CHANGES OF LAND USE, ASSOCIATED LIVELIHOOD, AND PLANT BIODIVERSITY IN TRADITIONAL TEA AGROFORESTRY IN YUNNAN, CHINA

Yi Wang (B.SC)

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DECLARATION

I hereby declare that this thesis is my original work and it has been written by me in its entirely. I have duly acknowledged all the sources of information which have been used in the thesis.

This thesis has also not been submitted for any degree in any university previously.

WANG YI

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Table of Contents

ABSTRACT

Agriculture intensification is one of the leading causes of biodiversity loss. Traditional tea agroforestry systems provide a potential model for the reconciliation between biodiversity conservation and socioeconomic developments. The tea market experienced a dramatic boom in Yunnan from 2002 to 2008, especially for "old tea", produced in traditional tea agroforests. The niche price premiums given to "old tea" production led to changes in land use, livelihoods and management practices, as well as plant biodiversity. Whether the economic incentive have a role in protecting these systems or, conversely, in driving the degradation of these systems was explored in terms of plant biodiversity. A re-survey was conducted in 2012 based on the base survey conducted in 2002 on the plant biodiversity of tea agroforests and the socioeconomic factors of associated livelihoods. My results show that the price premium protected tea agroforests from being transformed to other intensified land uses such as monocultures. However, the systems were still under degradation in terms of plant biodiversity. Athough the changing pattern of trees was relatively stable, important species and giant trees were still lost. Intensified management was an important driving force for plant species richness loss, while more increase in profitability or average price of "old tea" corresponded to less richness loss. In addition, management strength did not necessarily positively correlate with profitability under increased market interferences. Therefore, better marketing of "old tea" products and setting environment-friendly policies against intensified land use are suggested for sustainable development, which balances both ecological needs and economic benefits.

LIST OF TABLES

LIST OF FIGURES

Chapter 1 INTRODUCTION

1.1 Background and justification

Agricultural intensification is one of the leading reasons for biodiversity loss (Perfecto and Vandermeer, 2008). Facing the increasing human-environment conflicts, two strategies are proposed. One is land sparing, which is to protect biodiversity by increasing the agricultural yield, thereby sparing more forests (Perfecto and Vandermeer, 2008). Second is agricultural extensification, which protects biodiversity by extensive farming on large areas such as agroforestry. Extensification may both reduce pressures on forest resources and improve the living standards of the rural poor (Ewel, 1999).

Therefore, the importance of research on agroforestry is two-fold. Firstly, how biodiversity changes across intensification gradient should be tested in agroforestry systems with multiple types of management practices (Toledo, 1999; Perfecto *et al.*, 2003; Wanger *et al.*, 2009). Secondly, agroforestry systems may provide a sustainable model to investigate the relationship between biodiversity and yield or profitability (Gordon *et al.*, 2007; Steffan-Dewenter *et al.*, 2007).

Some current research has explored this issue at on the landscape level by exploring biodiversity change across a land use intensification gradient (Toledo, 1999; Perfecto *et al.*, 2003; Wanger *et al.*, 2009). The relationship between biodiversity and the degree of management intensification is usually examined in a land use matrix usually generated by natural agroforestry systems such as coffee and cacao (Perfecto *et al.*, 2003; Wanger *et al.*, 2009). Although a general decline in biodiversity along the intensification gradient is usually discovered, trends seem to differ among taxonomic groups and the pattern of the landscape matrix plays an important role as well (Perfecto *et al*., 2003).

Alternatively, some studies aim to reconcile between biodiversity conservation and agriculture by focusing on existing agroforestry systems themselves (Ewel, 1999). Traditional agroforestry systems provide an effective model for doing this. Research on homegardens, for example, explores the relationship between biodiversity and multiple socioeconomic factors such as education level, access to market and farm size in order to find which socioeconomic conditions the biodiversity can root best (Kabir and Webb, 2008; Nair, 2010). Studies on shade coffee have also tried to understand the relationship between biodiversity and yield or the relationship between biodiversity and profitability in order to understand whether there are trade-offs or synergies (Kinnaird, 2003; Gordon *et al*., 2007).

Agroforestry systems, especially those managed in traditional ways, stand as an important models for research on sustainable development because they potentially balance both the ecological needs of biodiversity conservation and economic benefits. Multiple agroforestry systems have been shown to harbor considerable biodiversity and support large number of poor livelihoods at the same time (Ewel, 1999; Fifanou *et al*., 2011; Okubo *et al*., 2010; Kinnaird, 2003; Nair, 2010; Toledo and Moguel, 2012). For example, shade coffee has conservation value for birds, butterflies, amphibians, ants, etc., although not equivalent to natural forests (Toledo, 1999; Perfecto *et al.,* 2003; Kinnaird, 2003). Meanwhile, millions of smallholders manage shade coffee systems and depend on coffee for their livelihoods (Jha, 2011).

Despite the importance of traditional agroforestry systems, sustainability of these systems is threatened by dramatic socioeconomic changes. Economic prosperity and international trade has led to considerable biodiversity loss (Naidoo and Adamowicz, 2001; Lenzen *et al.*, 2012). Market interferences also threaten the sustainability of traditional agroforestry systems (Ahmed *et al.*, 2010; Jha, 2011). In 1999, the coffee crisis caused ecological crisis in many coffee growing regions as well as changes in coffee landscapes (Jha, 2011). Thus, a better understanding of the dynamics of traditional agroforestry systems under increased market interference could foster the development of more effective strategies to maintain them alongside socioeconomic developments. It is important to understand both which socioeconomic scenarios support biodiversity, and how socioeconomic development correlates with the change of biodiversity (Nair, 2010).

Moreover, a study of agroforestry on the relationship between biodiversity and profitability can also contribute to the solutions of multiple environment-human problems. Knowledge of the relationship between biodiversity and profitability is valuable, as it can tell us whether biodiversity and profitability can be realized at the same time or whether an optimal point can be found to maximize the benefits for both environmental and economic sides (Gordon *et al.*, 2007). However, given that cash crops prices fluctuate with market forces, the question on whether an increase in profits over time can lead to better protection of the system or severe degradation is hardly explored and answered.

Research on the temporal view of the traditional agroforestry system as well as its associated livelihoods can help us better understand the relationship between biodiversity conservation and agricultural practices. It can also shed light on how to develop effective strategies to either mitigate the conflicts or strengthen the synergies between biodiversity conservation and economic development.

1.2 Statement of the problem

Yunnan, located in southwestern China, is known for its extraordinary biological and cultural diversity, as it is home to 26 ethnic groups and at least 18,000 vascular plant species (Li, 2010). James Scott has labeled Yunnan as a part of "Zomia", which shares similar highland cultures with a stateless status (Scott, 2009). The tea cultivation history in Yunnan dates back to Tang dynasty; and Yunnan is believed to be one of the origins of the broad-leaf tea plant (*Camellia sinesis var. assamica*) since multiple aged wild tea trees are found in the forest and many traditional tea agroforestries still remain today (Ahmed *et al*., 2010; Li, 2010) .

Traditional tea agroforestry in Yunnan was a natural as well as cultural heritage. Dai, Akha, Bulang, Ang and Jinuo are ethnic groups with record of this type of tea production as one of their traditional land use practices (Zou and Sanford, 1990). Apart from the cultural value, traditional tea agroforestry also supports considerable biodiversity and valuable genetic diversity of the tea plant. Qi et al. (2005) found that the plant biodiversity of Jingmai's traditional tea agroforestry was similar to neighboring forests. They also found multiple protected plant species were also identified in the tea agroforests. Using ISSR (Inter-Simple Sequence Repeat) analysis, Ji et al. (2011) found that high level of genetic variation was harbored in the traditional agroforestry tea populations. Moreover, the semi-natural system still retains the mechanisms of nutrient cycling and pest control without chemical input, thereby providing additional ecological services (Jiang, 2008).

Although of important conservation value, traditional tea agroforestry has recently been threatened by dramatic socioeconomic phenomena, including land use change driven by state promoted projects and increased market integration. In the past decades, large area of forests and swidden-cultivation in Yunnan were converted to rubber plantations with considerable loss in natural and agricultural biodiversity (Fox, 2009; Ziegler *et al.*, 2009; Guo Huijun *et al.*, 2002). In the case of tea agroforests, "Jingmai ancient tea garden", the best protected and the largest traditional tea agroforest with an area around 27,000 hectares, was converted to tea plantations in 1990s as a state promoted tea industrialization project (Ahmed *et al.,* 2010). Moreover, the growth of the human population was a threat to tea agroforests as well. In the 1980s, about 95% of farmers built new houses, using as much as 10,000 cubic meters of wood, mainly cut from traditional tea agroforests (Yunnan, Institute of Tea, pers.comm.).

The recent tea market boom in Yunnan from 2002 to 2008 may also have threatened traditional tea agroforestry because of the dramatic demand for "old tea" driven by the high market price. Yunnan Pu'er tea, which has been produced since the Ming Dynasty (1368-1644) and marketed throughout Aisa (Ahmed *et al.*, 2010), had attained its reputation for decades. Recently, labeled with "history", "eco" and "health", Pu'er tea today has become a promoted brand (Ahmed *et al.*, 2010). Investment on Pu'er tea drove up the prices for "old tea", which is produced in traditional tea agroforests. The tremendous demand catalyzed by the Pu'er tea market boom drove the price to 20 times the original value in just a few years when the market recognized the inherent value and limited supply of "old tea" (Ahmed *et al*., 2010; Li, 2010). A natural price premium for "old tea " cultivation in environment-friendly ways was generated from current market mechanisms in comparison with "new tea" production in tea plantations.

However, few studies have been done to evaluate the consequence of the considerable economic incentives for traditional tea agroforestry especially in the terms of biodiversity. Moreover, it is largely unknown what strategies can best conserve this heritage and can realize sustainable development at the same time under increased market interferences. For example, coffee and cacao shade certification programs aim to provide economic incentives to discourage intensification of coffee and cacao agroforestry systems, conserve biodiversity harbored by these systems and enhance economic benefits of associated livelihoods (Bisseleua *et al.,* 2009; Kinnaird, 2003). Currently it is not known if there can be a balance between biodiversity conservation and economic benefits of traditional tea agroforestry?

Therefore, a study of the temporal change of Jingmai ancient tea garden, which was surveyed in 2002 and re-surveyed in 2012, can partly provide answers to the above question. In conclusion, the present research aims to fill the knowledge gap of dynamics of traditional agroforestry systems and explore effective strategies to protect biodiversity and realize economic benefits in the systems concurrently under increased market interferences.

1.3 Objectives

Traditional tea agroforestry in Yunnan has important conservation value especially in terms of plant biodiversity and provides a model for research on sustainability, which balances both ecological needs and economic benefits. Unfortunately, socioeconomic impacts such as state projects of tea industrialization resulted in a transition of tea agroforests to monoculture plantations. Recently, an emerging price premium for "old tea" produced in tea agroforests, catalyzed by the Pu'er tea market boom in Yunnan, provided dramatic economic incentives for tea cultivation in traditional tea agroforestry. A win-win situation for rural livelihoods and conservation might be realized under niche market mechanisms. However, the rapid increase in price for "old tea" might also lead to degradation of this system as is the case with natural resources of considerable economic values (Naidoo and Adamowicz, 2001).

The objectivies of this study on the dynamics of traditional tea agroforestry and associated livelihoods are as following.

(1) The study aims to answer how the high price premium for "old tea" influences land use, management practices and plant biodiversity in tea agroforestry systems. Is the land use of tea agroforests being maintained? Does tea production in the systems still follow traditional methods of management? Does the system still protect plant biodiversity similar to that of ten years ago?

(2) Another goal of this study is to understand factors driving the changes in plant biodiversity. Which factor has a strong impact and should be taken into consideration for better conservation? What strategies best allow livelihoods to capitalize high prices but also protect biodiversity?

To conclude, by evaluating the dynamics of traditional tea agroforestry as well as associated livelihoods over a ten year period, this study will shed light on strategies to maintain biodiversity conservation in traditional tea agroforestry and promote sustainability under increased market interference.

Chapter 2 LITERATURE REVIEW

2.1 Concept of traditional agroforestry

"Agroforestry" is a traditional land use practice for which farmers cultivate trees together with agricultural crops. These practices can be traced back thousands of years throughout the world. European farmers started cultivating food crops in clear-fell forests from the middle ages (Nair, 1993). Agroforestry was merely the "handmaiden" of forestry in the ancient times, however it is now used more as an agricultural system and a technique for sustainable production.

Agroforestry is a relatively new name for a set of old practices influenced by a series of changes. The green revolution converted a large area of old agroforestry into modern plantations. In tropical America, shade coffee was still the main production practice until the 1970s when a modernization of coffee from shade to sun spread through the region (Nair, 1993). Shifting cultivation was accused of being a main reason for deforestation by FAO in 1982 (Nair, 1993). Marked by the establishment of ICRAF (International Centre for Research in Agroforestry) in 1977, the ancient practices were first institutionalized and listed in least priority of the research (Nair, 1993; Nair, 1997). Based on the accumulated knowledge of the science of agroforestry especially in the field of soil fertility improvement, more artificially designed agroforestry appeared, usually with a combination of several cash crops and several nitrogen-fixing tree species. Many old practices of agroforestry gradually disappeared with socioeconomic development, which are now termed as "traditional agroforestry" (Nair, 1997).

Although the old practices were considered outdated, the value of traditional agroforestry systems could not be overlooked. Because of the ecological, socioeconomic and scientific values, these systems need to be given more attention in the future.

2.2 Conservation values of traditional agroforestry

2.2.1 Role of traditional agroforestry in biodiversity conservation

Although not equivalent to natural forests, multiple studies have found considerable biodiversity harbored in diverse traditional agroforestry systems. Perfecto et al. (2003) found different responses for birds, butterflies and ants to the land use intensification, but a general decrease in species richness with an decrease in shade cover. Apart from shade coffee, other traditional agroforests also harbor considerable biodiversity such as traditional agroforestry parkland systems in Benin, West Africa, which recorded 21 tree species belonging to 14 botanical families; three types of traditional agroforests in Sumatra, Indonesia, which stands for a valuable compromise between rain forest bird diversity and sustainable development; and traditional cocoa agroforests locally known as cabruca which show important conservation values for birds, bats, dung beetles, ants, amphibians and reptiles (Thiollay, 1995; Wanger *et al*., 2009; Fifanou *et al*., 2011; Bos *et al*., 2007). Besides species richness, traditional agroforestry systems also stand as tools for conservation of genetic diversity (Ouinsavi and Sokpon, 2008).

In addition to protection of the valuable endemic and endangered species by multi-species traditional agroforests themselves, these systems also play an important role in biodiversity conservation on a regional or landscape level due to their unique locations. One study in Mexico found that at least 14 of 155 conservation priority regions, having high number of species and endemics, overlap with or are near traditional coffee-growing areas (Toledo, 1999). Jha et al. (2011), examing the spatial relationship between coffee cultivation and protected areas in Central America, found that 100% of the protected areas are within 50 km of coffee growing areas in El Salvador; 84% in Costa Rica; and less than 40% in remaining countries. If grown in the traditional way, coffee agroforestry can serve as a natural buffer around the protected areas.

2.2.2 Ecosystem services provided by traditional agroforestry

Apart from biodiversity conservation, traditional agroforestry provides other valuable ecosystem services on local, regional, and global levels. At the local level, pest control, pollination and nitrogen fixing are the three main benefits brought by associated biodiversity in traditional agroforestry practices. Ants and spiders can reduce damage to coffee plants caused by coffee berry borer or coffee leaf miner (Jha, 2011). Coffee production may benefit from pollinator visits (Klein *et al*., 2003). Alnus nepalensis-based agroforestry systems provide nitrogen fixing services and augment the nutrient contents of soils (Guo Huijun, 1997). Other services such as the supply of fuel woods, regulating fungal diseases and erosion control also show the potential of traditional agroforests to provide ecosystem services at the local scale (Jha, 2011).

At the regional level, traditional agroforestry may contribute to ecosystem services such as water conservation and soil conservation. In regions where coffee is grown on mountain slopes and in steep areas, shade-grown coffee systems guard against soil degradation and maintain water quality through vegetative cover (Jha, 2011; Toledo and Moguel, 2012).

At the global level, traditional agroforestry also plays a role in carbon sequestration. A study on shade coffee systems in Mexico found that carbon sequestration through agroforestry on indigenous shaded coffee systems contained more carbon than traditional maize and pastures without trees, finding a high value of total carbon fixed by organic soil, dead organic matter, and living biomass (Toledo and Moguel, 2012).

2.2.3 Socioeconomic values of traditional agroforestry

Traditional agroforestry provides multiple socioeconomic benefits including providing fuel woods, food security, medical care, and income. Traiditonal bamboo-tree gardens in West Java are the main source of fuel woods for local people (Okubo *et al*., 2010). Tropical homegardens were believed to contribute to socioeconomic sustainability under conditions of high population densities by providing energy needs, nutritional security, medical care and income generation (Nair, 2010). Millions of families worldwide are actively involved in coffee production and depend on coffee for their livelihood, and the majority of producers are smallholders managing less than 10 ha of coffee in a traditional manner (Jha, 2011). The "Zomia" region described by James Scott (2009) is characterized by highland cultures, which historically maintained stateless structures and rely on multiple traditional agroforests for living especially swidden cultivation.

2.3 Traditional agroforestry as a model of sustainable development

In the past decade, land use simplification and agriculture intensification have caused biodiversity loss, environmental deterioration and detrimental consequences to human welfare (Mooney *et al*., 2005). Traditional agroforestry, as summarized above, demonstrates its important role in biodiversity conservation, providing environmental services as well as socioeconomic benefits, and thus draws scientific interests to be a model of sustainability which provides original insights to balance human-environment conflicts (Ewel, 1999).

However, the potential of traditional agro-ecosystems for biodiversity conservation and ecological functioning is dependent on many other factors including the vegetation structure, composition and management, the location of remnant native forests in the landscape as well as associated socioeconomic conditions (Cassano *et al*., 2009). In order to better balance biodiversity conservation and economic development, multiple studies especially on shade coffee try to understand the relationships among biodiversity, shade cover, yield, profitability, income and various other socioeconomic factors such as sex and education of landholders (Gobbi, 2000; Kinnaird, 2003; Perfecto *et al*., 2005; Gordon *et al*., 2007; Kabir and Webb, 2008; Okubo *et al*., 2010; Clough *et al*., 2011). Further research on the relationship between biodiversity and biophysical factors, or between biodiversity and socioeconomic factors, is necessary to better maintain the sustainability of agroforestry systems.

2.4 Traditional agroforestry under threats

Traditional agroforestry, characterized by low yield and high labor consumption, while harboring a high level of biodiversity and providing key environmental services, is gradually disappearing due to dramatic economic threats and politic changes (Fox, 2009; Ziegler *et al*., 2009). The green revolution converted large areas of shade coffee to sun coffee in tropical America (Nair, 1993). Recent research on the changing patterns of homegardens of Kerala, India also indicated the trend of transforming naturally growing species homegardens into single species dominant systems (Chandrashekara and Baiju, 2010).

Market interference is another important driving force among multiple socioeconomic changes. Much research has explored the impact of market forces on biodiversity loss for example in coffee growing areas in Mexico and Latin America, oil palm plantations in Indonesia and Malaysia (Koh, 2008), and rubber plantation in China (Perfecto, 2003; Lian, 2008; *Ziegler et al.,* 2009). It has been shown that local threats to species are driven by economic activity and consumer demand across the world (Lenzen *et al.*, 2012). In the case of traditional agroforestry, biodiversity threats and sustainability challenges driven by market interference become increasingly severe. In 1999, the coffee crisis caused in some cases an ecological crsis in many coffee growing regions as well as changes in coffee landscapes (Jha, 2011). More recently, a tea market boom in Yunnan quickly incorporated Ang minority people into China's market economy and led to ideological transformation from traditional value-oriented ones towards market-based ones in Akha upland regions. These changes may cause a breakdown of socioeconomic foundations that support local biodiversity and sustainability (Ahmed *et al.*, 2010; Li, 2010).

Because of the market threats on biodiversity and sustainability, multiple programs were initiated aiming to solve the market problems by applying market mechanisms. Examples include bird-friendly coffee and shade certification programs for coffee and cacao. The programs provide economic incentives to slow down intensification and biodiversity loss (Perfecto *et al.*, 2005; Bisseleua *et al.*, 2009). Multiple studies explored whether an optimal balance could be achieved between biodiversity and economic benefits in traditional agroforestry systems such as traditional bamboo-tree gardens in West Java, Indonesia (Okubo *et al.*, 2010).

However, the relationship between biodiversity and profitability is not simple. The relationship is often assumed to be a trade-off, whereby high profits can only be achieved in low-biodiversity agroforestry. This is not necessarily the case and synergistic interactions may exist because of increased natural pollination services, pest control or nutrient cycling provided by high-biodiversity agroforestry (Gordon *et al.*, 2007). In one example of traditional bamboo-tree gardens, the annual gross income also increased with increased plant biodiversity before an optimal point was reaseached (Okubo *et al.*, 2010). While the relationship between biodiversity and profitability, which may be further influenced by both yield and market, is still in its infancy, more research is needed to find the optimal balance between biodiversity conservation and socioeconomic development under increased market interference.

2.5 Traditional tea agroforestry in Yunnan

While shade coffee has recently received much attention from conservation organizations, less is known regarding the biodiversity associated with traditional tea agroforestry. In traditional tea agroforestry, tea (*Camellia sinesis var assamica*) is produced under a multi-species tree canopy (Refer to Figure 2.1).

