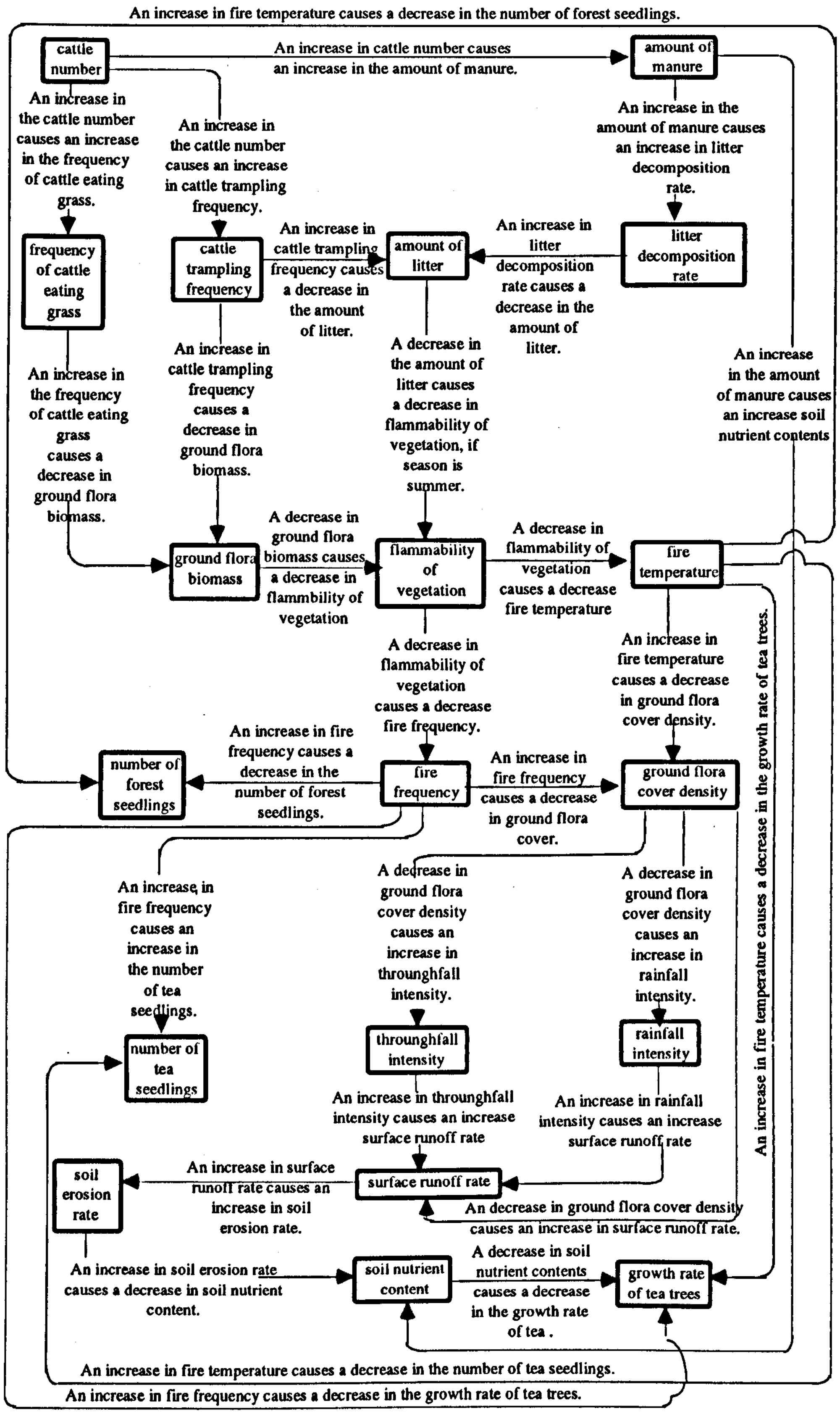


Figure 4.4 *Miang* tea farmers' indigenous knowledge about the role of cattle in recycling nutrients and controlling fire.

In summary, the farmers thought that, when limited to the carrying capacity of the *miang* tea garden ecosystem, cattle would benefit the tea tree growth rate. Without cattle, the biomass and ground flora would increase during the summer season. This led to farmers spending more time or paying more money to weed their gardens.

4.4.4.2 The role of cattle in germinating tree seeds

The farmers suggested that cattle help to reforest the gardens and are one of the factors affecting plant succession.

The farmers said that cattle eat the fruits of several forest tree species: *Elaeocarpus stipularis, Choerosondias axillaris, Mangifera longipetiolate* and *Melia toosendan* and then disgorge the seeds. They suggested that cattle encourage the germination of forest trees by breaking the dormancy and scattering the seeds. The farmers believed that cattle are necessary to germinate some forest tree seeds.

During interviews, farmers suggested that they would ask permission from the village committee to raise cattle in their *miang* tea gardens again. This shows that the farmers have derived knowledge from their experience of keeping cattle, which they accept are an important component of the *miang* tea garden ecosystems.

4.4.5 Farmers' management in the *miang* tea gardens

The activities of farmers in the *miang* tea gardens consists of growing tea trees, picking tea leaves, weeding, collecting firewood, growing and maintaining forest trees and making a fire barrier (an area surrounding the tea garden cleared of ground flora and litter to prevent fire in the summer season). The farmers grew tea trees from both seedlings and seeds. They maintained that tea trees grown from seedlings had a faster growth rate than those grown from seeds. The farmers grew tea trees in the beginning of raining season, so that the young tea trees received water from rain and dew. The farmers do not grow tea trees every year. They only plant tea trees when they want to expand the gardens, establish new gardens, increase the density of tea trees or replace dead tea trees. Growing tea trees is not the main activity of the farmers.

Picking tea leaves is one of the main activities of the farmers (see Section 2.4.6.9). The farmers spend eight months of the year picking tea leaves and processing the *miang* tea (see Figure 2.9). Some farmers spent a further three months picking tea leaves for green tea .

Collecting firewood is another activity of the farmers, especially, male farmers. Processing and cooking *miang* needs a lot of firewood (see Section 1.1.2). This has caused some officers of the Royal Forest Department to censure the production *miang* tea due to it being a cause of deforestation. Moreover, Castillo (1990) suggested that *miang* tea farmers should grow their own firewood rather than cut down the natural forest. He also suggested using *Eucalyptus camaldulensis* and *Melia azedarach,* which are fast growing trees. However, the farmers maintained that the activity of reforestation is not necessary in the area because the process of planting, succession and the system of farmers' siliviculture (see Section 2.4.5.2 and Section 4.4.4) can increase the number of forest trees. The farmers said they were careful of forest seedlings, when weeding their gardens. Sometimes, they reforest by transferring seedlings from other areas, especially when the fire barrier surrounding a garden is cleared. The farmers argue that this not only protects the tea trees but also provides forest seedlings and litter that decomposes to provide nutrients.

Weeding is the other main activity that takes up farmers' time. They said that they allowed shade and cattle to control the growth rate of the ground flora. After weeding, the farmers leave ground flora in the gardens to decompose. Weeding in the gardens is carried out in the raining season due to the plants decomposing at a faster rate.

The farmers were not interested in the introduction of new technology for making terraces to control erosion. They maintained that the ground flora has a high efficiency in reducing the energy of rain and surface water. They also do not want to change the spacing of tea trees from irregular spacing to narrow spacing and to cut the stems of the tea trees to form tea bushes, even though extension workers have insisted that the farmers change the tea garden system in this way. The farmers said that tea bushes produce leaves that are too small for *miang* production. However, farmers had adopted a new kind of stove and pot for steaming tea leaves, which has reduced the firewood requirement. This suggests that while farmers would adopt technologies that met their needs and did not violate constraints they would not adopt new technologies they knew or supposed would have a detrimental impact.

4.5 Discussion

The study showed that indigenous ecological knowledge about the sustainability of tea gardens in the hill evergreen forest is based on three principal concepts.

Firstly, the *miang* tea farmers use natural resources as tools for controlling the ecological balance in the *miang* tea gardens. For example, forest trees were used to control the balance of water and nutrients. The farmers also used cattle to control the growth rate of the ground flora. They had not adopted new technologies extended to them: e.g. terracing, irrigating, ploughing, chemical fertilisers, pesticides or tea pruning methods.

Secondly, the farmers conserved the biodiversity of the ecosystem rather than constructing a monoculture. *Miang* tea gardens in northern Thailand are different from those in many tea plantations in that they support many species of plants and animals including a diverse ground flora, bamboos, epiphytes, fungi and fruit trees. The *miang* tea farmers derive an income from selling tea leaves, whilst also collecting mushrooms, chestnuts, bamboo shoots and herbs for home consumption, using forest trees for house building and firewood or using grass from the gardens for pasture or fodder.

Finally, the farmers maintain the structure of *miang* tea garden ecosystems similar to that of natural forest ecosystems. As a result, they believe that the *miang* tea garden ecosystem is sustainable. Tea gardens may be used as a tool for controlling and developing other natural resources; such as a catchment area supplying water for drinking, hydroelectricity and fire protection and action as a buffer zone for protecting natural forest or preventing shifting cultivation.

4.6 Summary

Analysis of the knowledge base established that the farmers recognised two kinds of tea, at least 17 forest trees species and four dominat groud flora in the *miang* tea gardens. The forest trees were believed to be the dominant plants in the *miang* tea gardens ecosystem; controlling the microclimate and both water and nutrient cycles. A comparison was made between the ground flora; *E. adenophorum, P. aquilinium, D. linearis* and *I. cylindrica,* and their effect in controlling surface run-off and soil erosion. *I. cylindrica* is believed to be most efficient in controlling soil erosion and *P. aquilinium, D. linearis* in reducing surface water run-off. Finally, the role of cattle was analysed, and their effect on the nutrient cycle and the germination of seeds.

4.7 Conclusion

The results of this research provides an insight into the level of indigenous ecological knowledge held by the *miang* tea farmers about the sustainability of tea gardens. This includes knowledge about the components and processes within the ecosystem; the role of the forest, the ground flora and the cattle and their effect on the growth of the tea crop. It has led to an understanding of the land use management employed by farmers. The farmers have established an agroforestry system; maintaining the tea crop within the forest and allowing the natural biodiversity. The tea farmers' knowledge appears to have been developed through their own experience. They manage their gardens and the biodiversity in their gardens because they spend a large amount of time working in their gardens. However, it is very difficult for the farmers to explain their understanding of fundamental components and ecosystem processes because of their low levels of education. Some of their knowledge contrasts with basic scientific knowledge. For example, farmers said that the root system of forest trees is connected to the root system of tea trees, that they had observed better tree growth and yield when tea trees were planted close to forest trees. A comparison of farmers' and scientific knowledge is made in Chapter 6. The knowledge was derived from a small sample of key informants selected because they were knowledgeable and articulate. The extent to which this knowledge is representative of the knowledge held by the majority of the farmers in the village is explored in Chapter 5.

CHAPTER 5
REPRESENTATIVENESS OF KNOWLEDGE

5.1 Introduction

In any community, people may differ in experience, education, behaviour, culture, age, gender, socio-economic status, race, nationality and religion. It is reasonable to assume, therefore, that different people will have different knowledge. This applies to *miang* tea villages in the highlands of northern Thailand as much as anywhere else. Socio-economic and demographic research at the study site has established that the people vary in age, size of land holding, location of *miang* tea gardens and economic status. Mass communication, especially radio and television has also influenced farmers' knowledge through programmes about agricultural technology and the environment. Extension workers also have an influence on the farmers' knowledge through introduction of new technologies. Thus indigenous ecological knowledge about the sustainability of *miang* tea gardens in the hill evergreen forest may be constantly changing and developing. The tea farmers may also have differing ideas, knowledge and experience about the management of their gardens depending upon their exposure to various external influences as well as differences in their activities and abilities. However, most *miang* tea farmers rarely travel from their villages', that are far from neighbouring towns, so that there is much exchange of knowledge within the community but less opportunity for external interaction. This has consequences for their approach to tea planting. For example, the pattern and structure of gardens are similar amongst farmers. It is logical to assume, therefore, that the knowledge held by the *miang* tea farmers, especially that about garden ecosystems will also be similar amongst people. The research described in this chapter addressed the following two objectives:

- to evaluate the representativeness of the indigenous ecological knowledge acquired from a small sample of key informants in relation to the knowledge of the whole community, and

- to identify knowledge that is common to most of the tea farmers in the village.

5.2 Evaluation of the representativeness of the knowledge base

A questionnaire was designed for testing the attitude of the tea farmers in the study area to the knowledge represented in the knowledge base. It is not immediately apparent how best to measure representativeness. There are essentially two broad types of approach. The first involves asking people non-leading questions to see if the same knowledge as is already in the knowledge base is obtained from a statistically based rather than purposively selected sample of informants. Such an approach was adopted by Thapa (1994), but essentially represented a further knowledge elicitation exercise, and being time and labour intensive, could only involve a very small and highly focused part of the knowledge base. A second and potentially more efficient alternative, however, adopted here, is to present what is in the knowledge base to people and explore their attitude to it. Measuring attitudes, however, is a complex field. Soothasupa *et al.* (1993) stated that attitude is a way of feeling or thinking about someone or something, especially as this influences one's behaviour. Krech *et al.* (1962) elaborated that an attitude is a system of evaluation, in which people cling to their own beliefs or ideas. Foster (1971) suggested that people have different attitudes because of their individual experience, value systems and judgement. Freedman *et al.* (1970) divided attitude into three components: a cognitive component, a feeling component and a behaviour component whereas Newcomb (1950) simply saw attitude as a function of the characteristics of the environment that affects the knowledge of people. In the present context, the concern is with peoples' attitude to specific items of knowledge, so that attitude may be grossly classified as either agreement or disagreement. However, Intarawicha (1972) has suggested that there are, in fact, three useful classes of attitude in such circumstances. The first attitude is positive: to agree, confirm or please; the second attitude is negative: to disagree, challenge or displease; and the final attitude is one of indifference, no action, or 'don't know'. One of the key issues in evaluating ecological knowledge represented as disaggregated sets of unitary statements, however, is its conditionality. Thapa (1994), for example, found that many apparent contradictions during his evaluation of knowledge were caused by respondents implicitly assuming different contexts within which statements might be true. For example, when evaluating statements about effects of tree attributes on leaf drip erosion, some respondents assumed that rainfall was heavy and others that it was light, and thus, although they had the same underlying knowledge, they gave different responses because they were assuming different rainfall conditions. To allow for this in the present work, four basic responses were anticipated: agreement, agreement with conditions, disagreement or 'don't know'.

The basic approach adopted to eliciting information on people's attitude was to present information to them in the form of a questionnaire to which respondents were asked which of the four responses, explored above, most accurately reflected their view of the item of knowledge under consideration in each question. The questionnaire was divided into two parts: the first part was for testing individual statements (Section 5.2.1), the second part was designed to test linked sets of statements as depicted in diagrams where the linkages between statements were evaluated as well as the statements themselves (Section 5.2.2).

5.2.1 Testing individual statements

The first part of the questionnaire survey, tested the farmers agreement with individual statements. The knowledge base contained 375 statements, 20 statements excluding the statements tested in Section 5.2.2 were randomly selected to be presented to informants for them to confirm or refute. Half of these 20 statements were then randomly allocated to remain in the form in which they appeared in the knowledge base while the other half were inverted so that disagreement with the statement indicated agreement with the knowledge base. The ten statements that were selected to remain in their original form consisted of six causal statements and four attribute statements. The answers allowed were: 'agree', 'agree with conditions', 'disagree' and 'do not know'. An example from the questionnaire is shown in below:

"an increase in ambient atmospheric temperature causes an increase in the amount of dew".

	Agree
	Agree with conditions
	Disagree
	Do not know

Conditions specified:

Only one answer could be chosen. If the interviewees gave the answer 'agree with conditions', they were asked to give details of the conditions.

To allow for the possibility that informants tend to simply agree with statements the other 10 statements were 'inverted'. The statements that were inverted consisted of six causal statements and four attribute statements. These statements were inverted, as follows.

The selected causal statements were changed to have the opposite meaning so that 'an increase' was changed to 'a decrease' or 'a decrease' to 'an increase', For example;

"an increase in shading intensity causes a decrease in the softness of tea leaves"

was inverted to

"an increase in shading intensity causes an increase in the softness of tea leaves"

In the selected attribute statements, the elements being compared were reversed, for example:

"*Sapium baccatum* has dense crowns, IF *Sapium baccatum* is mature."

was changed to

"*Sapium baccatum* has light crowns IF *Sapium baccatum* is mature."

The percentage agreement with the statements was computed. The mean values of the percentage agreement with the statements, the standard deviation and 95 % confidence limits were calculated. When the confidence limit of the sample of people disagreeing with the knowledge base included zero (or those agreeing included 100 %), there was no significant disagreement. Where there was a significant level of disagreement, the type of people who disagreed were examined to discern any trends in those members of the community who disagreed with the knowledge.

5.2.2 Testing diagrams and statements linking nodes

Two parts from each diagram in Chapter 4 (See Figures 4.3 and 4.4) and the statements used to link between nodes in these diagrams were selected as a basis for testing the representativeness of the diagrammatic integrity of the knowledge base. These were:

- the influence of forest trees on soil nutrients and moisture that cause an increase in the quantity of tea leaves, and
- the influence of cattle on the incidence of fire and hence the growth of tree seedlings.

The questionnaire was divided into two sub sections. The intention of the first sub section was to test sets of statements that were grouped into causal chains (e.g. a causes b, b causes c) in diagrams resulting from analysis of the contents of the knowledge base. This section did not give any indication of the validity of the chains themselves, but did test the conclusions that can be drawn from the chain (e.g. a causes c). For example see Figure 5.1.

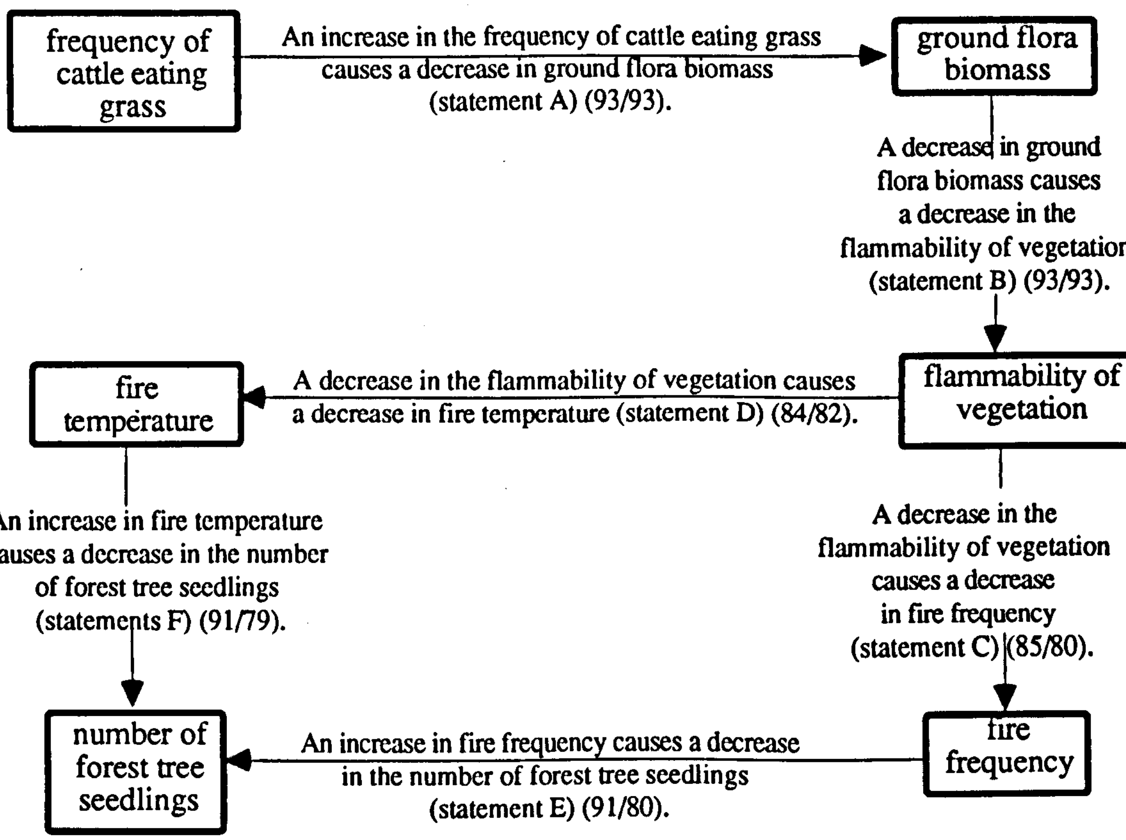


Figure 5.1 Indigenous knowledge about the role of cattle on the number of forest tree seedlings used for testing *miang* farmers' knowledge.The first number in brackets is the percentage confirming that particular statement. The second number is the accumulated percentage of people confirming all statements up to that point in the chain of linked statements.

In this case the allowable answers were 'confirm' or 'not confirm'. The informants were tested using the following procedure;

i) Which of the following occur the when number of cattle in the tea garden is increased :

☐	Ground flora biomass and flammability of vegetation increases
☐	Ground flora biomass and flammability of vegetation does not change
☐	Ground flora biomass and flammability of vegetation decreases
☐	Don't know

If the third option was chosen statement A and B in Figure 5.1 were confirmed.

ii) When do fires occur most frequently :

☐	Where ground flora is heavy
☐	Where ground flora is light
☐	There is no difference in relation to density of ground flora
☐	Don't know.

If the first option was chosen statement C in Figure 5.1 was confirmed.

iii) Which fires are the hottest :

☐	Fires in light ground flora
☐	Fires in heavy ground flora
☐	No difference
☐	Don't know

If the second option was chosen statement D in Figure 5.1 was confirmed

iv) Where will there be the greatest number of forest tree seeds?

☐	where fires are frequent and very hot
☐	where fires are frequent and not very hot
☐	where fires are not very frequent but are very hot
☐	where fires are not very frequent and are not very hot.

If the third or fourth option was chosen statement E in Figure 5.1 was confirmed. If the second or fourth option was chosen statement F in Figure 5.1 was confirmed.

v) Where will the greatest number of forest tree seeds be found?

☐	Where many cattle are grazed
☐	Where few cattle are grazed

If the first option was selected then, "an increase in the frequency of cattle eating grass causes an increase in the number of forest tree seedlings", was confirmed. The percentage of confirmed statements linking nodes and the accumulated percentage of confirmation along each chain were computed, as shown in Figure 5.1 and Table 5.1.

The second sub section was intended to give an indication of the validity of the chains of causal connections in a diagram (e.g. a causes b if a causes c and c causes b). The questions in this section were to test the understanding of whole chains of causal connections. The informants were asked a non-leading question and the elements of their answer categorised according to whether or not connecting statements had been articulated. An example of the implications of a statement set (that in Figure 5.1) are shown in Table 5.2. The percentage of agreement of whole chains causal connections was computed.

Table 5.1 Percentage confirmation and accumulated confirmation of the chain of statements that shows the role of cattle in facilitating the growth of tree seedlings by reducing fire frequency.

Statements being tested	Confirmation (%)	Accumulated confirmation (%)
An increase in the frequency of cattle eating grass causes a decrease in ground flora biomass.	93	93
A decrease in ground flora biomass causes a decrease in flammability of vegetation.	93	93
A decrease in flammability of vegetation causes a decrease in fire frequency.	85	80
An increase in fire frequency causes a decrease in the number of forest tree seedlings.	91	80
THEREFORE An increase in the frequency of cattle eating grass causes an increase in the number of forest tree seedlings.	82	

Table 5.2 An example of a question which tested the understanding of a whole chain of causal connections.

The implications of Figure 5.1 are that there will be more forest tree seedlings where cattle eat heavily than where cattle eat lightly because ground flora biomass and flammability of vegetation will be decreased, thereby decreasing fire frequency and temperature.

What effect will increasing the frequency of cattle eating grass have on the number of forest tree seedlings and why?

TICK FACTS IF CONFIRMED IN ANSWER (contents of brackets count as one tick):

Cattle reduce ground flora biomass and flammability of fire.

BECAUSE

(Reduced ground flora biomass and flammability of fire reduces fire frequency
AND
Reduced ground flora biomass and flammability of fire reduces fire temperature) [ ]

(Increased fire frequency causes reduction in the number of forest tree seedlings
AND
Increased fire temperature causes reduction in the number of forest tree seedlings) [ ]

5.3 Sampling and the socio-economic and demographic status of respondents

A tenth of the tea farmers in the village (100 farmers over 15 years old, excluding those previously interviewed) were randomly selected and interviewed using the questionnaire described above.

The respondents were well balanced in relation to gender, 45 % male and 55 % female, closely representing the sample of key informants in the knowledge elicitation where 50 % of each sex were represented purposefully. The breakdown of respondents in terms of age range and land holding size is consistent with the socio-economic description in Chapter 2. There were twice as many female as male respondents in the 26-35 year old age range reflecting the migration of males in this age range to work in the cities (Figure 5.2). Half of the respondents had a land area more than 0.8 ha, while 10 % were landless (Figure 5.3).

5.4 Results and discussion

The results of testing and analysing the representativeness of the knowledge base are divided into two parts: agreement with individual text statements (Section 5.4.1) and agreement with linked statements in diagrams (Section 5.4.2).

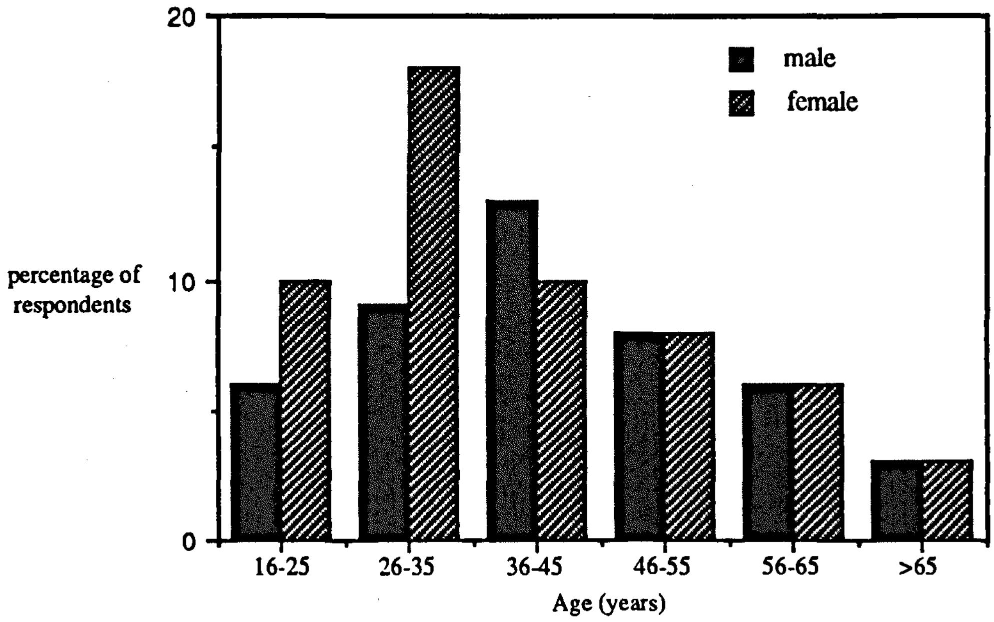


Figure 5.2 Gender status of respondents (n=100).