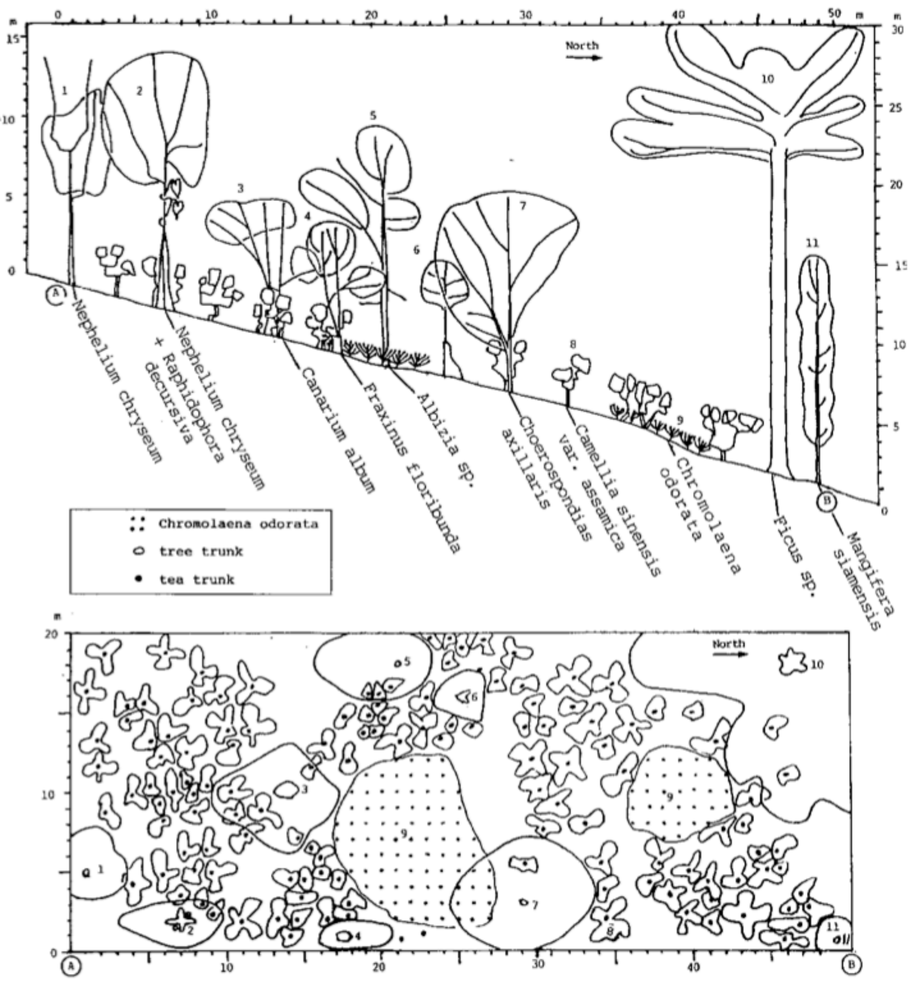


Figure 2.1 Structure of traditional tea agroforestry (Adapted from C.Saint-Pierre, 1991)

The ways of tea production in traditional tea agroforestry versas modern tea plantations can be quite different in several aspects (see Figure 2.2). Firstly, in terms of vegetation structure, in agroforests tea shrubs are arbitrarily planted in the understory of natural forest. In plantations tea plants are planted in straight lines. Tea density is also lower in traditional practices; and the bushes are only slightly pruned, thus they can reach heights of more than 3 meters (C.Saint-Pierre, 1991). Records show that there are almost 100 shade trees per hectare, which consists of approximately 100 species in the traditional tea agroforestry in Longpa, while there is usually no shade tree species for tea plantations (C.Saint-Pierre, 1991). Secondly, the ways of management also differ in the two systems. In traditional tea agroforestry, fertilizer, herbicides or pesticides are not applied. Weeding or cutting epiphytes is usually conducted once or twice a year, while in tea plantations, these management practices are usually intensified. Thirdly, the quality of tea is generally considered to be higher when produced in traditional tea agroforestry, although the yield is much lower compared to tea plantations. Others propose that shade trees might create a beneficial microclimate for tea as well as the process of nutrient accumulation (Zhang, 2005; Jiang, 2008).

Figure 2.2 Traditional tea agroforestry (left) and tea plantation (right)

The majority of tea production today is grown in plantations. This way of tea production was discovered in Laos, North Myanmar, Yunnan, South Vietnam and some forests of India previously occupied by England (Ukers, 2007). Traditional tea agroforestry is also referred to as jungle tea in India, shade tea or Miang tea forest in Thailand, and ancient tea gardens in China (Ukers, 2007; Sysouphanthong *et al.*, 2010; Qi *et al.*, 2005).

Traditional tea agroforestry has both obvious ecological and economic roles, which may also stand for a successful model of sustainability balancing both environmental services and socioeconomic development. Firstly, traditional tea agroforestry harbors considerable biodiversity and provides multiple ecosystem services. A study conducted in northern Thailand suggested that shade tea forest or Miang tea forest is a sustainable way to produce tea while maintaining considerable fungi biodiversity (Sysouphanthong *et al*., 2010). The authors suggested that developing Miang forests in the same way as shade coffee could save large areas of forests from deforestation. Another study conducted in Mensong and Jinuo in Yunnan Province found that a high level of bird biodiversity still exists in traditional economic forests, including traditional tea agroforests (Wang, 2003). Qi et al. (2005) demonstrate that the plant biodiversity of traditional tea agroforests in Jingmai was close to that of neighboring natural forests and much higher than that of tea planations. These systems also conserve valuable genetic diversity because the tea plants (*Camellia sinesis*) are still propagated by seed, rather than cloning (Ji, 2011), which provides precious materials for research on the evolution of tea and for genetic improvements of the tea plant. As for ecosystem services, some studies found higher nutrient (N, P and K) concentrations, greater enzyme activity, and better microclimate conditions in tea agroforests compared with tea plantations (Zhang, 2005; Jiang, 2008).

In addition to ecological functioning, the tea agroforests also perform important socioeconomic roles. Tea contributes to household income, shade trees are also a source of domestic fuel wood, timber, and edible fruits. Some organisms may also be used for medical care, for example *Viscum articulatum* (Wang, 2003; Qi, 2005). Traditional tea agroforests are also part of cultural heritages for diverse minority groups such as Bulang people who took tea as a totem in ancient worship culture, and the Ang people who have a distinctive ethnic culture of drinking tea (Li, 2010). The ecological and economic importance of traditional tea agroforestry presents an excellent opportunity to develop research for sustainable development by combining conservation and economic goals.

Yunnan province in Southwestern China is believed to be one of the origins of broad leaf tea (*Camellia sinesis var assamica*). There is a long history of tea cultivation in this area dating back to Tang dynasty (618-907 A.D.) and harbors multiple traditional tea agroforests which still coexist today with diverse minority cultures. Dating back to Song Dynasty (960-1279 A.D.), Pu'er County was then a worldwide tea trade center and Yunnan Pu'er tea became a famous tea brand widely exported to Tibet and many Southeast Asia countries (Ji, 2011). The trend of tea industrialization converted large areas of traditional tea agroforestry to tea plantations throughout the province from the 1950s to 1990s, leading a significant decrease in land area from 32000 ha to 13000 ha (Zhou, 2004). Today, Longpa, Mengsong, Jingmai and Mangjing are examples of the remaining tea agroforests managed by ethnic groups Jinuo, Akha, Dai and Bulang, respectively. Labeled "eco", "health" and "culture", Yunnan Pu'er tea experienced a market boom in the past decades. Because of the limited supply and inherent quality of tea produced in the traditional tea agroforestry, the price rose as high as $220 USD per kilogram, which was hundreds of times the common tea price (Ahmed *et al*., 2010). Driven by huge economic incentives, it will be not only necessary to evaluate the current status of the systems to estimate the effect of market interference but also necessary to develop effective strategies to maintain sustainability of the system under dramatic market changes.

Chapter 3 MATERIALS AND METHODS

3.1 Study site selection

"Jingmai ancient tea gardens" was chosen to be the study site. It is the best protected and largest traditional tea agroforest in Yunnan with a total area around 27,000 hectares. It contains a high level of plant biodiversity and a considerable number of protected plant species have been found in this area in a survey conducted in 2002 (Qi, 2005). "Jingmai" means market in the language of Dai and it was indeed an important tea trading center from ancient times to now. Considering both the ecological importance and tea market interference, "Jingmai ancient tea gardens" provides a perfect model to study the questions proposed and thus was selected.

3.2 Study site description

Figure 3.1 Location of study site (Notes: the bold line shows the main road in the region and the thin line shows the boundaries of neighboring traditional tea agroforests in which six villages are nested: JM is Jingmai village; MB is Mengben village; MG is Manggeng village; WJ is Wengji village; MJ is Mangjing village; MH is Manghong village.)

“Jingmai ancient tea gardens” is located in the Huimin Township Lancnag County, Pu’er State, Southern Yunnan Province, P.R. China, which is between 22°8’ to 22°12’ N latitude, 99°59′ to 100°3’ E longitude (see Figure 3.1). It is about 70 km away from Huimin Town. “Jingmai ancient tea gardens” include two pieces of neighboring tea agroforestry which belong to two administrative villages: Jingmai and Mangjing, and six sub-villages: Jingmai (JM), Mengben (MB), Manggeng (Mg), Manghong (MH), Mangjing (MJ) and Wengji (WJ).

The elevation of this area ranges from 1250m to 1550m. The climate of this region is typical subtropical mountain monsoon climate (Qi, 2005). The average temperature is around 18.4 ºC and the average rainfall is about 1680 mm and the relative humidity is around 80% with a distinctive dry season and wet season (Qi, 2005).

There are several types of land use apart from traditional tea agroforestry in the region including collective forest, of which the vegetation type is mainly tropical South Asia monsoon evergreen broadleaf forest, tea plantation, dry land utilized to produce maize and cane, paddy utilized to produce rice, small amounts of orchard and homegardens around the villages, and rubber plantations cultivated in the last three years.

The study site belongs to Huimin Township with an area of 194 square km and population around 5000, which consists of multiple ethnic groups including Akha, Dai, Bulang, Lahu, Wa, etc. The administrative village Jingmai administers three sub-villages: Jingmai, Mengben and Manghong, which are dominated by Dai minority. And the other adiministrative village Mangjing administers the other three sub-villages: Mangjing, Manghong and Manggeng, which are dominated by Bulang minority. According to the local historical records of ethnic groups, “Jingmai ancient tea gardens” has had a tea cultivation history of one thousand years. In the ancient times, wild tea plants grew in the Jingmai Mountains which were then domesticated by Bulang minority. Wild tea trees were cut down and fertilized around with fire ashes. Then the seeds were collected and sown in the understory of the natural forest.

Several recent events severely impacted “Jingmai ancient tea gardens”. In the 1950s, more than 500 giant trees were cut down due to the demand from army construction. In the 1970s, fire accidents happened in Jingmai village and more 1000 trees were cut down to rebuild houses for about 80 households. In the 1980s, around 95% households built a new house due to dramatic economic development and the wood was mainly sourced from tea agroforests. In the 1990s, the expansion of tea plantations led to large forest loss as well as loss of tea agroforests.

3.3 Sampling methods and data collection

3.3.1 Sampling Structure

This study was based on a former project conducted in 2002, which was named “Promotion and conservation of Jingmai ancient tea gardens” and conducted by Xishuangbanna Tropical Botanical Gardens (XTBG), with a focus on plant biodiversity and associated livelihoods (Qi, 2005). A household-based agrobiodiversity assessment was applied in order to understand both biodiversity of tea agroforests and the associated utilization of this system. 360 households were randomly chosen from the roster of six sub-villages to do socoioeconomic investigations. Sampling size in each village was based on the total number of households in each village, which was around 50% of total households for each village in 2002. 78 sampling plots were randomly chosen from the 360 sampled households' tea agroforests. The sampling structure is summarized in Table 3.1.

Table 3.1 Summary of sampling structure (Notes: numbers in the brackets indicate re-sampled households and plots in 2012.)

	Jing Mai	Meng Ben	Mang Geng	Mang Jing	Mang Hong	Weng Ji	Total
Households (2002)	167	78	44	110	172	74	645
Households (2012)	-	-	-	-	-	-	-
Sampled Households (2002)	100	47	27	55	86	45	360
Sampled Households (2012)	(94)	(45)	(27)	(54)	(80)	(44)	(344)
Sampled plots (2002)	20	10	6	16	18	8	78
Sampled plots (2012)	(20)	(10)	(6)	(16)	(18)	(8)	(78)

3.3.2 Socioeconomic survey

In order to understand the changes of livelihoods specialized in land utilization, agricultural production and income under increased market interference, a socioeconomic re-survey tracing the same 360 households was conducted according to the list of households surveyed in 2002 with 16 households not found. Semi-structured interviews were conducted based on a standardized questionnaire (see Appendix I). Data on land utilization, yield of agricultural products, income and household expense were collected. Several terms in the questionnaire were adjusted for new conditions such as the term "tax". Since tax of agricultural products was exempted from 2006 in China, the tax term was not included in the re-survey. Both data collected from 2002 and 2012 were utilized in the analyses. All household survey data (16 missing data for 2012) were used to analyze the change of livelihoods in terms of land use, profitability of agricultural production and income. Only 78 household data (2 missing data for

2012), which correspond with the 78 sampling plots, was used to analyze the correlation between changes in biodiversity and change of profitability of "old tea".

3.3.3 Plant biodiversity survey

To explore the dynamics of tea agroforests in terms of plant biodiversity, a plant biodiversity re-survey on five plant lifeforms including trees, seedlings, shrubs, vines & epiphytes and herbs, was conducted in the same 78 20m x 20m sampling plots of the traditional tea agroforests from December to April 2012. The same plots were located by four permanent cement marks, which were set in the corners of the plots during the former survey from November to March 2002 by Qi, *et al*. (2005). The abundance and names of species was recorded for all lifeforms while only the DBH (Diameter of Breast Height) of trees were measured. Five 1m x 1m sampling units were set up inside the 20m x 20m sampling plot to record the names of species and abundance of herbaceous plants. Tea shrubs in the sampling plots were counted in diagonal and measured for height as well as basal diameters. The plant species which could not be identified in the field, were collected and sent for identification by experts in Xishuangbanna Tropical Botanical Gardens (XTBG). Since plant identification of the re-survey was not conducted at the same level as the first survey, the level of identifications of the first survey were adjusted to those of the re-survey (see Appendix II). Both data collected in 2002 and 2012 were utilized in the analyses of plant biodiversity change.

3.4 Data analysis

To summarize the changes of socioeconomic aspects of tea production, yield, average tea price and profitability of both "old tea" production in tea agroforests and "new tea" production in tea plantations were calculated. We used the responses from the socioeconomic survey to create the three variables. Household tea agroforestry tea yield was expressed in terms of kilogram of tea leaves harvested per hectare.Tea prices were the same for the households in the same village for the same season, however, some households in the same village had naturally low tea prices scenarios due to less yield in the high price season or more yield in the low price season. Average tea price was used to better represent the tea market influence on the household level, which was calculated by dividing total annual net profit (which was calculated by subtracting expenses from gross profit) by the yield. Profitability was calculated by dividing total annual net profit by the area under tea agroforestry. Variable costs were subtracted, which only included the labor costs since utilization of fertilizer, herbicide and insecticide were forbidden for both old tea production and new tea production in the studied regions. Inflation was adjusted based on Consumer Price Index (CPI) from 2002 to 2012.

To summarize the changes of management practices implied by vegetation variables, density of trees, density of tea shrubs and density of herbs were used. Shade cover, density of shade trees and density of cash crops are widely used in research on coffee and cacao agroforestry to indicate the degree of management intensification (Deheuvels *et al.,* 2009; Gordon, *et al.,* 2007). In the case of tea agroforestry, only the density of trees was used since many shade trees defoliated in winter. Since weeding was an important practice in tea agroforests, the density of herbs was used to imply the intensification of weeding practices. Vegetation indicators were calculated based on plant survey data by dividing the total individuals of trees, tea shrubs and herbs by the total area of one plot, which is 400 square meters.

To summarize the changes of plant biodiversity, the abundance, species richness and Shannon-Wiener diversity index were calculated by R package Biodiversity R (version 2.0-3) on both overall level and plot level. To summarize the changes on species level, the change of abundance and the change of occurrence were used. The occurrence referred to the occurrence of species in one plot.

Because of non-normality of majority of data, which was tested by Shapiro-Wilk normality test, the median was utilized instead of mean for most terms (usage of mean was indicated specificly) and Wilcoxon rank-based test was applied to test whether the changes from 2002 to 2012 were significant. The Spearman correlation test was applied to test the correlation between profitability and other variables since it was based on rank and had no assumptions for normal distribution.

A MANOVA test by Pillai's Trace was applied on plant richness data by treating richness of trees, seedlings, shrubs, epiphytes & vines, herbs as five dependent variables and the time, village and time: village interaction terms were all tested to explore whether there were significant differences of richness over year or among villages across all lifeforms or whether the changing trends for each village were significantly different across all lifeforms.

To examine biodiversity-geology, biodiversity-management and biodiversity-profitability relationships, linear mixed-effect regression analyses were applied on the longitudinal data by treating plant species richness as the dependent variable and elevation, slope, distance from village center, density of tea shrub, profitability as independent variables. The random structure “1|plot” was chosen because of lower AIC (Akaike’s Information Criterion) compared with random structure “fyear|plot”. Residuals were checked with no violation of independence and homogeneity. The composite model with three kinds of independent variables was used as the start model to select effective predictors. Both directions stepwise method was applied for selection based on AIC. The best model was selected with the least AIC. In each year, generalized least squares regression analyses were conducted with the same predictors and residuals were checked with no violation of independence and homogeneity. Tea yield and average tea price were tested instead of profitability as well. All the statistical analyses were performed using R software (version 2.15.0; (Team, 2012)).

Chapter 4 RESULTS

4.1 Socioeconomic changes over ten years

4.1.1 Change of tea price

In 2002, the tea prices were the same across villages, which were around only 1~2 yuan per kilogram for both "old tea" (produced in tea agroforestry) and "new tea" (produced in tea plantations) fresh leaves (see Table 4.1). Now, the tea prices are different among villages. Jingmai has the highest average tea price due to its recognized high quality of tea while tea from Mengben was sold at a relatively low price. Both "old tea" prices and "new tea" prices increased in the past years due to a tea market boom, however, dramatic differences were generated between the two. In Jingmai village, the prices of dry tea leaves increased dramatically from 2002 to 2007 mainly due to the speculation on Pu'er tea from urban capitals (Ahmed et al., 2010), suddenly dropped down in 2008 and then rose up again recently. The price fluctuations were drastic especially for "old tea", of which the price once rose up to as high as 430 yuan per kilogram in 2007, contrasting with the original price of 2 yuan per kilogram in 2002. The price premiums of old tea were generally two to three times of the new tea prices surveyed in 2012, and once rose up to as high as about five times in the bulk market around 2007 (see Figure 4. 1).

4.1.2 Changes of profitability

In 2002, profitability of new tea production in tea plantations was higher than that of old tea in most villages. However, new tea production became less competitive compared with old tea in 2012 since the profitability of old tea was usually 2 to 4 times higher than that of new tea. In comparison with tea production, other agricultural production including maize, cane and fruits became relatively less profitable, and less productive activities were applied (see Figure 4.2).

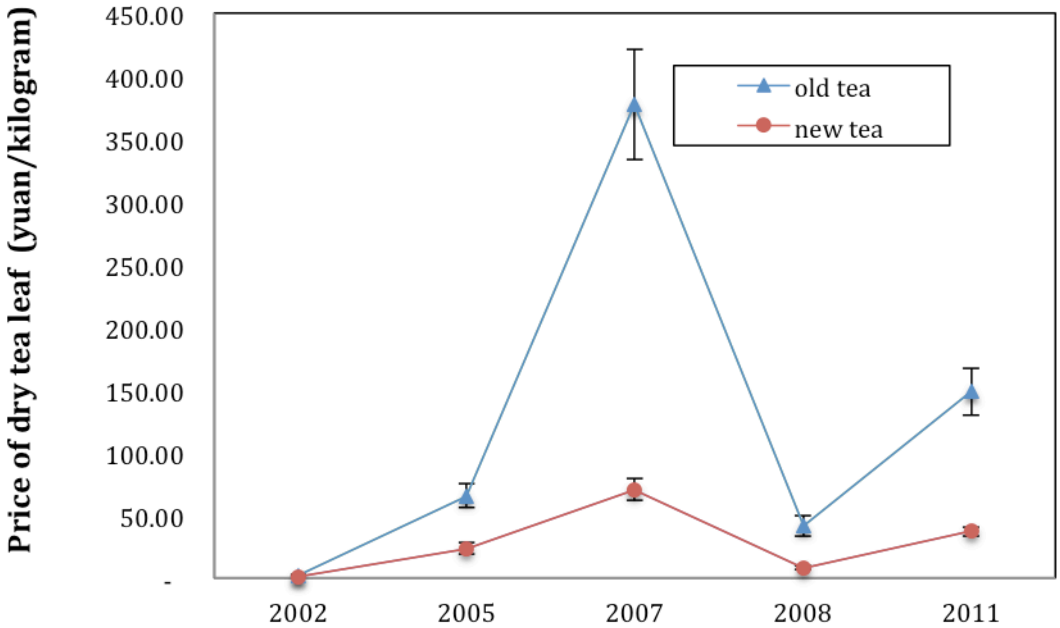


Figure 4.1 Fluctuation of tea price from 2002 to 2011 in Jingmai village (Notes: values are mean ± one standard deviation; n=50 for each years.)

Table 4.1 Change of tea production among villages

Village	Yield (kilo/ha)		Price (yuan/kilo)		Profitability (yuan/ha)	
Old Tea fresh leaves						
	2002	2012	2002	2012	2002	2012
JM	100.75	175.00**	1.81±1.30	27.22±4.11***	133.33	4660.49***
MB	66.67	66.67	1.79±0.95	13.38±0.93***	166.67	755.56***
MG	40.91	80**	1.48±0.13	16.81±1.08***	62.5	4100.74***
MH	11.31	50.67***	0.73±0.59	20.89±2.95***	23.50	1320.99***
MJ	27.50	116.67***	1.50±0.80	21.74±6.53***	32.51	1283.95***
WJ	21.82	41.67***	1.49±0.25	23.28±2.07***	150.00	1351.85***
New Tea fresh leaves						
Village	**Yield (kilo/ha)**		**Price (yuan/kilo)**		**Profitability (yuan/ha)**	
	2002	2012	2002	2012	2002	2012
JM	116.03	97.73	1.25±0.17	5.82±1.39***	250.00	1025.49***
MB	62.69	65.04	1.25±0.73	5.29±0.39***	274.70	277.78**
MG	92.40	113.33	1.32±0.09	6.29±0.30***	230.77	1125.93***
MH	196.25	245.00	1.42±0.53	6.33±0.98***	285.71	740.74***
MJ	133.33	153.85	1.21±0.37	4.74±1.30***	176.64	477.09***
WJ	70.83	71.43	1.14±0.47	6.15±0.33***	150.00	414.81***

(Notes: means were used for tea price; ***, **, *, are the confidence levels of 0.01, 0.05 and 0.1, respectively)

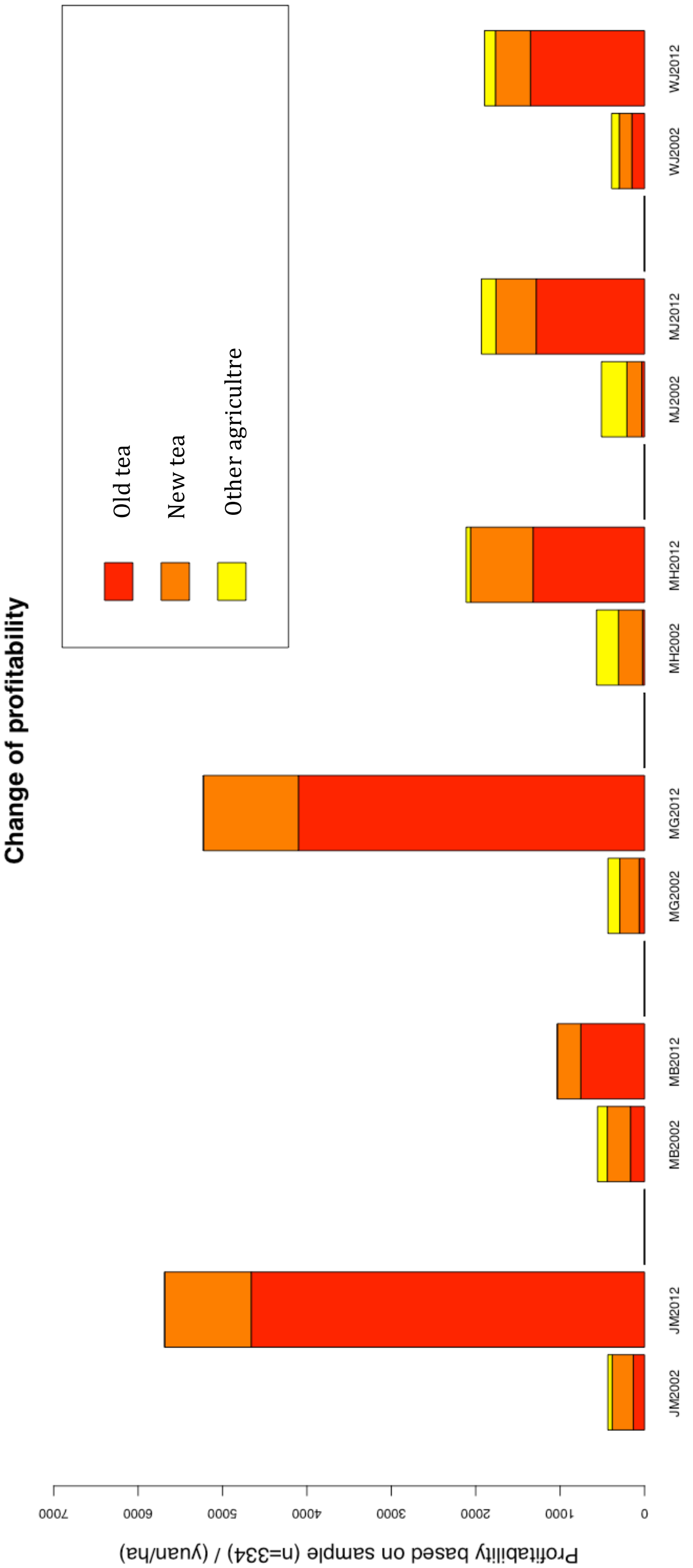


Figure 4.2 Change of profitability

4.1.3 Change of income structure

Income structure comparison indicates that tea became the dominant source of income in 2012. While income from new tea and from other agricultural products originally had a big proportion in 2002, income from new tea, old tea and tea processing became the three major sources in 2012. The percentage of income from old tea in total annual income per household increased from 11.5% to 40.4%, and percentage of income from tea processing in total annual income per household increased from 7.2% to 35.8%. Proportion of income from other non-tea agricultural activities and from other non-agricultural non-tea processing activities decreased greatly (see Figure 4.3). Multiple paddies were abandoned, and local farmers became more reliant on outside markets or period markets to purchase rice, vegetables, fruits and other non-tea agricultural products instead of producing them on their own lands.

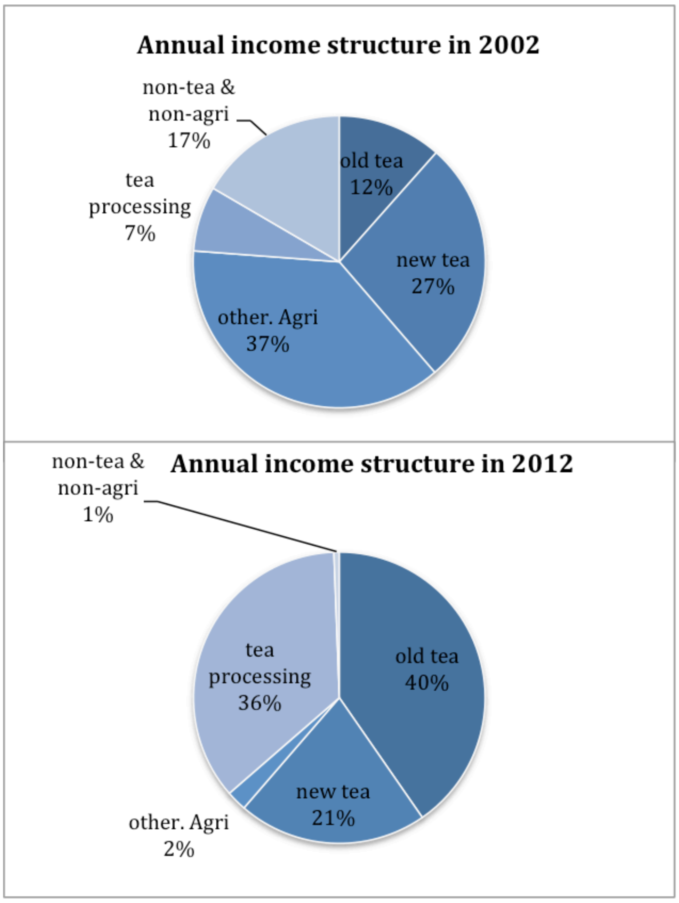


Figure 4.3 Change of income structure

4.2 Land use changes

Forest, traditional tea agroforestry and agricultural land were the three major land use types in this region. The forests were collective and community forests, of which three hectares were evenly distributed to each village member, and logging was forbidden as a recent government policy (Guo Huijun *et al.,* 2002). The vegetation type was mainly tropical South Asian monsoon evergreen broadleaf forest. Traditional tea agroforestry was also an important land use type. The ownership of tea agroforestry could only be passed through marriage and inheritance. Recently, however, the ownership could be exchanged through trading as well. Logging in the tea agroforest and transformation of tea agroforest to the other land use has been forbidden since 2002. Paddy, dry land and tea plantation were the three main categories for agricultural land. In 2009, the local government began to promote an "eco tea" project, which aims to convert all the tea plantations to eco tea gardens by decreasing the density of tea shrubs and planting trees. In 2012 survey, most of the tea plantations were converted to eco tea gardens with a distance between two tea shrubs of at least 1.5 meters. Orchards and homegardens were relatively less important land use types. Rubber had become an increasing new land use in last three years especially in village MH (see Figure 4.4).

It was found that the land use of tea agroforests was stable and even increased in some villages. There was an obvious increase of tea plantations utilized in every village. Land use of forests was stable since the distribution policy did not change. Land use of tea agroforests was stable or slightly increased, while the area of tea plantations increased a lot after ten years. Rubber expansion happened in village MB and MH. As for other agricultural land used, both the utilization of paddy and dry land decreased (see Figure 4.4).

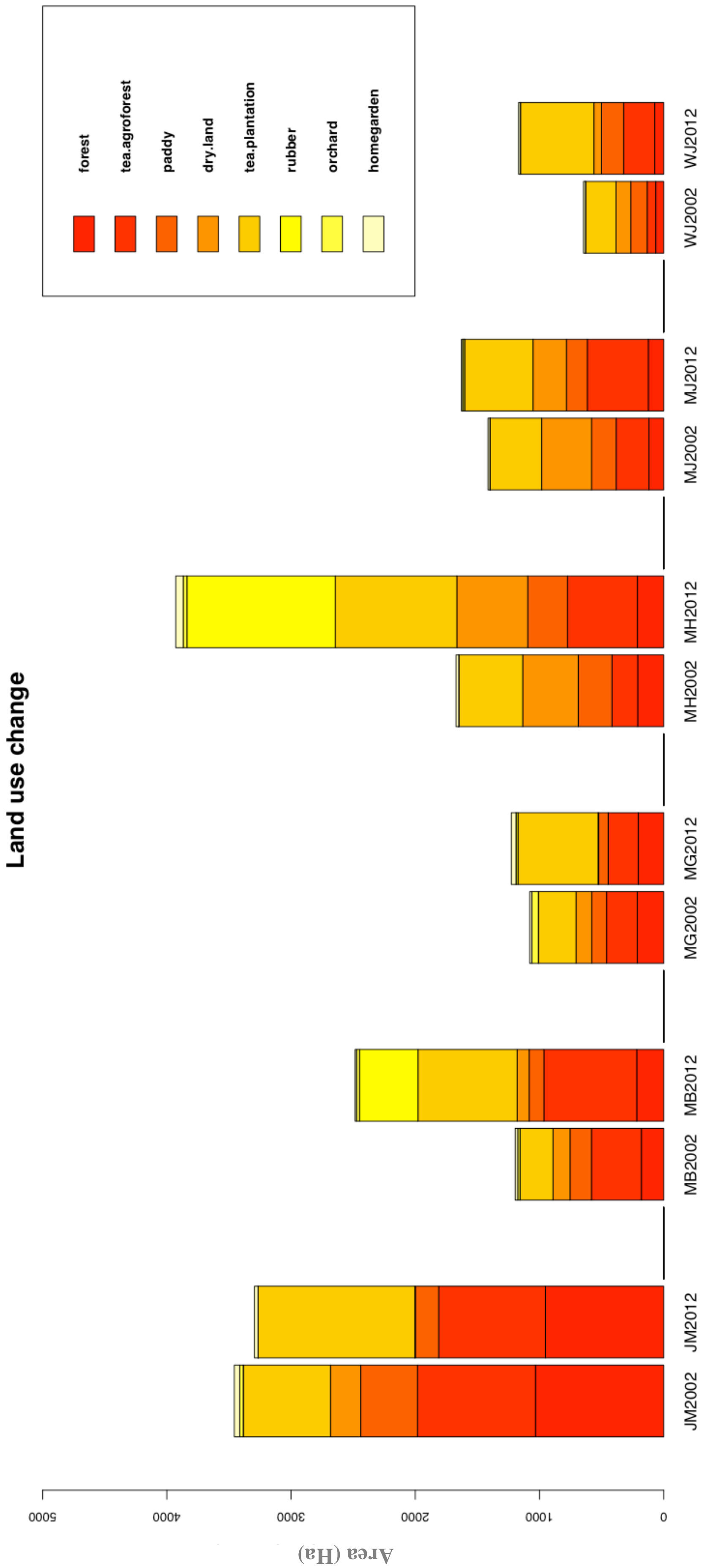


Figure 4.4 Landuse distribution in six villages in 2002 versus 2012

4.3 Change of management practices

4.3.1 Change of practices on shade trees

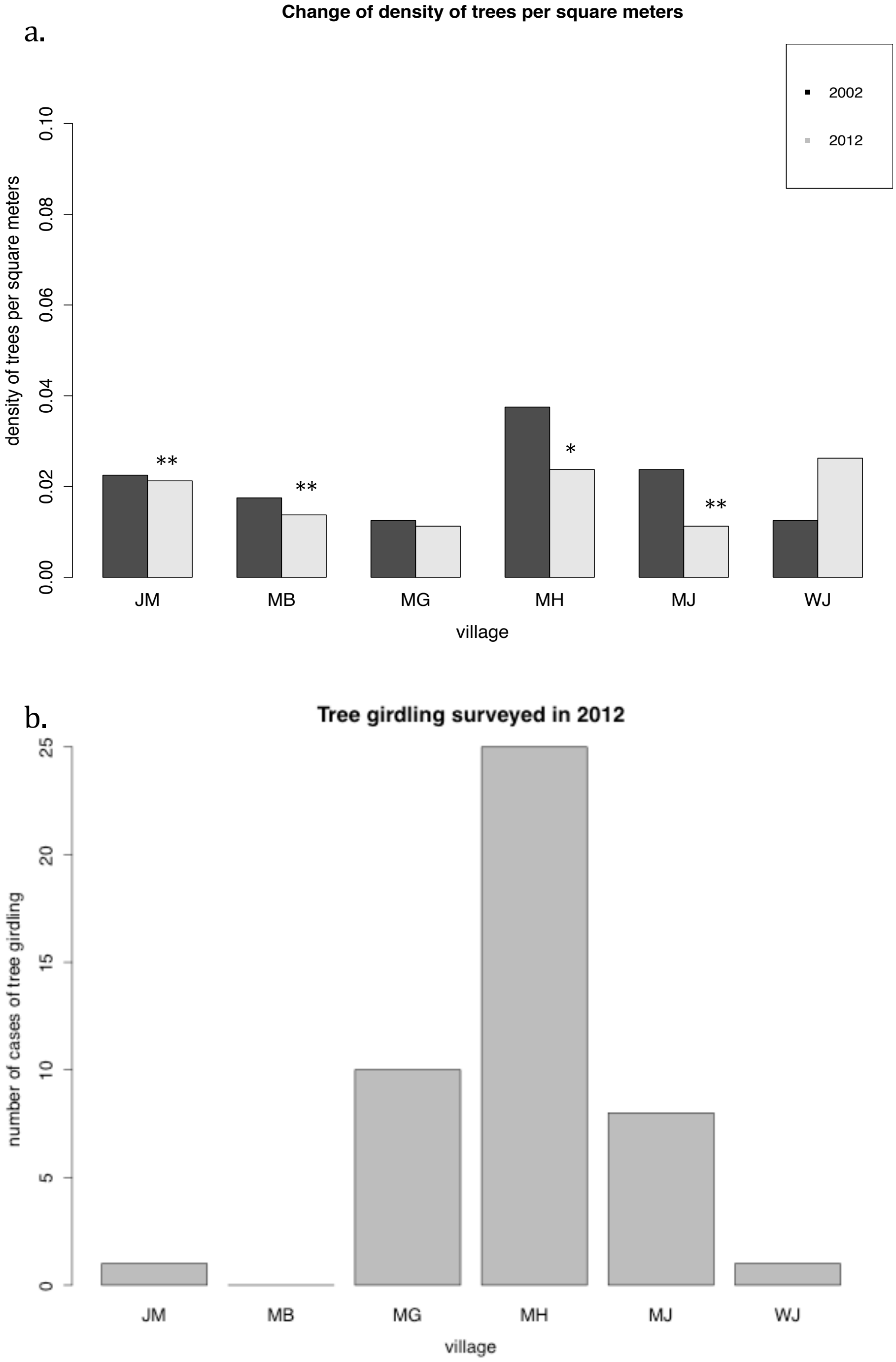


Figure 4.5 Change of management on trees: (a) Change of density of trees, (b) Tree girdling surveyed in 2012 (Notes: Wilcoxon tests were applied to test the significance of changes over years; ***, **, *, are the confidence levels of 0.01, 0.05 and 0.1, respectively.)

The density of trees in tea agroforests significantly decreased in four villages however did not change significantly in the other two villages. A considerable number of trees were cut down in MH and MJ while WJ had an increase of trees however not on a significant level. As for tree girdling cases, there were a total of 25 tree girdling cases happened at MH in 2012 while a case of tree girdling was not found before in 2002, which indicates management changes on shade trees in the tea agroforestry especially in village MH (see Figure 4.5).

4.3.2 Changes of weeding practices

Except for MB, all the villages had a significant decrease in density of herbs, indicating an intensified weeding activity. In MB, the density of herbs was1.55 individuals per square meters before and was 1.79 now with no significant difference, which indicates traditional weeding practices continued to be applied in this village (see Table 4.2).

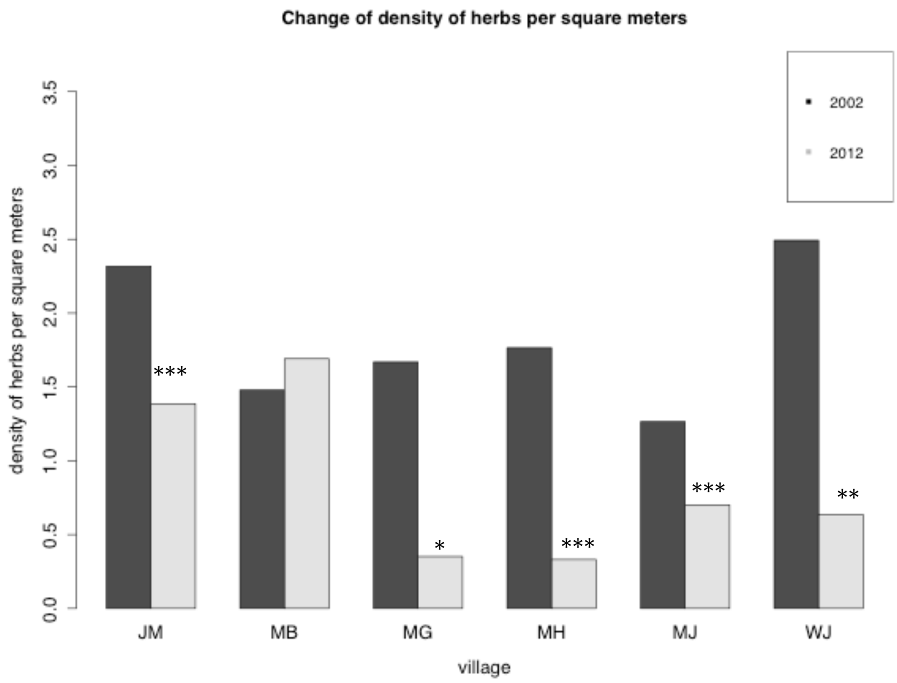
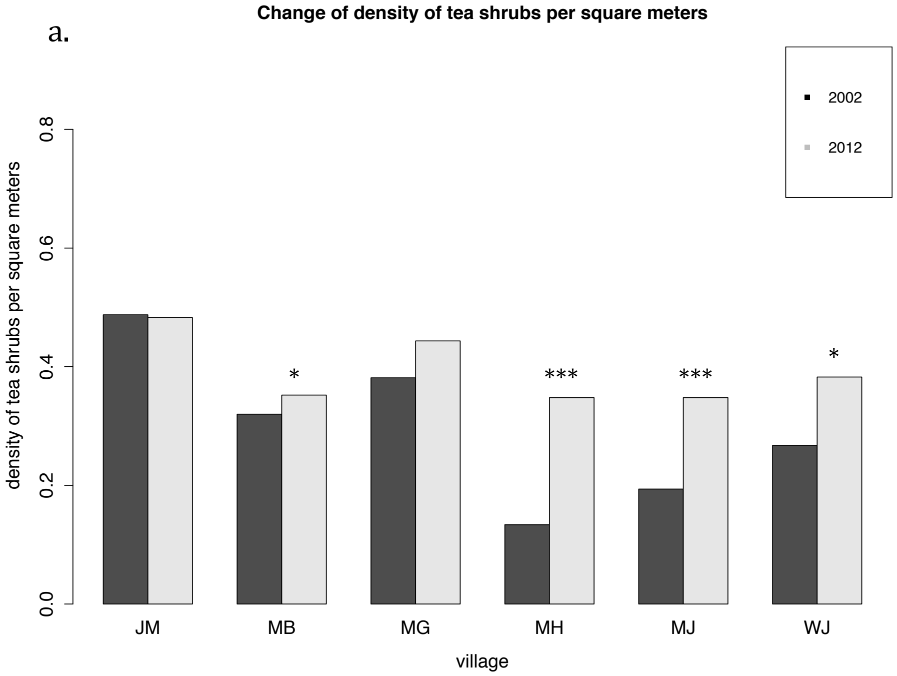


Figure 4.6 Change of weeding implied by density of herbs (Notes: Wilcoxon tests were applied to test the significance of changes over years; ***, **, *, are the confidence levels of 0.01, 0.05 and 0.1, respectively.)

4.3.3 Change of practices on tea shrubs

a.



b.

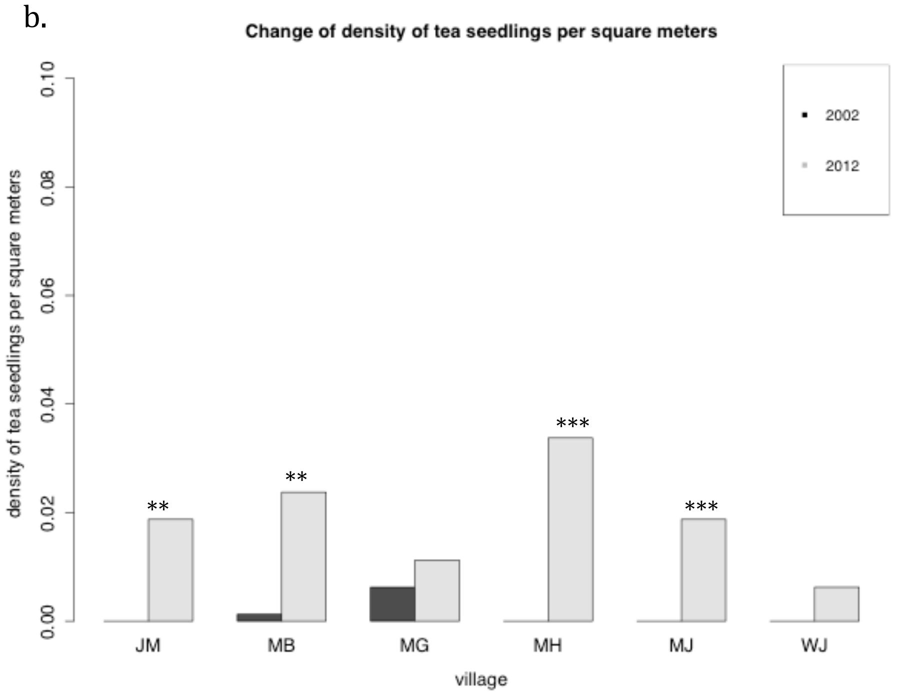


Figure 4.7 Change of management on tea shrubs: (a) Change of density of tea shrubs, (b) Change of density of tea seedlings (Notes: Wilcoxon tests were applied to test the significance of changes over years; ***, **, *, are the confidence levels of 0.01, 0.05 and 0.1, respectively.)