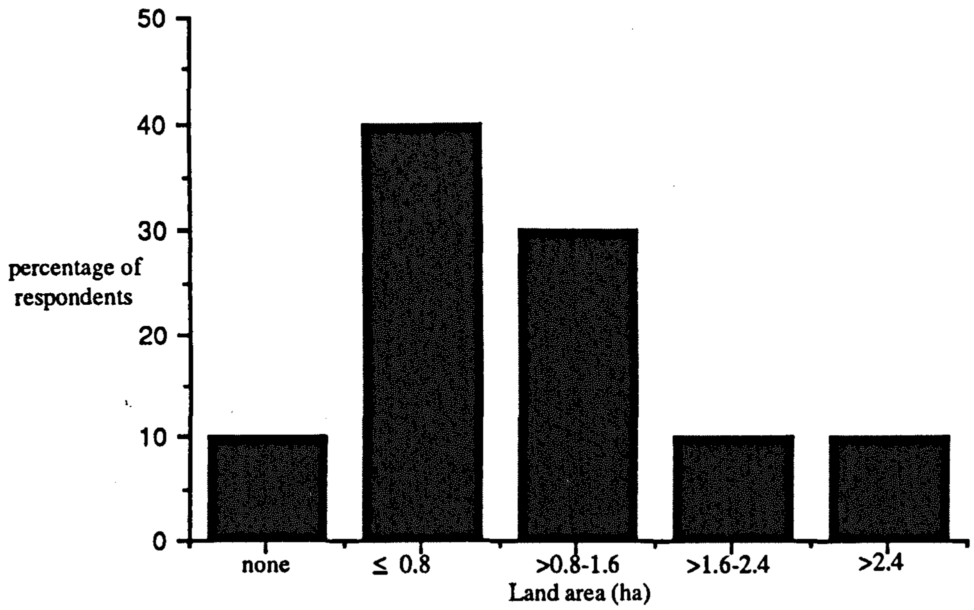


Figure 5.3 Total land area used by household of respondents (n=100 household) including area of *miang* tea gardens and homegardens.

5.4.1 Testing the agreement of individual text statements

Over three quarters of the respondents confirmed the statements (either by agreeing to statements in original format or disagreeing with inverted statements) and only a remarkably few of respondents (around 5 %) failed to make a judgement (Table 5.3).

Table 5.3 Overall percentage of *miang* farmers' agreement with individual statements (n=100 farmers for each statement means ± standard error for n=10 statements).

	(1)	(2)	(3)	(4)	(5)
Kind of statement	Agreement without condition	Agreement with condition	Disagreement (confirmation for inverted statements)	Did not know	Confirmation for original statements (1)+(2)
Original	63.70±25.24	24.30±22.55	6.60±4.64	5.40±3.58	88.00±5.52
Inverted	17.70±7.47	1.40±2.51	74.30±9.43	6.60±3.20	

Most of the respondents who disagreed with statements were male farmers who had little or no lands. Most of them are not original *miang* tea farmers. They were from the lowlands and came to the village because they got married to a villager or wished to grow *miang* tea. Six male respondents and seven female respondents were migrants. They were between 16-35 years old and had no lands or held less than 0.8 ha. Most of them had migrated to the village in the last 10 years. It may be expected, therefore that most of the people in these circumstance have less knowledge about *miang* tea gardens than the original villagers. The cropping systems in the lowlands is different from the *miang* tea gardens in the highlands. They may be expected, therefore, to have different knowledge from that of *miang* tea farmers. For example, they refute that cattle do not eat tea leaves or eat young leaves of *Imperata cylindrica* because most of the lowland farmers used machinery on their farm rather than using cattle for cultivation. This disagreement may, therefore, arise because they had little experience regarding the behaviour of cattle. A few respondents appeared not to understand the statements. Most of them were young female farmers who also were from the lowlands. By comparison with the male migrated respondents, these young female respondents said 'did not know' rather than 'disagree'. This suggests that most of the young migrant male farmers had different knowledge about cultivation compared with the original tea farmers, while most young migrant female farmers had less knowledge. However the percentage of respondents who replied 'do not know' to the statements about some plant species was high (Tables 5.4 and 5.5), for example, 15 % of respondents did not know about the growth process of *Dicranopteris linearis* and *Imperata cylindrica* or characteristics of *Sampium baccatum* crowns. This may be because some *miang* tea farmers had none of these kind of plants in their gardens and therefore had no direct experience of these species. It is possible that younger women were less able or willing to articulate knowledge then other groups of respondents for cultural reasons, which may contribute to the high 'don't know' frequency in their responses.

The standard errors for the overall percentage of agreement with the original statements (n=10) with and without conditions were very high because a high proportion of respondents chose each of these categorises from different questions. Most respondents agreed without conditions with the link statements and the attribute value statements. With most causal statements, a high proportion of respondents only conditionally agreed. For example, in the statement about the process of erosion, explanation given by farmers for their categorisation revealed that they said the kind of ground flora affected surface run-off that in turn caused an increase soil erosion. Most of conditions proferred by respondents had appeared in other statements in the knowledge base.

Table 5.4 Percentage agreements with original statements. (n=100 respondents) Abbreviation: Ag+Ac=Agreement with and without condition, Ag=Agreement without condition, Ac=Agreement with condition, D=Disagreement and DK='don't know'.

Statements being tested	(1) Ag (%)	(2) Ac (%)	(3) D (%)	(4) DK (%)	(5) (1)+(2) (%)	95 % confidence interval of (5)
A decrease in ambient atmospheric temperature causes an increase in the amount of dew.	10	80	6	4	90	90±5.88
Special condition (1) if forest canopy is dense.		80				
Cattle don't eat tea leaves.	95	0	3	2	95	95±4.27
An increase in surface run-off rate causes an increase in soil erosion rate.	15	70	5	10	85	85±7.00
Special condition (1) if *Imperata cylindrica* cover is dense.		30				
Special condition (2) if other ground flora cover is light.		40				
Cattle eat *Mangifera longipetiolate* fruits.	86	0	10	4	86	86±6.80
Elaeocarpus floribundus has dense crowns, if *Elaeocarpus floribundus* is mature	70	8	20	2	78	78±8.12
Special condition (1) if the trees grow in the valley.		4				
Special condition (2) if the trees grow on the mid-slope		2				
Special condition (3) if the trees grow near the river bank.		2				
An increase in *Dicranopteris linearis* growth rate causes a decrease in *Imperata cylindrica* growth rate, if shade intensity is high.	20	55	10	15	75	75±8.49
Special condition (1) if soil nutrient is high.		40				
Special condition (2) if soil moisture is high.		10				
Special condition (3) if site is burned.		5				
Elaeocarpus adenophorum has heavy shade, if *Elaeocarpus adenophorum* is mature.	98	0	0	2	98	98±2.74
Rate of nutrients transfer to tea roots of *Castanopsis armata* roots is high, if *C. armata* roots entwine tea roots.	70	17	12	1	87	87±6.59
Special condition (1) if soil moisture is high.		17				
Rate of preventing surface run-off of land is medium, if *Dicranopteris linearis* grow into soil.	75	13	0	12	88	88±6.37
Special condition (1) if site is on slope.		13				
Castanopsis armata has small leaves.	98	0	0	2	98	98±2.74

Table 5.5 Percentage agreement with inverted statements, therefore, disagreement is equivalent to confirming what is in the knowledge base. (n=100 respondents) Abbreviation: Ag=Agreement without condition, Ac=Agreement with condition, D=Disagreement and DK='don't know'.

Statement being selected	(1) Ag (%)	(2) Ac (%)	(3) D (%)	(4) DK (%)	95 % confidence interval of (3)
cattle don't eat *Imperata cylindica* young leaves.	10	0	87	3	87±6.59
Dicranopteris linearis has dense roots, if *Dicranopteris linearis* is mature.	13	0	85	2	85±7.00
Dicranopteris linearis has dense cover, if *Dicranopteris linearis* is mature.	20	3	75	2	75±8.49
Special condition (1) If site is in top of hill		3			
An increase in shading intensity causes a decrease in the softness of tea leaves.	10	11	75	4	75±8.49
Special condition (1) If tea is grown near forest trees.		6			
Special condition (2) If tea is grown in high soil moisture area.		5			
An increase in *Eupatorium adenophorum* growth rate causes an increase in *Pteridium aquilinium* growth rate, if shade intensity is high.	30	0	60	10	60±9.60
Sapium baccatum has light crowns, if *Sapium baccatum* is mature.	20	0	65	15	65±9.35
Castanopsis armata has light crowns, if *Castanopsis armata* is mature.	14	0	79	7	79±7.98
Pteridium aquilinium has dense cover, if *Pteridium aquilinium* is mature.	25	0	65	10	65±9.35
Rate of transfer of water from the root system of *Ficus hirta* is high, if root system of *Ficus hirta* entwines the tea root system.	35	0	55	10	55±9.75
Weeding garden causes an increase soil moisture content, if it is the summer.	0	0	97	3	97±3.34

After combining the confirmation with and without the original statements, it was found that the standard error was low. This shows that most of the respondents agreed with the original statements. From the Table 5.3, it is clear that a high percentage of respondents agreed with most of the statements.

The data show that when the villagers were shown inverted statements, most of them refuted these statements indicating they did not always follow the statement by agreement. However, the respondents disagreed with inverted statements less than they agreed with original statements. It was found that the standard error for the inverted statements was almost two times higher than the standard error for the original statements. This suggests that there was an underling tendency to agree with the statements or a reluctance to disagree biasing the result according to whether confirmation required agreement or disagreement. Most of the respondents did not confirm the action statements, link statements and attribute value statements, while just over half of the respondents confirmed conditional process statements and causal statements. This may be because some respondents did not have the confidence to confirm complicated knowledge like that contained in causal statements or in conditional process statements, whereas most of the respondents were able to confirm the simple knowledge in link statements and attribute statements.

5.4.2 Testing the agreement of parts of a diagram and sets of statements linking nodes in the diagrams

5.4.2.1 The influence of forest trees on *miang* tea leaf production

Testing the diagram about the role of forest trees on *miang* tea gardens consisted of three parts. Firstly, the *miang* tea farmers' knowledge about the direct influence of the forest canopy on the soil moisture by maintaining evaporation was evaluated, and then the indirect effect of forest shade on evapotranspiration by controlling the cover of dominant ground flora in the gardens was tested. Finally, the indirect influence of the shade on nutrient recycling and tea tree growth was investigated.

(1) The direct influence of the forest canopy on soil moisture

Percentage confirmations are given for each statement and accumulated percentages propagated along chains of connected sentences to show how many people confirmed all the statements up to that point in the chain (Figure 5.4). There was 75 % accumulated confirmation that shading causes an increase in soil moisture by reducing evaporation rate. Considering the whole diagram, 75 % of respondents agreed that 'tea trees grow more under shade because the soil is wetter'

This observation was founded in the tea farmers' experience of working in the gardens underneath the dense canopy of forest, which allowed them to observe increases in soil moisture. They can compare between the growth rate of tea trees with shade and those in the open with less shade, this is one reason why most of the farmers grow tea seedlings or seeds underneath the crowns of forest trees.

van Roy (1971) observed that tea groves were found growing wild in the highland jungles. The *miang* tea gardens often serve as the nuclei around which upland villages are formed. Clearing the jungle growth from around such a grove is one way in which a peasant may enter the industry. The alternative is clearing suitable land and planting tea seeds or seedlings. The farmers usually just occupy an area in the forest where *miang* tea gardens are abundant.

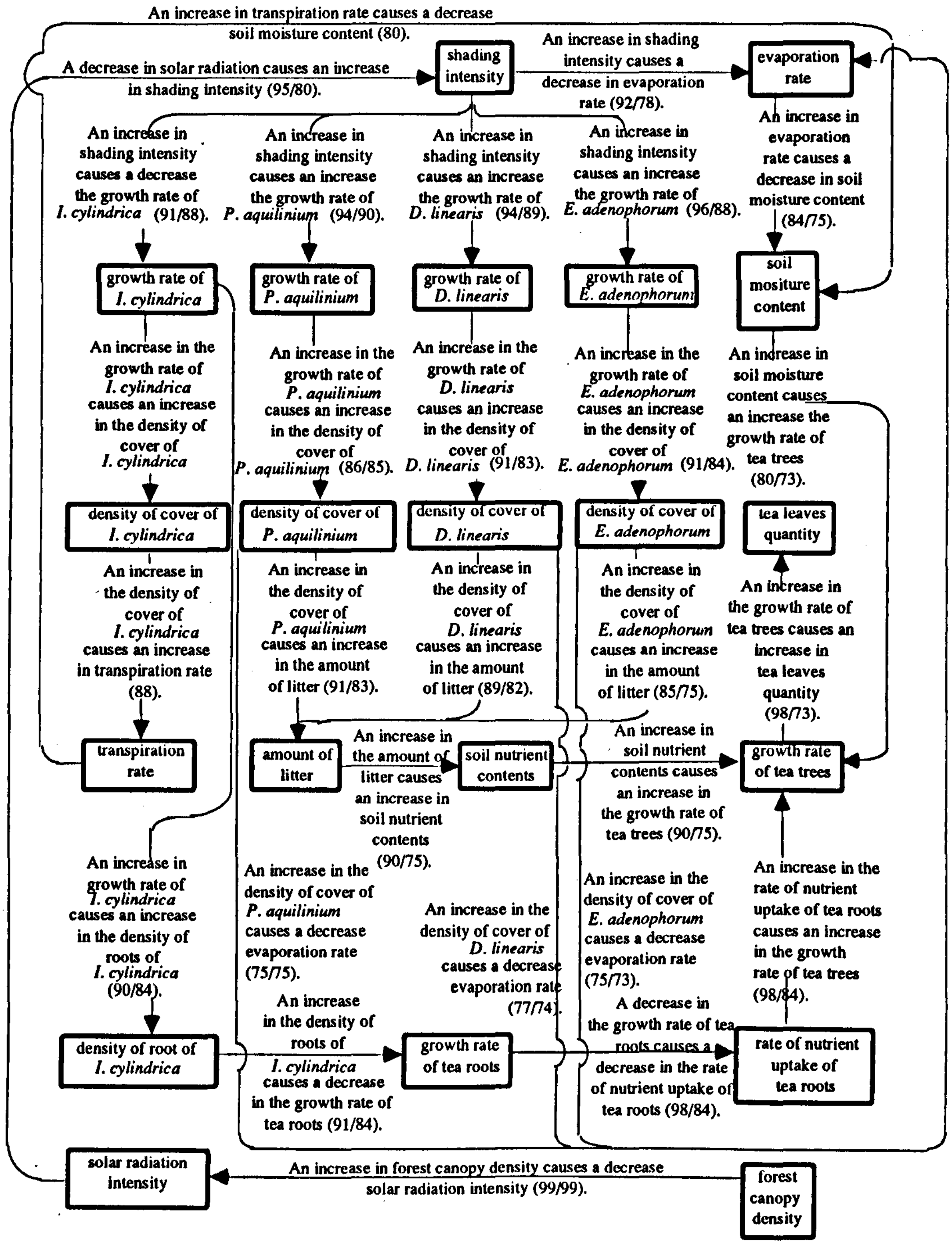


Figure 5.4 The indigenous ecological knowledge about the role of forest trees in controlling microclimate and nutrient cycling used for evaluating *miang* tea farmers' knowledge. The first number in brackets is the percentage confirming that particular statement. The second number is the accumulate percentage of people confirming all statements up to that point in the chain of linked statements. For statements not tested, an accumulated percentage could not be calculated because at least two statement in the chain was not tested.

Keen (1978) reported that the customary method of establishing a *miang* tea garden, at least in the past, has been simply to clear the forest from around already growing trees. Keen (1978) illustrated that a garden may be only a walking path, perhaps twenty feet wide, cut through the forest for several hundred meters, wherever the tea trees may be growing. The farmers grow Assam tea (*Camellia sinensis* var. *assamica*) which grows well under heavy shade. Hadfield (1968) commented on the characteristics of Assam tea describing that its bushes are large and its leaves are oriented horizontally. Sangchai (1993) stated that over 80 % of *miang* tea farmers of one village in the north west of Chiang Mai grow Assam tea. The result of the inventory of the tea gardens at the study site (see Section 2.4.5.2) outlined that there has been only one kind of *C. sinensis* var. *assamica* in the area.

The data from the questionnaire shows that about a quarter of the farmers denied that increased forest canopy density causes a decrease in evaporation rate. A small number of the farmers believed that tea trees can grow without shade. Tea gardens occur on different land forms that have varying aspects. For example, tea grown in a valley catchment will receive a lower intensity of solar radiation than tea on upland slope areas with low insulation and may not, therefore, need forest tree shade. Also, tea trees on the north and east aspect of mountains need less forest tree shade than in the south and west aspect because of receiving short periods of sun shine and low intensity solar radiation.

A few farmers believed that it was not necessary to plant tea trees under a high intensity of shade, if the farmers could irrigate the gardens. They believed that irrigated *miang* tea gardens gave high production without shade.

The irrigation system is new knowledge that the farmers had received through mass media (radio and television programs) or from extension workers. This shows how new knowledge has had an influence on the understanding of some of the *miang* tea farmers. Sangchai (1993) infers that some *miang* tea farmers want to build irrigation systems in the gardens for increasing their own production.

(2) The indirect influence of forest shade on soil moisture

It is widely accepted that shade influences the growth rate of ground flora. Most of the respondents (see Figure 5.4) mentioned that high shade suppresses the growth rate and cover of *Imperata cylindrica* and supports the growth rate and cover of *Eupatorium adenophorum, Pteridium aquilinium* and *Dicranopteris linearis.*

It is very easy for most of the farmers to have observed the relationship between the intensity of shade and the growth rate and ground cover of these ground flora because each species of ground flora is obviously separated from other species by different levels of shading intensity from forest trees.

The results show that most of the respondents confirmed that *I. cylindrica* causes an increase in transpiration and *E. adenophorum, P. aquilinium* and *D. linearis* can reduce evaporation, while 99 % of respondents confirmed the statement " An increase in shading intensity causes a decrease in evapotranspiration". This suggested that most of the *miang* tea farmers maintained forest canopy, and the cover of ground flora excluding *I. cylindrica,* to keep soil moisture in their gardens. However, some tea farmers did not confirm this suggesting that it may not be as easy for some farmers to observe the relationship between the foliage of ground flora and the rate of evaporation and transpiration, perhaps because the evaporated and transpirated water is invisible. Moreover, the rainy season in the highland area spans a long period, when total annual rainfall and annual atmospheric humidity are high (see Section 2.4.3). This also causes some farmers to believe that the process of evaporation and transpiration are not influenced by growth rate and the cover of ground flora. Some farmers denied that the forest tree canopy affected tea trees and ground flora. This may be because some tea farmers received lower levels of incident radiation as a consequence of topographical variation.

(3) The indirect influence of forest shade on tea tree growth and soil nutrients

Most of the respondents said that *I. cylindrica* suppressed the growth rate of tea trees and other seedlings. Most of the respondents (85 %) also confirmed the statement 'An increase in the growth rate of *I. cylindrica* causes a decrease in the growth rate of tea trees'. *I. cylindrica* can not grow well in the dense shade, therefore the farmers prevent the spreading of *I. cylindrica* by allowing forest trees to grow and form a large and dense canopy .

The information also demonstrates that most of the respondents confirmed that *P. aquilinium* and *D. linearis* and *E. adenophorum* provide litter. A larger number of respondents confirmed that *P. aquilinium* and*D. linearis* produce litter than those confirming that *E. adenophorum* produce litter. It is very easy to observe that *P. aquilinium* and *D. linearis* shed dry leaves and dry branches because the canopy of *P. aquilinium* and *D. linearis* is light. Litter can be seen. In contrast, it is very difficult to observe litter of *E. adenophorum* because of the dense canopy of

E. adenophorum and the colour of its compost is similar to the colour of soil. *E. adenophorum* is also rapidly decomposed due to the soft texture of its leaves.

The research shows that a large number of the farmers accepted that litter increases soil nutrient content. Most of the respondents (89 %) also confirmed the statement ' An increase in *P. aquilinium* and *D. linearis* and *E. adenophorum* growth rate causes an increase soil nutrient content'. The farmers maintain and manage these ground flora, excluding *I. cylindrica*, through using shade rather than eradicating them. Most of the farmers do not view these ground flora as weeds but regard them as useful for the tea trees. The knowledge that the *miang* tea farmers have about ground flora is different from the perception of other non-tea farmers in Thailand generally who think of ground flora as weeds. It is generally accepted by the *miang* tea farmers that litter decomposes to become fertiliser. They expressed the idea that tea trees take up nutrients from fermented leaves and branches. For this reason most of the farmers refused the knowledge of extension workers to make a compost from fallen leaves and stems of ground flora and forest trees. Most of them estimated the soil fertility status by observation of the kind of ground flora found.

It can be concluded that the vast majority of the farmers considered that forest tree shade has an influence on the nutrient cycle and water balance in the gardens by controlling biotic and abiotic elements. The data show that 75 % of respondents confirmed the statement 'An increase in shading intensity causes an increase in soil nutrient content', and also 'An increase in shading intensity causes an increase in tea tree growth rate'. The results show that most of the tea farmers can indicate whether or not the land and the soil are suitable for growing tea by observation of the type of forest and ground flora growing. The data of the test of the whole diagram show that 80 % of respondents believed that 'sites with light shade are drier and less fertile than sites with heavy shade because sites with light shade have more *I. cylindrica* which increases transpiration rate and decreases growth rate of tea trees' roots, while the other sites have more of the other species which reduce evaporation and put nutrients back into the soil through litter'. Othieno (1992) suggests that the use of certain indigenous vegetation (indicator plants) which grow in soil where tea has established successfully, has helped in indicating the suitability of a soil for tea. All the indicator plants associated with areas suitable for tea growing require high and well distributed rainfall and intensively weathered and leached soils. It has been previously pointed out (Mann, 1935) that in north India *Albizia chinensis, A. lebbeck* and *A. procera* are useful indicator plants for tea and that in Sri Lanka people considered *A. moluccana* as a good indicator plant while Georgia in the USSR *A. julibrissim* has been associated with soil suitable for tea. In Uganda, *Dissotis violacea, D. brazzaei, D. irringiana* and *Craterispermum laurium* have been similarly used in identifying soil suitable for tea (Othieno, 1992). In Kenya, a number of indigenous species including *Pteridium aquilinum* have been associated with good tea soil (Brown, 1966).

5.4.2.2 The influence of cattle in preventing fires and in facilitating the growth of tree seedlings

From the results of the questionnaire, it was found that the vast majority of the farmers confirmed that grazing by cattle reduces the probability of fire and the intensity of fires by reducing the biomass of ground flora and also reducing the flammability of vegetation (see Figure 5.1). Most of the respondents questioned said that cattle were a cause of increasing the number of forest tree seedlings through grazing. The data shows that 82 % of respondents also confirmed the statement 'An increase in frequency of cattle eating grass causes an increase in the number of forest tree seedlings.'

Through the results of this research, it was discovered, that a high proportion of farmers inferred that cattle cause an increase in forest area. Considering the whole diagram 82 % of respondents confirmed the statement 'There will be more tree seedlings where cattle graze intensively than where cattle graze sparsely because the ground flora biomass will be decreased, there by decreasing the frequency and intensity of fire'. The farmers commented that cattle graze the biomass of herbs that provide fuel for fires. Cattle walk and graze on most of the garden. The cattle grazed not only in the gardens of their owner but also throughout the area of the *miang* tea gardens in the village. Keen (1978) points out that cattle are far more commonly used than horses. When not working, they graze among the tea trees on the native grasses, which thrive in the sunlight let in by removal of the forest. The animals help to keep the land clear while finding their own food and they are permitted to roam freely on any person's land. This is another example of the peasant proprietor's concept of ownership being directed toward specific trees rather than the land area within which they grow.

Some of the farmers mentioned that cattle trample on forest tree seedlings. They also eat leaves of forest saplings and seedlings. Therefore, some of them refuted the statement that cattle cause an increase in the number of forest trees. However, the farmers who supported the statement that cattle increase the forest area suggested that there were a large number of forest seedlings in the gardens. The forest inventory showed that there was a high density of forest seedlings in the tea gardens. Most of the farmers distinguish between fire and cattle, that fire can burn all forest seedlings, while cattle destroy only some of the seedlings. Moreover, cattle can reduce the competition of seedlings, allowing some seedlings to grow tall.

It can be concluded that most of the *miang* tea farmers agreed that cattle cause an increase in forest area rather than reducing it. It can be estimated that the vast majority of the farmers agreed with the influence of cattle on preventing fire and facilitating the growth of tree seeds. These processes are not complicated for the farmers to comprehend because they can see how cattle reduce the biomass of herbs and they can see how the forest seedlings grow. Soothasupa *et al.* (1990) supported the conclusion that the system of tea gardens helps to prevent forest fires. Watanabe *et al.* (1990) state that *miang* tea gardens with cattle is a pattern of agroforestry, they classified this pattern as silvopastural and commented that it was sustainable.

There are seven reasons why most of the farmers agreed with the representativeness of the knowledge base.

(1) Traditional oral transmission

The first reason is that the *miang* tea farmers knowledge is very old (see Section 1.3.2). Ganjanapan and Khoasa-ad (1991) illustrated that the *miang* tea villagers have been scattered in valleys surrounding the mountains in the history of the community in *Lanna* (the old name of north region). The *miang* tea villages and *miang* tea farmers have a history of deforestation in the northern regions of Thailand. There is a background of culture and a relationship between the forest and the villages. Knowledge has been developed and accumulated by the *miang* tea farmers, the farmers have developed their knowledge from their own experience and exchanged knowledge with each other. Most of the farmer's knowledge is received by learning from experience in the gardens and natural forest.

(2) Geographical isolation

Most of the *miang* tea villages are settled in the narrow valley on the highlands surrounding the tea gardens and natural forest (see Figures 2.2 and 2.3). In the past, it was very hard for the farmers to travel to the lowlands. The *miang* tea farmers have to walk to visit their neighbours. At present, even though there are roads passing through the villages, most of the farmers still have to walk because there are few cars and motor bikes in the village. This isolation causes the *miang* tea farmers to have similar knowledge. Due to travel being quite difficult, there are only a few extension workers that come to work in these villages. Therefore, the tea farmers knowledge has been changed very little. The television and radio has had more of an influence in changing the farmers knowledge as the farmers spend a lot of time watching television and listening to the radio (see Section 2.4.6.17).

(3) Environmental restrictions

It is very difficult to grow other crops such as, peaches, persimmon, mangoes, litchi, cabbage, or tomato that are grown in open areas in the *miang* tea gardens or to grow tea plants for producing green tea or black tea because most commercial crops and other tea varieties or tea trees for producing green tea and black tea need high solar intensity, while the shading intensity in the *miang* tea gardens is high. Tea farmers will occasionally pick tea leaves for producing green tea, but production from this is small due to the green tea being made from young leaves.

Within the tea gardens there are few young leaves on the tea trees due to the high shade and wide spacing compared to tea plantations with narrow spaced trees. Therefore, most of the *miang* tea farmers do not have the knowledge for planting other crops to compare or change their knowledge.

(4) Cropping pattern

The *miang* tea farmers also refuse to clear the land for planting different crop varieties because they still need the forest trees for firewood, building materials and water supply. The farmers also collect non-wood products for home consumption. Somnasang, Rathakette and Rathanapanya (1990) suggested that natural foods, hunted or gathered from the local environment, are exploited as an important source of energy, protein, vitamins and minerals. Farmers obtain natural food throughout most of the year, at no cost, and are also able to sell some natural food to obtain cash.

(5) Limited market information

Another reason for only growing tea is that the farmers do not know the markets for other crops. In contrast, they know only the situation of the market for *miang*. It is very difficult for them to change the cropping system, if they do not know the market. Most of the *miang* tea farmers spend more time working in their own gardens rather than finding out the market of other crops.

(6) Limited extension agencies

There are few extension agencies introducing new agricultural knowledge to the *miang* tea farmers. Due to most of the *miang* tea villages being located in the natural forest, the extension workers at the district agricultural extension office have not wanted to introduce the knowledge to the *miang* tea farmers. The policy of the Royal Thai government also has been not to allow the introduction of crops and animals in the natural forest because the non native species might distort the biodiversity of the native forest and wildlife and disturb the ecosystem of the natural forest. Therefore, there has been little knowledge introduced to the *miang* tea farmers.

(7) Limited research

There has been little research on *miang* tea gardens in the hill evergreen forest, most of the research has been about socio-economic aspects of the *miang* tea gardens and has been carried out by universities. Hardly any research has been carried out on the productivity and ecosystem processes of the *miang* tea gardens. Most organisations within the Thai government are not interested in the *miang* tea gardens because *miang* production is not an important output of the country. It is only produced for consumption by people in the north of the country. Therefore, there is no scientific knowledge to change the farmers' knowledge. At the moment, some government organisations, such as the Agriculture Department, Ministry of Agriculture and Co-operation, Faculty of Agriculture, Chiang Mai University and Faculty of Horticulture, Mae Jo University have carried out research about growing tea. Yet, much of this research is about tea plantations for producing black tea or green tea. The method of planting and producing these teas is quite different from the method of planting and producing *miang*. Tea plantations for producing black tea and green tea need to plant tea trees on terraces, with narrow spacing and no shade or a low intensity of shading. Therefore, most of the tea farmers did not change to plant tea trees for producing black tea or green tea.