As shown in Figure 4.7, significant increases in tea shrub density were found in village MB, MH, MJ and WJ while no significant changes happened in village JM and MG, of which the tea shrubs densities were already on a relatively high level. Few tea seedlings were found before while a significant increase in tea seedlings was found in 2012 survey. Although natural germination processes are still applied in traditional tea agroforestry, the strongest factor influencing tea shrub density is management practices such as replanting tea branches, replanting tea trees and planting tea seedlings.

4.4 Changing patterns of plant biodiversity

4.4.1 Changing patterns on the overall level

Plant species surveyed in 2002 and 2012 are listed in Appendix III. Considerable losses of plants were found in the terms of abundance and richness as well as Shannon-Wiener index. As shown in Table 4.2, a net loss of 37528 individuals was found, which is almost the half of original number. As for richness, the total plant richness was 588 in 2002 and decreased to 477 in 2012 with a total loss of 111 species, which was around 19% of the original richness. To encapsulate both richness and evenness, Shannon-Wiener diversity Index was used, and a decrease of 0.45 from 4.23 to 3.77 was calculated on the overall level.

When grouping the results into plant lifeforms, as shown in Table 4.2, herbs contributed more than half of the total abundance and 72% abundance loss came from loss of herbs. All the life forms had losses of plant species richness, and trees were the least lost life form. Shannon's diversity index indicates similar results, all life forms had a decrease but still stayed at a considerably high level of diversity, and trees again had relatively small change.

Table 4.2 Summary of plant biodiversity changing patterns on the overall level

		Total		Tree		Seedling		Shrub		Epiphytes &Vines		Herb	
	Parameter	2002	2012	2002	2012	2002	2012	2002	2012	2002	2012	2002	2012
Total	Plots	78	78	78	78	78	78	78	78	78	78	78	78
	Abundance	73757	36229	869	672	5534	1836	4794	1351	6025	2846	56535	29524
	Richness	588	477	135	123	145	108	113	93	144	108	162	124
	Shannon	4.23	3.77	3.85	3.80	4.06	3.71	2.85	2.78	3.80	3.41	3.36	3.02
	Density	2.36	1.16	0.03	0.02	0.18	0.06	0.15	0.04	0.19	0.09	1.81	0.95
JM	Plots	20	20	20	20	20	20	20	20	20	20	20	20
	Abundance	21789	13701	222	172	878	575	1130	417	1755	976	17804	11561
	Richness	259	232	55	52	**60**	**60**	**34**	**35**	62	44	83	71
	Shannon	3.53	3.18	3.30	3.29	3.05	3.09	2.15	2.08	3.17	2.69	2.85	2.54
	Density	2.72	1.71	0.03	0.02	0.11	0.07	0.14	0.05	0.22	0.12	2.23	1.45
MB	Plots	10	10	10	10	10	10	10	10	10	10	10	10
	Abundance	7977	7825	78	48	264	72	638	144	798	413	**6199**	**7148**
	Richness	170	131	29	22	36	18	20	14	44	33	61	54
	Shannon	3.79	3.23	2.93	2.54	2.95	2.57	2.11	1.65	2.87	2.48	3.13	2.90
	Density	1.99	1.96	0.02	0.01	0.07	0.02	0.16	0.04	0.20	0.10	**1.55**	**1.79**
MG	Plots	6	6	6	6	6	6	6	6	6	6	6	6
	Abundance	5417	1472	**28**	**32**	478	80	464	44	620	238	3827	1078
	Richness	176	109	**16**	**18**	48	21	23	14	44	26	55	36
	Shannon	4.12	3.30	**2.51**	**2.65**	3.17	2.63	2.53	2.28	2.90	2.46	3.32	2.43
	Density	2.26	0.61	**0.01**	**0.01**	0.20	0.03	0.19	0.02	0.26	0.10	1.59	0.45
MH	Plots	18	18	18	18	18	18	18	18	18	18	18	18
	Abundance	17037	4598	302	224	1919	508	1076	210	1225	380	12515	3276
	Richness	342	210	53	49	96	56	64	26	83	51	89	56
	Shannon	3.92	3.81	**2.74**	**2.86**	3.74	3.14	3.03	2.44	3.58	3.36	2.90	2.85
	Density	2.37	0.64	0.04	0.03	0.27	0.07	0.15	0.03	0.17	0.05	1.74	0.46
MJ	Plots	16	16	16	16	16	16	16	16	16	16	16	16
	Abundance	11932	5848	195	116	1444	370	1034	343	1182	507	8077	4512
	Richness	325	226	58	49	96	43	50	34	83	60	81	69
	Shannon	4.27	3.58	3.62	3.61	3.76	3.14	2.70	2.55	3.48	3.44	3.22	2.68
	Density	1.86	0.91	0.03	0.02	0.23	0.06	0.16	0.05	0.18	0.08	1.26	0.71
WJ	Plots	8	8	8	8	8	8	8	8	8	8	8	8
	Abundance	9605	2785	**44**	**80**	551	231	452	193	445	332	8113	1949
	Richness	228	192	**23**	**24**	55	45	38	33	49	43	79	60
	Shannon	**3.68**	**4.07**	2.86	2.47	3.44	3.36	**2.63**	**2.67**	**3.00**	**3.13**	**3.07**	**3.13**
	Density	3.00	0.87	**0.01**	**0.03**	0.17	0.07	0.14	0.06	0.14	0.10	2.54	0.61

(Notes: Bold numbers indicate no change or positive changes.)

Table 4.3 Summary of plant biodiversity changing patterns on the plot level

		Total		Tree		Seedling		Shrub		Epiphyte &Vine		Herb	
	Parameter	2002	2012	2002	2012	2002	2012	2002	2012	2002	2012	2002	2012
T	plots	78	78	78	78	78	78	78	78	78	78	78	78
O	Abundance	910.5	397.5***	8.5	8***	56.5	19***	60	16***	66	28***	686	310***
T	Richness	70.5	40.5***	6	5***	14.5	6***	10	4***	14	8***	29	17.5***
A	Shannon	3.15	2.71***	1.56	1.39***	2.32	1.54***	1.87	1.09***	2.42	1.69***	2.46	2.07***
L	Density	2.28	0.99***	0.02	0.02***	0.14	0.05***	0.15	0.04***	0.17	0.07***	1.72	0.78***
	Plots	20	20	20	20	20	20	20	20	20	20	20	20
J	Abundance	1070	671.5***	9	8.5**	41.5	23**	56	20.5***	81.5	42.5**	927	554.5**
M	Richness	66	44.5***	**5.5**	**6**	11	8**	8	5***	15	8.5***	29.5	20.5***
	Shannon	2.99	2.63***	**1.55**	**1.59**	2.06	1.75*	1.65	1.24***	2.33	1.77***	2.43	2.10***
	Density	2.68	1.68***	0.02	0.02**	0.10	0.06**	0.14	0.05***	0.20	0.11**	2.32	1.39**
	Plots	10	10	10	10	10	10	10	10	10	10	10	10
M	Abundance	**720.5**	**775.5**	7	5.5**	23	6**	52.5	14***	70.5	26.5**	**591.5**	**676.5**
B	Richness	54	36**	5	3**	7.5	3.5**	7	3**	11	7.5**	27	20.5*
	Shannon	3.04	2.65**	1.47	0.84**	1.85	1.05***	1.56	0.77**	2.04	1.65*	**2.43**	**2.39**
	Density	**1.80**	**1.94**	0.02	0.01**	0.06	0.02**	0.13	0.04***	0.18	0.07**	**1.48**	**1.69**
	Plots	6	6	6	6	6	6	6	6	6	6	6	6
M	Abundance	909	210.5*	**5**	**4.5**	80.5	12.5*	70.5	5.5*	98	39*	667.5	140.5*
G	Richness	82	35*	**3.5**	**3**	20	5*	11	2*	14.5	7.5*	33	15.5*
	Shannon	3.64	2.71 *	**1.17**	**0.95**	2.48	1.40*	2.00	0.48*	**2.09**	**1.70**	2.93	1.99*
	Density	2.27	0.53*	**0.01**	**0.01**	0.20	0.03*	0.18	0.01*	0.25	0.10*	1.67	0.35*
	Plots	18	18	18	18	18	18	18	18	18	18	18	18
M	Abundance	937	217***	15	9.5*	110.5	20**	58.5	6**	57.5	14**	706	132.5***
H	Richness	82.5	37*	**6**	**6**	25	8.5**	13	2.5**	15	7**	25	14**
	Shannon	3.17	2.71**	**1.50**	**1.57**	2.85	1.87***	2.22	0.64***	2.30	1.63***	2.23	1.97*
	Density	2.34	0.54***	0.04	0.02*	0.28	0.05**	0.15	0.02**	0.14	0.04**	1.77	0.33***
	Plots	16	16	16	16	16	16	16	16	16	16	16	16
M	Abundance	763	374***	9.5	4.5**	102.5	17***	64.5	16**	68.5	29.5**	506	280.5**
J	Richness	71	39***	7	4**	18.5	5***	9.5	4***	12	7**	26	17.5***
	Shannon	3.35	2.75**	1.93	1.39**	2.56	1.41***	1.79	1.13***	2.13	1.67**	2.46	2.08*
	Density	1.91	0.94***	0.02	0.01**	0.26	0.04***	0.16	0.04**	0.17	0.07**	1.27	0.70**
	Plots	8	8	8	8	8	8	8	8	8	8	8	8
W	Abundance	1199.5	408**	**5**	**10.5**	68	24**	52	22.5**	**42**	**32.5**	997	254.5**
J	Richness	85	46**	**4**	**5.5**	19.5	10**	14	7*	**14**	**10.5**	34.5	21.5**
	Shannon	**3.23**	**2.98**	**1.36**	**1.28**	2.53	2.11**	2.17	1.61*	**2.13**	**1.89**	**2.66**	**2.31**
	Density	3.00	1.02**	**0.01**	**0.03**	0.17	0.06**	0.13	0.06**	**0.11**	**0.08**	2.49	0.64**

(Notes: Bold numbers indicate no change or positive changes; Wilcoxon tests were applied to test the significance of changes over years; ***, **, *, are the confidence levels of 0.01, 0.05 and 0.1, respectively.)

Referring to each village and considering all lifeforms, the changing patterns are similar to total level, in which loss of herbs contributed the most to the total abundance and trees showed the least changes over ten years. As shown in Table 4.2, the bold highlights, which indicate no change or an increase, mostly fell into the tree column, which indicate a relatively stable pattern of trees. To compare the changing patterns among six villages, MH had the worst scenario with more than 75% loss of abundance and loss of species richness at 132, and JM had the best optimal scenario with no more than half loss of abundance and only 27 species loss, which indicates JM was relatively well protected and MH experienced severe degradation.

4.4.2 Changing patterns on the plot level

As shown in Table 4.3, there are significant changes in total in the terms of abundance, richness and Shannon-Wiener index on the plot level. More than half the abundance was lost and considerable richness was lost from 70.5 to 40.5 on a significant level. As indicated by the bold highlights, which show the terms with no change or an increase, MB did not change in the terms of herb abundance and WJ did not change in the terms of epiphytes and vines while four villages showed no significant change in trees, which again indicates relatively stable changing patterns of trees on the plot level. Villages behaved differently over the years on the plot level as well. Similar to findings on the overall level, JM stayed relatively stable while MH and MG experienced considerable negative changes with over 75% loss of abundance, a decrease of richness from 82.5 to 37 and from 82 to 35, and a decrease of Shannon-Wiener index from 3.17 to 2.71 and from 3.64 to 2.71 respectively.

4.4.3 Changing patterns across villages

A MANOVA test by Pillai's Trace was applied to test whether the changing patterns of richness were different among villages. Data from trees, seedlings, shrubs, epiphytes and herbs were treated as six dependent variables. As shown in Table 4.4, three tested factors "time", "village" and "time: village" were all on a significant level. The term "time " was significant (p< .001), indicating there were significant changes of richness from 2002 to 2012 across all lifeforms, which again confirmed results summarized above. The village factor was significant (p< .001), showing that there were significant differences in plant species richness between villages across all lifeforms. As for the changing patterns, it is demonstrated that different villages had different trends over time in changes of plant species richness since the time and village interaction term was significant (p< .001).

Table 4.4 MANVOA test by Pillai's Trace on plant species richness

Pillai's Trace	Df	Pillai approx	F	num Df	den Df	Pr(>F)	Significant level
time	1	0.72984	62.58	6	139	<2.2e-16	***
village	5	0.88652	5.14	30	715	<2.2e-16	***
time:village	5	0.50811	2.7	30	715	3.69E-06	***
Residuals	144						

Notes: ***, **, *, are the confidence levels of 0.01, 0.05 and 0.1, respectively.

4.4.4 Changing patterns of tree species

Similar to the above results, trees showed a relatively stable pattern of change. As shown in Table 4.5, although 73 tree species decreased in frequency and 86 tree species lost individuals after ten years, 80 tree species showed an increase or no change in terms of occurrence and 67 tree species showed an increase or no change in terms of abundance.

Table 4.5 Summary of chainging patterns of trees on species level

	Number of tree species		
	>0	=0	<0
Change of occurrence	28	52	73
Change of abundance	28	39	86

Table 4.6 Summary of top 10 tree species decreased and top 10 tree species increased

Scientific name	Family	Abundance		Occurrence		Notes
		2002	2012	2002	2012	
Decreasing						
Toona cilliata	Meliaceae	24	8	14	3	Nationally protected
Toxicodendron succedaneum	Anacardriaceae	30	19	21	15	
Alangium barbatum	Alangiaceae	14	7	12	6	
Choerospondias axillaris	Anacardriaceae	27	20	19	14	
Cassia agnes	Caesalpiniaceae	14	1	6	1	
Paramichelia baillonii	Magnoliaceae	7	3	7	2	Nationally protected
Euodia trichotoma	Rutaceae	6	3	6	2	
Mallotus paniculatus	Euphorbiaceae	11	2	6	2	
Dalbergia pinnata	Leguminosae	5	0	3	0	
Macaranga denticulata	Euphorbiaceae	10	2	4	1	
Increasing						
Paranephelium sp.	Sapindaceae	0	24	0	4	
Musa basjoo	Musaceae	0	8	0	4	Cultivated, medicinal and ornamental
Psidium guajava	Myrtaceae	0	6	0	3	Cultivated, edible fruit
Litsea glutinosa	Lauraceae	3	6	3	6	
Litsea cubeba	Lauraceae	2	4	1	4	
Erythrina indica	Leguminosae	0	2	0	2	
Glochidion hirsutum	Euphorbiaceae	5	14	3	5	
Castanea mollissima	Fagaceae	0	1	0	1	Cultivated, edible nuts
Sapindus delavayi	Sapindaceae	0	1	0	1	Used medicinally, timber
Mangifera indica	Anacardiaceae	0	1	0	1	Popular tropical fruit tree

However, important trees and giant trees were in fact decreasing while cultivated tree species such as fruit trees were planted and thus increased. As shown in Table 4.6, the protected species such as *Toona ciliata* and *Paramichelia baillonii* were disappearing, and cultivated trees such as *Musa basjoo*, *Psidium guajava*, *Castanea mollissima* and *Mangifera indica* were appearing. When carefully examining the dynamics of nationally protected tree species identified in the former study conducted in 2002 (Qi et al., 2005) and endemic species in Yunnan, as summarized in Table 4.7, it can be found that the majority of important species were losing out in the traditional tea agroforestry systems. Moreover, giant trees with a DBH of more than 50 cm were also cut down and lost as shown in Table 4.8.

Table 4.7 Summary of changes of important tree species

Scientific name	Important category	Abundance		Occurrence	
		2002	2012	2002	2012
Carallia lanceaefolia	Endangered	1	0	1	0
Toona ciliata	Endangered	24	8	14	3
Cinnamomum molifolium	Endangered	7	3	4	3
Ormosia yunnanensis	Engdangered	1	0	1	0
Canarium subulatum	Vulnerable	1	0	1	0
Hovenia acerba	Vulnerable	1	0	1	0
Calophyllum polyanthum	Vulnerable	2	2	2	2
Paramichelia baillonii	Vulnerable	7	3	7	2
Bauhinia variegate var. candida	Endemic	1	0	1	0
Ormosia yunnanensis	Endemic	1	0	1	0
Syzygium rockii	Endemic	1	0	1	0
Syzygium yunnanensis	Endemic	1	0	1	0

Table 4.8 Summary of change of giant trees

Scientific name	Family	Maximum dbh in 2002	Maximum dbh in 2012	Abundance		Occurrence	
				2002	2012	2002	2012
Alangium barbatum	Alangiaceae	102.2	28	14	7	12	6
Euodia trichotoma	Rutaceae	117	50	6	3	6	2
Dalbergia pinnata	Leguminosae	58	0	5	0	3	0
Syzygium oblatum	Myrtaceae	202	42.5	6	2	5	2
Pygeum arboreum	Rosaceae	150	34.1	4	3	4	3
Garuga floribunda	Burseraceae	52.2	0	1	0	1	0
Ormosia yunnanensis	Papilionaceae	52.4	0	1	0	1	0
Sapium insigne	Euphorbiaceae	50.7	0	1	0	1	0
Berberis heteropoda	Berberidaceae	158	28.7	3	1	1	1
Cerasus pseudocerasus	Rosaceae	101.8	38.8	2	1	2	1
Ehretia acuminata var. obovata	Boraginaceae	200	19.3	4	2	2	2

4.4.5 Changing pattern of epiphytes and vines

A considerable number of epiphytes & vines species were lost in terms of both abundance and occurrence in the plots. The epiphyte that lost the most was *Vicum articulatum*, which is a well-known medicinal plant and is added to old tea products to differentiate with other old tea products produced in other regions. The price of this plant has risen up to 2000 yuan per kilogram, and local people heavily collected this plant and sold it on the markets as observed. The huge loss of common vine species such as *Dioscorea sp.*, *Clitoria mariana* and *Smilax hypoglauca* was also found, which might be due to intensification of weeding.

Table 4.9 Top 10 lost epiphytes and vines

Top 10 lost species ranked by abundance				Top 10 lost species ranked by occurrence			
Scientific name	Family	Abundance		Scientific name	Family	Occurrence	
		2002	2012			2002	2012
Dioscorea sp. [v]	Dioscoreaceae	620	42	*Dioscorea sp.* [v]	Dioscoreaceae	57	22
Viscum articulatum [e]	Loranthaceae	560	123	*Bulbophyllum sp.* [e]	Orchidaceae	63	30
Drymaria cordata [v]	Caryophyllaceae	229	2	*Vanda sp.* [e]	Orchidaceae	55	23
Vanda sp. [e]	Orchidaceae	283	61	*Smilax corbularia* [v]	Smilacaeae	31	4
Clitoria mariana [v]	Papilionaceae	231	19	*Clitoria mariana* [v]	Papilionaceae	26	2
Bulbophyllum sp. [e]	Orchidaceae	300	153	*Smilax hypoglauca* [v]	Smilacaeae	47	23
Davallia cylindrica [e]	Davalliaceae	480	357	*Stemona tuberosa* [v]	Stemonaceae	28	4
Atylosia mollis [v]	Papilionaceae	166	45	*Embelia ribes* [v]	Myrsinaceae	23	6
Smilax hypoglauca [v]	Smilacaeae	175	74	*Cissus javana* [v]	Vitaceae	18	2
Lygodium japonicum [v]	Lygodiaceae	131	30	*Jasminum sp.* [v]	Oleaceae	20	4

(Notes: v stands for vines and e stands for epiphytes.)

4.5 Driving forces of plant species richness loss

4.5.1 Driving forces exploring

Dramatic socioeconomic changes happened in this area and the recent tea market boom provided considerable economic incentive for old tea production in tea agroforests. Although tea agroforests were not converted to other land use types and they were valued more than ever by local livelihoods, the plant biodiversity of traditional tea agroforestry systems still decreased and was threatened. Thus, it would be necessary to identify important factors driving the plant biodiversity loss, propose effective conservation strategies and provide references for other sustainability research.

Factor year was treated as a predictor since other factors, which were not considered in this study such as rainfall, humidity, soil fertility, etc. might drive the richness loss as well. The general factor year in the mixed-effect model could explain the changes of richness that could not be explained by other predictors in the model. Physical or geographical factors were considered, which included elevation of the plot, slope of the plot and distance from village centers to the plot as summarized in Table 4.10. As for the management predictors, only density of tea shrub was considered since the density of trees and density of herbs had inherent correlations. Profitability of old tea and annual profits from tea processing were considered as economic predictors. Tea Yield and average tea prices were used to replace the profitability and tested in the same model to better understand the mechanisms of economic driving forces.

Table 4.10 Summary of geographical features of 78 plots

Village	Sample Plots	Elevation (m)	Slope (°)	Distance to village centers (m)
JM	20	1532.9±95.0	17.2±6.0	814.4±381.0
MB	10	1326.8±40.8	22.2±9.6	580.0±307.3
MG	6	1288.5±47.9	20.3±8.4	802.2±411.0
MJ	16	1365.8±115.9	19.8±9.3	717.7±249.8
MH	18	1436.3±99.8	18.6±9.2	825.0±294.7
WJ	8	1440.6±48.6	16.9±5.6	979.8±241.9
Total	78	1419.8±119.4	18.9±8.1	780.3±323.8

(Notes: means were used for elevation, slope and distance.)

Model selection process based on AIC was shown in Table 4.11. Model 1 was selected and summarized in Table 4.12. By comparing the AIC or BIC values of the paired models, it was found that geographical (Model 6) and economic predictors (Model7) are not as powerful as the management predictor implied by density of tea shrub (Model 3) but still contributed to the model or explained part of the change in plant species richness. Slope and annual profits of tea processing did not indicate explanation power and could not predict the change of richness in this study, and was thus excluded from the following analysis. Moreover, Model 8 was significantly better than Model 9, which again indicates that significant changes of plant species richness over years.