5.5 Conclusions

The results of this research provide an assessment of the representativeness of the indigenous knowledge base. Knowledge as articulated by the key informants is representative of the knowledge of most of the tea farmers. Conceptual understanding of the *miang* tea garden ecosystem was consistent among farmers. However, detailed knowledge held by some farmers was different to community knowledge as their tea gardens had a different geography and a different plant biodiversity. This affected some aspects of the farmers understanding. Thapa (1994) summarising farmers' ecological knowledge about tree fodder in the mid-hills of eastern Nepal describes detailed understanding about species-specific tree attributes such that practical management varied among farmers according to local conditions. This indicates that *miang* farmers' knowledge may be largely utilitarian in nature and little affected by scientific knowledge.

The study showed that the vast majority of farmers cited that forest trees, ground flora and cattle controlled the sustainability of the ecosystem of the gardens. Most of the farmers know how to manage forest trees and ground flora to balance microclimate and recycle water and nutrients and use cattle to control fire and facilitate plant succession. These factors mean that *miang* tea farmers have no need of other areas of land for rotating crops and therefore, *miang* tea gardens do not cause deforestation in other areas. This contrasts with the tradition of swidden cultivation by Lua' farmers in the hills of south western Chiang Mai. Here Kunstadter (1988) found that they each farm a large block of land for only one year after it has been cleared and subsequently fallow it for about nine years to improve soil fertility.

CHAPTER 6
COMBINING INDIGENOUS AND SCIENTIFIC KNOWLEDGE

6.1 Introduction

The use of scientific knowledge to improve agricultural systems in Thailand, has been encouraged for more than 30 years (Boonkrid, 1989). The aim of this was to change cropping systems from subsistence agriculture, for home consumption, to modern agriculture for producing cash crops (Arbhabhirama *et al,* 1987; Kunstadter, 1992; Rundel and Boonprakob, 1995). Knowledge of monoculture systems, new crops and domestic animal varieties, chemical substances and heavy machines were made available in an attempt to increase agricultural production and, therefore, the farmers' incomes. However, there are growing fears that this knowledge has, in some circumstances, contributed to environmental degradation by disturbing the biosphere of the soil and water through pollution and erosion. There has been a reduction of forest area, water yield and an increase in waste land. In the case of tea plantations, extension workers encouraged tea farmers to use the new technologies of planting tea at narrow spacing, without other tree species for shade and nutrient cycling purposes. They also promoted the use of terracing with tea or the cultivation of other cash crops, such as; mangoes, coffee, potato or tomato, instead of tea. The tea farmers have not, however, changed their practice. There is, in fact, very little evidence that any scientific knowledge of tea plantation management that has been introduced to the indigenous tea farmers since 1937 has been accepted by them (La-ongsri, 1992).

Results in Chapter 4 indicated that the tea farmers in the study area have little knowledge about the fundamental concepts of ecology. The farmers have some knowledge of ecology and species biodiversity in the tea gardens, but cannot explain the details of the interrelationships among the various components in the tea garden ecosystem. This study, on the combination of the indigenous and scientific ecological knowledge, has been undertaken in order to understand the complementarity and gaps between indigenous and scientific knowledge and from this to synthesise extension recommendations. The combined knowledge base and resulting recommendations will then be suitable for transfer back to the farmers, making sure the added knowledge augments, but does not displace, the indigenous knowledge.

The objective of the research described in this chapter was, therefore, to develop an approach to making more effective use of existing ecological knowledge in supporting target communities in improving the productivity and sustainability of their cropping system by merging scientific knowledge and indigenous knowledge and developing appropriate recommendations. This was achieved by:

- acquiring scientific knowledge about the *miang* tea farming domain,
- investigation of the indigenous knowledge that the scientists did not articulate and the scientific knowledge that the *miang* tea farmers did not mention,
- identification of similar and conflicting indigenous and scientific knowledge, and

- formation of recommendations combining indigenous and scientific knowledge, where appropriate, to provide a more powerful means of improving the sustainability of the *miang* tea gardens than could be achieved by using either knowledge system alone.

6.2 Combining indigenous and scientific knowledge

It has been found elsewhere that farmers and scientists can collaborate to develop better technologies than either group could invent alone (Bentley, 1994). Farmers generally know some things that scientists know and some things that scientists do not know, it is also generally found that farmers do not know some things that scientists do know. There are, in addition, a lot of things that neither group knows (Chambers, 1991). Walker (1994) suggested that farmers have a much more intimate experience of their production practices than external professionals and that it is reasonable to assume that as the people who have been operating production systems they have developed some understanding of them. Richards (1994) concurs, further suggesting that farmers are generating knowledge that, while in conformity with general scientific principles, embodies place-specific experience that allows a better assessment of risk factors to be incorporated in their decisions. The knowledge held by farmers can provide a resource for science irrespective of the participation of the farmers in the use of that knowledge. Investigating local knowledge may be a powerful and efficient means of rapidly filling gaps in scientific understanding, particularly in a young science such as agroforestry (Rocheleau, 1987). Amalgamating specific local knowledge and general scientific knowledge may, therefore, be more powerful in designing appropriate land use practices than the use of either alone. Niamir (1990) states that indigenous knowledge does not devise general principles and absolutes but allows an understanding of the heterogeneity of local conditions, while formal science seeks general applicability but, particularly in natural science, has difficulty in attempting to cope with the variability that is found in the real world. By operating at different scales, this view regards the two systems as complementary but of a fundamentally different nature and held in different conceptual frameworks.

In this study, a combination of indigenous and scientific knowledge about sustainability of *miang* tea gardens in hill evergreen forest is attempted.

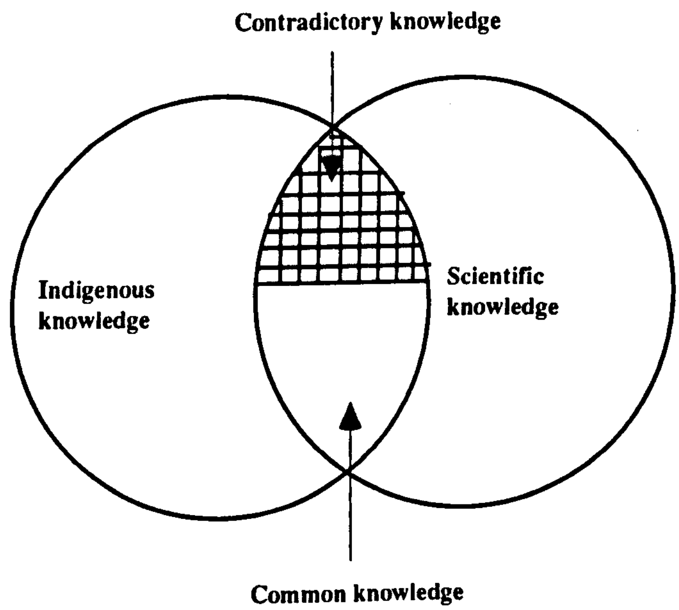


Figure 6.1 The structure of the combined knowledge hypotheses.

Four fundamental hypotheses are addressed as depicted in Figure 6.1 and pin pointed below:

- Scientists have knowledge that farmers do not.
- Farmers have knowledge that scientists do not.

- Scientists and farmers hold some of their knowledge in common.

- Some of the knowledge held by farmers and scientists is contradictory.

6.3 Acquisition of scientific knowledge

The indigenous ecological knowledge held by the tea farmers reviewed in Chapter 4 was used to design a questionnaire for interviewing scientists. The questions used in the interview are set out in Table 6.1, they are open-ended questions, directed by the knowledge that farmers had articulated.

Eight scientists were selected for interview, using a selective sampling system. Each scientist was interviewed on only the topics that they were professionally involved in. For example, those scientists who worked in hydrology were asked about the water cycle in the tea gardens. This resulted in five informants for topic 1, four for topic 2 and three for topic 3. None of the scientists interviewed were directly involved in research about the traditional *miang* tea gardens, only in research on the ecosystem of the hill evergreen forest more generally or on modern tea plantations. Therefore, the interviewer described the general background of tea gardens in the hill evergreen forest to the interviewees.

The pattern of land use (Figures 2.2 and 2.3), stand profile and crown cover of the tea gardens in the hill evergreen forest (Figure 2.5) were used as tools for communication during the interviews.

Table 6.1 Semi-structured questionnaire survey used to interview the scientists for acquisition of ecological knowledge about tea gardens in the hill evergreen forest.

FIRST TOPIC: the role of forest trees in controlling microclimate and cycling nutrients

1.1 What direct impact does shade have on tea leaf quality? Why? What kind of forest trees are suitable for shading?
1.2 What impact does atmospheric temperature have on tea leaf quality and quantity? Why? When is a suitable time for picking tea leaves?
1.3 What direct impact does shade have on soil moisture content? Why?
1.4 What direct impact does shade have on rain and dew? Why?
1.5 What are the main factors influencing rain and dew? Why?
1.6 Which of the following ground flora grow well in sites with heavy shade, light shade or no shade? (*Dicranopteris linearis, Eupatorium adenophrum, Imperata cylindrica* and *Pteridium aquilinium*) Why?
1.7 What interaction, if any, is there between the root systems of forest trees and the root systems of tea trees? Why?
1.8 What impact does the forest canopy have on frost? Why?
1.9 What impact does frost have on tea leaf quality? Why?
1.10 What impact do the trees in the hill evergreen forest have on soil nutrient content? Why?
1.11 What interaction is there between different kinds of ground flora, if the intensity of shading increases? Why?
1.12 What impact, do different kinds of ground flora have on the nutrient content of the soil and the growth rate of tea trees? Why?

SECOND TOPIC: Comparison of four dominant ground flora in erosion control
2.1 What impact do different ground flora have on the amount of soil moisture, solar radiation, transpiration and litter? Why? (NB: high increase+++ or high decrease- - -, medium increase ++ or medium decrease - - and low increase + or low decrease - and no change (0)).
2.2 What impact do different kinds of ground flora have on throughfall energy, surface water, soil erosion and water infiltration? Why? (NB : high increase +++ or high decrease - - -, medium increase + + or medium decrease - - and low increase + or low decrease - and no change (0))

THIRD TOPIC: The role of cattle in cycling nutrients and germinating tree seed
3.1 What impact do cattle have on tea trees and tea seedlings? Why?
3.2 What relation is there between cattle and the cycling of nutrients? Why?
3.3 What is the impact of cattle grazing and trampling on nutrient status of soil? Why?
3.4 What relation is there between cattle grazing and trampling and fire in the gardens? Why?
3.5 What relation is there between cattle eating tree fruit, and the germination of forest seeds in the gardens? Why?
3.6 What relation is there between cattle trampling and forest seedlings in the gardens? Why?

If the information derived was contradictory or ambiguous, the informant was interviewed again. Interviewing technique, recording of information, extracting statements, assessing knowledge and knowledge representation followed a similar pattern to the process of elicitation of indigenous knowledge (see Sections 3.3, 3.4

and 3.5). Some scientific knowledge was also elicited from literature reviews, books, theses and public reports to augment the verbal responses from the eight scientists interviewed.

6.4 Merging indigenous and scientific knowledge knowledge bases

Walker *et al.* (1994) stated that before the combination of two or more knowledge bases, there has to be consistency of terminology within each of the knowledge bases. Terms in each of the knowledge bases are then compared. Therefore, if the meaning of a term found in both the indigenous and the scientific knowledge bases was different, the term was tagged and then made different. For example, the farmers understood that fertiliser was a form of plant nutrient and did not, in fact, distinguish between fertiliser and plant nutrients. Yet to the scientist fertiliser within the tea gardens was generally of an organic form, whereas plant nutrients referred to the inorganic constituent elements taken up by plants. Therefore, within the indigenous knowledge base the term fertiliser was changed to 'fertiliser_indigenous' and within the scientific knowledge base the term was changed to 'fertiliser_ scientific' before the scientific knowledge was merged with the tea farmers' knowledge.

6.5 Comparison of indigenous and scientific knowledge

The scientific knowledge base contained two diagrams one describing the role of forest trees in controlling microclimate and nutrient cycling and the other describing the role of cattle in controlling nutrient cycling and forest seed germination, one sub diagrams and 180 statements. After merging with the indigenous knowledge base, the combined knowledge base contained four diagrams, one sub diagram and 555 statements. The diagrams in both knowledge bases were compared to identify similarities and differences. Differences between the indigenous and scientific knowledge were identified by comparing diagrams from each knowledge base. Four pairs of statements were found to contain different knowledge about the same system components (Table 6.2) and contradictions are discussed in Section 6.6.3.

Table 6.2 Statements from the indigenous and scientific knowledge bases with different information about the same components identified by comparison of diagrams.

Indigenous knowledge	Scientific knowledge
An increase in *Imperata cylindrica* root density causes a decrease in soil porosity.	An increase in *Imperata cylindrica* root density causes an increase in soil porosity.
An increase in shading intensity causes an increase in the growth rate of *Eupatorium aquilinium*.	An increase in shading intensity causes a decrease in the growth rate of *Eupatorium aquilinium*.
An increase in the growth rate of *Eupatorium aquilinium* causes a decrease in the growth rate of *Dicranopteris linearis*, if shading intensity is high.	An increase in the growth rate of *Dicranopteris linearis* causes a decrease in the growth rate of *Eupatorium aquilinium*, if shading intensity is high.
An increase in the growth rate of *Eupatorium aquilinium* causes a decrease in the growth rate of *Pteridium aquilinium*, if shading intensity is high.	An increase in the growth rate of *Pteridium aquilinium*, causes a decrease in the growth rate of *Eupatorium aquilinium*, if shading intensity is high.

Much of the information, 91 statements articulated by the scientists, was not held by the farmers (Table 6.3). By contrast, there was little information (four statements) held by the *miang* tea farmers that the scientists did not articulate (Table 6.4). However, it might be expected that a larger sample of scientists including plant physiologists familiar with tea productivity may have articulated similar knowledge.

Table 6.3 An example of scientific knowledge (25 out of a total of 91 statements) that the *miang* farmers had not articulated, identified by comparison of node and link diagrams.

An increase in forest canopy density causes an increase in intercepted rain amount.
An increase in intercepted rain amount causes an increase in evaporation rate.
An increase in stem flow rate causes an increase in soil moisture content.
An increase in forest canopy density causes an increase in transpiration rate.
An increase in atmospheric humidity causes an increase in dew amount.
A decrease in ambient atmospheric temperature causes a decrease in tannin content in tea leaves.
A decrease in tannin content in tea leaves causes a decrease in bitterness content in tea leaves.
An increase in throughfall intensity causes an increase in splash erosion rate.
An increase in rainfall intensity causes an increase in splash erosion rate.
An increase in solar radiation intensity causes an increase in photosynthesis rate.
An increase in photosynthesis rate causes an increase in the growth rate of tea trees.
A decrease in ambient atmospheric temperature causes a decrease in decomposition rate, if litter is under forest canopy.
An increase in shading intensity causes a decrease in decomposition rate, if litter is under forest canopy.
An increase in forest canopy density causes a decrease in wind velocity rate.
An increase in wind velocity rate causes a decrease in atmospheric humidity.
An increase in forest canopy density causes an increase in litter amount.
An increase in litter amount causes an increase in animo acid acidity.
An increase in allelopathy toxin toxicity causes a decrease in the growth rate of microorganism.
A decrease in the growth rate of microorganism causes a decrease in litter decomposition rate.
An increase in allelopathy toxin toxicity causes a decrease in seed germination rate.
An increase in root surface area causes an increase in uptake nutrient rate of forest trees, if forest is *Castanopsis spp, Lithocarpus spp and Quercus spp.*
An increase in uptake nutrient rate of forest trees causes an increase in the growth rate of forest trees.
A decrease in soil porosity causes a decrease in water infiltration rate.
A decrease in water infiltration rate causes an increase in surface run-off rate.

Table 6.4 *Miang* farmers' knowledge that the scientists did not articulate as identified by comparison of node and link diagrams.

An increase in shading intensity causes an increase in softness of tea leaf.
An increase in shading intensity causes an increase in yellowness of tea leaf.
An increase in softness of tea leaf causes an increase in tea leaf quality.
An increase in yellowness of tea leaf causes an increase in tea leaf quality.

Further comparison of the knowledge bases was enabled using automated reasoning by application of the query tool (see Section 4.3). Queries were made to explore more specific knowledge about each of the attributes of processes and how they were influenced by ground flora. The query procedure involves setting parts of the query to a variable (denoted by capital letters) so that the system returns all statements that satisfy the query with the variables taking each of the appropriate arguments in term. In the present case the following query was used:

```
att_value(process (part (X,W),V),Y,Z)
```

with X set to the particular species concerned, once for each type of ground flora, which requested the system to return all the attribute-value statements about all processes (V) of each part (W) of each ground flora species (X), thus returning all the attributes (Y) and values (Z) used in the knowledge bases. Inconsistencies identified from the knowledge bases generated by using this query, amounted to 12 statements examples of which are shown in Table 6.5.

Table 6.5 Inconsistent information about attributes of processes influenced by ground flora between the indigenous and scientific knowledge, generated by the query: att_value(process (part (X,W),V),Y,Z), where X was instanced to each of the four types of ground flora. English equivalents of these statements are given in Appendix 6.2.

Indigenous knowledge	Scientific knowledge
att_value(process(part('Dicranopteris linearis', canopy), 'filtering out of solar radiation'), rate, medium)if att_value('Dicranopteris linearis', maturity, mature)	att_value(process(part('Dicranopteris linearis', canopy), 'filtering out of solar radiation'), rate, low)if att_value('Dicranopteris linearis', maturity, mature)
att_value(process(part('Pteridium aquilinium', canopy), 'filtering out of solar radiation'), rate, medium)if att_value('Pteridium aquilinium', maturity, mature)	att_value(process(part('Pteridium aquilinium', canopy), 'filtering out of solar radiation'), rate, low)if att_value('Pteridium aquilinium', maturity, mature)
att_value(process('decreasing soil erosion'), rate, low)if link('grow into', part('Dicranopteris linearis', root), soil).	att_value(process('decreasing soil erosion'), rate, medium)if link('grow into', part('Dicranopteris linearis', root), soil).
att_value(process('decreasing soil erosion'), rate, low)if link('grow into', part('Pteridium aquilinium', root), soil)	att_value(process('decreasing soil erosion'), rate, medium)if link('grow into', part('Pteridium aquilinium', root), soil)
att_value(process('decreasing surface run-off'), rate, low)if link('grow into', part('Eupatorium adenophorum', root), soil)	att_value(process('decreasing surface run-off'), rate, medium)if link('grow into', part('Eupatorium adenophorum', root), soil)
att_value(process(part('Eupatorium adenophorum', canopy), 'throungfall interception'), rate, medium)	att_value(process(part('Eupatorium adenophorum', canopy), 'throungfall interception'), rate, high)
att_value(process(part('Eupatorium adenophorum', leaf), transpriration), rate, low)if att_value('Eupatorium adenophorum', maturity, mature)	att_value(process(part('Eupatorium adenophorum', leaf), transpriration), rate, high)if att_value('Eupatorium adenophorum', maturity, mature)

The query tool was similarly used to investigate inconsistencies in link statements about the effect of forest tree roots on tea roots. This was achieved through the use of the query procedure:

link(X,part('forest tree', root), part(tea, root) which requested the system to return all link statements about forest tree roots, where X represents the various link types returned. Only three contracdictory statement pairs were generated by this query as shown in Table 6.6.

Table 6.6 Inconsistent information extraction about the effect of forest tree roots in tea roots. The query used to generate this information was: link(X,part('forest tree',root'),part(tea,root). English equivalents of these statements are given in Appendix 6.3.

Indigenous knowledge	Scientific knowledge
link(connect,part('forest tree',root),part(tea, root))	link (not_connect,part('forest tree',root), part (tea, root))
link('transfer water to',part('forest tree',root), part(tea, root))	link('not_transfer water to', part ('forest tree', root), part(tea, root))
link('transfer nutrient to',part('forest tree', root), pert(tea, root))	link('not_transfer nutrient to',part('forest tree', root), part(tea, root))

Inconsistent link statements about the effect of cattle on plants in tea gardens were also investigated. This was achieved through the use of the query procedure:

link(X,cattle,Z)

which requested the system to return all link statements about the effect of cattle on other objects (Z). Z took the form of any kind of plant or part of plant, while X any link type between cattle and Z. No inconsistencies in link statements were identified between the knowledge bases using this procedure.

A final comparison was made by comparing lists of all the attribute-value statements in each of the knowledge bases. In general knowledge articulated by farmers was qualitative (see Tables 4.1), while scientists sometimes expressed their understanding quantitatively. There were, for example, 20 statements made by scientists that mentioned specific numerical quantities (Table 6.7). Scientists also mentioned the throughfall factor of forest canopies, allelopathy, the process of cattle digestion facilitating the germination of forest tree seeds, and three types of blight not articulated by farmers (17 statements) (Table 6.8).

6.6 Contents of comparison of indigenous and scientific knowledge

The comparison of indigenous and scientific knowledge about sustainability of tea gardens in the hill evergreen forest can be divided into the following subject area: the role of forest trees in controlling microclimate (Section 6.6.1); the role of forest trees in nutrient cycling (Section 6.6.2); the comparison of four dominant ground flora in erosion control (Section 6.6.3); the role of cattle in recycling nutrients (Section 6.6.4) and the role of cattle in the germination of forest tree seeds (Section 6.6.5).

6.6.1 The role of forest trees in controlling microclimate

Forest mountainous areas in the north of south east Asia are where tea originates from. This is an area of monsoon climates with a warm, wet summer and a cool, dry (or less wet) winter (Kingdon-ward, 1950). Willson (1992) stated that because the indigenous Assam tea was originally found in the understorey of the forest it was assumed that the ideal environment for tea was under shade. Most tea was, therefore, planted with shade. Scientists concluded that shade increased the quality of tea leaves by reducing the intensity of solar radiation, atmospheric temperature and evapotranspiration rate, so it was felt that reduction of transpiration rate of the tea leaves was especially important.

Table 6.7 Quantitative scientific knowledge that *miang* tea farmers did not articulate, identitified by comparison of lists of all attribute-value statements. English equivalents of these statements are given in Appendix 6.4.

att_value(stemflow,‘nitrogen content’,'25 kg $ha^{-1}yr^{-1}$') if link(‘fall into’,rain,‘hill evergreen forest')
att_value(stemflow,‘phosphorous content’,'2 kg $ha^{-1}yr^{-1}$') if link(‘fall into’,rain,‘hill evergreen forest')
att_value(stemflow, ‘potassium content’, '70 kg $ha^{-1}yr^{-1}$') if link (‘fall into’, rain, ‘hill evergreen forest')
att_value(stemflow,‘calcium content’,'20 kg, $ha^{-1}yr^{-1}$') if link(‘fall into’, rain, ‘hill evergreen forest')
att_value(stemflow,‘magnesium content’,'20 kg, $ha^{-1}yr^{-1}$') if link(‘fall into’,rain,‘hill evergreen forest')
att_value(rain,‘nitrogen content’,'6.5 kg, $ha^{-1}yr^{-1}$')
att_value(rain‘phosphorous content’,'0.5 kg, $ha^{-1}yr^{-1}$')
att_value(rain,‘potassium content’,'7.3 kg, $ha^{-1}yr^{-1}$')
att_value(rain,‘calcium content’,'3.6 kg, $ha^{-1}yr^{-1}$')
att_value(rain,‘magnesium content’,'1.3 kg, $ha^{-1}yr^{-1}$')
att_value(process(part(‘hill evergreen forest’, canopy) 'shedding litter'), rate, '247.4 kg, $ha^{-1}yr^{-1}$')
att_value(process(litter,decomposition), rate, '174.3 kg, $ha^{-1}yr^{-1}$')
att_value(soil,‘nitrogen content’, '400 kg, ha^{-1}') if att_value(forest, type,‘hill evergreen forest')
att_value(soil,‘phosphorous content’, '16 kg, $ha^{-1}yr^{-1}$') if att_value(forest, type,‘hill evergreen forest')
att_value(soil,‘calcium content’, '176 kg, ha^{-1}') if att_value(forest,type,‘hill evergreen forest')
att_value(soil,‘phosphorous content’, '536 kg, $ha^{-1}yr^{-1}$') if att_value(forest,type,‘hill evergreen forest')
att_value(soil,‘magnesium content’, '173 kg, ha^{-1}') if att_value(forest,type,‘hill evergreen forest')
att_value(process('water perculation'),rate,'280 mm hr^{-1}').
att_value(process(‘soil loss’),rate,'38 kg $ha^{-1}yr^{-1}$') if att_value(part(‘ground flora’,canopy),density, low))
att_value(process(‘soil loss’),rate,'21 kg $ha^{-1}yr^{-1}$') if att_value(part(‘ground flora’,canopy),density, high))

Hadfield (1974) calculated that dense shade of forest trees can reduce the mean level of incident radiation to only 200 J m^{-2} S^{-1}.

Table 6.8 Qualitative scientific knowledge that *miang* tea farmers did not articulate, identitified by comparison of lists of all attribute-value statements. English equivalents of these statements are given in Appendix 6.5.

att_value(part('forest tree',leaf), kind, broadleaved) if att_value(forest,type,'hill evergreen forest')
att_value(throughfall,factor,high) if att_value(process(rainfall),intensity,high)
att_value(throughfall,factor,low) if att_value(process(rainfall),intensity,low)
att_value(throughfall,factor,low) if att_value(part (forest,canopy),density,'70%')
process('allelopathical toxin',toxicity) causes1way att_value(process(part(tea,part(root,'apical meristerm'),growth,rate,decresae)
process('allelopathical toxin',toxicity) causes1way att_value(process(microorganism, growth),rate, decrease)
process('allelopathical toxin',toxicity) causes1way att_value(process(litter,decomposition),rate, decrease)
process(cattle,ingestion) causes1way att_value(process(part('forest tree',seed),dormancy), rate,decrease) if att_value(seed,size,small)
process(cattle,disgorging)causes1way att_value(process(part('forest tree',seed),dormancy), rate,decrease) if att_value(seed,size,big)
process('gastric juices',digestion)causes1way att_value(process(part('forest tree',seed), dormancy),rate,decrease) if link(secrete,part(cattle,rumen),'gastric juices)),
process(bacteria,digestion)causes1way att_value(process(part('forest tree',seed),dormancy),rate, decrease) if link(inhabit,bacteria,part(cattle,rumen))
process(fungi,digestion)causes1way att_value(process(part('forest tree',seed),dormancy),rate, decrease) if link(inhabit,fungi,part(cattle,rumen))
process(protozoa,digestion)causes1way att_value(process(part('forest tree',seed),dormancy), rate, decrease) if link(inhabit,protozoa,part(cattle,rumen))
process('hydrochloric acid,digestion)causes1way att_value(process(part('forest tree',seed), dormancy),rate, decrease) if link(secrete,part(cattle,'small investines'),'hydrochloric acid')
process('*Pestalotiopsis theae*','attack on tea leaf') causes1way att_value(process('Grey blight',spreading),rate,increase)
process('*Exobasidium vexans*', 'attack on tea leaf') causes1way att_value(process('Blister blight',spreading),rate,increase)
process('*Collectotrichum camilleae*', 'attack on tea leaf') causes1way att_value(process('Brown blight',spreading),rate,increase)

La-ongsri (1992) reported that tea leaf quality, especially smell and flavour, are related to atmospheric temperature. This is consistent with the work of Sekiya *et al.* (1984) who elucidated that low temperature on the one hand reduces compounds such as tannins, catachin and caffeine which cause bitterness and astringency within tea leaves and on the one hand increases amino acids and nitrogen which are thought to heighten sweetness in tea leaves. They conclude that since high quality tea will be that of tea leaves with high sweetness and low bitterness it may be grown at lower ambient temperatures. This shows that scientists estimate tea leaf quality by considering biochemical constituents in the tea leaves, in contrast the farmers estimate quality by the physical appearance of the tea leaves (see Section 4.4.2.1.1).

It was suggested by the scientists that normally in the mountains of Thailand, there is no need to shade tea trees because there is a lot of cloud, fog and atmospheric humidity. Precipitation can reduce solar radiation and atmospheric temperature. The land form of mountains, a south facing aspect or a valley that lies perpendicular to the solar track can also reduce the solar radiation reaching the tea trees. The scientists also inferred that the high elevation of land can reduce atmospheric temperature because low pressure in the highlands causes the air mass to enlarge and lose heat, the vapour then condenses to become rain. The scientists, therefore, concluded that the mountains of Thailand in the tropical zone, provide good conditions for producing high quality tea. Laycock (1964) and Carr (1972) suggest that the climate in these areas is warm during the day, having high humidity and adequate rainfall, preferably in overnight showers, which is ideal to support the growth of the tea.

Therefore, both the scientists and the farmers have the same knowledge about the influence of shade on tea leaf quality, yet they differ in their knowledge of what actually provides shade and reduces solar radiation reaching the tea plants. The scientists commented that reduced insolation as a result of precipitation and land form are more than enough to reduce solar radiation to acceptable levels for tea, while the farmers suggested that further shade given by forest trees is necessary for optimum tea quality. The scientists considered that planting tea in some areas, such as those having a south facing aspect or valleys that lie along the path of the sun and have high solar radiation would require the shade provided by forest trees indicating general agreement with farmers.

The scientists commented that soil moisture and nutrient content are the main factors that affect of the growth rate of the tea. They explained that if moisture and nutrient content in the soil are enough, unshaded tea will grow faster than shaded tea because high solar radiation and long periods of sunshine increases growth rate when there is no competition from forest trees for water and nutrients. They suggested that tea grown in a land plain where it is easy to irrigate, supply fertiliser and have a high intensity of solar radiation will produce a greater amount of tea that can be harvested compared to that produced from sloping areas. However, Hadfield, (1968) described that in Assam and Bangladesh, maximum daily atmospheric temperatures in the summer can often exceed 30 °C. These high temperatures combined with high levels of radiance during the middle of the day may lead to leaf-to-air saturation deficits, with resultant reductions in the rate of shoot extension and (probably) net photosynthesis. The farmers also believed that soil moisture and nutrients increase the number of leaves on tea trees. They considered that shade conserves soil moisture. The farmers did not appear to appreciate the relationship between tea production and photosynthesis of tea leaves, a process which it is very difficult to imagine the farmers observing. Also, the scientists explained in greater detail the role of forest tree leaves in controlling microclimate. The farmers and scientists both agreed that forest trees reflect and absorb solar radiation and reduce soil moisture loss. Scientists said that forest trees in hill evergreen forest reflected and absorbed a lot of solar radiation because the leaves of most of the forest trees were small and the canopy was dense.

Bhumibhamon and Wasuwanich (1970) divided the canopy of hill evergreen forest into 2-3 height levels (see Table 1.4). The scientists state that the dense forest canopy causes vapour to condense underneath because of the cold air mass in the canopy. Moreover, forest trees were described by the scientists as not only increasing but also reducing soil moisture because forest trees absorb water from the root zone and transpire water to the atmosphere. It was also inferred that rain interception by the forest canopy is a cause of losing some gross rain in the tea gardens because of interception and evaporation. Hill evergreen forest intercepted 8.9 % of the total annual rainfall on a mountain near Chiang Mai City (Chunkao *et al.*, 1971). However, the scientists described that the evapotranspiration from tea gardens within the forest is less than the evaporation from those areas without forest. Farmers did not show evidence of weighing up such positive and negative fluxes in terms of soil water content but appeared to talk about a net positive influence of the presence of trees.

The scientists said that the forest trees indirectly increase the number of tea leaves by increasing the amount of rain. They also, however, said that forest trees were not the main factor in increasing precipitation, in contrast to farmers who said that forest trees caused higher rainfall. Scientists said that the forest trees were only a minor factor and topography and proximity to sources of water were main important factors. Mahannop (1981) elucidated that air masses with water vapour, flow up along the slope of mountains by wind and condense to become rain on hill evergreen forests, the water vapour rising from the sea is also a fundamental factor in the causation of the rain. Rain from the South China Sea, the Pacific Ocean and from the Andraman Sea, Indian Ocean falls in the mountains of North Thailand in the rainy season. Carr (1972) described that in most tea growing areas 150 mm of rain fall each month will ensure continuous crop production, i.e. an annual total of 1 800 mm of rain, but tea should not normally be grown in areas where the rainfall is below 1 150 mm, unless irrigation is available. The distinction in knowledge between farmers and scientists is that whereas farmers notice precipitation in hill evergreen forest that occurs in a specific attitudinal range and attribute the rainfall to the presence of the trees, scientists suggest that the rain would fall regardless of the trees as a result of the geography and topography of the mountains.

The scientists said, however, that the dense forest canopy also has an influence on atmospheric humidity. Chunkao (1979) reported that humidity in the hill evergreen forest was reduced by 0.7 %, after cutting down forest trees. Chunkao (1979) explained that forest trees reduce wind velocity and solar radiation both of which cause high humidity. Kosolanontavong (1981) stated that forest trees reduce wind velocity outside the forest area for a distance of up to five times the height of the wind break and inside forest for distance up to 20 times the height of the wind break. Redhead and Hall (1992) also suggested that air movement increases plant evaporation. Scientists stated that high humidity in the hill evergreen forest is also a major cause of dew, because the high amount of water vapour is condensed at night by low temperatures. Farmers, in contrast, only mentioned low temperature as a cause of precipitation without referring to the water content of air.

The scientists said that shade was indirectly involved in affecting the growth rate of tea, because the intensity of shade is related to the growth of ground flora underneath the forest canopy. The growth rate of ground flora is in turn related to the soil moisture content of the soil. However, the scientists suggested that high shade suppresses the growth rate of *Eupatorium adenophrum* whereas the farmers contradict this by saying that shade supports the growth of *E. adenophorum*. The scientists mentioned that *E. adenophrum* has a high evapotranspiration rate because its canopy is dense and the characteristic position of leaves are horizontal, therefore, most of the leaf surface is directly touched by solar radiation. Moreover, the canopy of *E. adenophroum* reduces gross rainfall by intercepting rain. However, the scientists inferred that evapotranspiration and interception loss by the canopy of *E. adenophorum* are less than evaporation in the open.

The farmers and the scientists agreed that *Pteridium aquilinium* and *Dicranopteris linearis* are not effective in conserving soil moisture, because the leaves of *P. aquilinium* and *D. linearis* are slim and angle of leaf is predominantly vertical. It is easy for solar radiation to penetrate the canopy of both these ferns to evaporate soil moisture. However, the scientists maintained that *P. aquilinium* and *D. linearis* provide a high amount of litter and the leaves of *P. aquilinium* and *D. linearis* transpire little water.

The farmers and the scientists also agreed that dense shade suppresses the growth rate of *Imperata cylindrica* and that *I. cylindrica* reduces the infitration of water into soil because of the presence of a dense root mat. Moreover, the scientists add that the characteristic position of leaves of *I. cylindrica* is vertical making it easy for solar radiation to penetrate and so evaporate soil moisture from the soil surface. However, the scientists nevertheless suggested that *I. cylindrica* conserves soil moisture when compared with bare land where infiltration rates are very low and much water is lost as run-off.

The scientists denied that the root system of forest trees could be connected to the root system of the tea trees because they are different species and, therefore, the root system of the forest trees cannot directly supply the root system of tea trees with water. There are, however, references in the scientific literature to the possibility of nutrient and water transfer amongst plant species sharing a mycorryhizal infection (Brownlee *et al.*, 1983; Newman, 1988; Eason *et al.*, 1991). However, scientists described other processes, namely that of stemflow draining water from the forest canopy down the stems to the area near forest trees which could account for the belief of the farmers that root systems were connected. The intensity of shading near the stem is high, therefore, there is high soil moisture content in the area near the stem of forest trees. This information shows that there are similarities in the indigenous and scientific knowledge in understanding of the influence of forest trees on the water absorbed by the root system of tea trees but that there are large difference in the mechanisms proposed.

The scientists supported the farmer's view that in the winter the forest canopy can prevent frost because heat absorbed by the relatively still air within the forest canopy in the day is not replaced by cooler air at night because the canopy obstructs air movement, decoupling the canopy space from the cold night atmosphere and so buffering temperature at night. Frost wounds the leaves of tea trees and is a cause of spreading tea leaf diseases, such as Grey blight (*Pestalotiopsis theae*), Blister blight (*Exobasidium vexans*) and Brown blight (*Colletotrichum camilleae*). Rattan (1992) described this in more detail saying that they usually occur together on weak or injured bushes (for example, bushes affected by lack of nitrogenous fertiliser, herbicide injury, hail or sunscorch damage or exposure to cold wind and frost).

6.6.2 The role of forest trees in nutrient cycling

The scientists said that the root systems of forest trees would not directly supply the root system of tea trees with nutrients, but suggest that decomposed bark, leaves, flowers, small branches and waste products of animals, such as: birds, squirrels and insects will increase the nutrients in the soil available to tea trees. Johns (1986) determined that the enhancement of nitrogen was due to leaching from nitrogen fixing epiphyllous algae. Naprakob and Chunkao (1977) calculate that the nutrients in stemflow from forest trees in the hill evergreen forest consist of 25, 2, 70, 20 and 9 kg ha^{-1} yr^{-1} of N, P, K, Ca and Mg respectively.

Whitmore (1992) inferred that some nitrogen is converted to nitrate in thunderstorms and dissolved in the rain. Naprakob and Chunkao (1977) calculated that inorganic nutrients in rainfall in a hill evergreen forest on mountains near Chiang Mai consisted of 6.5, 0.5, 7.3, 3.6 and 1.3 kg ha^{-1} yr^{1}, of N, P, K, Ca and Mg respectively. These nutrients are in an available form. The scientists mentioned that this is of importance for tea plants and other flora because the root system of the plants can absorb these nutrients directly after they are released down from the stems of trees, there is no need for the process of decomposition.

The scientists said that forest trees cycle nutrients by taking up nutrients from the soil to the canopy and then return nutrients to the soil through shedding litter. The scientists characterised that the roots of forest trees can take up nutrients from deep in the soil. The litter decomposes to give available nutrients in the topsoil. Sukon (1969) found that hill evergreen forests on the mountains near Chiang Mai City shed litter at a rate of 247.4 kg ha^{-1} yr^{-1}, of that 174.3 kg ha^{-1} yr^{-1} is decomposed. This compares with nutrient contents in the top soil of 400, 16, 176, 536 and 173 kg ha^{-1} of N, P, K, Ca and Mg respectively (Naprakob and Chunkao, 1977). Scientists explained that the leaves of trees in the hill evergreen forest are broadleaved and contain high levels of macro nutrients and organic acids. These acids contribute cations which control the timing of nutrient release so that it is slow and often. The rate of decomposition of litter underneath forest is also slow because the atmospheric temperature is low and the intensity of shade is high. It was also suggested that most of the nutrients are taken up and stored in the stem and canopy of the trees, shedding of litter by the forest trees is a frequent, though a gradual process. The scientists inferred that forest trees in the hill evergreen forest synchronise nutrient release with crop requirements by controlling the quality, timing and manner of addition of plant residues. This process prevents nutrient loss by reducing soil erosion and surface run-off. The scientists stated that the nutrients found in the top soil are enough for the sustained growth of plants in the area, including tea. Willson (1992) characterised that shaded tea without nitrogen fertiliser yields at a higher level than unshaded tea without nitrogen fertiliser.

The scientists described that the roots of some kinds of trees in hill evergreen forest like *Castanopsis spp.*, *Lithocapus spp.* and *Quercus spp.* are surrounded by mycorryhiza fungal infection. This causes an increase in nutrient absorption by increasing the surface area of the roots. ILCA (1986) describe that mycorrhiza absorb carbohydrates from the host plant. In return, the carbohydrates effectively expand the plant's root system, assisting in the extraction of nutrients from the soil. Nutrient ions only travel short distances in soil, hence this expansion of the root system allows a larger nutrient pool to be tapped, and can thus increase uptake relative to leaching. Mycorrhiza are of particular value in improving plant access to phosphorus, because of the very short transmission distance of phosphate ions in soil. This applies also to phosphate added as fertiliser. Moreover, the scientists described that the decay of forest tree roots and mycorrhizae is a source of nutrients for the tea trees. However, at present, there was no report to show that roots of tea trees are linked with other plant species.

The scientific and indigenous knowledge about the connection between the roots systems of forest trees and the roots system of tea trees is contradictory. The *miang* tea farmers believed that roots of forest trees graft with roots of tea trees and transfer water and nutrients to support the growth of tea trees, while the scientists said that this was impossible because the roots of different plant species can not graft on to each other. The scientists, however, suggested that the forest trees transfer water and nutrients to the root system of tea trees indirectly by the process of stemflow, also that the forest trees themselves, in association with mycorrhizas, cause an increase in the process of uptake of water and nutrients. The scientists also described that forest trees in hill evergreen forest synchronise the process of nutrient cycling, while the *miang* tea farmers only described that forest litter causes an increase in nutrients in the soil, but did not mention the process of nutrient cycling from lower soil horizons. Graham and Bormann (1966) described that plants, even when they grow close together, are normally assumed to be physiologically separate from each other. When the roots of trees come into contact natural grafts can sometimes form, but this has usually been observed only between members of the same species. Many of the fungi that form mycorrhizas have low host specificity and they can infect many plant species, and this had led to the suggestion that the fungi may link plants. The mycelial network of a particular fungus in the soil is connected directly to the fungal structures within the roots of two or more plants, thus forming hyphal links between their mycorrhizal roots. There is evidence that the links influence the species composition and structure of plant communities and ecosystem processes such as nutrient cycling (Newman, 1988). Newman also described that links can occur between annuals, herbaceous perennials or tree species, and that the linked species need not belong to the same family or even closely related families. Mycorrhizas are conveniently divided into a few major types. Most herbaceous species and some woody species have vesicular-arbuscular mycorrhizas; ectomycorrhizas are confined entirely to woody species. Roots of pairs of species between which mycorrhizal links have been observed are, for example: a vesicular-arbuscular mycorrhizai link of *Lolium perenne* with *Plantago lanceolata* (Heap and Newman, 1980), *Festuca ovina* with *Plantago lanceolata* (Read *et al*, 1985), *Clarkia rubicunda* with *Plantago erecta* (Chiariello *et al.*, 1982), while ectomycorrhizai links have been reported between *Pinus sylvestris* and *Pinus contorta, Picea abies, Picea sitchensis* or *Betula* *pubescens* and between *Pinus contorta* and *Picea abies, Picea sitchensis* or *Betula pubescens* (Read *et al.,* 1985). It is possible that the roots of trees and herbs can link with roots of tea tress. Observations by Fleming (1983) suggested that in oak-chestnut *(Quercus-Castanea)* stands in England, birch seedlings *(Betula pubescens)* became infected by hyphal links from the trees. There is strong evidence that carbon (Read *et al.,* 1985; Duddridge *et al.,* 1988) and phosphorus (Whittingham and Read, 1982; Newman and Ritz, 1986) can be transported from one plant to another by mycorrhizal links. Transfer of water and nutrients from oak-chestnut trees in the gardens to tea trees via mycorrhizal links can not be scientifically dismissed ever though there is little evidence that the net quantities of such transfer would be large.

The scientific and indigenous knowledge about the influence on nutrients of *I. cylindrica* is similar. The farmers and scientists agreed that the profilic root growth of *I. cylindrica* stunts the growth rate of the root system of tea. However, scientists also hold that the roots of *I. cylindrica* produce an allelopathical toxin which affects the process of biochemical change in the apical meristems of the roots of other plants, including tea. The toxin also affects microorganisms causing a reduction in the decomposition rate of organic matter which reduces the rate of nutrient cycling. The scientists and tea farmers also have similar ideas about the shade given by the forest trees that indirectly increases the growth rate of tea. It was explained that the root systems of forest trees such as, *D. linearis* and *P. aquilinium* maintain soil structure and nutrients that cause tea to grow well. Both knowledge systems agreed that *E. adenophorum* produced a large amount of litter. The scientists explained in more detail that the dense shade of *E. adenphorum* provided good conditions for the activity of microorganisms, fauna and flora in the soil to increase the rate of decomposition.

6.6.3 The comparison of four dominant ground flora in erosion control

Most of the scientific knowledge and indigenous knowledge about the comparison of ground flora in erosion control was similar, perhaps because erosion is easily observed. The tea farmers spent a lot of time picking tea leaves and the main period of picking is during the rainy season. The scientists have done research on soil and water conservation in the highlands. However, there are three topics that scientific and indigenous ecological knowledge differ on:

- The scientists suggested the leaf cover of *E. adenophorum* is more effective in reducing throughfall intensity than the leaf cover of *I. cylindrica* because the leaf cover of *E. adenophorum* is more dense than that of *I. cylindrica.*

- The scientists believed that *D. linearis* and *P. aquiliunium* are as effective in controlling soil erosion as *E. adenophorum* because *D. linearis* and *P. aquiliunium* provide more litter and their roots are more effective in increasing soil porosity, while *E. adenophorum* has dense leaf cover.

- The scientists believed that *I. cylindrica* increases water infiltration because even though the root system of *I. cylindrica* weaves together, it increases soil porosity compared with bare soil whereas farmers articulate the contradictory view that *I. cylindrica* reduces soil porosity and, therefore, reduces infiltration and increases surface run-off. This is an unresolved contradiction that would require experimental research to resolve.

Splash erosion was considered by the scientists, while the farmers did not cover this topic. It was noted that rainfall and throughfall causes splash erosion and that the forest canopy can increase or decrease throughfall intensity. Young (1989) reports that raindrops reach over 95 % of their terminal velocity in a free-fall distance of 8 m, whilst drop size may increase through accumulation of rain on leaf surfaces and fall from their tips. Wiersum (1985) calculated in an experimental study based on artificially removing the canopy of an *Acacia auriculaeformis* plantation in Java, that the presence of the canopy increased erosive power by 24 %. Hall and Calder (1993) found that a large difference occurred between the cumulative normalised drip spectra obtained for different tree species. The median-volume drop diameters of the throughfall were 2.3 mm, 2.8 mm and 4.2 mm for *Pinus caribaea, Eucalyptus camaldulensis* and *Tectona grandis*. The data shows that large leaves like *Tectona grandis* stored a large amount of water so that when water spills off the leaf the drops causes a heavy throughfall intensity. However, small sized leaves like those of *Pinus caribaea* and *Eucalyptus camaldulensis* can reduce rainfall intensity because the small leaves divide the rain drops into droplets when the rain falls down into their canopy. Preechapanya (1984) discovered that the throughfall intensity underneath the canopy of hill evergreen forest is higher than rainfall intensity occurring at the same time, particularly when there are thunderstorms or heavy rain. During the monsoon period, the throughfall factor was found to be about twice that of the rainfall factor due to the size of the throughfall drops being bigger than the size of rain drops. However, if rain amount is slight or the rainfall intensity low, the rainfall intensity is more than the throughfall intensity. Moreover, the research carried out by Naksiri (1963) elaborated that the rate of water percolation was 280 mm hr^{-1} in the hill evergreen forest. This was consistent with Ruangpanit (1971) who commented that there was little opportunity for surface run-off, even in the middle and the end of rainy season. This shows that most of the soil underneath the forest canopy is eroded by throughfall intensity. Preechapanya (1984) found that soil loss from an area underneath forest canopy without ground flora was 38 kg $ha^{-1} yr^{-1}$, while soil loss from an area under forest canopy with ground flora was 21 kg $ha^{-1} yr^{-1}$. This shows that ground flora has more of an influence in erosion control than that normally attributed to the forest alone. Chunkao *et al.* (1976) explained that if ground flora in the hill evergreen forest is cleared or burnt, it takes at least three years before ground flora re-establishes to an extent that it reduces soil and water losses in comparison with sites which were not cleared. Wischmeier (1976) demonstrated that ground flora has an influence on soil erosion and surface run-off because the roots of ground flora grow well and weave together in the top soil. Litter was described as increasing soil organic matter which then improves soil structure and helps to reduce rainfall energy, throughfall energy and surface run-off energy. Young (1989) concludes that the tree canopy cannot be expected to reduce throughfall erosivity to any substantial degree. For erosion control purposes alone, there is no purpose served in attempting to maximise canopy cover in an agroforestry design. Ruangpanit (1971) suggested that 70 % forest canopy of hill evergreen forest is suitable for reducing throughfall intensity. However, Khemnark *et al.* (1971) noted a differential between hill evergreen forest without activities of humans and hill evergreen forest where human activities have included agroforestry, such as the *miang* tea garden system. It was elucidated that the soil structure of *miang* tea gardens was compacted by farmers and cattle walking on the soil which caused surface run-off.

6.6.4 The role of cattle in recycling nutrients

Scientists and farmers both agree that cattle help to increase nutrients in the gardens. The decay of cattle waste not only increases soil nutrient content but also increases the rate of decomposition of litter. The scientists explained that cattle droppings provide a lot of ammonia which decreases the acidity of soil and causes an increase in the availability of soil nutrients. Both scientists and farmers agree that cattle traffic results in compaction of soil structure, which can lead to an increase in surface water run-off and nutrient losses. Bezkorowajnyj *et al.* (1993) report that water infiltration and nitrogen uptake were reduced in soils treated with a simulated medium and high level of soil compaction by cattle, resulting in a slower rate of seedling growth. Phothitai (1992) commented that stocking rate must be carefully controlled and consideration must be given to forest tree species, their size, age and spacing, as well as adequate water for the cattle. The scientists suggested that the farmers should allow cattle to graze not more than 10 % of the total biomass of natural grass in the gardens because the area is highly sloping and natural grass is low in nutrients.

Scientists and farmers held the same knowledge that cattle graze the young leaves of *I.cylindrica*. Humphreys (1994) characterised that the erect-growing *I.cylindrica* disappears under frequent grazing or cutting conditions; it may be replaced by useful low growing species, and broad leaved weeds may invade the gap created from the disappearance of *I. cylindrica* resulting from heavy grazing.

Both tea farmers and scientists agreed that grazing and trampling by cattle indirectly reduces fire: both spatially and temporally by reducing the biomass of ground flora. Kamnalrut and Everson (1992) described how burning grassland and crop residues limits the opportunities for accumulation of carbon in the soil mass. Most tropical grasslands have resilient growth responses to fire. Humphreys (1994) suggested that burning leads to a gradual decrease in soil organic matter. Fire also reduces earthworm populations and microbial biomass (Thompson, 1991). The scientists and the farmers knowledge agreed that loss of vegetative ground cover by fire results in exposed soil and increases soil erosion.

6.6.5 The role of cattle in the germination of tree seeds

The scientists have the same knowledge about the role of cattle in germinating tree seeds as the farmers. Scientists were also aware that cattle eat the fruit of some forest trees and drop the seeds after they have passed through their digestive tract. However, the scientists explained that small seeds pass through the digestive system of cattle but big seeds may be disgorged. Scientific knowledge contains more details regarding this process including the fact that tissues of fruit trees are digested not only by the action of gastric juices, but also by bacteria, fungi and protozoa in the rumen of cattle. The germination of forest seeds is accelerated by treatment with hydrochloric acid in the small intestines of the cattle. The scientists discussed how treated seed has a higher germination rate than untreated seed because it is easier for water to penetrate the hard seed coat of the seeds. However, the scientists commented that cattle destroy seedlings through trampling and browsing. Therefore, the density of cattle should be low enough to sustain the area with minimal damage.

The scientists suggested that cattle indirectly increase the number of germinated seeds and seedlings because cattle reduce the density of *I.cylindrica* by grazing. Cattle thus encourage the germination of tree seeds in two ways:

- by reducing the density of *I. cylindrica* which reduces seedling germination due to allopathic toxins;

- grazing action opens up areas for seeds to come in contact with bare soil enhancing germination.

6.7 Synthesis of appropriate knowledge

Indigenous knowledge may not contain a robust broad conceptual framework, but knowledge about particular components of systems and their interactions may, nevertheless, be robust (Walker, 1994). By contrast, scientific knowledge can produce useful and predictive knowledge based on a mechanistic understanding of fundamental processes but lack widespread experimental validation (Nair, 1990). Budd *et al.* (1990) stated that there was a widespread perception amongst agroforestry professionals of a pressing need for more effective means of accessing and using existing information. Systematically collating, evaluating and synthesising scientific and indigenous knowledge may provide a more accessible and usable store of existing knowledge than is achieved by informal synthesis.

One aim of this research was to synthesise knowledge in the form of recommendations. The new forest-tea plantation recommendations should not distort the indigenous knowledge, but augment parts of that knowledge and be appropriate for the tea farmers. Augmentation of knowledge may be developed by synthesis of related indigenous and scientific knowledge and addressing deficiencies in the synthesised knowledge base. National Research Council, USA (1993) discussed a general methodology to overcome professional and institutional division. They proposed that local and national agencies in the humid tropics need to foster cross-sector communication and action. Integrated management requires closer co-operation among hydrologists, soil scientists, agronomists, foresters, livestock and fishery managers, conservation biologists, cartographers and geographic information specialists, economists, sociologists and other professionals. It also requires close co-operation between resource professionals, farmers and other rural residents. Sustainable forest-tea plantation practice, particular in the north of Thailand, requires conservation of soil, water, nutrients, biodiversity and microclimate, and a whole range of resources on which production depends.

The objectives of the *miang* tea gardens in the hill evergreen forest mentioned by both farmers and scientists were multipurpose: production of tea leaves for *miang*, gathering products from forest flora and fauna and maintenance of a sustainable microclimate, soil system and water yield. Due to the *miang* tea gardens acting as a buffer zone between the natural forest, catchment areas and national parks and because of the lack of labour for picking the tea, it is reasonable to view *miang* tea gardens into the future as not only satisfying commercial interests but also those of conservation. Given this balance of objectives, maintaining a cropping pattern of *miang* tea gardens that integrates tea with many other kinds of flora and fauna can be considered advantageous. Besides forest trees, tea trees and the four dominant types of managed ground flora, opportunity for other flora and fauna to be allowed to grow wild should be provided.

Miang tea is a kind of Assam tea (see Section 2.4.5.2). Scientists' knowledge suggests that Assam tea grows well under forest trees (see Section 6.6.1). Farmers and scientists who were interviewed suggested that this is because it has large leaves, while Banerjee (1992) added that it has horizontal, broad and mostly non-serrated leaves, so that it can photosynthesise at low light intensity. Selection criteria for suitable tea species for cultivation in hill evergreen forest might, therefore, include those with large, horizontal and non-serrated leaves.

The study has provided insights into farmers' and scientists' current knowledge about interactions amongst forest trees, ground flora, tea trees microclimate and soil erosion. Knowledge from both sources showed that forest trees should be allowed to grow tall in order to filter out and reflect solar radiation. Farmers and scientists are aware that this helps to control microclimate thus increasing soil moisture content (see Sections 4.4.2.1 and 6.6.1). They also stated that the forest trees increased soil nutrients and reduced soil erosion by controlling the growth rate of ground flora (see Sections 4.4.2.3, 4.4.3, 6.6.2 and 6.6.3). Farmers and scientists also mentioned that the dense forest canopy reduces damage to the tea leaves from frost in the winter. The attributes which forest trees and ground flora must possess in order to control microclimate, nutrient cycling and soil erosion are well known. For example, forest trees with small leaves were known by farmers and scientists to promote nutrient cycling more effectively than trees with big leaves. Farmers said that this was because small leaved trees led to more nutrients in soil whereas scientists were of the view that smaller leaves decomposed more rapidly, resulting in more appropriate timing of nutrient release. Scientists were aware that forest trees with small leaves also caused a significantly lower throghfall effect than trees with big leaves. Moreover, both farmers and scientists had the knowledge that ground flora having a dense canopy and shedding more litter conserved soil moisture and maintained soil nutrients more than ground flora offering sparse shade and shedding less litter. Selection criteria for suitable forest tree species for cultivation in *miang* tea gardens might, therefore, include: small leaf size and a dense canopy and selection criteria for ground flora species: dense canopy, horizontal leaf orientation and prolific litter production.