Table 4.11 Summary of Mixed-effect model selection

Linear Mixed-effect Model fitted by ML	df	AIC	BIC	logLik	Test	L.Ratio	p-value
1.SPR~fyear+ ELEV+DIST+DENS+PROF+(1|plot)	7	1216.078	1240.373	-600.0389	1vs3	9.65	0.0218
2.SPR~fyear+ DENS +PROF+(1|plot)	5	1217.506	1235.728	-602.7532	2vs3	4.22	0.0400
3.SPR~fyear+ DENS+ (1|plot)	5	1219.732	1234.908	-604.8615	3vs8	10.63	0.0011
4.SPR~fyear+ELEV+DIST+DENS +(1|plot)	7	1219.960	1241.218	-602.9799	4vs8	14.40	0.0024
5.SPR~fyear+ELEV+DIST+ PROF+ (1|plot)	7	1222.752	1244.011	-604.3761	5vs8	11.60	0.0089
6.SPR~fyear+ELEV+DIST +(1|plot)	6	1226.249	1244.470	-607.1244	6vs8	6.11	0.0472
7.SPR~fyear+PROF+(1|plot)	5	1227.280	1242.465	-608.6400	7vs8	3.08	0.0495
8.SPR~fyear+ (1|plot)	4	1228.355	1240.503	-610.1777	8vs9	147.36	< .0001
9.SPR~+(1|plot)	3	1373.712	1383.823	-683.8562	-	-	-
10.SPR~fyear+ELEV+DIST+DENS+PROF+ PRTP+(1|plot)	9	1218.049	1245.381	-600.0244	10vs1	0.03	0.8646
11.SPR~fyear+ELEV+DIST+DENS+PROF+ SLOP+(1|plot)	9	1218.045	1245.378	-600.0227	11vs1	0.03	0.8569

Notes:
SPR, plant species richness in tea agroforests;
fyear, year was considered as a factor;
ELEV, elevation of the plot (meters);
DIST, distance from the plot to the village centers (meters);
DENS, density of tea shrubs;
PROF, profitability of old tea production in tea agroforests per household (thousand yuan/ha);
PRTP, annual profits of tea processing per household (thousand yuan);
SLOP, slope of the plot (degree).

4.5.2 Driving forces analysis based on linear mixed-effects model

As summarized in Table 4.12 Model I, in the linear mixed-effects model, five predictors were selected. Firstly, the terms year2012 explained the average effect of richness changes over years. It was a significant predictor, which means that there were other factors not considered in the model driving the richness loss. Secondly, it was found that elevation level did not influence the change of richness when considering other factors at the same time. Distance from village centers to the tea agroforests influenced the changing patterns of richness, and farther away tea agroforests tended to have less richness loss. However, the influence of distance was relatively weak. Thirdly, tea shrubs density positively correlated with richness, which indicates that intensified management was one of the important driving forces for loss of plant species richness (see Figure 4.8). Lastly, the profitability of old tea was also one of the driving forces, however, in a positive direction. Increased profitability of old tea over years corresponded to more richness over years or less richness loss, which indicates that economic incentives could have help plant biodiversity conservation (see Figure 4.8).

Table 4.12 Summary of models

Model I: Plant species richness in tea agroforests~									
Composite				**2002**			**2012**		
Linear Mixed-effects model fitted by REML:				**Generalized least squares model fit by REML:**			**Generalized least squares model fit by REML:**		
	Value	DF	p-value		Value	p-value		Value	p-value
(Intercept)	93.89	75	0.0000						
year2012	**-34.14**	**73**	**0.0000**	(Intercept)	123.23	0.0000	(Intercept)	16.58	0.3224
ELEV	-0.015	75	0.1427	**ELEV**	**-0.037**	**0.0112**	ELEV	-0.016	0.2133
DIST	**0.007**	**75**	**0.0384**	DIST	0.010	0.0509	DIST	0.005	0.2126
DENS	**-18.46**	**75**	**0.0043**	DENS	-15.90	0.1203	DENS	-9.92	0.2045
PROF	**2.30**	**73**	**0.0183**	PROF	-10.81	0.4963	PROF	1.06	0.2545

Model II: Plant species richness in tea agroforests~									
Composite				**2002**			**2012**		
Linear Mixed-effects model fitted by REML:				**Generalized least squares model fit by REML:**			**Generalized least squares model fit by REML:**		
	Value	DF	p-value		Value	p-value		Value	p-value
(Intercept)	97.08	75	0.0000						
year2012	**-43.82**	**72**	**0.0000**	(Intercept)	122.94	0.0000	(Intercept)	20.74	0.1912
ELEV	-0.018	75	0.0778	**ELEV**	**-0.036**	**0.0117**	ELEV	0.007	0.6015
DIST	0.060	75	0.0829	**DIST**	**0.010**	**0.0333**	DIST	0.002	0.5601
DENS	**-19.39**	**72**	**0.0028**	DENS	-16.89	0.1104	DENS	-11.94	0.1211
YIELD	0.018	72	0.3169	YIELD	0.016	0.5641	YIELD	0.006	0.7592
PRICE	**0.50**	**72**	**0.0105**	PRICE	-2.14	0.1975	**PRICE**	**0.45**	**0.0210**

Notes:
ELEV, elevation (m);
DIST, distance from village centers (m);
DENS, density of tea shrub per square meters;
PROF profitability of old tea production in tea agroforests (thousand yuan per ha);
YIELD, yield of old tea production in tea agroforests (kilogram per ha);
PRICE, average old tea price (yuan).

When breaking profitability into yield and average tea price as summarized in Table 4.12 Model II, similar results were found. Factor year still indicate there is still considerable richness loss which could not be explained by factors considered in the model. Both elevation and distance did not significantly influence the changing patterns of richness when considering other factors at the same time. Management intensification was still an important driving force for richness loss. Yield of old tea did not significantly correlate with the change in richness. However, average old tea price negatively correlated with richness loss. While profitability was calculated based on yield and average tea prices, Model II indicates average tea price was the major economic driving force on change in plant species richness.

When exploring the relationships in individual years, it was found that geographical factors were correlated with plant species richness in 2002. Elevation negatively correlated with richness while distance positively correlated with richness. However, the correlations were not found in 2012. Moreover, density of tea shrub, yield and profitability did not correlate with richness over plots in both 2002 and 2012, which indicate no significant spatial influences of these factors on richness since all the plots were under the same land use type-traditional tea agroforestry. Only in 2012, average old tea price positively correlated with richness, which corresponds to the results of mixed-effect Model II.

Figure 4.8 Relationships between plant species richness loss and driving forces (Notes: SPR stands for plant species richness of tea agroforests.)

4.6 Management intensification and profitability of "old tea"

While intensified management drove richness loss, it did not necessarily correspond to an increase in profitability of old tea. No correlations were found between profitability and change of herb density and change of tree density on the plot level. Either increase or decrease of herb density or tree density could match with high profitability. In the terms of tea shrub density, the density even negatively correlated with profitability, indicating a potential vicious circle. While density of tea shrub positively correlated with yield and profitability in 2002, the relationship in 2012 was not significant, which indicates a potential threshold of the land limited by soil nutrients or other factors. In both 2002 and 2012, density of herbs positively correlated with yield and profitability, and the intensified weeding might disturb natural nutrient cycling in traditional tea agroforestry.

Table 4.13 Correlation between profitability & yield and management practices implied by vegetation variables

Change from 2002 to 2012			2002			2012		
	PROF	YIELD		PROF	YIELD		PROF	YIELD
YIELD	0.53***		YIELD	0.89***		YIELD	0.95***	
TEA	-0.28*	-0.03	TEA	0.46***	0.39**	TEA	0.18	0.16
HERB	-0.01	0.15	HERB	0.43***	0.47***	HERB	0.34*	0.39***
TREE	0.03	-0.12	TREE	-0.26*	-0.21#	TREE	0.07	-0.002

Notes:
PROF profitability of old tea production in tea agroforests (thousand yuan per ha);
YIELD, yield of old tea production in tea agroforests (kilogram per ha);
TEA, density of tea shrubs per square meters;
HERB, density of herbs;
TREE, density of trees;
Spearman tests were applied to test the significance of correlations;
Significance codes: 0’***’0.001’**’0.01’*’0.05’.’0.1’’1.

Chapter 5 DISCUSSION

5.1 Economic incentives for traditional tea agroforestry

As introduced in the previous chapter, Yunnan experienced a recent dramatic tea market boom from 2002 to 2008 (Ahmed *et al*., 2010). However, this boom is not neccesarily cause solely by increased promotion. China's emerging free market economy and advanced demand from tea consumers from Asian countries with increasing health concerns may have played roles. As reported by Times Business, buying tea was become an investment just like Europeans buy wines, and speculations on Yunnan Pu'er tea might drive the Pu'er tea price to be many times higher than the original level.

During the Pu'er tea market boom, the "old tea" emerged, which was naturally harvested in undeveloped upland areas with a long history of tea cultivation by minority people. The "old tea" shrubs were cultivated in the traditional tea agroforestry systems with an inherent good quality but limited supply. Thus its price was much higher than the common tea or "new tea" produced in tea plantations. Ahmed et al. (2010) reported that the price of dried leaf old tea in Baljalpuxeevq (Bulang Mountains, Menghai County, Xishuangbanna, Yunnan, China) had increased from USD $1.18 per kilo in 2002 to USD $220 per kilo in 2008, similar to the observations in this study, in which the dried leaf old tea priced in Jingmai increased to as high as USD $70 per kilo in 2007 from USD $0.5 per kilo in 2002. The price of old tea was once 5.4 times higher than that of new tea in 2007 and is still about 4 times higher now during the survey. The income structure also suggested that tea harvesting and marketing has become the most important economic activity in this area and an industrial chain of tea has appeared characterized by an increased number of tea processing businesses and tea factories. There was a dramatic hundred times increase of profitability of tea production and this was mainly due to the increase in tea price since there was a several times increase in yield. Consequently, the niche tea market provides considerable economic incentives for the "old tea" harvesting in traditional tea agroforestry.

5.2 Land use change associated with traditional tea agroforestry

The considerable economic incentivies of "old tea" have an important role in maintaining this kind of traditional land use in the region. Corresponding to price premiums of "old tea" production, the land use of traditional tea agroforestry was successfully conserved and even showed a trend of expansion, which might probably be due to the ownership transfer through marriage or trading. The local farmers argued that the majority of their tea agroforests were inherited from ancestors and no transformation and tea planting were allowed in the neighboring natural forests. The data collected from interviews also showed no distinct change of land use of forests since 3 hectare community forests were evenly distributed to one person and thus the land size of forests corresponded to the number of family members.

However, the land use expansion of tea agroforests might come from community forests nearby, which needs further investigation. In another study on Yunnan tea agroforests, it was found that previously active swidden areas were being transformed to tea agroforests and tea agroforests expanded from 267 ha to 467 ha through planting tea in forests and swidden fields under the market forces (Ahmed *et al.*, 2010). The expansion of tea plantations and rubber plantations may come from forests as well as dry land, which usually grew maize and cane. Driven by economic incentives, the natural forests may be under threats from not only the expansion of tea agroforests but also the expansion of tea plantations as well as rubber plantations especially in the village MangHong.

There was also a trend of land use simplification, which has been documented in other areas of southern Yunann and is driven by state projects and globalization (Xu *et al.*, 2005; Fox, 2009; Ziegler *et al.*, 2009). The land use of paddy, dry land, orchard and homegardens becomes less important in the land use structure considering their profitability was very low. According to the interviews, local people have started to purchase rice, vegetables, fruits or other agricultural crops in local periods markets instead of cultivating themselves. Rubber expansion just happened recently in the last three years and has not generated profits yet. The land use has become more economically driven and has started to focus on tea and rubber.

Another interesting phenomenon is the transformation of tea plantations. With the aim to further promote "ecological tea" and "organic tea" brand in this region, the local government initiated the project to make tea plantations environmental friendly. By decreasing the density of tea shrubs, planting trees inside the tea plantations, forbidding utilization of chemicals, the tea plantations were gradually transformed to "eco tea" plantations. It was the resons why the yield of new tea did not increase or was found to be lower than that of 2002. However, it was not been explored as to whether the "eco tea" systems can work in the same way as tea agroforests and whether the price of "eco tea" could be high enough to compensate the loss of yield.

To conclude, the market incentives given to "old tea" successfully protected this type of traditional land use from being converted to more intensified land use type. However, the trend of land use simplification mainly driven by economic incentives still indicates potential ecological threats especially on neighboring forests in this region.

5.3 Management intensification in traditional tea agroforestry

Driven by the economic incentives, local farmers did value their tea agroforests more than ever and a trend in management intensification was found. Ahmed et al. (2010) evaluated land use importance among Akha people, which indicated a higher role of tea agroforests in livelihoods as well as intensified management. Shade tree density decreased slightly, however, multiple cases of selective girdling were found in the survey conducted in 2012 although logging is forbidden in tea agroforests by the governments since the past six years.

The weeding activities were intensified, corresponding to the decrease in the density of herbs from 2002 to 2012. Ploughing appeared in 2012; none was recorded in 2002. Bottles of herbicides were occasionally found in tea agroforests during the 2012 field survey although farmers did not admit the application of any chemicals during the interviews. Removing epiphytes and vines was also applied with weeding, however, was just applied casually. It is believed by local farmers that epiphytes and vines growing on the tea shrubs would extract nutrients from tea trees and thus caused the death of tea shrubs. However, collecting epiphytes especially *Vicum articulatum* and wild orchids has now become a profitable business. The price of *Vicum articulatum*, a medicinal plant claimed to have functions of lowering blood pressure, rose up to USD $300 per kilo in 2012 while only USD $5 per kilo in 2002 survey.

Moreover, management practices on tea shrubs has also intensified. Firstly, the density of tea shrubs was increased in order to increase the yield according to the conversations with local farmers. More tea seedlings were found in 2012 while there were just a few cases before, indicating replanting was becoming a widely applied practice. Secondly, frequency of tea leaves collection increased at the same time with the aim of increasing the yield. Tea production has changed from occasional harvesting to fundamental production from March to October with increased market interferences. Outside laborers are hired during the tea shooting seasons recently, to support the intensified harvest of old tea sources. An overall trend of management intensification was found however it differed among villages.

5.4 Changes of plant biodiversity in traditional tea agroforestry

Although the land hold of traditional tea agroforestry has been relatively well maintained, the tea agroforests still showed degradation over time in the term of plant biodiversity based on the basal survey conducted in 2002. The total plant abundance, richness and Shannon-Wiener Diversity Index reduced on the overall level and significantly decreased on the plot level.

Despite a general negative change was found in all six sub-villages, the changing patterns were different among villages on both overall level and plot level. It is suggested that the changing patterns were adjusted to different socioeconomic scenarios or biophysical scenarios inherent in different villages. A more careful investigation on the socioeconomic conditions of villages might give more insights on the driving forces of plant biodiversity loss and strategies to promote sustainability.

Although the changes of trees were found to be relatively small compared with other lifeforms in terms of abundance, richness and Shannon-Wiener Diversity Index, some negative changes occured at the species level. Firstly, important species decreased such as national level protected species including *Toona ciliata* and *Paramichelia baillonii* . On the other hand, cultivated trees were increasingly planted, such as *Musa basjoo*, *Psidium guajava, Castanea mollissima* and *Mangifera indica*. Eight protected species listed in the former study decreased in terms of abundance and occurrence in all plots except for one (Qi, 2005). Four endemic tree species native in Yunan also disappeared from the sampling plots. Secondly, logging was found for multiple species. Giant trees with DBH more than 50 cm were cut down according to the data since exactly the same plot were resurveyed. Thus, the abundance, richness and Shannon indicators might not represent a healthy shade if ignoring the importance of tree species or the size of trees.

Epiphytes were lost probably due to commercial factors. The loss of the epiphytes was driven by the direct economic incentives as well as the intensified management associated with tea market boom. Although little supportive data were collected, the harvest and trading of *Viscum articulatum*, *Bulbophyllum sp*. and *Vanda sp*. were observed in the field during the survey. Market prices and demands rose for specific epiphytes especially *Viscum articulatum* and orchids. The rising price of these plants might due to the tea branding. Adding Viscum articulatum to the old tea was a distinct feature for tea production in this area. Orchids were widely utilized as the tea brand logo in this area. Increased market interference might increasingly threaten this group of species.

5.5 Driving forces of plant species richness loss in traditional tea agroforestry

The driving forces of the change of plant species richness were explored and regressed against total plant species richness in the mixed-effected models. While the change of vegetation composition might be different and more meaningful compared with species richness, the comparison between vegetation composition over time is still under theorical building. Moreoever, although cultivated tree species increased as demonstrated before, most of plant species are still associated ones instead of "planned" ones, and both cultivated species and natural grown tree species were combined into the model.Last, both "planned" biodiversity and associated biodiversity were important in agroforestry systems since they both serve important ecosystem functions especially by providing heterogeneity at the landscape scale. Thus, it is necessary to conserve and promote multi-species agroforestry including both planned biodiversity and associated biodiversity (Vandermeer *et al.,* 1998).

The results suggested that management factor implied by tea shrub density was the most influential driving force while geographical and economic factors were found to be less important but still impact richness change. While geology was generally considered to be a strong factor influencing biodiversity, the results of this study suggest it plays a weak role in shaping plant richness. It might be because only elevation, slope and distance from village centers were considered and more important geographical factors such as humidity and soil type were not considered (Corlett, 2009). Moreover, the weak influences of geographical factors suggest strong influences of human activities. Negative correlation between elevation and richness, and positive correlation between distance and richness were found in the 2002 model however lost significance in 2012, which indicate a strengthened impact from human activities. Because of road construction and wide use of motorcycles, the access to tea agroforests became easier now than ten years ago, even for the longer and higher ones, and thus geographical features did not influence the richness after development.

Increase of tea shrub density significantly correspond to the loss of total plant richness, which suggests that management intensificaiton was an important driving force for plant species richness loss. This finding supported the results of research on shade coffee and cacao with a spacial view on the relationship between biodiversity and management intensification. Shade cover generally serves as the indicator of management intensification in the research on coffee and cacao (Perfecto *et al*., 2005; Steffan-Dewenter *et al*., 2007; Bisseleua *et al*., 2009), and shade cover usually positively correlated with richness although different taxa might have different trends (Perfecto *et al*., 2005; Perfecto and Vandermeer, 2008). The relationship between biodiversity and management intensification could be doubted from a spatial view since the patterns of landscape matrix might have an influence. The closer the location of the agroforest to native forest nearby, the higher biodiversity would be found even under a relatively low shade cover (Cassano *et al.,* 2009). By applying a temporal view of the same plot over ten years on the same relationship in this study, it is further confirmed that intensified management was an important force driving richness loss in tea agroforests, although tea shrub density could only partially represent the management strength.

It is interesting to find that profitability was a positive driving force on change in plant species richness. While households with more profitable tea agroforests did not concurrently manage higher plant species richness in their tea agroforests for individual year, households with higher increase of profitability of "old tea" were likely to manage the tea agroforests with less plant species richness loss. The results suggest that richness and profitability could work in synergies over time. The relationship between biodiversity and profitability of ecosystems is usually assumed to be a trade-off over space: biodiversity need to be paid, and conversely, that the highest profits are usually achieved in low-biodiversity ecosystems such as monoclutures (Steffan-Dewenter *et al.*, 2007). However, this is not necessarily the case. In Mexico, Gordon et al. (2007) examined the relationships between bird and small mammal species richness and profitability across a coffee intensification gradient. No clear relationship was found between profitability and biodiversity. Another study on cacao also found that species richness of trees, fungi, invertebrates and vertebrates did not decrease with yield, which indicates agroforests can in some situations be designed to optimize both biodiversity and crop production benefits (Clough *et al.*, 2011). Biodiversity and profitability might have a non-linear relationship across agroforests with different management scenarios. A study conducted in traditional bamboo-tree gardens in West Java found that the regression model between gross income and Simpson's diversity index with the best fit was a unimodal curve, suggesting a win-win situation can be met at an intermediate level of income (Okubo *et al.*, 2010). Results of this study show no clear linear relationship between biodiversity and profitability over 78 sampled tea agroforests, which is similar to studies mentioned above. However, if more profits from "old tea" could be made over a year, it could probably stand as an incentive to conserve more richness.

What are the underlying mechansims for the synergistic interaction between biodiversity and profitability over time? While profitability was calculated based on yield, average tea price and variable cost, yield and average tea price were tested in the model replacing profitability to find the underlying mechansims since variable cost was relatively small. No clear relationships were found between biodiversity and yield over 78 sampled tea agroforests. This might also imply a complicated non-linear relationship betweenthe two variables. While the trade-off between biodiversity and yield over a management intensification gradient in agroforestry systems can be eaily understood, there are multiple studies exploring the fundamental mechanisms for synergistic interation between biodiversity and yield, including pest control provided by beneficial predators, pollination services to crop plants by native pollinators and soil nitrogen improvement by leguminous plants (Gordon *et al*., 2007). While productive tea agroforest did not necessarily negatively correlate with plant species richness, increasing yield of the same tea agroforest over time did not significantly impact richness as well. Since intensified management may not necessarily lead to an increase in yield, which will be discussed later, yield can be increased in an environmentally friendly way without sacrificing biodiversity, however, which might have a threshold. More sophisticated analyses based on field data of yield instead of data based on interviews are needed to better understand the relationship between biodiversity-management-yield.

When considering average tea price, positive correlation between price and richness of tea agroforest was found in 2012, and change in price positively correlated with change in richness over time. It is suggested that the price scenarios may influence richness. While the price of "new tea" was generally the same, average "old tea" price differs due to multiple reasons. Firstly, individual villages had different price scenarios because of different reputation and marketing strategies. Secondly, in each village, households had a different average tea price because different propotion of the tea were sold in different seaons although the tea prices in each season were the same in the same villages. The quality and price of tea was strongly correlated with the time of collection (Ukers, 2007). It is believed that the best quality tea was made of the first shooting leaves in early spring. The spring tea has the highest price while summer tea usually has lowest price. Tea shooting time lagged for some households' tea agroforest and thus only small propotion of their tea leaves could be sold at high price season according to interviews. Under increased market interference, the different price scenarios influenced by many other factors had a role to encourage or discourage biodiversity conservation.