The present research indicated that farmers and scientists considered intense overhead shade as an important factor increasing tea leaf quality and quantity. It was known by farmers and scientists that shade reduces solar radiation, conserves soil moisture and indirectly controls nutrient cycling. It was thought by scientists that tea gardens should possess 70 % forest crown cover in order to minimise throughfall intensity (see Section 6.6.3). While this knowledge articulated about the effect of shade and percentage forest crown cover could be used as a basis to develop an interim management recommendation, neither farmers nor scientists articulated knowledge about the level of shading intensity that would optimise tea leaf production and quality while controlling soil erosion. Further research is required to determine this.

There was prodigious indigenous and scientific knowledge about the relationship between roots of forest trees and tea trees. Forest trees were said by farmers and scientists to enhance the growth of tea trees. Scientists strongly commented that nutrients and water from forest trees are supplied to the root system of tea trees via the process of stemflow and water infiltration into the surface soil profile near the root zone of forest trees (see Sections 6.6.1 and 6.6.2). Thus, growing tea seedlings near forest trees can be recommended. However, there was contradiction between *miang* tea farmers' and scientists' knowledge about the process by which water and nutrients were made available to tea trees as a result of their proximity to forest trees. Farmers assert that there are direct linkages between the root systems of forest trees and tea trees through which nutrients and water are transferred. It is possible that nutrients and water from forest trees are supplied to the root systems of tea via mycorrhizal connections, but research would be required to confirm this. The relationship between the root system of both forest trees, tea trees and mycorrihza should be investigated, so that if such connections exist they can be exploited. Also, the relationship between the roots of ground flora, forest trees and tea tree roots should be studied. It is by no means clear how important mycorrhiza might be in this context. While it has been suggested that nutrient and water transfer may occur amongst plants connected via mycorrhizal hyphae, Christie *et al.* (1978) and Lawley *et al.* (1982) grew pairs of British grass-land plant species in mixtures and separately, and found that species that had a lower amount of vesicular-arbuscular mycorrhizal infection when alone did not usually show an increased infection when in a two-species mixture. In fact, most of the statistically significant differences between mixture and monoculture showed species having higher vesicular-arbuscular mycorrhizai infection when growing on their own. Another possible means by which deep rooting forest trees might improve the water relations of tea growing close to them is via hydraulic lift, where water drawn from depth is exuded into the soil by surface roots (Caldwell and Richards, 1989). This phenomenon originally observed in arid environments has more recently been found to be important in temperate conditions (Dawson, 1993). Given the insistence by farmers that there are direct linkages between root systems, while there are many possible scientific explanations for improved water relations of tea associated with forest trees, research to ascertain what mechanisms are in fact important, may lead to an enhanced ability to manage the interactions involved.

The root system of *Imperata cylindrica* is known by both farmers and scientists to cause a decrease in the growth rate of tea trees (see Sections 4.4.2.3, 4.4.3, 6.6.1 and 6.6.2). Moreover, an allelopathic toxin from the root tip of *I. cylindica* is thought by the scientists interviewed to affect the growth rate of tea trees and forest seedlings. However, both farmers and scientists were aware that *I. cylindica* is fodder for cattle (see Sections 4.4.4.1 and 6.6.4) and can be discouraged by intense shade. This knowledge about the control of *I. cylindrica* can be formulated as a management recommendation.

Farmers and scientists had knowledge that litter from forest trees and ground flora is useful for controlling soil moisture, soil nutrients and soil erosion. However, they were also aware that ground flora and litter increase the risk of fire in the summer. The suggestion by farmers is that making fire barriers by clearing the dry grass and litter around gardens, and using cattle to graze the ground flora as well as scattering the litter to reduce fire risk, which may form an appropriate basis for developing management recommendations. However, it was more frequently mentioned that raising cattle in the forest, especially on sloping lands is a cause of soil erosion because cattle trampling compacts soil structure and may be an obstacle in the process of plant succession due to forest tree seedlings being eaten by cattle. Farmers and scientists were aware that when cattle eat some forest tree fruits, passage through the digestive system facilitates germination. This sort of information could form the basis of management recommendations, however, there were few forest tree species mentioned by farmers or scientists. The species of forest tree whose germination is facilitated by cattle should be identified both by further interviewing farmers and scientists and experimentation. No information was provided by the farmers and the scientists to indicate the optimum number of cattle that should be allowed in the *miang* tea gardens that would be suitable to maintain sustainability of the tea garden ecosystem. Therefore, further research on the optimum number of cattle per unit area for *miang* tea gardens should be carried out. Recent research carried out by Ismail (1994) in Malaysia has indicated that the number of sheep per unit area kept in rubber plantations is determined mainly by the amount and growth rate of palatable undergrowth available. The present recommendation is 6-8 animals per hectare for immature rubber trees (the rubber plants must be over 2 m high and at least 18 months old) and 3-5 animals per hectare for mature areas. He suggests that understocking leads to inefficient utilisation of undergrowth vegetation, but that high stocking rates may lead to depletion of palatable species and even erosion. The situation is complicated in the *miang* tea gardens because the agroecosystem is more diverse, and rather than maximise animal output from understorey resources, a balance of ecological roles is desired, including impacts on long term successional processes.

The indication from information articulated by both farmers and scientists was that *E. adenophorum*, *P. aquilinium* and *D. linearis*, mixed with other ground flora excluding *I. cylindrica*, would be suitable to reduce throughfall and surface run-off as well as increase soil porosity and conserve soil moisture (see Sections 4.4.3 and 6.6.3). This knowledge articulated by farmers, including comparative information about dominant ground flora species in controlling soil erosion and soil moisture, could be used to develop management recommendations. However, there is contradictory information amongst scientists and farmers on the relationship between the intensity of shading and the growth rate of *E. adenophorum*, therefore, further research is required in this area.

6.8 Discussion

Analysis of the combined indigenous and scientific knowledge about the sustainability of the *miang* tea gardens in the hill evergreen forest shows various subsets of knowledge that are in agreement, are contradictory or that partially overlap. The scientists show a more comprehensive understanding of the details of the processes of energy flow, nutrient cycling and the interrelationships between organisms and environment within the *miang* tea garden ecosystem than the farmers. However, the scientists' ecological knowledge of the gardens is derived from ecological theory and their experience of research in the hill evergreen forest rather than with disturbed agroecosystems like the *miang* tea gardens. The scientists used fundamental concepts in ecology as tools to explain the agroecosystem function of tea gardens in the hill evergreen forest. It was also evident, however, that the farmers had a more detailed knowledge of the components of the *miang* tea garden ecosystem compared with the scientists, such as their knowledge of particular forest trees and ground flora species. The scientific knowledge gathered here was different from that about commercial tea plantations, because most of the scientists interviewed had more knowledge about ecology rather than agriculture. It is apparent that, combining knowledge from ecologists and farmers creates a new resource for agricultural science that may be more appropriate for designing interventions in the *miang* tea gardens than that derived from research on tea monocultures which has not diffused amongst the people managing *miang* tea gardens despite attempts having been made to extend it.

6.9 Summary

The aim of combining indigenous and scientific knowledge was to identify similarities and differences in both sources of knowledge and to examine to what degree they were consistent and complementary. Eight scientists were selected, using a selective sampling system; they participated in an interview survey using semi-structured questionnaires. Their knowledge was represented and combined with the previously acquired farmers' knowledge on a computer using knowledge-based system software. Sections of the resulting knowledge base were selected for analysis. The farmers and scientists agreed that forest trees reduce solar radiation, buffer atmospheric temperature, increase dew and rain, prevent frost and provide litter that has a role in controlling soil erosion and promoting nutrient cycling. Forest trees indirectly prevent soil moisture evaporating and increase nutrients by suppressing *I. cylindrica*. *I. cylindrica* increases water loss and reduces soil loss more than other dominant ground flora. Cattle increase the rate of nutrient cycling and break the dormancy of forest seeds. As for differences between the knowledge bases, the main points of difference include sub topics, such as: shade increasing tea leaf quality, forest trees increasing rain, control of the growth rate of *E. adenophorum* , the relationship between the root system of forest trees and the root system of tea trees and the relationship between the root system of *I. cylindrica* and the root system of other plants.

6.10 Conclusion

Comparison of indigenous *miang* tea farmers' knowledge and scientific knowledge shows that, in general terms there is a similarity in the understanding of the overall effects of forest trees and ground flora on tea production and ecosystem sustainability. However, in specific terms, it was found that there were some inconsistencies. For example, the mechanism by which interactions between tea trees and other plants occurs and also the effects of raising cattle in the gardens. The study revealed that most knowledge about the fundamentals of ecology articulated by scientists was not known by the farmers. By contrast, the farmers had more knowledge of the biodiversity in the gardens. Thapa (1994) also found that Nepalese farmers had detailed species-specific knowledge, whereas research workers had more mechanistic understanding of fodder quality evaluation.

The present study has revealed that scientific knowledge has not dominated *miang* tea farmers' knowledge. The farmers still used mainly their traditional knowledge in making decisions about cultivation. By contrast, Salas (1994) found that professional knowledge has replaced the local Andean knowledge in Peru. Other workers have reported developmental gains through combining local and external knowledge and effort. Millar (1994), for example describes how the results of farmer experimentation with cereals and tubers in northern Ghana was incorporated in NGO projects through dialogue between extension staff and farmers. Bentley (1994) reports how scientists were able to stimulate farmers to experiment with biological pest control in Honduras by explaining ecological relationships, such as the existence and behaviour of parasitoids and entomopathogens, that were unknown to farmers because they were difficult to observe.

While consideration of the encyclopaedic knowledge of farmers and scientists suggests some fairly clear management guidelines for *miang* tea gardens, the requirement for research focused on key trade-offs in the system (for example determining the optimum forest crown cover and cattle stocking density) is more immediately apparent. It appears, therefore, as though accessing farmers' knowledge is more likely to assist in the planning of appropriate location-specific research and development strategies than to result in large gains in our knowledge of ecological processes in polycultures *per se.* On farm research approaches that continue to combine farmer and scientific approaches and knowledge could be expected to yield more appropriate optima in relation to key trade-offs in the system than either less participatory approaches or leaving farmers to their own devices.

CHAPTER 7

SUMMARY OF CONCLUSIONS AND POLICY IMPLICATIONS

7.1 Introduction

This chapter critically reviews the principal findings and conclusions of this research which were fully presented in Chapters 3 to 6 and discusses the implications of the results for forest policy.

7.2 Achievement of objectives

This study set out to achieve the objectives stated in Section 1.2. The extent to which this was done in each case is discussed below, together with suggestions for future research.

7.2.1. Acquisition of knowledge

The initial objective was as follows.

- To acquire indigenous and scientific knowledge about key processes that may affect the sustainability of *miang* tea gardens in the hill evergreen forest and store it in a durable, accessible and transparent form.

This objective has clearly been achieved. Detailed indigenous knowledge about processes influencing the productivity and sustainabilty of *miang* tea gardens was acquired using the methods described in Chapter 3 and is presented in Chapter 4. This knowledge is stored as a knowledge base on computer and is thus a durable and accessible record. Similar methods were used to acquire scientific knowledge which is presented in Chapter 6. The transparency and accessibility of the knowledge is apparent both in the presentation of statements and diagrams in Chapter 4 and the fact that the computer coded knowledge was able to be used in the analyses subsequently presented in Chapters 5 and 6. The indigenous knowledge base now exists as a resource which may continue to be used:

- to educate research and extension workers about what farmers know and hence promote a more effective dialogue amongst professionals and farmers, and

- for further exploration of what farmers know, including analyses not necessarily formulated prior to knowledge acquisition.

The fundamental reason for the knowledge bases having this continuing utility is the use of a restricted syntax to represent farmers' knowledge, forcing an explicit representation of what they knew, and being able to access this knowledge via a computer interface. The major drawbacks to the methodology include:

- the methodology and syntax were developed together with the knowledge acquisition itself, so that there were many iterations in terms of collecting statements from farmers and having a sufficiently expressive syntax to represent these statements formally, thus extending the time required for the acquisition process;

- the techniques for representing knowledge and exploring the collected knowledge require access to computing resources and some expertise in their use, this effectively rules out access by the *miang* tea farmers themselves without interaction via a third party and restricts access by research and extension workers.

These drawbacks can to some extent be ameliorated by further work. Clearly, future knowledge acquisition will benefit from having a well-developed syntax with which to represent knowledge and access to knowledge bases may be improved for professionals and farmers respectively by:

- setting up tools using the task language available in AKT2 to assist research and extension workers unfamiliar with the knowledge bases in exploring their knowledge content, this effectively combines the knowledge-base creator's understanding of what is available with the interfacing capacity built into the software system, and

- producing, extension literature using text and diagrammatic output from the knowledge bases which may be used by extension agents to inform farmers about the collated knowledge.

In conclusion then, although the computer interface created some restrictions to direct access to the knowledge by farmers and professionals, these are likely to be outweighed by the facilities available for assisting the knowledge-base developer in the generation of paper-based outputs with a general utility. These facilities (basically assistance in fathering information relevant to a particular topic or question) are well illustrated in Chapters 3, 4 and 6. Comparison of this outcome, with previous research on indigenous knowledge, where knowledge is recorded in ethnographic field notes, suggests that a far more flexible and useful resource has been created. Given the investment required to acquire the knowledge, its subsequent utility for multiple purposes is likely to be important to ensure overall cost-effectiveness.

7.2.2 Evaluation of knowledge

The initial objective was as follows:

- analyse the coherence and distribution of knowledge within communities with special reference to gender, age, wealth, altitude, ethnicity and education;

- establish the extent to which the indigenous knowledge contained information about ecological processes;

- compare indigenous and scientific knowledge and where appropriate combine both types of knowledge in an encyclopaedic resource.

The extent to which each of the three parts of this objective were realised is discussed below.

7.2.2.1 Representativeness

A thorough investigation of the extent to which knowledge obtained from a small sample of farmers was held across the whole community is presented in Chapter 5. This revealed a remarkable homogeneity in knowledge held about the *miang* tea garden agroecosystem (the mean proportion of people agreeing with statements drawn randomly from the knowledge base was > 70 % with a range of 55 % to 98 %). This confirmed on the one hand that, in general, the farmers held a consistent knowledge base (more than half of the farmers agreed with every part of the knowledge base tested) but on the other hand that some farmers lacked or disagreed with certain specific knowledge items. Other researchers have similarly found that farmers knowledge was related to their specific experience of tree species and site conditions (Thapa, 1994) and this suggests that farmers may be able to gain useful knowledge via access to an encyclopaedic resource combining knowledge from diverse sources within the community.

Over the last couple of years there has been increased growth in the industrial economy of Thailand (The Economist, 1994). Pachachati (1995) reports that the rate of economic growth in 1995 was about 7-8 % yr^{-1}. Therefore, farmers are migrating to the cities for employment. During the present research, observations showed that the tendency for male *miang* tea farmers to migrate to urban areas was increasing. Women, children and old people were left to work in the *miang* tea gardens and women, therefore, often became the temporary heads of household, when their husbands were away from home. Given this demographic trend of male out migration from the study area specific research on gender differences in knowledge would be particularly useful, since it is likely to be women who will increasingly manage *miang* tea gardens, with a declining availability of labour. A first step would be to reanalyse the responses to the questionnaire in Chapter 5 using gender as a factor in a Chi-squared test to determine whether there were significant differences in the level of agreement obtained from the men and women in the sample. Further knowledge acquisition may also be required, specifically geared to the priorities and cultural position of women in the study area. Thapa (1994) found no evidence of differences in knowledge about tree fodder in Nepal attributable to gender, despite earlier work suggesting that men and women ranked fodders differently (Rusten and Gold, 1991). He explained the discrepancy as reflecting different priorities according to gender operating on a common underlying knowledge base. Similarly Jinadasa (1995) working in Sri Lanka found that age and the amount of time people allocated to farming influenced knowledge about plant selection and siting in homegardens far more than gender, although she did find differences amongst men and women in the fruit characteristics used in selecting mother plants, reflecting women's roles in use of fruits in food preparation. Obviously gender differences in knowledge and priorities are likely to be culture-specific, and while it is clear that differentiating between priorities and knowledge is important specific research for the *miang* tea gardens is required to assess the likely impact of male out migration on the residual knowledge base and garden management strategies.

7.2.2.2 Knowledge about ecological processes

The methodology employed and questions asked were specifically targeted at the elicitation and representation of ecological knowledge. The knowledge collected can be coarsely divided into two categories: taxonomic information represented in object hierarchies, and knowledge about ecological processes that link objects captured diagrammatically and as causal, link or comparison statements. The detailed presentation in Chapter 4, revealed that farmers had sophisticated knowledge of ecological processes related to the role of forest trees in the control of microclimate and consequences for *miang* tea production and ground flora, the role of ground flora in controlling soil erosion and the role of cattle in nutrient cycling and regeneration of forest trees. It was evident, therefore, that the traditional practice of maintaining a tea crop within a biodiverse forest ecosystem was based on active manipulation of the biota, driven by an understanding of components and processes largely developed through long experience of their manipulation. The fact that farmers have a fairly complex understanding of a biodiverse agroecosystem function may at least partly explain why monocultural tea production technologies have not been adopted. On the one hand, high input, monocultural practices represent a different conceptual attitude to management of productivity than the more biodiverse and environmentally benign system operated by farmers, and hence may be alien in fundamental terms. Parallels can be found historically in other societies, perhaps most notably in the way in which modernisers from outside, in introducing commercial maize production, destroyed a way of life amongst descendants of the Mayan Indians in Latin America that was based on maize as a sacred plant (Asturias, 1949).

There are, however, economic as well as conceptual reasons for farmers retaining biodiversity in their agroecosystem. These include the value of products cut, hunted and gathered in the thinned forest and possibly a value attached to the sustainability benefits of maintaining forest cover that is perceived to control soil erosion and maintain water yield of catchments. Further research would be required to obtain specific information on the economic value of these products and less tangible benefits. Price (1995), sets out methods for economic valuation of costs and benefits of agroforestry practices, including sustainability and the application of such methods at different scales and for the different actors associated with *miang* tea gardens would be useful. The actors principally include the *miang* tea farmers themselves and the Government Forest Department concerned with forest conservation and watershed management. The relevant scales include the *miang* tea garden plots, individual watersheds and the complex of watersheds in northern Thailand, including areas of undisturbed natural forest with a high conservation value.

The ecosystem in *miang* tea gardens varies according to climatic conditions, and hence season. More detailed information on ecological processes may, therefore, be obtained by collecting knowledge concerning microclimatic amelioration and nutrient cycling following the seasonal variation in weather conditions. In this way information specific to certain topics could be collected at the appropriate time of year. For example, information concerning soil erosion and surface runoff would be collected in the rainy season whereas, in the summer, the researchers could interview the key informants about the effect of fire on the ecosystem.

Characteristically, mountainous areas consist of many small watersheds that are divided by the topography. As such, each small watershed has an obvious boundary. *Miang* tea villages have been established in the valleys, but farming activities revolve not only around the *miang* tea gardens but also the natural forest and homegardens. Some small watersheds also consist of paddy fields. Research into the indigenous ecological knowledge of *miang* tea farmers, therefore, should in future encompass the entire watershed rather than just the *miang* tea gardens. This more complete information will provide a greater understanding of the *miang* tea farmers' knowledge concerning ecology of the watershed that relates to current land use patterns, the interaction between each type of land use and the effect of the watershed area on water yield. Models of the watershed could be used in participatory activities as developed by the Thailand Upland Social Forest Pilot Project investigating highland farmers' knowledge about forest management of their farms (Royal Forest Department, 1989).

7.2.2.3 Comparison of indigenous and scientific knowledge

A detailed comparison of indigenous and scientific knowledge is presented in Chapter 6 and an encyclopaedic knowledge base combining knowledge from the two types of source was constructed. This revealed large areas of broad agreement amongst farmers and scientists as well as some significant contrasts and a few contradictions. The three most significant contrasts relate to the level of detail of mechanistic understanding of ecological processes, the number of species about which specific knowledge was held and the level of quantification. Scientists had a more comprehensive and quantitative understanding of the general processes of energy, water and nutrient fluxes within the garden ecosystems derived from ecological theory and research on hill evergreen forest, whereas, the farmers had a more detailed knowledge of particular forest trees and ground flora species utilised in their gardens. With respect to contradictions, the most notable related to explanations for particular observed phenomena. Thus, farmers and scientists agreed that tea trees planted close to forest trees would have access to more soil moisture, but while farmers explained this in terms of connections between forest tree and tea root systems, the scientists interviewed considered such connections impossible but suggested that higher soil moisture contents around forest trees could be caused by stem flow. Interestingly, the scientific literature includes recent work on two phenomena not mentioned by the scientists interviewed that may be relevant: mychorrizal connections between plants of different species and hydraulic lift. Research to determine the mechanisms involved and, therefore, how they can be manipulated would be worthwhile. Other differences between the indigenous and scientific knowledge bases were more observational in character and would, therefore, be more easily resolved by controlled measurement and/or experimentation. These include the role of shade in improving tea quality and controlling the growth rate of *Eupatorium adenophorum* and whether *Imperata* *cylindrica* reduces (farmers) or increases (scientists) soil porosity and hence water infiltration.

The fact that relevant information existed in the scientific literature that was not articulated by the eight scientists interviewed and the fact that scientific expertise is sparsely distributed in northern Thailand suggests that there is a utility in gathering together scientific information relevant to particular land use systems in a knowledge base that may then be widely consulted. Clearly interviewing a larger sample of scientists, from a broader range of disciplines, might be expected to yield a richer knowledge base.

7.2.3 Synthesis of knowledge

The initial objective was as follows:

- To investigate the potential to synthesise information from analysis of the encyclopaedic resource appropriate for use in agroforestry research and extension.

This objective was addressed in detail in Section 6.7. At the outset of the present research it was anticipated that combining local and scientific knowledge might lead to new extension recommendations. In practise the situation is more complex. For those aspects of the system where farmers and scientists agree, robust recommendations can be formulated (for example, exclusion of *Imperata cylindrica*), however, there is little requirement for such recommendations since farmers are already aware of the message. Conversely, for aspects where farmers and scientists' knowledge was different, further research is required before robust recommendations could be formulated. The largest gain from the present research was, therefore, to pinpoint key areas for future research on the *miang* tea gardens which might best be done collaboratively by scientists and farmers. Such a participatory approach, acknowledging the considerable knowledge of farmers and involving them in the design and execution of the work is likely to have a larger impact on farmer practice through incremental change than previous attempts at transformation to monocultural production practices. The priority areas for research relate to defining optima. These include:

- the optimum level of overhead shade from forest trees to achieve tea quantity and quality benefits together with an appropriate ground flora understorey;

- the optimum ground flora coverage required to enhance nutrient cycling and control water infiltration and soil erosion while minimising fire hazard in summer; and,

- the optimum cattle stocking density and grazing pattern to reduce fire hazard by grazing and scattering ground flora while minimising soil compaction and balancing the positive (promotion of seed germination) and negative (browsing of seedlings) impacts of cattle on the regeneration of forest trees.

In addition to research priorities identified on the basis of the complementarity of scientific and local knowledge additional research requirements can be identified on the basis of anticipated changes in the economic and ecological context in which *miang* tea garden agroecosystems are operated. Two key areas in this category are as follows:

- Crops to replace *miang* production. The demand for *miang* is decreasing and with the decreasing price of *miang* in the future, other crops or other types of tea production might be usefully introduced to *miang* tea farmers which could increase their income. The farmers could be encouraged to harvest tea leaves to produce black or green tea or to plant other understorey crops instead of tea without cutting down forest trees. Other crops for planting in tea gardens should be shade tolerant and be able to grow well underneath the forest canopy. Research to generate knowledge to support these activities is required. Research to develop plants to substitute for the *miang* tea within the gardens is crucial if sustainable forest gardens are to be continued into the future, as is the prospect of generating sufficient income from the gardens to keep people on the land and able to maintain sustainable vegetative cover.

- Reducing the use of firewood. Given rising concern about the extent of the tree removal from forest areas and *miang* gardens themselves, fuelwood substitutes and more efficient firewood use could usefully be explored and studied to contribute to the lowering of the farmers' consumption of firewood. In the short term, research could also be carried out on types of stove for processing *miang* which use less firewood but process the same amount of tea leaves, as well as on harnessing hydroelectricity as a potential energy source for steaming tea leaves.

In summary, the present research has identified a series of collaborative research requirements, based on analysis of what is already known by farmers and scientists. Firstly, there are requirements to investigate areas of uncertainty, where knowledge is incomplete or contradictory, including the nature of interaction between forest and tea tree root systems, the effect of shade on *Eupatorium adenophorum*, the effect of *Imperata cylindica* on soil porosity and water infiltration and the tree species for which seed germination is promoted by ingestion by cattle. Secondly, there are requirements derived from areas where farmers and scientists agree on the qualitative processes involved, to investigate optimal levels of shade from forest trees, ground flora cover and cattle stocking densities. Thirdly, there are additional requirements derived from anticipated changes to garden ecology and economics in the future; specifically, crops to substitute for *miang* tea as demand for *miang* declines and ways of reducing fuelwood use by farmers to reduce pressure on forest resources.

7.3 Policy implications

The Government appears to have had little inclination to develop the *miang* tea gardens through the development of agroforestry systems. The indigenous knowledge held by the *miang* tea farmers has been largely ignored by governmental and non-governmental agencies alike. These agencies have insisted that the *miang* tea farmers accept new and completely different agricultural technology and crops. It is obvious that few *miang* tea farmers have absorbed this knowledge and that most of the tea farmers still maintain their farms using their indigenous knowledge.

A more successful approach might be to view the large number of *miang* tea villages and *miang* tea gardens surrounding the natural forest as a buffer zone for the natural forest, like the multistoreyed agroforestry garden system in West Sumatra, Indonesia that is used as a buffer zone around forest reserve areas

(Michon, et al., 1994). Similar support zone activities have been investigated in Africa and the Amazon (Oldfield, 1988; WWF, 1990a; 1990b). The *miang* tea farmers might be enlisted to assist the foresters to conserve natural resources and biodiversity which is more realistic than expecting the Royal Forest Department to achieve this on their own. The farmers will be more effective in doing this, if they have a better understanding of ecosystem processes and are able to benefit from the natural resources that they are conserving. Such a strategy can also be viewed as a way to reduce the funding required of the government to promote conservation in these watersheds. The positive attitude of the majority of the respondents to conserving the natural forest suggests that participatory forestry would be a viable intervention programme in the area. Harnessing and enhancing local expertise in managing biodiverse forest margins, appears more realistic than attempting to prevent their use of the resource but requires a careful research and development strategy, based on what people already know and directed towards inevitable changes in social structure and garden ecology that will be wrought by the rapid economic development in Thailand and the cultural changes brought in its wake.

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APPENDICES

Appendix 1.1 System properties.

Productivity defined after Conway (1987) as measure of output over a specific time period, usually expressed as efficiency on an annual basis (eg. yield of grain in t ha^{-1} in a particular year or its monetary value).

Sustainability defined after Conway (1987) as the capacity of a system to produce as evidenced by long term trends in productivity and resilience of the system to major perturbation.

Appendix 1.2 Plant species mentioned.

Scientific name	Common name	Local name
Acacia auriculaeformis Cunn.		
Acacia megaladena Desv. var. *megaladena*		
Acacia sp.		
Acalypha kerrii Craib		
Acanthopanax trifoliatus Merr.		
Acracarpus fraxinifolius Wight & Arn.		
Actinodaphine henryi Gamble.		
Adinandra integerrima T. Anders. ex Dyer		Phi kun paa
Aeschynanthus longicaulis Wall.		
Alangium kurzii Craib		
Albizia chinensis Merr.		
Albizia julibrissim Durdzz.		
Albizia lebbeck Benth.		
Albizia monoccana		
Albizia procera Benth.		
Albzia odoratissima Benth.		Kaang kheemot
Allium cepa Linn.	Onion	
Allium sativum Linn.	Garlic	
Alocasia cucullata Schott	Taro	
Amoora cucullata Roxb		
Ananas comosus Merr.	Pineapple	
Antidesma bunius Spreng.		
Apodytes dimidiata E. Mey. ex Arn.		
Aporusa villosa Baill		
Arachis hypogaea Linn.	Peanuts	
Archidendron clypearia Nielsen		
Ardisia vestita Wall		
Artocarpus heterophyllus Lamk.	Jack fruits	
Averrhoa carambola Linn.		
Bambusa arundinacea Willd.		
Bambusa tulda Roxb.		
Betula alnoides Buch.-Ham..		Kamlang suea khrong
Brassica oleracea Linn. var. *capitata* Linn.	Cabbage	
Breynia retusa (Denn.) Alston		
Calliandra callothyrsus Meisser		
Callicarpa arborea Roxb. var. *arborea*		
Callicarpa rubella Lindl.		
Camellia oleifera Abel. var. *confusa* Sealy		Miang ee aam
Camellia sinensis Ktze. var. *assamica* Kitamura		Miang rerng
Cannabis sativa Linn.		
Capillipedium parviflorum Stapf		
Capsicum annuum Linn.	Chillies	
Capsicum frutescens Linn.		
Castanopsis acuminatissima Rehd.		Ko duie
Castanopsis argyrophyll King		
Castanopsis armata Spach		Ma ko
Castanopsis brevispinula Hickel & A. Camus		
Castanopsis calathiformis Kurz		Ko muu doi
Castanopsis cerebrina Barnett		Ko taa muu
Castanopsis crassifolia Hickel & A. Camus		
Castanopsis diversiflolia King		Ko paen
Castanopsis fissa Rehd. & Wils.		
Castanopsis indica A. DC.		
Castanopsis spp.		
Casuarina equisetifolia J.R.&G. Forst.	Polynesian wood	
Catanopsis lancaefolia Rehd. & Wils.		
Catanopsis pierrei Hance		
Catanopsis puspurea Barnett		
Catanopsis tribuloides A.DC.		
Catimbium malaccense Holtt.		

Celletotrichum camilleae	Brown blight	
Choerospondias axillaris Burtt&Hill		
Chrysanthemum sp.		
Cissus discolor Bl. var. *discolor*		
Citrus limon Burm. f.	Lemons	
Citrus maxima Merr.	Pummeloes	
Clarkia rubicunda		
Cocos nucifera Linn.		
Codiaeum variegatum Bl.		
Coffea arabica Linn.	Coffee	
Colocasia esculenta Schott		
Combretum procursum Craib		
Commelina diffusa Burm. f.		
Cordyline fruticosa Goppert		
Craterispermum laurium		
Crateva magna Dc.		
Cucumis sp.	Squash	
Cucurbita moschata Decne.	Pumpkins	
Cyathea lateborosa Copel.		
Cycas micholitzii Dyer var. *simplicipinna* Smitin		
Cymbidium insigne Rolfe		Samphao ngaam
Cymbium insigne		
Dalbergia abbreviata Craib		
Dalbergia cultrata Grah. ex Benth.		
Dalbergia dongnaiensis Pierre		
Davallia lobbiana S. Moore		
Decaspermum fruticosum Forst		
Dendrobium sp.		
Dicranopteris linearis Underw.		Kuut Pit
Dillenia parviflora Griff.		
Dimocarpuslongan Lour	Longans	
Diospyros kaki Linn.	Persimmon	
Diospyrosglandulosa Lace		
Dipterocarpus obtusifolius Teijsm. ex Mig.		
Dipterocarpus tuberculatus Roxb.		
Dissotis brazzaei		
Dissotis irringiana		
Dissotis violacea		
Dracaenafragrans Ker-Gawl.		
Dracontomelon sp.		
Dysoxylum andamanicum King		
Elaeocarpus floribundus Bl.		Mueat doi
Elaeocarpus nitidus Jack		
Elaeocarpus stipularis Bl.		
Erythina sp.		
Eucalyptus camaldulensis Dehn.		
Eucalyptus sp.		
Eucalyptus teretiornis Sm.		
Eugenia albiflora Duthie		Chom phuu paa
Eugenia malaccensis Linn		
Eugenia subviridis Craib		
Euodia glomerata Craib		
Euonymus similis Craib		
Eupatorium adenophorum Spreng.		Yaa pee wan
Eupatorium odoratum Linn.		
Eurya acuminata DC.		
Exobasidium vexans	Blister blight	
Ficus altissima Bl.		
Ficus fistulosa Reinw.		
Ficus hirta Vahl		Haat
Ficus pubigera Wall.		
Fragaria chiloensis Decne.	Starwberry	
Gigantochloa albociliata Munro		
Gigantochloa apus Kurz		
Glochidion sphaerogynum Kuiz		
Gluta obovata Craib		

Glycine max Merr.	Soy beans	
Gmelina arborea Roxb.		
Haldina cordifolia Ridsd.		
Haven brasiliensis Muell. Arg.	Rubber	
Hedychium coronarium Roem.	Ginger	
Hedyotis capitellata Wall.		
Helianthus annuus Linn.	Sunflower	
Helixanthera parasitica Lour.		
Hibiscus rosa-sinensis Linn.		
Hoya lacunosa Bl.		
Ilex umbellulata Loesn.		
Imperata cylindrica Beauv.		Yaa khaa
Ipomoea batatas Lamk.	Sweet potato	
Jasminum sambac Ait.		
Jatropha curcas Linn.		
Lagerstroemia calyculata Kurz		
Leea indica Merr.		
Lentinus edodes (Berk.) Sing	Black mushroom	
Leucaena leucocephala de Wit		
Lithi chinensis Sonn.	Litchi	
Lithocarpus calathiformis Rehd.		
Lithocarpus elegans (Bl) Hatus.ex Soepadmo		Ko mon
Lithocarpus elegans Hatus.ex Soepadmo		
Lithocarpus spp.		
Lithocarpus trachycarpus A. Camus		Ko waai
Litsea monopetala Pers.		
Lolium perenne Linn.		
Ludwigia parviflora Roxb.		
Lycopersicon esculentum Mill.	Tomato	
Macaranga denticulata Muell. Arg.		
Macrosolen cochinchinnsis V. Tiegh		
Maesa montana A. DC.		
Mallotus philippensis Muell.		
Mangifera indica Linn.	Mangoes	
Mangifera longipetiolate King		
Manihot esculenta Crantz		
Markhamia stipulata Seem.		
Melastoma normale D. Don		
Melia sp.		
Melia toosendan Sieb. & Zucc.		Hian
Mischocarpus pentapetalus Radlk.		
Momordica charantia Linn.		
Musa acuminata Colla		
Mussaenda sanderiana Roxb.		
Oryza sativa Linn.	Rice	
Ostodes paniculata Bl.		
Papaver somniferum Linn.	Opium poppy	
Passiflora foetida Linn.	Passion fruit	
Pestalotiopsis theae	Grey blight	
Phyllanthus sootepensis Craib		
Picea abies Linn.		
Picea sitchensis (Bong.) Carr.		
Pinus contorta Douglas ex London		
Pinus contorta Douglas ex Loudon		
Pinus kesiya Royle ex Gordon		
Pinus merkusii Jungh. & de Vriese		
Pinus sylvestris Linn.	Scots pine	
Piper nigrum Linn.		
Plantago erecta		
Plantago lanceolata Linn.		
Protium serratum Engler		Ma faen
Prunus persica Batsch.	Peache	
Psidium guajava Linn.		
Psychotria monticola Kurz		
Pteridium aquilinium Kuhn var.*wightianum* Tryon		Kuut kai
Pterocarpus macrocarpus Kurz		

Pueraria candollei Grah.		
Quercus kingiana Craib		Ko daeng
Quercus spp.		
Ricinuscommunis Linn.	Castor bean	
Saccharum officinarum Linn.		
Salvia splendens Ker-Gawl.		
Sambucus javanica Reinw.		
*Sapium baccatum*Romb		Salee dong
Schefflera clarkeana Craib		
Schima wallichii Korth.		Tha lo
Scleria terrestris Fassett		
Scurrula gracilifolia Dans.		
Selaginella roxburghii Spreng.		
Semecarpus cochinchinensis Engler		
Shorea obtusa Wall.		
Shorea siamensis Miq.		
Solanum spirale Roxb.		
Solanum torvum Sw.		
Sorghum vulgare Pers.	Sorghum	
Stereospermum colais Kurz		
Styrax benzoides Craib		
Tamarindus indica Linn.		
Tectona grandis Linn. f.		
Terminalia alata Heyne ex Roth		
Thysanolaena maxima Ktze		
Toona sp.		
Toxicodendron rhetzoides Trad.		
Trevesia palmata Vis.		
Trewia nudiflora Linn.		
Tupistra albiflora K. Larsen		Naang laeo
Tupistra albiflora K. Larsen		
Turpinia montana Kurz		
Vanda denisoniana Bens. & Reichb. f.		
Viburnum cylindricum Ham. ex Don		
Vigna sinensis Savi ex Hassk.	Cow pea	
Vitex pinnata Linn.		
Wendlandia paniculata A.Dc.		
Xylia xylocarpa Taub.		
Zea mays Linn.	Maize	
Zizyiphus oenoplia Mill.		

Appendix 2.1 Questionnaire used to survey the socio-economic and demographic status of the villagers.

Respondent's Name: ____________________ Questionnaire No: .________________

Address: ____

Time started/finished: ____

Quality of information in the interviews

1 POPULATION

1.1 Did you or any of your farmily member move into this area?

1 Status in household						
2 Last address (district)						
3 Occupation before moving						
4 Age at the time of moving (yr)						
5 Timing (Year)						
6 Reason						

1.2 Family members characteristics

Name	Sex	Status	Nat.	Citi.	Age	Edu.	Rel.	Maj.O

Note: Nat. Nationality, Citi. Citizenship, Edu. Education, Rel. Religion, Maj.O. Major occupation, For a child less than 1 year old, their age is to be given in months.

1.3 How many children are there whose age is less than 1 year?________________________

1.4 How many people are there in the household?________________________________

2 ECONOMIC STATUS

2.1 How many rai of land are you cultivating?____________________rai (0.16ha)

No.	Land size	Document	Tenure status	Landuse pattern

2.2 Investment for gardens in 1992 (Bath)

Type of production	*miang huapi*	*miang glang*	*miang soi*	*miang moei*	green leaves	tea seeds	Coffee	Mush-room	Total
1 picking tea leaves									
2 packing tea leaves									
3 steaming tea leaves									
4 weeding									
5 food for labour									
6 bamboo strips									
7 baskets									
8 pesticides									
9 fertiliser									
10 plastic bags									
11 transportation									
12 firewood									
13 gathering firewood									
14 renting land									
15 fertilisers									
16 pesticides									
17 interset in loans									

Note: 1-4 were wage of labourers excluding the labourers in family. Their value were calculated using the price of labour day^{-1} by number of day. 11 was paid for vehicles or labour for transportation.

2.3 Income from gardens in 1992

Type of product	*miang huapi*	*miang glang*	*miang soi*	*miang moie*	Green tea	Tea seeds	Coffee	Mush-room	Total
1 total production (kg)									
2 price (Baht kg^{-1})									
3 value of production (Baht)									
4 Type of buyer									

2.4 Homegardens

(1) Do you have a homegardens? ____

(2) If yes, what kind of plants do you have and for what purpose? ____________________

____

____

(3) If no, from where do you get vegetables, fruits, or herbs for home consumption? __________

____

____

2.5 Animal husbandry

(1) Do you keep domestic animals and for what purpose, food or selling? (Including meat and other animal products)________________________________

(2) If yes, how much did you use or sell from animal production in 1992? (Baht)

Types of domestic animal				Total
1 for home consumption (numbers of animals or kg)				
2 for selling (numbers of animals or kg)				
3 income from selling animals or their product (Baht)				

Note: The income from selling animals or their product was calculated using the price of unit divided by the number of animals or kgs.

2.6 Home industry production in 1992

Types of production				Total
1 Total amount (number)				
1.1 use in home (number)				
1.2 for selling (number)				
2 Total payment (Baht)				
2.1 raw material (Baht)				
2.2 labour cost (Baht)				
2.3 transportation (Baht)				
3 Source of raw material				
4 Price/unit of procution (Baht unit^{-1})				
5 Net income (baht)				

Note: 2.1 was calculated from the unit of raw material used multiplied by the price of raw material unit^{-1}. The raw material did not include material from their own areas. 2.2 did not include family laboures. 2.3 included price payed for vehicles, labourers or hireed open carts

2.7 working for wage

Are there any people in your home who work for a wage ?________________

Agricultural work.

Name	Sex	Period (month)	Type of work	Place (district)	Income (Baht.yr^{-1})

Other work

Name	Sex	Period (month)	Type of work	Place (district)	Income (Baht.yr^{-1})

2.8 Other income in 1992 (Baht)______________________________

2.9 Expenditure in 1992

List	Baht yr^{-1}
1 Rice	
2 Foods	
3 Soft drink and liquors	
4 Cigarettes	
5 Medicine and treatment	
6 Fuel	
7 Electricity	
8 Recreation	
9 Education	
10 Clothes	
11 Decoration	
12 Kitchen equipment	
13 Travelling	
14 Repairs	
15 Interest on bank	
16 Insurance	
17 Other	
Total	

3. SOCIAL STATUS

3.1 Social group

(1) Are you or any member of your household, a member of any community organisation?______

if yes, please give detrails.

Name of organisation	Husband	Wife	Member of household			

3.2 Communication

Type of media	Radio	Television	Newspaper	Posters	Announce-ments	Other
Never						
Seldom						
Once/month						
Once/2-3days						
Everyday						

Appendix. 2.2 List of trees and lianas of girth at breast height of 10 cm or more occurring on a transect 100 m long and 6 m wide in natural hill evergreen forest.

Number	Species	Family	Grirth at dbh. (cm)	Total Height (m)	Height at lower Branch:m	dbh (cm)	Vol. (m^3)
1	*Protium serratum*	Burseraceae	98.3	13.2	7.5	32.27	0.3600
2	*P. serratum*	Burseraceae	172.6	31.9	9.9	54.91	2.5190
3	*Lithocarpus elegans*	Fagaceae	168.6	23.1	3.6	53.64	1.7407
4	*Dillenia parviflora*	Dilleniaceae	67.4	8.5	4.2	21.44	0.1023
5	*Euonymus similis*	Celastraceae	30.5	3.4	1.6	9.70	0.0083
6	*P. serratum*	Burseraceae	36.6	7.3	3.5	11.64	0.0259
7	*L. elegans*	Fagaceae	36.9	8.6	7.4	11.74	0.0309
8	*L. elegans*	Fagaceae	92.2	5.2	2.6	29.33	0.1171
9	*P. serratum*	Burseraceae	63.4	12.5	8.5	20.17	0.1331
10	*E. similis*	Celastraceae	84.6	8.6	6.5	26.91	0.1631
11	*Ficus fistulosa*	Moraceae	30.3	3.0	2.0	9.64	0.0073
12	*Mallotus philippensis*	Euphorbiaceae	35.6	12.0	3.8	11.32	0.0402
13	*D. parviflora*	Dilleniaceae	33.6	7.4	3.9	10.69	0.0221
14	*L. elegans*	Fagaceae	158.6	7.7	5.1	50.36	0.5114
15	*Castanopsis armata*	Fagaceae	115.6	14.6	4.8	36.78	0.5172
16	*Aporusa villosa*	Euphorbiaceae	48.9	9.0	3.6	15.55	0.0569
17	*L. elegans*	Fagaceae	177.1	10.7	3.9	56.35	0.8898
18	*L. elegans*	Fagaceae	242.4	17.0	6.1	77.12	2.6405
19	*E. similis*	Celastraceae	106.6	19.6	5.1	33.91	0.5902
20	*F. fistulosa*	Moraceae	130.6	5.3	3.9	41.55	0.2396
21	*L. elegans*	Fagaceae	144.3	36.7	7.1	45.91	2.0259
22	*E. similis*	Celastraceae	55.5	17.6	9.9	17.65	0.1435
23	*E. similis*	Celastraceae	68.4	15.0	7.7	21.76	0.1860
24	*E. similis*	Celastraceae	43.7	10.7	7.1	13.90	0.0541
25	*E. similis*	Celastraceae	55.9	15.5	6.7	17.78	0.1283
26	*Styrax benzoides*	Styracaceae	42.6	8.2	3.5	13.55	0.0394
27	*E. similis*	Celastraceae	46.7	13.5	8.9	14.85	0.0779
28	*E. similis*	Celastraceae	61.4	13.9	6.8	19.53	0.1388
29	*L. elegans*	Fagaceae	44.3	6.4	3.0	14.09	0.0332
	Mean			86.29	12.36	5.41	13.8635

Appendix 2.3 List of trees and lianas of girth at breast height of 10 cm or more occurring on a transect 100 m long and 6 m in *miang* tea gardens vegetation.

Nunber	Species	Family	Grirth at dbh. (cm)	Total Height (m)	Height at lower Branch: (m)	dbh (cm)	Vol. (m^3)
1	*Eurya acuminata*	Theaceae	19.3	5.0	1.0	6.14	0.0049
2	*Schima wallichii*	Theaceae	39.3	7.4	2.2	12.50	0.0302
3	*Adinandra integerrima*	Theaceae	58.5	7.1	2.3	18.61	0.0208
4	*Camellia sinensis*	Theaceae	24.7	3.8	0.2	7.85	0.0061
5	*C. sinensis*	Theaceae	15.6	3.5	1.6	4.96	0.0022
6	*C. sinensis*	Theaceae	35.4	3.4	1.1	11.26	0.0112
7	*C. sinensis*	Theaceae	15.2	4.6	1.6	4.83	0.0028
8	*C. sinensis*	Theaceae	36.6	3.3	0.8	11.64	0.0117
9	*C. sinensis*	Theaceae	22.9	4.1	0.4	7.28	0.0056
10	*C. sinensis*	Theaceae	14.5	2.9	0.4	4.61	0.0016
11	*A. integerrima*	Theaceae	93.1	11.1	2.5	29.62	0.0255
12	*C. sinensis*	Theaceae	41.5	3.0	1.0	13.20	0.0136
13	*E. acuminata*	Theaceae	25.8	7.8	2.3	8.20	0.0137
14	*E. acuminata*	Theaceae	28.7	8.1	4.6	9.13	0.0056
15	*Archidendron clypearia*	Mimosoideae	23.3	5.1	2.5	7.41	0.0073
16	*C. sinensis*	Theaceae	37.3	3.6	1.1	11.86	0.0132
17	*E. acuminata*	Theaceae	28.1	7.0	3.0	8.94	0.0146
18	*C. sinensis*	Theaceae	14.8	3.5	2.0	4.70	0.0020
19	*S. wallichii*	Theaceae	35.1	10.8	5.8	11.16	0.0352
20	*A. integerrima*	Theaceae	57.0	8.8	2.7	18.13	0.0757
21	*Illx umbellulata*	Aquifoliaceae	61.5	15.0	2.1	19.56	0.1503
22	*A. integerrima*	Theaceae	45.5	13.9	3.4	14.47	0.0762
23	*S. wallichii*	Theaceae	96.1	10.5	2.8	30.57	0.2569
24	*I. umbellulata*	Aquifoliaceae	91.4	8.4	2.7	29.08	0.1860
25	*E. acuminata*	Theaceae	14.6	5.2	3.1	4.64	0.0029
26	*Eugenia albiflora*	Myrtaceae	21.2	8.4	2.7	6.74	0.0099
27	*A. integerrima*	Theaceae	25.5	7.0	3.8	8.11	0.0120
28	*Amoora cucullata*	Meliaceae	30.5	7.8	3.3	9.70	0.0192
29	*A. integerrima*	Theaceae	32.6	7.4	3.7	10.37	0.0092
30	*C. sinensis*	Theaceae	59.6	3.4	1.1	18.96	0.0320
31	*Toxicodendron rhetzoides*	Anacardiaceae	15.5	5.5	2.3	4.93	0.0035
32	*E. albiflora*	Myrtaceae	92.3	12.8	3.6	23.36	0.1829
33	*C. sinensis*	Theaceae	27.7	3.5	1.1	8.81	0.0071
34	*C. sinensis*	Theaceae	25.1	2.9	1.8	7.98	0.0048
35	*T. connaroides*	Meliaceae	47.4	10.3	3.9	15.08	0.0613
36	*E. albiflora*	Myrtaceae	19.2	3.0	0.6	6.10	0.0029
37	*S. wallichii*	Theaceae	134.4	21.2	6.2	42.76	1.0152
38	*Stereospermum neuranthum*	Bignoniaceae	43.5	7.4	2.8	13.84	0.0371
39	*S. wallichii*	Theaceae	44.4	7.8	4.2	14.12	0.0407
40	*C. sinensis*	Theaceae	105.7	3.7	1.1	33.63	0.1095
41	*Glochidion sphaerogynum*	Euphorbiaceae	120.1	16.5	3.6	38.21	0.6309
45	*Macaranga denticulata*	Euphorbiaceae	25.6	7.6	2.8	8.14	0.0131
46	*C. sinensis*	Theaceae	101.8	3.9	1.7	32.39	0.1071
47	*S. wallichii*	Theaceae	44.6	7.0	4.1	14.19	0.0369
	Mean		45.10	7.27	2.50	14.83	4.2471

Appendix 3.1 The definite clause grammar. Terms in bold are reserved in the grammar, terms starting with a capital letter are variable.

Formal_sentence ==> Statement **if** Formal_condition.
Formal_sentence ==> Statement.
Statement ==> Cause **causes1way** Effect.
Statement ==> Cause **Causes2way** Effect.
Statement ==> Attribute_statement.
Statement ==> **not** (Attribute_statement).
Statement ==> **link** (influence, Thing, Thing)
Statement ==> **link** (Link, Object, Object)
Statement ==> **link** (link, Process_bit, Process_bit).
Statement ==> **comparison** (Attribute, Object, Comparison, Object)
Formal_condition ==> Formal_conditions **or** Formal_condition.
Formal_condition ==> Formal_conditions **and** Formal_condition.
Formal_condition ==> Statement.
Formal_condition ==> Action_bit.
Formal_condition ==> **att_value** (Action_bit, Attribute, Value)
Attribute_statement ==> **att_value** (Object, Attribute, Value).
Attribute_statement ==> **att_value** (Process_bit, Attribute, Value).
Attribute_statement ==> **att_value** (Action_bit, Attribute, Value).
Cause ==> Attribute_statement.
Cause ==> Process_bit.
Cause ==> Action_bit.
Action_bit ==> action (Action_name, Object, Object).
Action_bit ==> action (Action_name, Object).
Effect ==>. Attribute_statement.
Effect ==> Process_bit.
Process_bit ==> **process** (Proc).
Process_bit ==> **process** (Object, Process).
Process_bit ==> **process** (Object, Process, object).
Thing ==> Object.
Thing ==> Process_bit.
Attribute ==> {something that appears in the attribute glossary}
Process ==> {something that appears in the process glossary}.
Link ==> {something that appears in the link glossary}.
Object ==> Atomic_object.
Object ==> **part** (Object, Atomic_Object).
Atomic_object ==> {Something that appears in the keyword hierarchies}
Action_name ==> {Something that appears in the action glossary}.
Comparison ==> **greater_than** / **less_than** / **same_as** **different_from**
Value ==> **increase** / **decrease** / **change** / **no_change**
Value ==> **Range** (X, Y) {where X and Y are atoms}
Value ==> >X / <X / =X / <=X / >=X { X is an atom}
Value ==> X (atom)

Source: Walker *et al.* (1994)
Note: ==> ='can take the form of'.

Appendix 5.1 The questionnaires used to evaluate the representativeness of the content of knowledge base.

1 Testing individual statements

1.1 A decrease in ambient atmospheric temperature causes an increase in the amount of dew.

- [ ] Agree
- [ ] Agree with conditions
- [ ] Disagree
- [ ] Don't know.

Conditions specified:

1.2 Cattle do not eat the young leaves of *Imperata cylindrica.*

- [ ] Agree
- [ ] Agree with conditions
- [ ] Disagree
- [ ] Don't know.

Conditions specified:

1.3 *Dicranopteris linearis* has dense roots, if *Dicranopteris linearis* is mature.

- [ ] Agree
- [ ] Agree with conditions
- [ ] Disagree
- [ ] Don't know.

Conditions specified:

1.4 Cattle don't eat tea leaves.

- [ ] Agree
- [ ] Agree with conditions
- [ ] Disagree
- [ ] Don't know.

Conditions specified:

1.5 *Dicranopteris linearis* has a dense crown, if *Dicranopteris linearis* is mature.

- [ ] Agree
- [ ] Agree with conditions
- [ ] Disagree
- [ ] Don't know.

Conditions specified:

1.6 An increase in surface run-off rate causes an increase in soil erosion rate.

- [ ] Agree
- [ ] Agree with conditions
- [ ] Disagree
- [ ] Don't know.

Conditions specified:

1.7 Cattle eat *Mangifera longipetiolate* fruits.

- [ ] Agree
- [ ] Agree with conditions
- [ ] Disagree
- [ ] Don't know.

Conditions specified:

1.8 *Elaeocarpus floribundus* has dense crowns, if *Elaeocarpus floribundus* is mature

- [ ] Agree
- [ ] Agree with conditions
- [ ] Disagree
- [ ] Don't know.

Conditions specified:

1.9 An increase in shading intensity causes a decrease in the softness of tea leaves.

- [ ] Agree
- [ ] Agree with conditions
- [ ] Disagree
- [ ] Don't know.

Conditions specified:

1.10 An increase in *Dicranopteris linearis* growth rate causes a decrease in *Imperata cylindrica* growth rate, if shade intensity is high.

☐ Agree
☐ Agree with conditions
☐ Disagree
☐ Don't know.

Conditions specified:

1.11 An increase in *Eupatorium adenophorum* growth rate causes an increase in *Pteridium aquilinium* growth rate, if shade intensity is high.

☐ Agree
☐ Agree with conditions
☐ Disagree
☐ Don't know.

Conditions specified:

1.12 *Sapium baccatum* has light crowns, if *Sapium baccatum* is mature.

☐ Agree
☐ Agree with conditions
☐ Disagree
☐ Don't know.

Conditions specified:

1.13. *Castanopsis armata* has light crowns, if *Castanopsis armata* is mature.

☐ Agree
☐ Agree with conditions
☐ Disagree
☐ Don't know.

Conditions specified:

1.14. *Pteridium aquilinium* has dense crowns, if *Pteridium aquilinium* is mature.

☐ Agree
☐ Agree with conditions
☐ Disagree
☐ Don't know.

Conditions specified:

1.15 *Elaeocarpus adenophorum* has heavy shade, if *Elaeocarpus adenophorum* is mature.

- ☐ Agree
- ☐ Agree with conditions
- ☐ Disagree
- ☐ Don't know.

Conditions specified:

1.16 Rate of nutrient transfer to tea roots of *Castanopsis armata* roots is high , if *Castanopsis armata* roots entwines tea roots.

- ☐ Agree
- ☐ Agree with conditions
- ☐ Disagree
- ☐ Don't know.

Conditions specified:

1.17 Rate of water transfer to tea roots of *Ficus hirta* roots is high , if *Ficus hirta* roots entwines tea roots.

- ☐ Agree
- ☐ Agree with conditions
- ☐ Disagree
- ☐ Don't know.

Conditions specified:

1.18. Rate of preventing surface run-off of land is medium, if *Dicranopteris linearis* grows into the soil.

- ☐ Agree
- ☐ Agree with conditions
- ☐ Disagree
- ☐ Don't know.

Conditions specified:

1.19. *Castanopsis armata* has small leaves.

- ☐ Agree
- ☐ Agree with conditions
- ☐ Disagree
- ☐ Don't know.

Conditions specified:

1.20 Weeding gardens causes an increase in soil moisture content, if season is summer.

- ☐ Agree
- ☐ Agree with conditions
- ☐ Disagree
- ☐ Don't know.