As suggested by the "year" term in the mixed-effect model, there are considerable richness losses that could not be explained by the factors explored. Climate change would be another important factor. By using temperature and rainfall data, one study on Yunnnan climate change over the last 50 years found that Yunann experienced climate warming, and the frequency of heat waves and drought events increased as well (Chen Jianggang, 2008). According to the Yunnan Statistical Yearbook, the annual average rainfall in Lancang County fluctuated from 1680.3 in 2002 to 1482.9 in 2010 with a peak of 1893.7 in 2006, although the annual average temperature was relatively stable in the range of 19.8℃ to 20.2℃ throughout 9 years. Since the quality and yield of tea were highly impacted by microclimate factors such as humidity and temperature (Zhang, 2005; Ukers, 2007), the recent climate change may not only impact the vegetation cover but also influence tea yield in tea agroforestry. Moreover, soil features such as soil fertility and soil microbiology might have an important role in the changing process. By comparing the soil nutrient and soil enzyme activity between tea agroforests and tea plantations, one study found higer organic N, P, K concentration and enzyme activity in tea agroforests (Jiang, 2008). Thus, soil change associated with changes in nutrient cycling would have a considerable impact on both vegetation cover and tea production in tea agroforestry as well.

5.6 Relationship between intensified management and profitability

By exploring the relationship between vegetation indicators for management intensification and profitability, no significant correlations were found, which indicates that intensified management does not necessarily lead to increased profitability. First, the intensified management did not necessarily lead to the increase of yield. The relationship between management intensification and yield in coffee and cacao agroforestry has been widely explored however is still in its infancy. Soto-Pinto et al. found that the shade cover and coffee yield had a positive correlation when shade cover was 23% to 38%, while coffee yield dropped down when shade cover exceeded 50% (Soto-Pinto *et al.*, 2000). Dheuvels O. et al (2012) indicated that changes in vegetation structure reflected differences in farmers' management strategies but did not affect overall cacao yield (Deheuvels *et al.*, 2012). In Jingmai, change of tea shrubs density actually negatively correlated with change of profitability, which indicates a potential vicious cycle, that is less profitability led to more intensified practices and thus worse productive conditions and less profits. The relationship between management practices and yield in tea agroforestry has been rarely studied and further investigations are needed to better understand the relationships and mechanisms behind them.

Secondly, as shown before, the profitability increased dramatically mainly due to the increase in tea prices, rather than increase in yield. Successful tea marketing could bring more benefits without harming the environments to reach a win-win situation, however, the market crisis could be a potential risk for the sustainability of these agroecosystems. A tea market crash happened in 2007. Luckily, only local middle merchants lost hundred thousands yuan and the old tea price remained relatively high in comparison with new tea.

5.7 Implications for Policy

Two different development scenarios might co-exist by comparing the two villages JM and MH. MH had the greatest loss of plant biodiversity in terms of abundance, richness and Shannon, which correspond to the largest rubber expansion, relatively low average tea price, less profitability of old tea production, as well as the most intensified management practices indicated by tree girdling, increase of tea shrub density and decrease of herbs density. The development of this village might be a vicious cycle. Relatively low profitability due to original low yield and unsuccessful marketing led to intensified management, large species richness loss, increased yield but still low profits. As indicated before, the intensified farming did not lead to high profitability and may reversely destroy the sustainability inherited in the agroecosystems. Conversely, in village JM, less plant biodiversity loss happened under relatively extensive management, successful tea marketing, better price scenarios, and higher profitability, in which a win-win situation was reached.

Thus, a better development model might include marketing of "old tea" products with an emphasis on biodiversity instead of yield. The tea price was generally based on reputation, quality and marketing although more research is still needed to investigate the pricing mechanism of "old tea". As suggested before, the microclimate is of great importance to shape the quality of tea (Ukers, 2007). A better tea agroforest with rich biodiversity could not only provide good tea producing conditions and good quality tea but also bring ecotourism and help build the reputation of the "old tea" products. Policies controlling intensified farming are needed to prohibit further degradation of the systems especially by controlling tea tree replanting activities and the density of the tea shrubs. Other intensified managements although not proven to be related to richness loss still need to be paid attention. Extensive weeding should be encouraged, tree girdling and collection of wild epiphytes such as *Viscum articulatum* and orchids need to be forbidden and supervised. Thus, an "eco-tea" certification might work, however, more research on either the acceptance of consumers or willingness of participation is still needed. Moreover, the risk of a tea market crisis needs to be evaluated to avoid the pothential abandonment of this ecosystem.

Chapter 6 CONCLUSION

Traditional tea agroforestry systems are important agroecosystems ecologically and economically, which provide a potential model for reconciliation between biodiversity conservation and socioeconomic development. Recently, considerable economic incentives driven by Pu'er tea market boom in Yunnan, emerged for "old tea", which was harvested in the traditional tea agroforestry. The corresponding changes associated with traditional tea agroforestry were explored in terms of land use, livelihoods, management intensification as well as plant biodiversity in this study.

Firstly, we found that "old tea" products harvested from tea agroforests became distinctly profitable compared to "new tea" products produced in tea plantations or compared to other non-tea agricultural activities. Niche price premium were generated for "old tea". Activities associated with tea became the dominant socioeconomic activities in the region and tea processing gradually became an important source of income. Under the price premium of "old tea "in the tea market, the land use of traditional tea agroforestry was highly valuated and thus maintained. However, expansions of tea plantations and rubber plantations were still found as well as forests declining. Moreover, trend of management intensificaiton in tea agroforests was found when taking key vegetation variables as indicators.

The traditional tea agroforestry was under degradation. As for the associated plant biodiversity in the tea agroforest, trend of decreasing was found across all lifeforms. While trees had relatively stable changing patterns, important species as well as giant trees were still lost.

Management intensification was found to be one of the major driving forces for plant species richness loss in tea agroforests, which was implied by the increased density of tea shrubs. However, intensified management did not necessarily lead to an increase of yield and profitability of “old tea”. Plant biodiversity in tea agroforests and yield of “old tea” had no clear linear relationship. However, households with a higher increase in profitability or average price of “old tea” were likely to manage the tea agroforests with less richness loss.

Better marketing of “old ” tea products with an emphasis on biodiversity and strict policies against instensified management in tea agroforests are suggested for sustainable development especially for those villages with relatively poor tea price scenairos.

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Appendix I Semi-structure interview questionnaires

Investigator	Household		Survey Date			
Recorder	ID of Household					
County	Village		Sub-Village			
1.No. of family member	1	2	3	4	5	total
Name						
Age						
Gender						
Ethnic Group						
Education level (years)						
relationship with houseowner						
landownership since 1982						
Resident or outsider						
Responsibility of work						
Time spent on agrarian practices						
2. Lands and crops						
(1) Paddy	1	2	3	4	5	total
Site Name						
Area						
Production per hectare						
Production in total						
Crop planted						
Distance to house						
Manager						
History of ownship						
Future plan						
(2)Dry land	1	2	3	4	5	total
Site Name						
Area						
Production per hectare						
Production in total						
Crop planted						
Distance to house						
Manager						
History of ownship						
Future plan						
(3)Tea agroforest	1	2	3	4	5	total
Site Name						
Area						
Production per hectare						
Production in total						
Crop planted						
Distance to house						

Appendix I Continued (1)

Manager						
History of ownship						
Future plan						
(4)Forest	1	2	3	4	5	total
Site Name						
Area						
Production per hectare						
Production in total						
Crop planted						
Distance to house						
Manager						
History of ownship						
Future plan						
(5)Tea plantation	1	2	3	4	5	total
Site Name						
Area						
Production per hectare						
Production in total						
Crop planted						
Natural Diasters						
Distance to house						
Manager						
History of ownship						
Future plan						
(6)Others	1	2	3	4	5	total
Site Name						
Area						
Production per hectare						
Production in total						
Crop planted						
Distance to house						
Manager						
History of ownship						
Future plan						

3. Aquaculture	Cattle	Buffalo	Swine	Goat	Chicken	Others
Species						
Number						
Diseases						
Manager						
No. of Self-consumed						
No. of sale						
Price for sale						

4. Household income

(1)Cash crop	1	2	3	4	5	total

Appendix I Continued (2)

Amount						
Price						
Total income						
(2)Tea	1	2	3	4	5	total
Amount						
Price						
Total income						
(3)Rice	1	2	3	4	5	total
Amount						
Price						
Total income						
(4)Forest products	1	2	3	4	5	total
Amount						
Price						
Total income						
(5)Aquaculture	1	2	3	4	5	total
Amount						
Price						
Total income						
(6)Other non-agricultural activities	1	2	3	4	5	total
Member						
Type of activities						
Time						
Price (Yuan/Day)						
Total income						
5.Household inputs						
(1)Production cost	Fertilizer	Chemical	seed and seedling	young animals	others	
Species						
Amount						
Price						
Utilizaion						
(2)Living cost	Education	Gasoline	Medical cares	Firewood	Timber	Electricity & Water
Type						
Amount						
Source						
(3) Transpotation						
Tool						
Use						
Member						
Purpose and time						
(4) Market	1	2	3	4	5	
Distance						
Product for sale						

Product for purchase

Member

Frequency

Appendix II Species Simplification

Scientific Name used in 2002	Scientific Name simplified in 2012
Dipliptera sp.	Dipliptera sp.
Dipliptera roxburghiana	Dipliptera sp.
Dipliptera riparia var. yunnanensis	Dipliptera sp.
Pseudoranthemum polyanthum	Pseudoranthemum sp.
Pseudoranthemum palatiferum	Pseudoranthemum sp.
Pseudoranthemum malaccense	Pseudoranthemum sp.
Rostellularia procumbens	Rostellularia sp.
Rostellularia diffusa	Rostellularia sp.
Rauvolfia verticillata	Rauvolfia sp.
Rauvolfia yunnanensis	Rauvolfia sp.
Combretum latifolium	Combretum sp.
Combretum griffithii	Combretum sp.
Commelinaceae sp.	Commelina sp.
Commelina paludosa	Commelina sp.
Pollia sp.	Pollia sp.
Pollia thyrsiflora	Pollia sp.
Pollia subumbellata	Pollia sp.
Vernonia arborea	Vernonia sp.
Vernonia parishii	Vernonia sp.
Vernonia solanifolia	Vernonia sp.
Vernonia sp.	Vernonia sp.
Vernonia volkameriifolia	Vernonia sp.
Zehneria maysorensis	Zehneria sp.
Zehneria marginata	Zehneria sp.
Microlepia hancei	Microlepia sp.
Microlepia calvescens	Microlepia sp.
Microlepia strigosa	Microlepia sp.
Dioscorea sp.	Dioscorea sp.
Dioscorea sp.	Dioscorea sp.
Dioscorea subcalva	Dioscorea sp.
Dioscorea pseudo-nitens	Dioscorea sp.
Dioscorea pentaphylla	Dioscorea sp.
Dioscorea nitens	Dioscorea sp.
Dioscorea henryi	Dioscorea sp.
Dioscorea bifomrmifolia	Dioscorea sp.
Dioscorea alata	Dioscorea sp.
Dioscorea triphylla var. reticulata	Dioscorea sp.
Breyhia rostrata	Breynia sp.
Breynia fruticosa	Breynia sp.
Croton sp.	Croton sp.
Croton hutchinsonianum	Croton sp.
Phyllanthus urinaria	Phyllanthus sp.
Phyllanthus sootepensis	Phyllanthus sp.

Appendix II Continued (1)

Phyllanthus flexuosus	Phyllanthus sp.
Engelhardia serrata	Engelhardtia sp.
Engelhardia spicata	Engelhardtia sp.
Engelhardtia roxburghiana	Engelhardtia sp.
Clinopodium chinense	Clinopodium sp.
Clinopodium gracile	Clinopodium sp.
Elsholtzia rugulosa	Elsholtzia sp.
Elsholtzia stachyodes	Elsholtzia sp.
Elsholtzia ciliata	Elsholtzia sp.
Elsholtzia blanda	Elsholtzia sp.
Isodon sp.	Isodon sp.
Isodon coetsa	Isodon sp.
Microtoena insuavis	Microtoena sp.
Microtoena patchouli	Microtoena sp.
Acacia farnesiana	Acacia sp.
Acacia confusa	Acacia sp.
Acacia tonkinensis	Acacia sp.
Acacia pennata	Acacia sp.
Desmodium sp.	Desmodium sp.
Desmodium renifolium	Desmodium sp.
Polygonatum sp.	Polygonatum sp.
Polygonatum odoratum	Polygonatum sp.
Melastoma candidum	Melastoma sp.
Melastoma normale	Melastoma sp.
Melastoma affine	Melastoma sp.
Osbeckia crinita	Melastoma sp.
Knema cinerea	Knema sp.
Knema erratica	Knema sp.
Jasminum attenuatum	Jasminum sp.
Jasminum grandiflorum	Jasminum sp.
Jasminum cinnamomifolium	Jasminum sp.
Jasminum polyanthum	Jasminum sp.
Jasminum wangii	Jasminum sp.
Jasminum nervosum	Jasminum sp.
Jasminum anisophyllum	Jasminum sp.
Piper sp.	Piper sp.
Piper sp.	Piper sp.
Pipera chaudocanum	Piper sp.
Piper szemaoense	Piper sp.
Piper sp.	Piper sp.
Piper flaviflorum	Piper sp.
Piper paepuloides	Piper sp.
Piper boehmeriaefolium	Piper sp.
Hedyotis auricularia	Hedyotis sp.

Appendix II Continued (2)

Hedyotis diffusa	Hedyotis sp.
Hedyotis mellii	Hedyotis sp.
Hedyotis scandens	Hedyotis sp.
Hedyotis tenellifloa	Hedyotis sp.
Hedyotis costata	Hedyotis sp.
Hedyotis calycina	Hedyotis sp.
Mussaenda multinervis	Mussaenda sp.
Mussaenda mollissima	Mussaenda sp.
Mussaenda hossei	Mussaenda sp.
Mazus pumilus	Mazus sp.
Mazus pulchellus var. wangii	Mazus sp.
Selaginella sp.	Selaginella sp.
Selaginella referi	Selaginella sp.
Selaginella biformis	Selaginella sp.
Solanum myriacanthum	Solanum sp.
Solanum spirale	Solanum sp.
Solanum touvum	Solanum sp.
Callicarpa bodinieri	Callicarpa sp.
Callicarpa bodinieri var. iteophylla	Callicarpa sp.
Callicarpa sp.	Callicarpa sp.
Callicarpa sp.	Callicarpa sp.
Vitex sp.	Vitex sp.
Vitex quinata var. puberula	Vitex sp.
Vitex quinata	Vitex sp.
Cayratia trifolia	Cayratia sp.
Cayratia sp.	Cayratia sp.
Cayratia sp.	Cayratia sp.
Cayratia japonica	Cayratia sp.
Lepisorus thumbergianus	Lepisorus sp.
Lepisorus sp.	Lepisorus sp.
Lepisorus sinensis	Lepisorus sp.
Lepisorus macrosphaorus	Lepisorus sp.
Lepisorus sp.	Lepisorus sp.
Lepisorus sp.	Lepisorus sp.
Pyrrosia gralla	Pyrrosla sp.
Pyrrosia sheareri	Pyrrosla sp.

Appendix III Plant species list (Notes: "+" stands for presence; "-" stands for absence)

NO.	Scientific Name	Family	Type	2002	2012
1	*Actinodaphne henryi*	Lauraceae	tree	+	+
2	*Adinandra sp.*	Theaceae	tree	+	+
3	*Alangium barbatum*	Alangiaceae	tree	+	+
4	*Alangium chinense*	Alangiaceae	tree	+	+
5	*Albizia crassiramea*	Mimosaceae	tree	+	+
6	*Antidesma montanum*	Euphorbiaceae	tree	+	-
7	*Antidesma sp.*	Euphorbiaceae	tree	-	-
8	*Artocarpus nitidus*	Moraceae	tree	+	+
9	*Bauhinia variegata var. candida*	Caesalpiniaceae	tree	+	-
10	*Beilschmiedia robusta*	Lauraceae	tree	-	+
11	*Berberis heteropoda*	Berberidaceae	tree	+	+
12	*Bischofia polycarpa*	Euphorbiaceae	tree	+	+
13	*Bombax sp.*	Malvaceae	tree	+	+
14	*Calophyllum polyanthum*	Guttiferae	tree	+	+
15	*Canarium subulatum*	Burseraceae	tree	+	-
16	*Carallia diplopetala*	Rhizophoraceae	tree	+	-
17	*Carallia sp.*	Rhizophoraceae	tree	+	+
18	*Cardiopteris moluccana*	Cardiopteridaceae	tree	+	-
19	*Cassia agnes*	Caesalpiniaceae	tree	+	+
20	*Castanea mollissima*	Fagaceae	tree	-	+
21	*Castanopsis argyrophylla*	Fagaceae	tree	+	+
22	*Castanopsis chunii var.spinuposa*	Fagaceae	tree	+	+
23	*Castanopsis hystrix*	Fagaceae	tree	+	+
24	*Castanopsis sp.*	Fagaceae	tree	+	+
25	*Castanopsis tribuloides*	Fagaceae	tree	+	+
26	*Celtis sp.*	Ulmaceae	tree	+	+
27	*Cerasus pseudocerasus*	Rosaceae	tree	+	+
28	*Choerospondias axillaris*	Anacardriaceae	tree	+	+
29	*Cinnamomum bejolghota*	Lauraceae	tree	+	+
30	*Cinnamomum mollifolium*	Lauraceae	tree	+	+
31	*Cinnamomum sp.*	Lauraceae	tree	+	-
32	*Cinnamomum tamala*	Lauraceae	tree	+	+
33	*Cinnamomum tenuipilum*	Lauraceae	tree	+	+
34	*Cipadessa baccifera*	Meliaceae	tree	+	+
35	*Clausena excavata*	Rutaceae	tree	+	+
36	*Cordia dichotoma*	Boraginaceae	tree	+	+
37	*Cordia furcans*	Boraginaceae	tree	+	+
38	*Cryptocarya brachythyrsa*	Lauraceae	tree	+	+
39	*Cunninghamia lanceolata*	Taxodiaceae	tree	-	+
40	*Dalbergia pinnata*	Caesalpiniaceae	tree	+	-
41	*Decaspermun fruticosum*	Myrtaceae	tree	+	+
42	*Dendrocalamus sp.*	Bambusoideae	tree	+	+
43	*Diospyros kaki*	Ebenaceae	tree	+	+

Appendix III Continued (1)

44	*Diospyros nigrocortex*	Ebenaceae	tree	+	+
45	*Docynia delavayi*	Rosaceae	tree	+	+
46	*Dysoxylum lenticellatum*	Meliaceae	tree	+	-
47	*Ehretia acuminata var. obovata*	Boraginaceae	tree	+	+
48	*Elaeocarpus prunifolioides*	Elaeocarpaceae	tree	+	+
49	*Elaeocarpus sp.*	Elaeocarpaceae	tree	+	+
50	*Elaeocarpus sphaericus*	Elaeocarpaceae	tree	+	+
51	*Elaeocarpus varunua*	Elaeocarpaceae	tree	+	-
52	*Erythrina indica*	Papilionoideae	tree	-	+
53	*Erythrina stricta*	Papilionoideae	tree	+	+
54	*Eudia trichotoma*	Rutaceae	tree	+	+
55	*Euodia austro-sinensis*	Rutaceae	tree	+	+
56	*Euodia lepta*	Rutaceae	tree	+	+
57	*Eurya groffii*	Theaceae	tree	+	-
58	*Ficus altissima*	Moraceae	tree	+	+
59	*Ficus benjamina*	Moraceae	tree	+	+
60	*Ficus gibbosa*	Moraceae	tree	+	+
61	*Ficus hispida*	Moraceae	tree	+	+
62	*Ficus hookeriana*	Moraceae	tree	+	+
63	*Ficus maclellandii*	Moraceae	tree	+	+
64	*Ficus vasculosa*	Moraceae	tree	+	+
65	*Ficus virens*	Moraceae	tree	+	-
66	*Flacourtia sp.*	Flacourtiaceae	tree	-	+
67	*Fordia cauliflora*	Leguminosae	tree	-	+
68	*Fraxinus chinensis*	Oleaceae	tree	-	+
69	*Garcinia cowa*	Euphorbiaceae	tree	+	+
70	*Garuga floribunda*	Burseraceae	tree	+	-
71	*Glochidion hissutum*	Euphorbiaceae	tree	+	+
72	*Glochidion puberum*	Euphorbiaceae	tree	+	+
73	*Glochidion sp.*	Euphorbiaceae	tree	+	+
74	*Glochidion sphaerogynum*	Euphorbiaceae	tree	+	-
75	*Glycosmis citrifolia*	Rubaceae	tree	+	-
76	*Grewia celtidifolia*	Tiliaceae	tree	-	+
77	*Grewia sp.*	Tiliaceae	tree	+	+
78	*Helicia nilagirica*	Proteaceae	tree	-	+
79	*Heteropanax fragrans*	Araliaceae	tree	+	-
80	*Hovenia acerba*	Rhamnaceae	tree	+	-
81	*Ilex godajam*	Aquifoliaceae	tree	+	+
82	*Ilex polyneura*	Aquifoliaceae	tree	+	+
83	*Ilex sp.*	Aquifoliaceae	tree	+	+
84	*Ilex triflora*	Aquifoliaceae	tree	+	+
85	*Knema sp.*	Myristicaceae	tree	+	+
86	*Lauraceae sp.*	Lauraceae	tree	+	+
87	*Lindera aggregata*	Lauraceae	tree	+	+

Appendix III Continued (2)