Conditions specified:

2 Testing diagrams and statements linking nodes

2.1 Set of statements linking nodes in diagrams

The intention of this section is to test sets of statements that are grouped into causal chains (e.g. a causes b, b causes c) in diagrams resulting from analysis of the content of the knowledge base. This section does not give any indication of the validity of the chains themselves but does test the conclusions that can be drawn from that chain (e.g. a causes c).

Tick the selected answer from the list of each question or fill in the table as appropriate. Instructions on the interpretation of the results allow you to fill in the table of results relating to the statements being tested.

PART OF DIAGRAM about the role of the forest in controlling microclimate and nutrient cycling (see Figure 5.4).

	Statements being tested	Confirmed	Not confirmed
A	An increase in forest canopy density causes a decrease in solar radiation intensity.		
B	A decrease in solar radiation intensity causes an increase in shading intensity.		
C	An increase in shading intensity causes a decrease in evaporation rate.		
D	A decrease evaporation rate causes an increase in soil moisture content.		
E	An increase in soil moisture content causes an increase in the growth rate of tea trees.		

Select the most correct of the following four statements:

- [ ] Solar radiation is the same under dense compared to light forest canopy.
- [ ] Solar radiation is lower under dense forest canopy than light forest canopy.
- [ ] Solar radiation is lower under light forest canopy than dense forest canopy.
- [ ] don't know.

If informant selects second answer then confirms statement A, otherwise fails to confirm.

- [ ] Shading intensity is the same under high solar radiation compare to low solar radiation.
- [ ] Shading intensity is higher under high solar radiation than light solar radiation.
- [ ] Shading intensity is higher under light solar radiation than high solar radiation
- [ ] don't know.

If informant selects third answer then confirms statement B, otherwise fails to confirm.

- [ ] Evaporation is the same under heavy shade compared to light shade.
- [ ] Evaporation is lower under heavy shade than light shade.
- [ ] Evaporation is lower under light shade than heavy shade.
- [ ] don't know.

If informant selects second answer then confirms statement C, otherwise fails to confirm.

- [ ] Soil moisture is the same under high evaporation compared to low evaporation.
- [ ] Soil moisture is higher under high evaporation than low evaporation.
- [ ] Soil moisture is higher under low evaporation than high evaporation.
- [ ] don't know.

If informant selects second answer then confirms statement D, otherwise fails to confirm.

- [ ] Tea trees grow less in moist soils than in drier soils.
- [ ] Tea trees grow the same rate in moist compared to drier soils.
- [ ] Tea trees grow more in moist soils than in drier soils.
- [ ] don't know.

If informant selects third answer then confirms statement E, otherwise fails to confirm.

	Statements being tested	Confirmed	Not confirmed
A	An increase in shading intensity causes a decrease in the growth rate of *I. cylindrica*.		
B	An increase in shading intensity causes an increase in the growth rate of *P. aquilinium*.		
C	An increase in shading intensity causes an increase in the growth rate of *E. adenophorum*.		
D	An increase in shading intensity causes an increase in the growth rate of *D. linearis*.		
E	A decrease in the density of cover of *I. cylindrica* causes a decrease in transpiration rate.		
F	An increase in transpiration rate causes a decrease in soil moisture content.		

G	An increase in the growth rate of *P. aquilinium* causes an increase in the density of cover of *P. aquilinium*		
H	An increase in the growth rate of *E. adenophorum* causes an increase in the density of cover of *E. adenophorum*.		
I	An increase in the growth rate of *D. linearis* causes an increase in the density of cover of *D. linearis*..		
J	An increase in the density of cover of *P. aquilinium* causes a decrease in evaporation rate.		
K	An increase in the density of cover of *E. adenophorum* causes a decrease in evaporation rate.		
L	An increase in the density of cover of *D. linearis* causes a decrease in evaporation rate.		
M	An increase in the density of cover of *P. aquilinium* causes an increase in the amount of litter.		
N	An increase in the density of cover of *E. adenophorum* causes an increase in the amount of litter.		
O	An increase in the density of cover of *D. linearis* causes an increase in the amount of litter.		
P	An increase in the amount of litter causes an increase in soil nutrient content.		
Q	An increase in soil nutrient content causes an increase in the growth rate of tea trees.		
R	A decrease in the growth rate of *I. cylindrica* causes a decrease in the density of the roots of *I. cylindrica* .		
S	An increase in the density of roots of *I. cylindrica* causes a decrease in the growth rate of tea roots.		
T	A decrease in the growth rate of tea roots causes a decrease in the rate of nutrient uptake of tea roots.		
U	An decrease in the rate of nutrient uptake of tea roots causes an decrease in the growth rate of tea trees.		
V	THEREFORE An increase in the growth rate of *P. aquilinium, E. adenophorum* or *D. linearis* causes an increase in soil nutrient content.		
W	ALSO THEREFORE An increase in the growth rate of *I. cylindrica* causes a decrease in the growth rate of tea trees.		
X	ALSO THEREFORE An increase in shading intensity causes an increase in soil nutrient content.		
Y	ALSO THEREFORE An increase in shading intensity causes a decrease in evapotranspiration.		
Z	ALSO THEREFORE An increase in shading intensity causes an increase in the growth rate of tea trees.		

i) For each species select the situation in which that species grows most and least:

	Heavy shade	light shade	no shade
I. cylindrica			
P. aquilinium			
E. adenophorum			
D. linearis			

If best is further right for *I. cylindrica* than worst then statement A confirmed. If best further left than worst for each of other species then statements B, C, D respectively correct.

ii) Transpiration is highest under :

- ☐ fast growing *I. cylindrica*;
- ☐ slow growing *I. cylindrica*.
- ☐ don't know.

If informant selects first option then statement E confirmed.

iii) Select the most correct of the following four statements:

- [ ] Soil moisture is the same under high transpiration compared to low transpiration.
- [ ] Soil moisture is higher under high transpiration than low transpiration.
- [ ] Soil moisture is higher under low transpiration than high transpiration.
- [ ] don't know.

If informant selects third answer then confirms statement F, otherwise fails to confirm.

iv) For each species select the situation in which that species is most abundant:

	Heavy shade	light shade	no shade
P. aquilinium			
E. adenophorum			
D. linearis			

For each if heavy shade is selected then statements G, H and I, respectively are confirmed.

v) For each species select the circumstances under which evaporation is at its lowest:

	High density	Low density
P. aquilinium		
E. adenophorum		
D. linearis		

If informant selects high density for all species then statement J, K and L respectively are confirmed.

vi) For each species select the circumstance under which litter is greatest

	Slow growing	Fast growing
P. aquilinium		
E. adenophorum		
D. linearis		

If informant selects fast growing for all species then statement M, N and O confirmed.

vii) Root of *I. cylindrica* is light because of (NB more than one option can be selected):

- [ ] fast growing *I. cylindica*
- [ ] slow growing *I. cylindica*
- [ ] don't know.

If second option is selected then statement R is confirmed (unless the first statement is also selected).

viii) Select the most correct of the following four statements:

- [ ] Tea roots grow less with dense roots of *I. cylindrica* than with light roots of *I. cylindrica.*
- [ ] Tea roots grow at the same rate with dense roots of *I. cylindrica* compared to light roots of *I. cylindrica.*
- [ ] Tea roots grow more with dense roots of *I. cylindrica* than with light roots of *I. cylindrica.*
- [ ] don't know.

If informant selects first answer then confirms statement S, otherwise fails to confirm.

ix) Select all the circumstances that cause an increase in nutrient concentration in the topsoil (NB more than one option can be selected):

- ☐ 1. an increase in litter onto the soil
- ☐ 2. a decrease in litter onto the soil
- ☐ 3. an increase in the growth rate of *P. aquilinium, E. adenophorum* or *D. linearis* growing on the soil
- ☐ 4. a decrease in the growth rate of *P. aquilinium, E. adenophorum* or *D. linearis* growing on the soil
- ☐ 5. an increase in the intensity of shading
- ☐ 6. a decrease in the intensity of shading

If first option is selected then statement P is confirmed (unless the second statement is also selected). If the third option is selected statement V is confirmed (unless the fourth is also selected). If the fifth statement is selected then statement X is confirmed (unless the sixth is also selected).

x). Select the most correct of the following four statements:

- ☐ Tea trees grow less rate in soil with a high nutrient status than in soil with a low nutrient status.
- ☐ Tea trees grow at the same rate in soil with a high nutrient status compared to in soil with a low nutrient status.
- ☐ Tea trees grow more rate in soil with a high nutrient status than in soil with a low nutrient status.
- ☐ don't know.

If informant selects third answer then confirms statement Q, otherwise fails to confirm.

xi) Select the circumstances that causes a decrease in the growth rate of tea trees (NB more than one option can be selected):

- ☐ 1 tea roots are dense
- ☐ 2 tea roots are light
- ☐ 3 an increase in the growth rate of *I. cylindrica*
- ☐ 4 a decrease in the growth rate of *I. cylindrica*
- ☐ 5 don't know

If first is selected then statement T and U confirmed (unless the second option is also selected). If third is selected then statement W confirmed (unless the forth option is also selected).

xii) Evapotranspiration is greatest under:

- ☐ heavy shade
- ☐ light shade
- ☐ don't know

If first option is selected then statement Y is confirmed (unless the second option is also selected).

xiii). Select the most correct of the following four statements:

- ☐ Tea trees grow less rate in heavy shade than in light shade.
- ☐ Tea trees grow the same rate in heavy shade compared to light shade.
- ☐ Tea trees grow more rate in heavy shade than in light shade.
- ☐ don't know

If informant selects third answer then confirms statement Z, otherwise fails to confirm.

Testing part of diagram about indigenous knowledge about the role of cattle on the number of forest trees seedlings see Section 5.2.2.

2.2 Part of diagrams

This section is intended to give an indication of the validity of the chains of causal connections tested in Section B.

1. The implication of part of the diagram in Figure 5.4 is that tea trees produce more leaves under shade because the soil is moister.

Do tea trees produce more leaves in heavy shade or light shade? Why?

TICK FACTS IN ANSWER

More tea leaves in heavy shade [ ]

BECAUSE

Soils in heavy shade are more moist. [ ]

If both ticked confirms chain of reasoning about the role of forest tree shade on tea trees production. If not, fails to confirm.

2. The implications of another part of the diagram in Figure 5.4 are that sites with light shade are drier and less fertile than sites with heavy shade because sites with light shade have more *Imperata cylindrica* which increases transpiration and decreases the rate of nutrient uptake of tea roots while the other sites have more of the other species of ground flora which reduce evaporation and put nutrients back in the soil through litter.

Are soils at lightly shaded sites more or less fertile and more moist or drier than soils under heavy shade and why?

TICK FACTS IN ANSWER (sets in brackets count as one tick):

Lightly shaded -> drier soils [ ]
Lightly shaded -> less fertile soils [ ]

BECAUSE

(lightly shaded soil more *I. cylindrica*
AND
heavily shaded soil more *D. linearis, E. adenophorum, P. aquilinium*) [ ]

AND
(*Imperata cylindrica* increases rate of transpiration
AND
D. linearis, E. adenophorum, P. aquilinium reduce rate of evaporation) [ ]

AND

(*I. cylindrica* decreases the rate of nutrient uptake of tea trees
AND
D. linearis, E. adenophorum, P. aquilinium increases nutrient content) [ ]

If all ticked then chain of reasoning confirmed, if not, not confirmed.

3. For the implications of part of the diagram in Figure 5.1 see Table 5.1.

Appendix 6.1 Scientists being interviewed.

No	Name	Professional field of work	Office	Topics in Table 6.1 articulated by the scientists		
				1	2	3
1	Dr Boonserm Cheva-isarakul	Animal husbandry	Department of Animal Husbandry , Faculty of Agriculture, ChiangMai University, ChiangMai.			*
2	Dr Nipon Tangtham	Watershed management	Department of Conservation, Faculty of Forestry, Kasertsart University, Bangkok.	*	*	
3	Dr Pongsak Sahunalu	Forest ecology	Department of Silvicuture, Faculty of Forestry, Kasertsart University, Bangkok.	*	*	
4	Dr San Kaleparnee	Forest fires	Department of Silvicuture, Faculty of Forestry, Kasertsart University, Bangkok			*
5	Mr Sirichai Leejeerajumne an	Plant Phathology	Division of Plant Pathology, Department of Agriculture, Bangkok.	*		
6	Dr Sooton Khamyong	Forest soils	Department of Soil Science and Conservation , Faculty of Agriculture, ChiangMai University, ChiangMai.	*	*	
7	Dr Suree Bhumibhamon	Forest Seed Science	Department of Silvicuture, Faculty of Forestry, Kasertsart University, Bangkok.			*
8	Dr Wichian Pooswang	Crop Physiology	Department of Horticuture , Faculty of Agriculture, ChiangMai University, ChiangMai	*	*	
Total number of scientists mentioning each topic				5	4	3

Appendix 6.2 English equivalents of statements in Table 6.5.

Indigenous knowledge	Scientific knowledge
The rate of filtering out of solar radiation of canopy of *Dicranopteris linearis* is <u>medium</u>, if *Dicranopteris linearis* is mature.	The rate of filtering out of solar radiation of canopy of *Dicranopteris linearis* is <u>low</u>, if *Dicranopteris linearis* is mature.
The rate of filtering out of solar radiation of canopy of *Pteridium aquilinium* is <u>medium</u>, if *Pteridium aquilinium* is mature.	The rate of filtering out of solar radiation of canopy of *Pteridium aquilinium* is <u>low</u>, if *Pteridium aquilinium* is mature.
The rate of decreasing soil erosion is <u>low</u>, if *Dicranopteris linearis* roots grow into soil.	The rate of decreasing soil erosion is <u>medium</u>, if *Dicranopteris linearis* roots grow into soil.
The rate of decreasing soil erosion is <u>low</u>, if *Pteridium aquilinium* roots grow into soil.	The rate of decreasing soil erosion is <u>medium</u>, if *Pteridium aquilinium* roots grow into soil.
The rate of decreasing surface run-off is <u>low</u>, if *Eupatorium adenophorum* roots grow into soil.	The rate of decreasing surface run-off is <u>medium</u>, if *Eupatorium adenophorum* roots grow into soil.
The rate of throungfall interception of canopy of *Eupatorium adenophorum* is <u>medium</u>.	The rate of throungfall interception of canopy of *Eupatorium adenophorum* is <u>high</u>.
The rate of transpiration of leaf of *Eupatorium adenophorum* is <u>low</u>, if *Eupatorium adenophorum* is mature.	The rate of transpiration of leaf of *Eupatorium adenophorum* is <u>high</u>, if *Eupatorium adenophorum* is mature.

Appendix 6.3 English equivalents of statements in Table 6.6.

Indigenous knowledge	Scientific knowledge
Forest tree roots <u>connect</u> tea roots	Forest tree roots <u>do not connect</u> tea roots
Forest tree roots <u>transfer water to</u> tea roots	Forest tree roots <u>do not transfer water to</u> tea roots
Forest tree roots <u>transfer nutrients to</u> tea roots	Forest tree roots <u>do not transfer nutrients to</u> tea roots

Appendix 6.4 English equivalents of statements in Table 6.7

Nitrogen content in stemflow is 25 kg, $ha^{-1}yr^{-1}$, if rain fall into hill evergreen forest.
Phosphorous content in stemflow is 2 kg, $ha^{-1}yr^{-1}$, if rain fall into hill evergreen forest.
Potassium content in stemflow is 70 kg, $ha^{-1}yr^{-1}$, if rain fall into hill evergreen forest.
Calcium content in stemflow is 20 kg, $ha^{-1}yr^{-1}$, if rain fall into hill evergreen forest.
Magnesium content in stemflow is 20 kg, $ha^{-1}yr^{-1}$, if rain fall into hill evergreen forest.
Nitrogen content in rain is 6.5 kg, $ha^{-1}yr^{-1}$.
Phosphorous content in rain is 0.5 kg, $ha^{-1}yr^{-1}$.
Potassium content in rain is 7.3 kg, $ha^{-1}yr^{-1}$.
Calcium content in rain is 3.6 kg, $ha^{-1}yr^{-1}$
Magnesium content in rain is 1.3 kg, $ha^{-1}yr^{-1}$.
Rate of shedding litter of hill evergreen forest canopy is 247.4 kg, $ha^{-1}yr^{-1}$.
Rate of litter decomposition in hill evergreen forest canopy is 174.3 kg, $ha^{-1}yr^{-1}$.
Nitrogen content in soil is 400 kg, ha^{-1}, if forest is hill evergreen forest.
Phosphorous content in soil is 16 kg, ha^{-1}, if forest is hill evergreen forest.
Potassium content in soil is 176 kg, ha^{-1}, if forest is hill evergreen forest.
Calcium content in soil is 536 kg, ha^{-1}, if forest is hill evergreen forest.
Magnesium content in soil is 173 kg, ha^{-1}, if forest is hill evergreen forest.
The rate of water percolation is 280 mm hr^{-1}.
The rate of soil loss is 38 kg $ha^{-1}yr^{-1}$, if density of ground flora canopy is low.
The rate of soil loss is 21 kg $ha^{-1}yr^{-1}$, if density of ground flora canopy is high.

Appendix 6.5 English equivalents of statements in Table 6.8.

Forest trees have broadleaved if forest is hill evergreen forest.

Throughfall factor is high, if rainfall intensity is high.

Throughfall factor is low, if rainfall intensity is low.

Throughfall factor is low, if forest canopy density is 70%.

Toxicity of allelopathy toxin causes a decrease the apical meristerms of tea root growth rate.

Toxicity of allelopathy toxin causes a decrease microorganism growth rate.

Toxicity of allelopathy toxin causes a decrease litter decomposition rate.

Cattle ingestion causes a decrease in seed dormancy rate of forest tree seeds, if seed is small.

Cattle disgorging causes a decrease in seed dormancy rate of forest tree seeds, if seed is big.

The digestion of gastric juices in cattle rumen causes an increase in seed germination rate of forest tree seeds, if cattle eat forest tree fruit.

The digestion of bacteria in cattle rumen causes an increase in seed germination rate of forest tree seeds, if cattle eat forest tree fruit.

The digestion of fungi in cattle rumen causes an increase in seed germination rate of forest tree seeds, if cattle eat forest tree fruit.

The digestion of protozoa in cattle rumen causes an increase in seed germination rate of forest tree seeds, if cattle eat forest tree fruit.

The digestion of hydrochloric acid in cattle small intestines causes an increase in seed germination rate of forest tree seeds, if cattle eat forest tree fruit.

The attack on tea leaves of *Pestalotiopsis theae* causes an increase in spreading of Grey blight.

The attack on tea leaves of *Exobasidium vexans* causes an increase in spreading of Blister blight.

The attack on tea leaves of *Collectotrichum camilleae* causes an increase in spreading of Brown blight.

GLOSSARY

agrisilvopastoral system an agroforestry system that combines crops, pastures (with or without animals) and trees.

agroecological zone Geographic areas in which ecological conditions (soil, water and climate) dictate the agricultural practices that are used areas (National Research Council, USA, 1993).

agroecosystem A model for the functioning of an agricultural system with all its inputs and outputs (National Research Council, USA, 1993).

Agroforestry Knowledge Toolkit (AKT) A pair of software toolkits and an associated methodology, for creation and use of knowledge base. The toolkit can be used to provide various levels of support and flexibility to suit different needs in knowledge analysis and decision making (Walker, *et al.*, 1994).

agroforestry A collective name for land use systems in which woody perennials (tree, shrubs, etc.) are grown in association with herbaceous plants (crops, pastures) and/or livestock in a spatial arrangement, a rotation or both, and in which there are both ecological and economic interactions between the tree and non-tree components of the system (Young, 1989)

allelopathic compound Various metabolic substances, such as terpenes, camphor, and cineole, released by plants that biochemically inhibit other plants or microorganisms (National Research Council, USA, 1993).

allelopathy Release into the environment by organism of chemical substance that acts as a germination or growth inhibitor to another organism. Typical substances include alkaloids, terpenoids, and phenolics. The phenomenon was described originally for heath and scrub communities, notably the *Californian chaparral,* but is now thought to be widespread anti-competion mechanism in plant (e.g.) barley inhibits competing weed by means of root secretions. It is also found in other organisms e.g. antibiotics may be produced by fungi to inhibit competing bacteria, when the term "antibiosis' may be used (Allaby and Attenborough, 1985)

ammonification The reduction of nitrate ions in soil to ammonium ions.

amphoe District, second subdivision of Thailand

anion a negatively charged ion; an ion that is attracted to the anode in electrolysis.

artificial intelligence or machine intelligence is a multidisciplinary subject that aims to understand the nature of human and animal intelligence and in particular problem solving, through the extensive use of computer programs. Machine learning and automated reasoning are but two of many mature research subjects that fall under this discipline.

Baht Thai currency (£1=40.00 Baht, as 16 May 1995)

Ban Mae Ton Luang A village belonging to Tape Sa Daje sub district, Doi Sa Kade district, Chiang Mai province. The main occupation of people of this village is tea plantation. It is in the north east of Chiang Mai.

Ban Yong Kog Noi A village in Chiang Mai province. It is in the north east of Chiang Mai.

ban village

biodiversity The variety and variability among living organisms and the ecological complexes in which they occur.

biomass The total weight of organic material present per unit area.

biotic Of or relating to life; caused or produced by living things.

birds-eye view A general view from above.

black tea The tea produce from leaves that are fully fermented before drying, also known as European tea.

Blister blight This disease caused by the fungus *Exobasidium vexans* Massee is now endemic throughout the tea growing areas of Asia. The most important and fortunate characteristic of the disease is that it can infect only young and succulent leaves and stems and does not affect the mature leaves or stem. The disease is first evident as pale yellow translucent spots on young leaves about nine days after infection. Seven to nine days later these spots became circular blisters, the upper surface becomes indented corresponding to the protrusion of the lower surface, to form the socalled blister. There to four day later (18-21 days after infection) the convex surface on the underside of the leaf becomes white and velvety as spore production begins. After sporulation the blisters turn brown and dry up. When several blisters develop on a single leaf, the leaf become curled and distorted. When young stems are affected by the disease, they become bent and distorted or girdled and may break off and die. The disease is more serious when this happens since this causes a severe set-back to growth and is particularly dangerous when the bush are recovering from pruning. During this period repeated attacks of blister blight can severely debilitate the bush or even kill it. The disease is more prevalent at the higher elevations and moisture and high relative humidity increase the incidence of the disease. It therefore occurs mainly during the rainy season (Arulpragasam, 1992).

Bo Keaw A province in Laos. It is in the north west of Vietiate.

breast height as high as the breast, most scientists use height at 130 cm.

broadleaf forests A type of closed forest where broadleaf species (dicotyledons or monocotyledons) predominate. The broadleaf trees (especially the dicotyledons) are often referred to as hardwoods (National Research Council, USA, 1993).

Brown blight A type of tea leaf disease occurred by *Colletotrichum camilleae* on old and young leaves and can cause defoliation and death of young plants under humid warm conditions. It usually occur together on weakened or injured bushes, e.g. bushes affected by lack of nitrogenous fertiliser, herbicide injury, hail or sunscorch damage, exposure to cold wind, waterlogging (Rattan, 1992).

buffer zone Areas on the edge of protected areas that have land use controls and allow only those activities that are compatible with protecting the core area.

caffeine An alkaloid drug with stimulant action, found in tea leaves and coffee bean.

Cambodia A country in Southeast Asia between Thailand and Vietnam; population (in 1995) 12 000 000, official language, Khmer; capital, Phnom Penh.

Cambodian a native or national of Cambodia, a person of Cambodian descent.

canopy The more or less continuous cover of branches and foliage formed collectively by the crowns of adjacent trees and other woody vegetation. Layers of the canopy may be distinguished (that is, understory and overstory) (National Research Council, USA, 1993).

cash crop Crops produced for sale (such as tea, coffee and cacao).

catchment area The area from which rainfall flows into a river.

catechin one kind of flavanol compound in tea leaves.

cation a positively charged ion; an ion that is attracted to the cathode in electrolysis.

cattle traffic Cattle moving

Chae Hom A district belonging to Lumpang province. It is in the north of Lumpang.

changwat province, first subdivision of Thailand

Chiang Mai This city is 761 km. by rail, approximately 700 km. by road north of Bangkok and is Thailand's second largest city. Chiang Mai is also a province, consisting of 21 districts, with an area of 20 107 km^2.

Chiang Mai University A governmental university in Chiang Mai, Thailand.

Chiang Rai This city is 785 km north of Bangkok, Chiang Rai is also a province which is Thailand's northern most province consisting of 13 districts, with an area of 11 768 km^2.

Chulalongkorn University A governmental university in Bangkok, Thailand.

Chumporn This city is about 300 km. south of Bangkok, Chumporn is also a province, consisting of 8 districts, with an area of 6 009 km^2.

climax stage A state of equilibrium reached by a plant community.

community forest Forest areas and forest trees managed and used by people in communities for the people.

compaction soil The squeezing together of soil particles by the weight of farm and construction equipment, vehicles and animal and foot traffic. Compaction reduces average pore size and total air space in the soil (National Research Council, USA, 1993).

compost Mixed manure, esp. of organic origin.

coniferous forest A type of forest, which dominant forest trees species are in the family Coniferous.

cover crop A low-growing, often spreading, often annual, crop grown all over a field before planting. This protects the soil against erosion and may provide some shelter for young plants.

crown cover The part of a plant just above and below the ground.

demographic profiles The data or information of the population.

Department of Agriculture A Thai Government organisation belonged to the Minitry of Agricultural and Cooperative to do researches about agriculture in Thailand.

Department of Extension Agricultural A Thai Government organisation belonged to the Ministry of Agricultural and Cooperative to extent agriculture to the farmers in Thailand.

diagrammatic approach The use of an explicit graphical node-link-node representation of statements encoded in AKT's knowledge base.

diagrams interface A decicated graphical user interface that allows the user to input/view sets of semantically linked statements that are encoded in the programs' knowledge base.

dischange A flow of water through the river.

Doi Chiang Khian A mountain near Chiang Mai city.

Doi Sa Kade district A district belonged to Chiang Mai province. It is in east of Chiang Mai.

doi mountain

domestic species Plants or animals that have evolved either naturally or through artificial selection to forms more useful to people. These characteristics of domestication are frequently absent in wild type of the organism and may constitute a negative genetic load for survival in the wild state.

dry dipterocarp forest A type of forest, which dominant forest trees species are in the family Dipterocarpaceae. The character of the forest is open forest. This forest occur in dry lands, unfertile soil and low slope lands.

ecosystem The complex of an ecological community, together with the nonliving components of the environment, that function together as a stable system and in which exchange of material follows a circular path (National Research Council, USA, 1993).

energy flow The exchange and dissipation of energy along the food chains and food webs of an ecosystem (Allaby and Attenborough, 1985).

ephiphy plants Plants that derives its moisture and nutrients from air and rain. It usually grows on another plant.

ethnic minorities Group differentiated from the main population of community by racial origin or cultural background.

evaporation The process by which moisture passes into the atmosphere as vapour (Kirkby, 1980).

evapotranspiration The process which water withdrawn from a land area by evaporation and moist soil, and by plant transpiration (Kirkby, 1980).

extension Agricultural or forestry activities that involve dissemination of materials, technologies, and information (for example, varieties, chemical inputs, dates of farm operation, special training) to a relatively large number of farmers or associated workers or agency.

extension workers Officers who involve dissemination of materials, technologies and information to a relatively large number of farmers or associated agricultural workers or agents.

fallow The period during which land is left to recover its productivity (reduce by cropping) mainly through accumulation of water, nutrients, attrition of pathogens, or a combination of all three. During this period, the land may be bare or covered by natural or planted vegetation. The term may be applied to the land itself or the crop growing on it (National Research Council, USA, 1993).

fire line An open space to prevent the spread of fire in a forest or in a garden.

fodder Dried or cured plant material of crops, such as corn and sorghum, grown and processed for animal feed (National Research Council, USA, 1993).

formal representation The process of coding knowledge using a restricted syntax as defined by a formal grammar. Formal representation results in statements with which you can reason automatically on computer (Walker, *et al.*, 1994).

formalisation The process of coding knowledge in natural form to formal form that can be stored, accessed and used.

fuelwood Wood used as fuel for cooking, heating or producing power; includes wood for charcoal, kilns and ovens (National Research Council, USA, 1993).

girth The distance around any more or less cylindrical object, as the trunk of a tree.

glang middle

graphical user interface (GUI) The explicit use of windows and graphics in the design of user-interfaces for the inputting and extraction of information to and from a computer program, cf. text base interface.

green tea tea produce from steam-dried, not fermented leaves, also known as Chinese tea.