88	*Linociera insignis*	Oleaceae	tree	+	+
89	*Lithocarpus tabularis*	Fagaceae	tree	+	+
90	*Litsea atrata*	Lauraceae	tree	+	+
91	*Litsea cubeba*	Lauraceae	tree	+	+
92	*Litsea glutinosa*	Lauraceae	tree	+	+
93	*Litsea greenmaniana*	Lauraceae	tree	+	-
94	*Litsea monopetala*	Lauraceae	tree	+	+
95	*Litsea sp.*	Lauraceae	tree	-	+
96	*Macaranga deheiculata*	Euphorbiaceae	tree	+	-
97	*Macaranga denticulata*	Euphorbiaceae	tree	-	+
98	*Macaranga indica*	Euphorbiaceae	tree	+	-
99	*Machilus robuste*	Lauraceae	tree	+	+
100	*Machilus rufipes*	Lauraceae	tree	+	+
101	*Magnoliaceae sp.*	Magnoliaceae	tree	+	+
102	*Mallotus paniculatus*	Euphorbiaceae	tree	+	+
103	*Mallotus philippinensis*	Euphorbiaceae	tree	+	+
104	*Mangifera indica*	Anacardiaceae	tree	-	+
105	*Mayodendron igneum*	Bignoniaceae	tree	-	+
106	*Measa macilentoides*	Myrsinaceae	tree	+	+
107	*Melia azedarach*	Meliaceae	tree	+	+
108	*Melia toosanden*	Meliaceae	tree	+	+
109	*Musa basjoo*	Musaceae	tree	-	+
110	*Olea ferruginea*	Oleaceae	tree	+	+
111	*Olea rosea*	Oleaceae	tree	+	+
112	*Ormosia yunnanensis*	Papilionaceae	tree	+	-
113	*Oroxylum indicum*	Bignoniaceae	tree	+	+
114	*Paramichelia baillonii*	Magnoliaceae	tree	+	+
115	*Paranephelium sp.*	Magnoliaceae	tree	-	+
116	*Phoebe lanceolata*	Lauraceae	tree	+	+
117	*Phoebe puwenensis*	Lauraceae	tree	+	+
118	*Phyllanthus emblica*	Euphorbiaceae	tree	+	+
119	*Pipleccellollcem clypsia*	Mimosaceae	tree	+	+
120	*Polyalthia viridis*	Annonaceae	tree	+	-
121	*Psidium guajava*	Myrtaceae	tree	-	+
122	*Pygeum arboreum*	Rosaceae	tree	+	+
123	*Pygeum macrocarpum*	Rosaceae	tree	+	+
124	*Pyrus pashia*	Rosaceae	tree	+	+
125	*Rapanea neriifolia*	Rosaceae	tree	+	+
126	*Rhus chinensis*	Anacardriaceae	tree	+	+
127	*Sapindus delavayi*	Sapindaceae	tree	-	+
128	*Sapindus rarak*	Sapindaceae	tree	+	+
129	*Sapium discolor*	Euphorbiaceae	tree	+	+
130	*Sapium insigne*	Euphorbiaceae	tree	+	-
131	*Schefflera chinensis*	Araliaceae	tree	+	-

Appendix III Continued (3)

132	*Schima argentea*	Theaceae	tree	+	+
133	*Schima wallichii*	Theaceae	tree	+	+
134	*Schoepfia fragrans*	Olacaceae	tree	+	+
135	*Solanum verbascifolium*	Solanaceae	tree	+	-
136	*Spondias pinnata*	Anacardriaceae	tree	+	+
137	*Styrax suberifolia var. caloneura*	Styracaceae	tree	+	+
138	*Styrax tonkinensis*	Styracaceae	tree	+	+
139	*Symplocos sp.*	Symplocaceae	tree	+	-
140	*Syzygium austro-yunnanensis*	Myrtaceae	tree	+	+
141	*Syzygium brachyantherum*	Myrtaceae	tree	+	-
142	*Syzygium cumini*	Myrtaceae	tree	+	+
143	*Syzygium oblatum*	Myrtaceae	tree	+	+
144	*Syzygium rockii*	Myrtaceae	tree	+	-
145	*Syzygium sp.*	Myrtaceae	tree	+	+
146	*Syzygium szemaoense*	Myrtaceae	tree	+	+
147	*Syzygium yunnanense*	Myrtaceae	tree	+	-
148	*Ternstroemia gymnanthera*	Anacardriaceae	tree	+	+
149	*Toona ciliate*	Meliaceae	tree	+	+
150	*Toxicodendron succedaneum*	Anacardriaceae	tree	+	+
151	*Wendlandia sp.*	Rubiaceae	tree	+	+
152	*Wendlandia tinctoria*	Rubiaceae	tree	+	-
153	*Xanthophyllum siamensis*	Xanthophyllaceae	tree	+	+
1	*Abelmoschus manihot*	Malvaceae	shrub	+	-
2	*Abelmoschus sagittifolius*	Malvaceae	shrub	+	-
3	*Acacia sp.*	Mimosaceae	shrub	+	+
4	*Acanthaceae sp.*	Acanthaceae	shrub	+	-
5	*Actinodaphne henryi*	Lauraceae	shrub	-	+
6	*Albizia bracteata*	Mimosaceae	shrub	+	-
7	*Albizia sp.*	Mimosaceae	shrub	+	+
8	*Alseodaphne andersonii*	Lauraceae	shrub	+	-
9	*Anacardiaceae sp.*	Anacardiaceae	shrub	-	+
10	*Anneslea fragrans*	Theaceae	shrub	-	+
11	*Antiaris toxicaria*	Moraceae	shrub	-	+
12	*Aphananthe aspera*	Ulmaceae	shrub	-	+
13	*Apocynaceae sp.*	Apocynaceae	shrub	+	-
14	*Araliachinensis sp.*	Araliaceae	shrub	+	+
15	*Ardisia crenata*	Myrsinaceae	shrub	+	-
16	*Ardisia neriifolia*	Myrsinaceae	shrub	+	-
17	*Baccaurea ramiflora*	Euphorbiaceae	shrub	+	-
18	*Bauhinia claviflora*	Caesalpiniaceae	shrub	+	-
19	*Bauhinia sp.*	Caesalpiniaceae	shrub	+	-
20	*Belvisia sp.*	Polypodiaceae	shrub	+	-
21	*Bignonia sp.*	Bignoniaceae	shrub	+	-

Appendix III Continued (4)

22	*Blumea balsamifera*	Compositae	shrub	+	-
23	*Breyhia sp.*	Euphorbiaceae	shrub	+	+
24	*Bridelia monoica*	Euphorbiaceae	shrub	-	+
25	*Broussonetia papyrifera*	Moraceae	shrub	+	-
26	*Buddleja officinalis*	Scrophulariaceae	shrub	-	+
27	*Callicarpa sp.*	Verbenaceae	shrub	+	+
28	*Canavium sp.*	Oleaceae	shrub	+	-
29	*Capparis tenera*	Capparidaceae	shrub	-	+
30	*Capparis trichocarpa*	Capparidaceae	shrub	+	-
31	*Carissa spinarum*	Apocynaceae	shrub	-	+
32	*Carpinus sp.*	Betulaceae	shrub	+	-
33	*Caryota sp.*	Palmae	shrub	+	+
34	*Cassia laevigata*	Caesalpiniaceae	shrub	+	+
35	*Cassia occidentalis*	Caesalpiniaceae	shrub	+	+
36	*Cassia siamea*	Caesalpiniaceae	shrub	+	-
37	*Celtis tetrandra*	Ulmaceae	shrub	-	+
38	*Cerasus serasoides*	Rosaceae	shrub	-	+
39	*Chasalis curviflora*	Rubiaceae	shrub	+	-
40	*Cissus javana*	Vitaceae	shrub	+	-
41	*Clausena lenis*	Rutaceae	shrub	+	-
42	*Clerodendron bungei*	Verbenaceae	shrub	+	+
43	*Clerodendron serratum*	Verbenaceae	shrub	+	+
44	*Clochidion lanceolarium*	Euphorbiaceae	shrub	+	-
45	*Colocasia sp.*	Araceae	shrub	+	-
46	*Colona floribunda*	Tiliaceae	shrub	+	-
47	*Cratoxylon ligustrinum*	Hypericaceae	shrub	-	+
48	*Crotalaria pallida*	Leguminosae	shrub	+	-
49	*Dalbergia assamica*	Leguminosae	shrub	+	+
50	*Dalbergia fusca*	Leguminosae	shrub	+	-
51	*Dalbergia mimosoides*	Leguminosae	shrub	-	+
52	*Dalbergia rimosa*	Leguminosae	shrub	+	-
53	*Dalbergia sp.*	Leguminosae	shrub	+	+
54	*Dalbergia stipulacea*	Leguminosae	shrub	+	+
55	*Derris robusta*	Leguminosae	shrub	+	-
56	*Dichroa febrifuga*	Hydrangiaceae	shrub	+	-
57	*Dolichandrone cauda-felina*	Bignoniaceae	shrub	+	-
58	*Engelhardia sp.*	Juglandaceae	shrub	+	+
59	*Eriolaena sp.*	Sterculiaceae	shrub	+	-
60	*Erythropalum sp.*	Olacaceae	shrub	-	+
61	*Euonymus bungeanus*	Celastraceae	shrub	+	-
62	*Eupatorium coelesticum*	Compositae	shrub	-	+
63	*Eupatorium odoratum*	Compositae	shrub	-	+
64	*Euphorbiaceae sp.*	Euphorbiaceae	shrub	-	+
65	*Eurya sp.*	Theaceae	shrub	+	+

Appendix III Continued (5)

66	*Euscaphis japonica*	Simaroubaceae	shrub	+	-
67	*Fagaceae sp.*	Fagaceae	shrub	+	+
68	*Ficus carica*	Moraceae	shrub	-	+
69	*Ficus chapaensis*	Moraceae	shrub	+	-
70	*Ficus chrysocarpa*	Moraceae	shrub	+	-
71	*Ficus curtipes*	Moraceae	shrub	+	-
72	*Ficus irregularis*	Moraceae	shrub	-	+
73	*Ficus pumila var. awkeotsang*	Moraceae	shrub	-	+
74	*Ficus sp.*	Moraceae	shrub	+	+
75	*Ficus virens*	Moraceae	shrub	+	-
76	*Gironniera subaequalis*	Ulmaceae	shrub	+	-
77	*Globba racemosa*	Zingiberaceae	shrub	+	-
78	*Glochidion assamicum*	Euphorbiaceae	shrub	+	-
79	*Glochidion eriocarpum*	Euphorbiaceae	shrub	+	+
80	*Gomphostemma microdon*	Labiatae	shrub	+	+
81	*Gomphostemma stellato-hirsutum*	Labiatae	shrub	+	-
82	*Gonatanthus pumilus*	Araceae	shrub	+	-
83	*Grewia sp.*	Tiliaceae	shrub	+	-
84	*Harpullia sp.*	Sapindaceae	shrub	+	-
85	*Helicia pyrrhobotrya*	Proteaceae	shrub	+	+
86	*Heliciopsis sp.*	Proteaceae	shrub	-	+
87	*Heliciopsis terminalis*	Proteaceae	shrub	+	+
88	*Helicteres lanceolata*	Proteaceae	shrub	+	-
89	*Helwingia himalaica*	Cornaceae	shrub	+	-
90	*Herba Inulae*	Compositae	shrub	+	-
91	*Indigofera simaoensis*	Fabaceae	shrub	+	-
92	*Kaempferia panduratum*	Zingiberaceae	shrub	+	-
93	*Kalanchoe daigremontiana*	Crassulaceae	shrub	-	+
94	*Kalimeris sp.*	Compositae	shrub	-	+
95	*Kydia calycina*	Malvaceae	shrub	+	-
96	*Leycesteria*	Caprifoliaceae	shrub	-	+
97	*Ligustrum quihoui*	Oleaceae	shrub	-	+
98	*Lindera communis*	Lindera Aggregata	shrub	+	-
99	*Lithocarpus fohaiensis*	Fagaceae	shrub	-	+
100	*Lonicera sp.*	Caprifoliaceae	shrub	-	+
101	*Lycianthes biflora*	Solanaceae	shrub	+	-
102	*Macaranga sp.*	Euphorbiaceae	shrub	+	+
103	*Macaranga tanarius*	Euphorbiaceae	shrub	-	+
104	*Macropanax chienii*	Araliaceae	shrub	-	+
105	*Maesa indica*	Myrsinaceae	shrub	+	+
106	*Maesa perlarius*	Myrsinaceae	shrub	-	+
107	*Mallotus macrostachys*	Euphorbiaceae	shrub	+	-
108	*Mananthes patentiflora*	Acanthaceae	shrub	-	+
109	*Maytenus inflata*	Celastraceae	shrub	+	-

Appendix III Continued (6)

110	*Measa sp.*	Myrsinaceae	shrub	-	+
111	*Melastoma sp.*	Melastomaceae	shrub	+	+
112	*Meliaceae sp.*	Meliaceae	shrub	+	+
113	*Meliosma arnottiana*	Sabiaceae	shrub	-	+
114	*Micromelum sp.*	Rutaceae	shrub	+	-
115	*Micromelum tntegerrimum*	Rutaceae	shrub	+	-
116	*Millettia griffithii*	Papilionaceae	shrub	+	+
117	*Mimosaceae sp.*	Mimosaceae	shrub	-	+
118	*Morus macroura*	Moraceae	shrub	+	-
119	*Mussaenda sp.*	Rubiaceae	shrub	+	+
120	*Mycetia sp.*	Rubiaceae	shrub	+	-
121	*Myrsine africana*	Myrsinaceae	shrub	-	+
122	*Neonauclea tsaiana*	Rubiaceae	shrub	+	-
123	*Nephelium chryseum*	Sapindaceae	shrub	-	+
124	*Opuntia sp.*	Cactaceae	shrub	-	+
125	*Oxyspora paniculata*	Melastomataceae	shrub	+	-
126	*Phlogacanthus curviflorus*	Acanthaceae	shrub	+	-
127	*Photinia sp.*	Rosaceae	shrub	-	+
128	*Picrasma quassioides*	Simaroubaceae	shrub	-	+
129	*Polygonum capitatum*	Polygonaceae	shrub	-	+
130	*Polyspora chrysandra*	Theaceae	shrub	+	-
131	*Premna sp.*	Verbenaceae	shrub	+	-
132	*Protium yunnanense*	Burseraceae	shrub	+	-
133	*Pseudoranthemum polyanthum*	Acanthaceae	shrub	-	+
134	*Psychotria siamica*	Rubiaceae	shrub	+	-
135	*Psychotria sp.*	Rubiaceae	shrub	+	-
136	*Pyrularia edulis*	Santalaceae	shrub	+	-
137	*Rauvolfia sp.*	Apocynaceae	shrub	+	+
138	*Rubus sp.*	Rosaceae	shrub	-	+
139	*Schisandra sp.*	Schisandraceae	shrub	-	+
140	*Schizomussaenda dehiscens*	Rubiaceae	shrub	+	-
141	*Selaginella sp.*	Selaginellaceae	shrub	-	+
142	*Sida acuta*	Malvaceae	shrub	+	+
143	*Sida szechuensis*	Malvaceae	shrub	+	+
144	*Smilax menispermoidea*	Liliaceae	shrub	-	+
145	*Solallum nigrum*	Solanaceae	shrub	+	+
146	*Solanum sp.*	Solanaceae	shrub	+	+
147	*Sonerila Roxb*	Melastomataceae	shrub	+	-
148	*Sorbus globosa*	Rosaceae	shrub	+	-
149	*Sterculia lanceaefolia*	Sterculiaceae	shrub	+	-
150	*Sterculia nobililis*	Sterculiaceae	shrub	-	+
151	*Sterculia sp.*	Sterculiaceae	shrub	-	+
152	*Stereospermum neuranthum*	Bignoniaceae	shrub	+	+
153	*Styracaceae sp.*	Styracaceae	shrub	-	+

Appendix III Continued (7)

154	*Tarennoidea wallichii*	Rubiaceae	shrub	-	+
155	*Thysanolaena maxima*	Gramineae	shrub	-	+
156	*Toxicodendron acuminatum*	Anacardiaceae	shrub	-	+
157	*Trema tomentosa*	Ulmaceae	shrub	+	+
158	*Triumfetta rhomboides*	Tiliaceae	shrub	+	-
159	*Typhonium giganteum*	Araceae	shrub	-	+
160	*Ulma sp.*	Ulmaceae	shrub	+	-
161	*Urena lobata*	Malvaceae	shrub	+	+
162	*Vernonia sp.*	Compositae	shrub	+	+
163	*Viburnum cylindricum*	Adoxaceae	shrub	-	+
164	*Viburnum sp.*	Adoxaceae	shrub	-	+
165	*Vitex sp.*	Verbenaceae	shrub	+	+
166	*Wallichia mooreana*	Palmae	shrub	+	+
167	*Xanthophyllum yunnanense*	Xanthophyllaceae	shrub	+	+
1	*Actinodaphne henryi*	Lauraceae	seedling	+	+
2	*Actinodaphne obovata*	Lauraceae	seedling	+	-
3	*Alangium barbatum*	Alangiaceae	seedling	+	+
4	*Alangium chinensis*	Alangiaceae	seedling	-	+
5	*Albizia crassiramea*	Mimosaceae	seedling	-	+
6	*Alnus nepalensis*	Betulaceae	seedling	+	-
7	*Antidesma montanum*	Euphorbiaceae	seedling	+	-
8	*Antidesma sp.*	Euphorbiaceae	seedling	-	+
9	*Aporusa yunnanensis*	Euphorbiaceae	seedling	+	+
10	*Ardisia villosa*	Myrsinaceae	seedling	-	+
11	*Ardisia virens*	Myrsinaceae	seedling	+	+
12	*Artocarpus nitidus*	Moraceae	seedling	+	-
13	*Berberis heteropoda*	Berberidaceae	seedling	+	-
14	*Calophyllun polyanthum*	Guttiferae	seedling	+	-
15	*Canarium Stickman*	Burseraceae	seedling	+	-
16	*Canarium subulatum*	Burseraceae	seedling	+	-
17	*Canthium parvifoliam*	Rubiaceae	seedling	+	+
18	*Carallia diplopetela*	Rhizophoraceae	seedling	+	+
19	*Carallia sp.*	Rhizophoraceae	seedling	+	+
20	*Cassia agnes*	Caesalpiniaceae	seedling	+	+
21	*Castanopsis argyrophylla*	Fagaceae	seedling	+	-
22	*Castanopsis chuii var.spinuposa*	Fagaceae	seedling	+	+
23	*Castanopsis hystrix*	Fagaceae	seedling	+	+
24	*Castanopsis sp.*	Fagaceae	seedling	+	+
25	*Celtis sp.*	Ulmaceae	seedling	+	+
26	*Cerasus pseudocerasus*	Rosaceae	seedling	+	+
27	*Choerospondias axillaris*	Anacardriaceae	seedling	+	+
28	*Cinnamomum bejolghota*	Lauraceae	seedling	+	+
29	*Cinnamomum mollifolium*	Lauraceae	seedling	+	-

Appendix III Continued (8)

30	*Cinnamomum tamala*	Lauraceae	seedling	+	+
31	*Cinnamomum tenuipilum*	Lauraceae	seedling	+	+
32	*Cipadessa baccifara*	Meliaceae	seedling	+	+
33	*Citrus reticulata*	Rutaceae	seedling	-	+
34	*Clausena excavata*	Rutaceae	seedling	+	+
35	*Cordia dichotoma*	Boraginaceae	seedling	+	-
36	*Cryptocarya brachythyrsa*	Lauraceae	seedling	+	+
37	*Cunninghamia sp.*	Taxodiaceae	seedling	+	-
38	*Cyclobalanopsis glaucoides*	Fagaceae	seedling	-	+
39	*Cyclobalanopsis rex*	Fagaceae	seedling	-	+
40	*Dalbergia pinnata*	Caesalpiniaceae	seedling	+	+
41	*Decaspermun fruticosum*	Myrtaceae	seedling	+	+
42	*Diospyros kaki*	Ebenaceae	seedling	+	+
43	*Docynia delavayi*	Ebenaceae	seedling	+	+
44	*Ehretia acuminata var. obovata*	Boraginaceae	seedling	+	+
45	*Ehretia tsangii*	Boraginaceae	seedling	+	+
46	*Elaeocarpus apiculatus*	Elaeocarpaceae	seedling	-	+
47	*Elaeocarpus austro-yunnanensis*	Elaeocarpaceae	seedling	+	-
48	*Elaeocarpus poilanei*	Elaeocarpaceae	seedling	+	-
49	*Elaeocarpus prunifolioides*	Elaeocarpaceae	seedling	+	-
50	*Elaeocarpus sp.*	Elaeocarpaceae	seedling	+	+
51	*Elaeocarpus sphaericus*	Elaeocarpaceae	seedling	+	+
52	*Elaeocarpus varunua*	Elaeocarpaceae	seedling	+	+
53	*Eribotrya japonica*	Rosaceae	seedling	+	-
54	*Erythrina Stricta*	Leguminosae	seedling	+	+
55	*Eudia trichotoma*	Rutaceae	seedling	+	-
56	*Euodia austro-sinensis*	Rutaceae	seedling	+	+
57	*Euodia lepta*	Rutaceae	seedling	+	+
58	*Eurya groffii*	Theaceae	seedling	+	+
59	*Eurya muricata*	Theaceae	seedling	+	-
60	*Eurya pittosporifolia*	Theaceae	seedling	+	+
61	*Eurya sp.*	Theaceae	seedling	+	-
62	*Ficus benjamina*	Moraceae	seedling	-	+
63	*Ficus gibbosa*	Moraceae	seedling	+	-
64	*Ficus hirta*	Moraceae	seedling	+	-
65	*Ficus hirta var. imberbis*	Moraceae	seedling	+	-
66	*Ficus maclellandii*	Moraceae	seedling	+	+
67	*Ficus nervosa*	Moraceae	seedling	+	-
68	*Ficus racemosa*	Moraceae	seedling	-	+
69	*Ficus sp.*	Moraceae	seedling	+	-
70	*Ficus subincisa*	Moraceae	seedling	+	-
71	*Ficus superba*	Moraceae	seedling	+	-
72	*Ficus variegata*	Moraceae	seedling	+	-
73	*Fordia cauliflora*	Leguminosae	seedling	-	+

Appendix III Continued (9)