Grey blight A type of tea leaf disease flourished as a saprophyte by *Pestalotiopsis theae* on the dead tissue of the bush tea, and may cause sporadic attacks old leaves. It usually occur together on weakened or injured bushes like brown blight (Rattan, 1992).

gross domestic product (GDP) Identical to gross national product (GNP), but, unlike GNP, GDP includes both nonresidents who contributed to the domestic economy and payment of foreign debt.

gross national product (GNP) The total market value of the final goods and services produced during a specific period of time (usually 1 year) by the residents of a country.

ground flora The flora growing undernearth the canopy of tree.

head-man The chief man of the villagers. She or he has been voted by villagers.

Highland Agriculture Division A Thai Government organisation belonged to the Ministry of Agricultural and Cooperative to cooperate agriculture activities of other organisation in the highland in Thailand.

Highland Agriculture Research Station An organisation belonged to the Facuty of Agriculture, Chiang Mai University to do researches about highland agriculture in the north Thailand.

Hill Tribe Minority groups who live on the mountains in the north and middle of Thailand.

hill evergreen forest A type of evergreen forest which is found on the mountains. The dominant forest tree species is in the family *Castanopsis, Lithocarpus* and *Quercus* species. This type of forest is the important catchment areas of Thailand.

Hinayana A name given by the followers of Mahayana Buddhism to the more orthodox and, as they thought, less central , school of early Buddhism. The Hinayana tradition died out in India by the 7th century AD but survived in Sri Lanka as the Theravada school and was taken from there to Myanmar, Thailand, and other regions of Southeast Asia.

Hmong or Mong are called Meo in Thai. This ethnic group belongs to the Meo-Tao branch of the Austro-Thai linguistic family. The Hmong are one of the most spread out minority groups. They are scattered throughout South Chiana. There are also Hmong communities in North Vietnam, Laos, Thailand and even a few in *Myanmar*. In Thailand, the number of Hmong people in 1995 was the second largest group after the Karen and made up about 18 % of all tribesmen in the country. The extended Hmong family is the most important basic unit of social organisation. Beyond the family level, the clan serves as the centre for all activities that mark the nuiqueness and unity of the Hmong people. The names and origins of these clans are recited in Hmong legends. Hmong religion is a combination of pantheism and shamanism with the emphasis on ancestor-workship. The Chinese influence is obvious in their beliefs and practices. The Hmong prefer to locate their villages at high altitudes (1 000-1 200 m). They are pioneer or primary-shifting cultivators. Rice and corn are the main subsistence crops and opium was the principal cash crop. The Hmong were more heavily engaged in opium production than any other highlanders in Thailand (Tribal Research Institute, 1995), but it is no longer a major producer because the Hmong and their neighbouring group changed to grow other crops that made more money growing opium (Grove, 1996).

homegardens Multistoried agroforestry systems where the canopies of the component species are arranged to occupy different vertical strata. The tallest species have foliage requiring or tolerating strong light and high evapotranspiration; the shorter species have foliage requiring or tolerating shade and high humidity. Usually, most of the upper strata is filled by banana, cassava and other crops. At ground level, vegetables and other herbaceous crops are grown (Gordon and Bentley, 1990).

huapi The beginning of the year

hydroelectric dam A dam is used to hold back a head of water, which generates electricity as it passes out past turbines that drive generators.

hydroelectric generators The generators producing electricity by the power of falling water.

hydroelectricity The electricity generated by the power of falling water.

hydrological systems/processes The system by which moisture reaches the ground and percolates through the soil to a particular water-course or body of water.

indigenous agroforestry A type of agroforestry developed with the farmers' experience and perception and handed from one generation to other generation.

indigenous knowledge Knowledge held by people about components of established production systems that they operate, and the interactions amongst those components and between them and their environments (Walker *et al.*, 1994).

indigenous vegetation Native vegetation

individual statements interface Part of AKT's GUI; more specifically a set of related windows that display to the user information to do with individual statements selected from those compiled in a knowledge base. Typically the information covers the natural language and formal representations of the given statement and additional information relating to the translation of the formalised statement using a restricted vocabulary of terms and constructs, as well as information covering sources and any keywords used.

infiltration The process of water through the surface of the soil, via pores or small opening, into the soil mass (Kirkby, 1980).

informants someone who gives information, esp. someone who gives details of their languages, social customs to a person who is studying them.

Ing river A river in the north of Thailand.

inputs Items purchased to carry out a farm's operation. Such items include fertilisers, pesticides, seed, fuel and animals feeds and drugs.

Institute of Population A organisation belonged to Chulalongkorn University to do research about population in Thailand.

Inter-marriage Marriage between people of different races, castes or families.

interception loss Water which is retained by plant surfaces and which is later evaporate away or obsorbed by the plant (Ward and Robinson, 1990)

intercropping Growing a second, or more, crops within the spaces between the main crop.

intermediate representation The process of recording simple natural language statements abstracted from text or interview material. This form is more restricted than natural dialogue, and provides an intermediate stage between articulation and formal representation (Walker *et al.*, 1994)

kam A small, fist-sized bundles of *miang* leaves

Kanchanaburi This city is about 100 km. west of Bangkok, Kanchanaburi is also a province, consisting of 10 districts.

Karen or *Yang* as they are called by the Northern Thai, or *Kariang* as they are known to Thais in other parts of the country, are the largest highland group in Thailand. In 1995, Karen population was estimated 46 % of the total hill tribe population of the country. Karen communities are located mainly in the mountainous area of the western provinces along the Thai-Myanmarese border and are scattered is some provinces in north and central Thailand. Over the past 200 years the past 200 years they have tended to move eastward away from Myanmar into Thailand because of political conflicts with the Myanmarese. Karen settlements tend to be in areas of lower altitude compared with those of other tribes. Most of them are located in valleys or mountain saddles at an average height of 500 m above sea level. Karen village are sedentary and some village have been established for more than a hundred years. Unlike other tribes, they have clearly recognised garden and village boundaries. Each village maintains its own sense of sovereignty and people from outside are not allowed to cultivate land within its territory unless they have right over paddy fields gained either through purchase or inheritance. Although many Karen construct terraced fields for wet rice, nearly all are also engaged in swidden cultivation. The shifting cultivation method of the Karen is called 'land rotation or cyclical bush fallow'. Rice and vegetables are their major crops. The Karen raise various kinds of domestic animals including pigs, chickens, cattle and elephants. Some animals, mostly chickens are killed for ceremonial offerings and feasts and others are used as beasts of burden. The Karen derive cash income from the sale of cattle and local produce from wage labour and by hiring out their elephants. Karen kinship and marriage custom are different from those of other highlanders. Kinship is traced through the maternal line and residence is matrilocal. The Karen practise monogamy and most family represents the most important basic cooperative unit in all domestic affairs. In Thailand, the Karen mostly practise the Buddhism and Animism (Tribal Research Institute, 1995).

Kasetsart University A governmental university in Bangkok, Thailand.

Khmer A native of the ancient kingdom of Khmer in Southeast Asia, which reached the peak of its power in the 11th century, when it ruled over the entire Mekong valley from the capital at Ankor, and was destroyed by Thai conquests in the 12th and 14th centuries. **Khmer** is also a native of the Cambodia and the official language of Cambodia.

Khmu The Khmu are one of the smallest tribal groups living in Northern Thailand, principally along the Thai-Laotian border. They belong to the Mon-

Khmer branch of the Austro-Asiatic linguistic family. In 1995 they numbered only 1.5 % of the total hill tribe population. Most of the Khmu in Thailand come from north of Laos. In Thailand, most of Khmu are concentrated in the province east of Chiang Mai and still make their livings in the mountains. They first migrated into the country as labourers and worked either in the teak forest or in similarly isolated places. At the end of their contracts, they decided to settle rather than return to their native village in Laos. They are also found in Middle area. The Khmu trace descent patrilineally and traditionally adhere to the custom of patrilocal residence. They live in small villages located on mountain slopes and survive on subsistence agriculture supplemented by hunting, fishing and trading. The Khmu practise an animistic religion (Tribal Research Institute, 1995).

knowledge base An articulated and defined set of knowledge stored in a computer in such a way that the knowledge can be accessed, evaluated and used for a variety of purposes in a research and development context aimed at improving the knowledge (Sinclair *et al.*, 1993).

knowledge elicitation The process whereby selected informants are encouraged to articulate their knowledge. Knowledge can also be abstracted from written material (Walker, *et al.*, 1994).

Kog-Ma Watershed Research Station An station belonged to the Faculty of Forestry, Kasertsat University to do research about watershed management.

Kok river A river in the north of Thailand.

Lahu or *Musur* as the Shan and the Thai call them, also belong to the Tibeto-Myanmarese branch of the Sino-Tibetan linguistic family. It is believed that they originated in the Tibetan Plateau and over the centuries migrated to China, Myanmar, Laos and Thailand. In Thailand Luha are found in provinces in North Thailand. In 1995 there were approximately 10 % of the total hill tribe population. Lahu villages are usually located high in the mountains at about 1 000 m. When they establish their communities at some distance from a source of water they build a series of bamboo pipes to bring water into the village. Lahu society is cognatic and monogamous. The nuclear family forms the most common domestic unit and plays the most important part in the social and political organisation of the village. When a Lahu man marries a woman from another village, he is expected to live with his parent-in-law (unorilocally) for a certain time to provide bride-service. In such cases, the household becomes extended but usually for not more than 5-6 years. Kinship ties are not particularly important in the Lahu society. However, it is possible for political leaders to gain high acceptance and respect. The Lahu base their economy primarily on swidden agriculture. Like other pioneer swiddeners, the Lahu clear fields in the forest by slash-and-burn. A plot of land is used for as long as they yields are good and after the soil become exhausted the owner looks for other places to exploit. Today, the Lahu staple crops are dry rice and maize. Many varieties of cash crops are also grown e.g. melon, peppers, beans, yams, millet and vegetables. Animal husbandry is also important and every household raise pigs, fowl, cattle for various purpose such as for feats and ceremonial offerings and for transport. The Lahu are theistic animals ruled by one god named *Geusha*. Like their highland neighbours, they also worship their ancestors. In Myanmar, the Lahu were considerably influenced by Buddhism and Christianity. A large number become Christian during and immediately following British rule. Most Lahu in Thailand follow their old beliefs. Religious practitioners remain prominent in Lahu society (Tribal Research Institute, 1995).

Lampang This city is 599 km. north of Bangkok. Lampang is also a province, consisting of 13 districts, with an area of 12 517 km^2.

Lanna The old name for north region of Thailand.

Laos A country in Southeast Asia; population (in 1991) 4 279 000, official language, Laotian; capital, Vientiane. Laos is a landlocked, mostly mountainous and forested country. The kingdom of Laos was established in 1353 by Thai Buddhists who had migrated southwards from China. In decline from the 16th century, Laos came under French colonial influence and was incorporated in French Indo-China. Laos became independent in 1949 and has became one of the world's poorest countriets.

leaching The removal of useful chemicals or other materials in solution from the soil through water perculation.

leaf area index A ration between total area of leaves and total area of crown cover.

lianas A woody tropical plant that climbs round trees, up walls, etc.

litter The surface layer of fallen, dead vegetation lying on the mineral soil (Kirkby, 1980).

local knowledge Knowledge held by local people.

Lua' one of minority people are indigenous people and are found only in Thailand. It is estimated that the Lua' people, once known as the *Milakkha* or *Lowa,* migrated into the northern region of the Mae Ping valley around 660 A.D. They are of Austro-Asiatic stock and according to protohistorical tradition, they are believed to be the first settlers in North Thailand. They are linguistically closely related to the Mon-Khmer and have largely been absorbed into Thai society. In 1995 those who retained a separate identity in the highlands about 2 % of the tribal population. Most were found to be living on the plateau southwest of Chiang Mai. The Lua' practise shifting cultivation of the rotational type and are skilful in making wet rice terraces. They are recognised as being the most conservation-minded land users in the highlands. The Lua' society is similar to that of other tribes in that descent is traced patrilineally and marriage is monogamous. Their society is regarded as having a dual structure. Most members are classified as Lua' or common people. A small group who trace descent from proto-historical Lua' King are called Kun. The Lau' are animists and ancestor-worship-pers who like the Thai, combine their traditional beliefs with Buddhism (Tribal Research Institute, 1995).

Luang Prabang This city is in Laos. It is in the north of Vietiante.

lumber To cut trees or wood into timber.

Mae Jo University An governmental university in Chiang Mai, Thailand.

Mae Rim A district belonging to Chiang Mai province. It is in the north of ChiangMai.

medium tea Medium black tea quality classified by International Tea Committee.

Mekong A river in Southeast Asia rising is Southwest China in Qinghai province; flows Southeast forming the border between Laos and Thailand, then continues south across Cambodia and Vietnam to South China Sea by an extensive delta, one of the greatest rice-growing area in Asia, length: about 4 025 km.

miang A kind of tea product which it is produced from fermented tea leaves without drying. Consumers use the product by chewing tea leaves. It is tradition tea production in North Thailand and Shan state in Myanmar.

miang daeng red fermented tea

miang fermented tea

miang kao white fermented tea

microclimate The immediate environmental conditions surrounding an individual organism, as in a crop canopy.

Ministry of Agriculture and Cooperative An organisation belonged to Thai Government for responsible of agriculture and cooperative.

mix deciduous forest A type of forest which is found on the lowlands or on middle slope. The dominant forest tree species are *Tectona grandis, Pterocarpus macrocarpus, Xylia xylocarpa, Afzelia xylocarpa* and *Gmelina aborea.*

mixed deciduous forest A type of forest are best developed from India to Thailand dominated by teak *(Tectona grandis).* Mean annual rainfall in this type is commonly 1 400-1 800 mm. The canopy is closed and high, often at 30 m or above. The general forest understory is relatively open, despite an understory canopy more than 7 m tall, a diverse assemblage of small trees and shrubs, and shrubs, and tall bamboos. Epiphytes and lianas are uncommon. Leaf fall normally begins in February, well after the onset of the dry season in early December, and continues at varying rates until the forest is leafless by the end of March. The leafless period extend for 3-4 months (Richards, 1952). The name mixed deciduous forest derives from the diversity of tree species in these stands. Teak is usually the dominant (most important) species, while *Xylia kerrii* is often abundant Rundel and Boonpragob (1995).

moei dew

monoculture The growing over a large area of a single crop species, or of a single variety of a particular species. Monoculture are especially vulnerable to pest and disease infestation, but uniformity of height, development, etc. in a crop facilitates management, especially harvesting. The economic and ecological wisdom of monoculture is widely debated (Allaby and Attenborough, 1985)

monsoonal climate A climate in southern Asia, esp. the wind blowing from the Indian Ocean where is the south west of the areas in the period May to September, bringing rain to fall down the west side of the areas and from the south China sea where is the east of the area in the period August to November, also bringing rain to fall down the east side of the areas. In the winter, there is a corresponding high over central Asia, and cold air spreads out over the areas, bringing prevailing dry weather from October to April, Monsoon wind are generally stready rather than strong.

Muang A district belonging to provinces. It is same area as the city of the province.

Muang Pang A district belonging to Lumpang province. It is in the north of Lumpang.

Multiple Cropping Centre (MCC) An institute belonged to Faculty of Agriculture, Chiang Mai University which aims to do researches and teach about multiple cropping in upper north of Thailand.

multistoreyed agroforestry gardens system The meaning is same home gardens.

Multriple Cropping Centre (MCC) The organisation belonged to the Faculty of Agriculture, Chiang Mai University to do researches about multiple cropping, especially in the upper north Thailand.

Myanmar A country on the Bay of Belgal in Southeast Asia, call **Burma** until 1988; capital Yangon; population (1989)-**Myanmarese.**

mycorrhiza The symbiotic association of the mycelium of a fungus with the roots of a seed plant.

Nan river The major river in the north of Thailand.

Nan This city is 668 km north of Bangkok, Nan is also a province, consisting of 10 districts, with an area of 11,472 km^2.

National Environmental Committee Office A Thai Government organisation established to set up Thai government policy to conserve environment and biodiversity

National Park An area of natural, historical, or scientific interest which is kept by the government for people to visit.

Non-hunting Area The public areas designated for not hunting the wild animal some times, such as immigrating season or breeding season.

Northern Regional Agricultural Development Centre (NADC) An organisation belonged to the Ministry of Agricultural and Cooperative to cooperated the activities about agriculture and forest in the north Thailand.

nutrient cycling The process of retaining and efficiently recycling essential nutrients within the ecosystem.

open-ended conversations The conservation having no predetermined limit or boundary.

opium poppy A poppy *Papaver somniferum,* native to Europe and eastern Asia, with white, red, pink or purple flower. The juice of the opium poppy used in medicine as an analgesic and narcotic.

organic matter Living biota present in the soil or the decaying or decayed remains of animals or plants. The living organic matter in the soil decomposes the dead organic matter. Organic matter in soil can reduce soil erosion and increase moisture and soluble nutrient retention, cation exchange, and water infiltration.

Pee Pan Num A mountain range in the north of Thailand and it is a catchment area of many important rivers of north and center of the country.

percolation The process of water downward through soil especially through soil that is saturated or closed to saturated (Allaby and Attenborough, 1985).

Phrao A district belonging to Chiang Mai province. It is in the north of Chiang Mai.

Ping river The major river in the north of Thailand.

plain tea Low black tea quality classified by International Tea Committee.

porosity The volume of voids or pore space in a soil or rock expressed as fraction of bulk volume (Kirkby, 1980)

pre-defined tools The suite of system-defined tools provided for the user in AKT2. Each tool is a program that is defined using the primitives and control-structures available within AKT's task language. See task language.

profile view A side view

Prolog An artificial intelligence programming language.

quasi politicoeconomic Being partly policy and economic.

query tool A simple tool that enables the user to retrieve sets of formal statement (and their parts). For example, the call to the query: att_value(process(process), Attribute,Value) will retrieve every statement in the loaded KB that has that underlying form. In this case the variables (indicated by strings of characters beginning with upper case letters) are duly substituted by name and predicates that match those contained in statements in the knowledge base. The set of statements returned is typically interpreted as either a set of conditional statements ('X if Y') or facts.

rai unit of field measurement equivalent to 0.16 hectare

rainfall factor A measure of the rainfall eroding the soil. It is a part of erosivity factor which is a factor of Universal Soil Loss Equation (USLE) (Hudson, 1995).

range A large area of open land for grazing or hunting.
rangers A keeper of a royal or national park, or of a forest.

rapid rural appraisal (RRA) A methodology of research which merge rural development-related research. It provided more than a cost-effective and timely means of acquiring useful information and improved and accelerated the process of learning, increased overall understanding of the rural areas, and made that understanding more effective for development. Use of RRA has also brought researchers into greater contract with rural inhabitants, and increased the former's sensitivity to the condition, problems and needs of rural areas (Subhadhira, Simaraks and Lovelace, 1990).

Roi Ad This city is about 300 km. west of Bangkok, Roi Ad is also a province.

Royal Forest Department (RFD) A Thai Government, an organisation belonged to the Ministry of Agricultural and Cooperative which aims to protect forest and wild life in Thailand.

Royal Project A non governmental agency that established by King Bhumipol, the king of Thailand which aims to render suitable assistance to hilltribes, to reduce the destruction of natural resources and to stop opium cultivation (Royal Project, 1995).

San Kam Pang A district belonging to Chiang Mai province. It is in the west of Chiang Mai.

San Sai A district belonging to Chiang Mai province. It is in the north of Chiang Mai.

scientific knowledge Knowledge held by scientists.

SEATO Southeast Asia Treaty Organisation; an organisation formed by Australia, Britain, France, New Zealand, the Philippines, Thailand and the US for giving military help to each other in Southeast Asia and the Southwest Pacific area.

Shan A Thai-Laos ethno-linguistic group living in the north Myanmar. Shan State now is under Kingdom of Myanmar.

Shan state The state in the north Myanmar. The people are Thai.

shifting cultivation Any farming system where land is periodically cleared, cropped and returned to fallow; synonymous with slash and burn or swidden agriculture.

silviculture The growing and tending of trees as a branch of forestry.

silvopastural system An agroforestry system that combines pastures (with or without animals) and trees (National Research Council, USA, 1993).

slash and burn systems The land use system in which vegetation is cut down, allowed to dry , and then burned off before seeds are planted.

Social Research Institute The organisation belonged to Chiang Mai university which aims to do researches about socioeconomic and demographic of the people, especially the people in the upper north Thailand.

social forestry The science or management of forests involved the community.

stemflow Water which trickles along twigs and branches and finally down the main stem or trunk to the ground surface (Ward and Robinson, 1990)

Su Wan Na Khate A district belonging to Roi Ad province.

suan miang tea gardens

surface run-off That part of runoff which travels over the soil surface to the nearest channel having not passed beneath the surface since precipitation (Kirkby, 1980).

sustainable agriculture An agricultural production system in which the farmer increases or maintains productivity at levels that are economically viable, ecologically sound and culturally acceptable through the efficient management of resources with minimum damage to the environment or human health (National Research Council, USA, 1993).

swidden A temporary agricultural plot produced by cutting back and burning off vegetative cover.

swidden cultivation A traditional food crop production system that involves partial clearing and short term mixed intercropping; synonymous with shifting cultivation or slash and burn agriculture. The fallow period must be sufficiently long to allow for soil regeneration and weed suppression. This system is based solely on the restorative properties of woody species (National Research Council, USA, 1993).

tambon Subdistrict, third subdivision of Thailand

tannin A reddish acid made from the bark of certain trees, esp. the oak, used in preparing leather making ink, etc. It is also found naturally in tea leaves.

Tape Sa Daje subdistrict A subdistrict belonged to Doi Sa Kade district, Chiang Mai province. It is in north-east of Chiang Mai.

task language A decicated procedural programming language that forms part of AKT2. The language has a set of primitives and control structures that are used by the user to write their own programs (or tools) for specific tasks. These tools function not unlike macros that are now commonly available in many word-processing and spreadsheet programs.

Taungya forest plantation A system of agroforestry which the farmers plant the seeds and seedlings of agricultural crop between forest plantation. The system was practised as early as 1856 in Myanmar in establishing teak plantation (Tran, 1978). Trees and wood production are the primary concern from this system, Jordan *et al.,* 1992).

tea garden a garden where the farmers plant tea bush mixed in the forest and other plants with irrigulate system.

tea leaf spot disease The type of tea disease which spots occurred

tea plantation A plantation where the farmers plant tea bush with monoculture system.

tea villages villages in which most of the inhabitants grow tea for *miang* production.

Thai-Australia Highland Agricultural and Social Development Project (HASD) An organisation aided by Australia Government which aims to develop highland agriculture in north Thailand.

Thai-Australia World Bank Land Development Project (TAWLD) An organisation aided by Australia Government and loaned by World Bank which aims to develop land in Thailand.

The Survey of Hliitribe Population Project A project was established to survey hilltribe population in Thailand between..

throughfall factor A measure of the throughfall eroding the soil. It is a part of erosivity factor which Preechpaya (1984) used for instead of rainfall factor is a factor of Universal Soil Loss Equation (USLE).

throughfall That portion of grass rainfall which directly reach the forest litter through spaces in the vegetative canopy and as drip from leaves, twigs and stem (Kirkby, 1980).

Tin are migratory swidden farmers in the northern Laos-Thailand border area. This ethic group is also classified as belonging to the Mon-Khmer branch of the Austro-Asiatic linguistic family. From available reports it appears that the Tin have lived in Thailand for a very long time. In 1995 they numbered 5% of the total hill tribe population. All of their villages are found in the province east of Chiang Mai. They live in houses built on piles with bamboo floors and walls. They practise swidden agriculture and grow glutinous rice, the staple rice, variety of Northern Thai lowlanders. The Tin are monogamous. After marriage, residence is initially matrilocal, in the house of the wife's parents. After the birth of several children, the couple normally move to a new dwelling. Except for those who live near the lowland Thai and have become Buddhists, the Tin are animists. Some Tin villages have the Buddhist temples (Tribal Research Institute, 1995).

tok A small bundle of bamboo laths which is about 1 cm. wide

transpiration The process by which water in plant is transferred to the atmosphere as water vapour (Kirkby, 1980).

ULTISOLS The soil type that occur intermittently in a global band that lies almost entirely between latitudes of 40°S. They occupy extensive areas in the south-eastern United States, east central Africa, north-east India, south-west China, the islands of south-east Asia, and north-eastern Australia. Soil taxonomy defines the ULTISOLS as mineral soils that (1) Do not have tongues of albic materials in the argillic horizon that have vertical dimensions of as much as 50 cm if there is > 10% weather able minerals in the 20-200 μ m fraction; but have one of the following combinations of characteristics: (a) Have an argillic horizon but not a fragipan and have base saturation (by sum of cations) of < 35% within the following depth: *(1)* If the argillic horizon has in some part a hue of 5YR or yellower, or a colour value, moist, of 4 or more, or a colour value, dry, that is more than 1 unit higher than the value, moist, the shallowest of the following: (a) 1.25 m below the upper boundary of the argillic horizon; (b) 1.8 m below the surface of the soil; or (c) immediately above a lithic or paralithic contract; (2) if the argillic horizon has some other colour or if the epipedon has a sandy or sandy-skeletal particle-size class throughout, the deeper of the 1.25 m below the upper boundary of the argillic horizon or 1.8 m below the surface of the soil, or immediately above a lithic contract if it is shallower; (b) Or have a fragipan that: *(1)* Meets all the requirements of an argillic horizon, or has clay skins >1 mm thick in some part, or underlies an argillic horizon; and *(2)* has base saturation (by sum of cations) of <35% at a depth 75 cm below the upper boundary of the fragipan or immediately above a lithic or paratithic contract, whichever is shallower. (2) Have a mesic, isomesic, or warmer temperature regime; (3) Do not have a spodic horizon, and do not have an oxic horizon unless it underlies an argillic horizon; and (4) Do not have plinthite that forms a continuous plase within 30 cm of the soil surface (Miller, 1983).

undergrowth bushes, small trees, and other plants growing around and under trees

upland rice Rice varieties planted on slop lands.

Uttradit This city is 490 km. north of Bangkok. Uttradit is also a province, consisting of 9 districts, with an area of 7 839 km^2.

Vietiante The capital city of Laos.

Vong river The major river in the north of Thailand.

Wa are migratory swidden farmers in the northern Laos-Thailand border area. This ethic group is also classified as belonging to the Mon-Khmer branch of the Austro-Asiatic linguistic family. From available reports it appears that the Tin have lived in Thailand for a very long time. In 1995 they numbered 5% of the total hill tribe population. All of their villages are found in the province east of Chiang Mai. They live in houses built on piles with bamboo floors and walls. They practise swidden agriculture and grow glutinous rice, the staple rice, variety of Northern Thai lowlanders. The Tin are monogamous. After marriage, residence is initially matrilocal, in the house of the wife's parents. After the birth of several children, the couple normally move to a new dwelling. Except for those who live near the lowland Thai and have become Buddhists, the Tin are animists. Some Tin villages have the Buddhist temples (Tribal Research Institute, 1995).one of minority people are indigenous people in Thailand and Laos. They are one group of the pioneer tea farmers producing *Miang* (Bar, 1967).

Waing Nern A district belonging to Lumpang province. It is in the north of Lumpang.

Watershed Development Division A Thai Government organisation belonged to the Royal Forest Department which aims to do researches and develop watershed in the mountain of Thailand.

watersheds A region or area draining ultimately to a particular watercourse or body of water.

Wiang Pa Pao A district belonging to Chiang Rai province. It is in the south west of Chiang Rai.

Wildlife Sanctuary The public areas have been designated for protecting wild animals.

Xieng Khoung This city is in Laos. It is in the north east of Vietiante.

Yom river The major river in the north of Thailand.