74	*Fraxinus chinensis*	Oleaceae	seedling	-	+
75	*Garuga floribunda*	Burseraceae	seedling	+	-
76	*Glochidion hissutum*	Euphorbiaceae	seedling	+	+
77	*Glochidion puberum*	Euphorbiaceae	seedling	+	+
78	*Glochidion sphaerogynum*	Euphorbiaceae	seedling	+	-
79	*Glycosmis citrifolia*	Rubaceae	seedling	+	-
80	*Helicia nilagirica*	Proteaceae	seedling	-	+
81	*Ilex atrata*	Aquifoliaceae	seedling	+	-
82	*Ilex godajam*	Aquifoliaceae	seedling	+	+
83	*Ilex polyneura*	Aquifoliaceae	seedling	+	+
84	*Ilex sp.*	Aquifoliaceae	seedling	+	+
85	*Ilex triflora*	Aquifoliaceae	seedling	+	+
86	*Lauraceae sp.*	Rosaceae	seedling	+	+
87	*Laurocerasus menghaiensis*	Rosaceae	seedling	+	-
88	*Laurocerasus sp.*	Rosaceae	seedling	+	-
89	*Lindera aggregata*	Lauraceae	seedling	+	+
90	*Lithocarpus leucostachyus*	Fagaceae	seedling	+	+
91	*Lithocarpus mekongensis*	Fagaceae	seedling	+	-
92	*Lithocarpus sp.*	Fagaceae	seedling	+	-
93	*Litsea atrata*	Lauraceae	seedling	+	-
94	*Litsea cubeba*	Lauraceae	seedling	+	+
95	*Litsea elongata*	Lauraceae	seedling	-	+
96	*Litsea euosma*	Lauraceae	seedling	+	-
97	*Litsea garrettii*	Lauraceae	seedling	-	+
98	*Litsea glutinosa*	Lauraceae	seedling	+	+
99	*Litsea greenmaniana*	Lauraceae	seedling	+	+
100	*Litsea longistaminata*	Lauraceae	seedling	+	-
101	*Litsea monopetala*	Lauraceae	seedling	+	+
102	*Litsea panamonja*	Lauraceae	seedling	-	+
103	*Litsea sp.*	Lauraceae	seedling	+	+
104	*Litsea umbellata*	Lauraceae	seedling	-	+
105	*llicium modestum*	Magnoliaceae	seedling	+	-
106	*Macaranga deheiculata*	Euphorbiaceae	seedling	+	-
107	*Macaranga denticulata*	Euphorbiaceae	seedling	-	+
108	*Macaranga indica*	Euphorbiaceae	seedling	+	+
109	*Macaranga kurzii*	Euphorbiaceae	seedling	+	+
110	*Machilus robuste*	Lauraceae	seedling	+	-
111	*Machilus rufipes*	Lauraceae	seedling	+	+
112	*Machilus sp.*	Lauraceae	seedling	+	+
113	*Mallotus paniculatus*	Euphorbiaceae	seedling	+	+
114	*Mallotus philippinensis*	Euphorbiaceae	seedling	+	+
115	*Mangifera indica*	Anacardiaceae	seedling	-	+
116	*Measa macilentoides*	Myrsinaceae	seedling	+	+
117	*Measa sp.*	Myrsinaceae	seedling	+	-

Appendix III Continued (10)

118	*Melia azedarach*	Meliaceae	seedling	+	+
119	*Melia toosanden*	Meliaceae	seedling	+	+
120	*Olea ferruginea*	Oleaceae	seedling	+	+
121	*Olea rosea*	Oleaceae	seedling	+	-
122	*Olea rosea*	Oleaceae	seedling	-	+
123	*Olea sp.*	Oleaceae	seedling	-	+
124	*Oroxylum indicum*	Bignoniaceae	seedling	+	+
125	*Paramichelia baillonii*	Magnoliaceae	seedling	+	-
126	*Paranephelium sp.*	Magnoliaceae	seedling	-	+
127	*Phoebe lanceolata*	Lauraceae	seedling	+	-
128	*Phoebe puwenensis*	Lauraceae	seedling	+	+
129	*Phyllanthus emblica*	Euphorbiaceae	seedling	+	+
130	*Pipleccellollcem clypsia*	Mimosaceae	seedling	+	+
131	*Psidium guajava*	Myrtaceae	seedling	+	+
132	*Pygeum arboreum*	Rosaceae	seedling	+	+
133	*Pygeum macrocarpum*	Rosaceae	seedling	+	+
134	*Pygeum sp.*	Rosaceae	seedling	+	-
135	*Pyrus pashia*	Rosaceae	seedling	+	+
136	*Rapanea neriifolia*	Myrsinaceae	seedling	+	+
137	*Rhus chinensis*	Anacardriaceae	seedling	+	+
138	*Sapindus rarak*	Sapindaceae	seedling	+	+
139	*Sapium discolor*	Euphorbiaceae	seedling	+	-
140	*Sapium insigne*	Euphorbiaceae	seedling	+	-
141	*Sapium sebiferum*	Euphorbiaceae	seedling	+	-
142	*Schefflera chinensis*	Araliaceae	seedling	+	+
143	*Schima argentea*	Theaceae	seedling	+	+
144	*Schima wallichii*	Theaceae	seedling	+	+
145	*Schoepfia fragrans*	Olacaceae	seedling	+	+
146	*Solanum verbascifolium*	Solanaceae	seedling	+	-
147	*Spondias pinnata*	Anacardriaceae	seedling	+	-
148	*Styrax suberifolia var. caloneura*	Styracaceae	seedling	+	+
149	*Styrax tonkinensis*	Styracaceae	seedling	+	-
150	*Symplocos hookeri*	Symplocaceae	seedling	+	-
151	*Symplocos sp.*	Symplocaceae	seedling	-	+
152	*Syzygium austro-yunnanensis*	Myrtaceae	seedling	+	-
153	*Syzygium brachyantherum*	Myrtaceae	seedling	+	-
154	*Syzygium cumini*	Myrtaceae	seedling	+	+
155	*Syzygium forrestii*	Myrtaceae	seedling	+	+
156	*Syzygium latilimbum*	Myrtaceae	seedling	+	-
157	*Syzygium oblatum*	Myrtaceae	seedling	+	+
158	*Syzygium rockii*	Myrtaceae	seedling	+	-
159	*Syzygium sp.*	Myrtaceae	seedling	+	+
160	*Syzygium szemaoense*	Myrtaceae	seedling	+	+
161	*Ternstroemia gymanthera*	Anacardriaceae	seedling	+	-

Appendix III Continued (11)

162	*Toona ciliata*	Meliaceae	seedling	+	+
163	*Toxicodendron succedaneum*	Anacardriaceae	seedling	+	+
164	*Ulmus lanceaefolia*	Ulmaceae	seedling	+	-
165	*Wendlandia sp.*	Rubiaceae	seedling	+	+
166	*Wendlandia tincotoria*	Rubiaceae	seedling	+	+
167	*Wendlandia uvariifolia*	Rubiaceae	seedling	+	+
168	*Xanthophyllum siamensis*	Xanthophyllaceae	seedling	+	-
1	*Acanthaceae sp.*	Acanthaceae	herb	+	+
2	*Achyranthes aspera*	Amaranthaceae	herb	+	+
3	*Adenostemma lavenia*	Compositae	herb	+	+
4	*Adiantum sp.*	Adiantaceae	herb	+	+
5	*Ageratum conyzoides*	Compositae	herb	+	+
6	*Agrostidoideae sp.*	Agrostidoideae	herb	+	+
7	*Amaryllida sp.*	Amarylidaceae	herb	+	-
8	*Ammannia auriculata*	Lythraceae	herb	+	-
9	*Arachniodes austro-yunnanensis*	Dryopteridaceae	herb	+	-
10	*Artemisia argyi*	Compositae	herb	+	+
11	*Arundinella Raddi*	Gramineae	herb	+	-
12	*Asparagus subscandens*	Liliaceae	herb	+	+
13	*Aspidistra elatior Blume*	Orchidaceae	herb	+	-
14	*Asplenium normale*	Aspleniaceae	herb	+	-
15	*Asplenium sp.*	Aspleniaceae	herb	-	+
16	*Athyrium dissitifolium*	Athyriaceae	herb	+	+
17	*Athyrium sp.*	Athyriaceae	herb	-	+
18	*Axonopus compressus*	Athyriaceae	herb	+	+
19	*Bidens pilosa*	Compositae	herb	+	+
20	*Blumea riparia*	Compositae	herb	+	+
21	*Boehmeria hamiltaniana*	Urticaceae	herb	+	+
22	*Boehmeria siamensis*	Urticaceae	herb	+	-
23	*Boehmeria zollingeriana*	Urticaceae	herb	+	-
24	*Brachystemma calycinum*	Caryophyllaceae	herb	+	-
25	*Buddleja lindleyana*	Loganiaceae	herb	-	+
26	*Callipteris sp.*	Athyriaceae	herb	+	+
27	*Cardamine hirsuta*	Cruciferae	herb	+	-
28	*Carex baccans*	Cyperaceae	herb	+	+
29	*Carex sp.*	Cyperaceae	herb	-	+
30	*Centella asiatice*	Umbelliferae	herb	+	+
31	*Chamabainia wight*	Urticaceae	herb	-	+
32	*Chroesthes lanceolata*	Acanthaceae	herb	+	-
33	*Cicuta virosa*	Umbelliferae	herb	+	+
34	*Clinopodium sp.*	Labiatae	herb	+	+
35	*Colquhounia elegans*	Labiatae	herb	+	+
36	*Commelina sp.*	Commelinaceae	herb	+	+

Appendix III Continued (12)

37	*Composita sp.*	Compositae	herb	+	-
38	*Compositae sp.*	Compositae	herb	-	+
39	*Conyza canadensis*	Compositae	herb	+	+
40	*Corydalis edulis*	Papaveraceae	herb	+	-
41	*Crassocephalum crepidioides*	Compositae	herb	+	+
42	*Cucubalus baccifer*	Caryophyllaceae	herb	+	-
43	*Curculigo orchioides*	Hypoxidaceae	herb	-	+
44	*Curculigo sp.*	Hypoxidaceae	herb	+	-
45	*Cyanotis arachnoides*	Commelinaceae	herb	+	+
46	*Cyclosorus parasiticus*	Dryopteridaceae	herb	+	-
47	*Cynodon dactylon*	Gramineae	herb	+	+
48	*Cyperaceae sp.*	Cyperaceae	herb	+	+
49	*Cyperus rotundus*	Cyperaceae	herb	+	+
50	*Cyrtococcum patens*	Poaceae	herb	+	-
51	*Debregeasia longifolia*	Urticaceae	herb	+	-
52	*Debregeasia orientalis*	Urticaceae	herb	+	-
53	*Dianella ensifolia*	Liliaceae	herb	-	+
54	*Dichondra repens*	Convolvulaceae	herb	+	+
55	*Dichrocephala integrifolia*	Compositae	herb	+	+
56	*Dicranopteris dichotoma*	Gleicheniaceae	herb	+	+
57	*Digitaria ciliaris*	Agrostidoideae	herb	+	+
58	*Digitaria ischaemum*	Agrostidoideae	herb	+	-
59	*Dipliptera sp.*	Acanthaceae	herb	+	+
60	*Disporopsis longifolia*	Liliaceae	herb	+	-
61	*Disporum sp.*	Liliaceae	herb	-	+
62	*Dryopterida sp.*	Dryopteridaceae	herb	+	+
63	*Duchesnea chrysantha*	Rosaceae	herb	+	+
64	*Duchesnea indica*	Rosaceae	herb	+	+
65	*Elephantopus scaber*	Compositae	herb	+	+
66	*Eleusine indica*	Agrostidoideae	herb	+	+
67	*Elsholtzia sp.*	Labiatae	herb	+	+
68	*Eragrostis japonica*	Agrostidoideae	herb	+	+
69	*Eragrostis nigra*	Agrostidoideae	herb	-	+
70	*Eragrostis pilosa*	Agrostidoideae	herb	+	+
71	*Eragrostis zeylanica*	Agrostidoideae	herb	-	+
72	*Eragrostis zeylanica*	Agrostidoideae	herb	+	-
73	*Eranthemum pulchellum*	Acanthaceae	herb	+	+
74	*Eryngium foetidum*	Apiaceae	herb	+	-
75	*Eupatorium coelesticum*	Compositae	herb	+	+
76	*Eupatorium odoratum*	Compositae	herb	+	+
77	*Eurysolen gracilis*	Labiatae	herb	+	+
78	*fern*	Na	herb	+	+
79	*Filipendula palmate*	Leguminosae	herb	+	-
80	*Geophila herbacea*	Rubiaceae	herb	+	+

Appendix III Continued (13)

81	*Geum aleppicum*	Rosaceae	herb	-	+
82	*Gnaphalium affine*	Compositae	herb	+	+
83	*Gonostegia sp.*	Urticaceae	herb	-	+
84	*Hedyotis sp.*	Rubiaceae	herb	+	+
85	*Hemiphragma heterophyllum*	Scrophulariaceae	herb	+	-
86	*Hemistepta lyrata*	Compositae	herb	+	+
87	*Herba Desmodii*	Leguminosae	herb	+	+
88	*Herba Saururi*	Leguminosae	herb	-	+
89	*Hydrocotyle pseudoconferta*	Umbelliferae	herb	-	+
90	*Hydrocotyle sibthorpioides*	Umbelliferae	herb	+	+
91	*Hypericum augustinii*	Guttiferae	herb	+	-
92	*Hypoestes triflora*	Acanthaceae	herb	+	-
93	*Hyporicum wightianum*	Hypericaceae	herb	+	-
94	*Hypoxis aurea*	Hypoxidaceae	herb	+	-
95	*Impatiens sp.*	Balsaminaceae	herb	+	+
96	*Imperata cylindrica*	Agrostidoideae	herb	+	-
97	*Isodon sp.*	Labiatae	herb	+	+
98	*Kyllinga brevifolia*	Cyperaceae	herb	+	+
99	*Labiata sp.*	Labiatae	herb	+	-
100	*Labiatae sp.*	Labiatae	herb	-	+
101	*Laggera pterodonta*	Compositae	herb	+	+
102	*Lepidagathis incurva*	Acanthaceae	herb	+	+
103	*Lepidium sativum*	Umbelliferae	herb	+	-
104	*Leucas ciliata*	Labiatae	herb	+	+
105	*Lindernia numularifolia*	Scrophulariaceae	herb	+	-
106	*Lindernia ruellioides*	Scrophulariaceae	herb	+	+
107	*Lindsaea yunnanensis*	Lindsaeaceae	herb	+	+
108	*Lophatherum gracile*	Agrostidoideae	herb	+	+
109	*Lysimachia congestiflora*	Primulaceae	herb	+	+
110	*Lysimachia lancifolia*	Primulaceae	herb	+	-
111	*Lysimachia lobelioides*	Primulaceae	herb	+	-
112	*Mazus sp.*	Scrophulariaceae	herb	+	+
113	*Melasma arvense*	Scrophulariaceae	herb	+	-
114	*Microlepia sp.*	Dennstaeditiaceae	herb	+	+
115	*Microstegium nodosum*	Gramineae	herb	+	-
116	*Microtoena sp.*	Labiatae	herb	+	+
117	*Myrsinaceae sp.*	Myrsinaceae	herb	+	-
118	*Ophiopogon sp.*	Liliaceae	herb	+	+
119	*Ophiorrhiza austro-yunnanensis*	Rubiaceae	herb	+	+
120	*Oplismenus undulatifolius*	Gramineae	herb	+	+
121	*Oreocnide frutescens*	Urticaceae	herb	+	-
122	*Ottochloa nodosa var. micrantha*	Gramineae	herb	+	-
123	*Oxalis corniculata*	Oxalidaceae	herb	+	+
124	*Paraphlomis japonica*	Labiatae	herb	+	-

Appendix III Continued (14)

125	*Paspalum conjugatum*	Agrostidoideae	herb	+	+
126	*Phaulopsis oppositifolia*	Acanthaceae	herb	+	+
127	*Phyllanthus sp.*	Euphorbiaceae	herb	+	+
128	*Pinellia pedatisecta*	Araceae	herb	+	-
129	*Plantago erosa*	Plantaginaceae	herb	+	+
130	*Pollia sp.*	Commelinaceae	herb	+	-
131	*Polygala arillata*	Polygalaceae	herb	-	+
132	*Polygala japonica*	Polygalaceae	herb	+	-
133	*Polygala sp.*	Polygalaceae	herb	+	-
134	*Polygalaceae sp.*	Polygalaceae	herb	+	+
135	*Polygonaceae sp.*	Polygonaceae	herb	+	+
136	*Polygonatum sp.*	Liliaceae	herb	+	+
137	*Polygonum capitatum*	Polygonaceae	herb	+	+
138	*Polygonum capitaum*	Polygonaceae	herb	+	-
139	*Polygonum chinense*	Polygonaceae	herb	-	+
140	*Polygonum muricatum*	Polygonaceae	herb	+	-
141	*Polygonum rude*	Polygonaceae	herb	+	+
142	*Pouzolzia sanguinea*	Urticaceae	herb	+	+
143	*Pouzolzia zeylanica*	Urticaceae	herb	+	+
144	*Pratia nummularia*	Lobeliaceae	herb	+	+
145	*Pseudoranthemum sp.*	Acanthaceae	herb	+	+
146	*Pteridium revolutum*	Pteridiaceae	herb	+	+
147	*Pteridrys australis*	Aspidiaceae	herb	+	-
148	*Pteris biaurita*	Pteridaceae	herb	+	-
149	*Pteris linearis*	Pteridaceae	herb	+	-
150	*Pteris sp.*	Pteridaceae	herb	+	+
151	*Ranunculaceae sp.*	Araceae	herb	-	+
152	*Rhaphidophora peepla*	Araceae	herb	+	-
153	*Rostellularia sp.*	Acanthaceae	herb	+	+
154	*Rubiaceae sp.*	Rubiaceae	herb	+	-
155	*Rubus multibracteatus*	Rosaceae	herb	+	+
156	*Rungia chinensis*	Acanthaceae	herb	-	+
157	*Salvis japonica*	Labiatae	herb	+	+
158	*Scrophularia sp.*	Scrophulariaceae	herb	+	-
159	*Scrophulariaceae sp.*	Scrophulariaceae	herb	-	+
160	*Scutellaria sp.*	Labiatae	herb	+	-
161	*Selaginella sp.*	Selaginellaceae	herb	+	+
162	*Senecio scandens*	Compositae	herb	+	-
163	*Siegesbeckia orientalis*	Compositae	herb	+	+
164	*Spermacoce latifolia*	Rubiaceae	herb	+	-
165	*Sphaeranthus indicus*	Compositae	herb	+	-
166	*Spilanthes paniculata*	Compositae	herb	+	+
167	*Spiraea sp.*	Rosaceae	herb	-	+
168	*Stellaria media*	Caryophyllaceae	herb	+	+

Appendix III Continued (15)

169	*Stenoloma chsanum*	Lindsaeaceae	herb	+	+
170	*Strobilanthes aprica*	Acanthaceae	herb	+	+
171	*Strobilanthes cusia*	Acanthaceae	herb	+	-
172	*Synedrella nudiflora*	Compositae	herb	+	-
173	*Thalictrum trichopus*	Ranunculaceae	herb	-	+
174	*Themeda caudata*	Agrostidoideae	herb	+	-
175	*Torenia concolor*	Scrophulariaceae	herb	-	+
176	*Torenia violacea*	Scrophulariaceae	herb	+	-
177	*Trigonotis peduncularis*	Boraginaceae	herb	+	-
178	*Typhonium divaricatum*	Araceae	herb	+	-
179	*Typonium divaricatum*	Araceae	herb	-	+
180	*Urtica atrichocaulis*	Urticaceae	herb	+	-
181	*Urticaceae sp.*	Urticaceae	herb	+	+
182	*Vernonia sp.*	Compositae	herb	+	+
183	*Viola diffusa*	Violaceae	herb	+	+
184	*Viola philippica*	Violaceae	herb	-	+
185	*Viola pilosa*	Violaceae	herb	+	+
186	*Viola sp.*	Violaceae	herb	+	+
187	*Viola yunnanensis*	Violaceae	herb	+	+
188	*Woodwardia sp.*	Blechnaceae	herb	+	+
1	*Abrus pulchellus*	Leguminosae	epiphyte & vine	+	+
2	*Acampe rigida*	Orchidaceae	epiphyte & vine	+	-
3	*Acanthaceae sp.*	Acanthaceae	epiphyte & vine	+	-
4	*Aeschynanthus sp.*	Gesneriaceae	epiphyte & vine	+	+
5	*Ampelopsis cantoniensis*	Vitaceae	epiphyte & vine	+	-
6	*Araliaceae sp.*	Araliaceae	epiphyte & vine	-	+
7	*Aristolochia debilis*	Aristolochiaceae	epiphyte & vine	+	-
8	*Asclepiadaceae sp.*	Asclepiadaceae	epiphyte & vine	+	+
9	*Atylosia mollis*	Papilionaceae	epiphyte & vine	+	+
10	*Bauhinia glauca*	Leguminosae	epiphyte & vine	+	-
11	*Bauhinia sp.*	Leguminosae	epiphyte & vine	+	-
12	*Belvisia sp.*	Polypodiaceae	epiphyte & vine	+	+
13	*Bengal Clockvine*	Zingiberaceae	epiphyte & vine	+	+
14	*Bulbophvllum peotinatum*	Orchidaceae	epiphyte & vine	+	+
15	*Bulbophyllum crassipes*	Orchidaceae	epiphyte & vine	+	+
16	*Bulbophyllum cylindraceum*	Orchidaceae	epiphyte & vine	+	-
17	*Bulbophyllum menghaiense*	Orchidaceae	epiphyte & vine	+	-
18	*Bulbophyllum polyrhizum*	Orchidaceae	epiphyte & vine	+	-
19	*Bulbophyllum sp.*	Orchidaceae	epiphyte & vine	+	+
20	*Bulbophyllum suavissimum*	Orchidaceae	epiphyte & vine	+	-
21	*Bulbophyllum wallichii*	Orchidaceae	epiphyte & vine	+	+
22	*Cajanus grandiflorus*	Leguminosae	epiphyte & vine	+	-
23	*Calanthe alismaefolia*	Orchidaceae	epiphyte & vine	+	+

Appendix III Continued (16)

24	*Campanumoea javanica*	Campanulaceae	epiphyte & vine	+	-
25	*Caulis Mucunae*	Papilionaceae	epiphyte & vine	-	+
26	*Caulis sp.*	Papilionaceae	epiphyte & vine	-	+
27	*Cayratia sp.*	Vitaceae	epiphyte & vine	+	+
28	*Celastraceae sp.*	Celastraceae	epiphyte & vine	-	+
29	*Celastrus angulatus*	Celastraceae	epiphyte & vine	+	+
30	*Celastrus stylosus*	Celastraceae	epiphyte & vine	+	-
31	*Chiloschista ynnanensis*	Orchidaceae	epiphyte & vine	+	+
32	*Chonemorpha sp.*	Apocynaceae	epiphyte & vine	+	-
33	*Cissus javana*	Vitaceae	epiphyte & vine	+	+
34	*Cissus kerrii*	Vitaceae	epiphyte & vine	+	-
35	*Clematis sp.*	Ranunculaceae	epiphyte & vine	+	-
36	*Clitoria mariana*	Papilionaceae	epiphyte & vine	+	+
37	*Cocculus orbiculatus*	Menispermaceae	epiphyte & vine	-	+
38	*Coelogyne viscosa*	Orchidaceae	epiphyte & vine	+	-
39	*Colebrookia oppositifolia*	Lamiaceae	epiphyte & vine	+	-
40	*Combretum sp.*	Combretaceae	epiphyte & vine	+	-
41	*Convolvulaceae sp.*	Convolvulaceae	epiphyte & vine	+	-
42	*Croton sp.*	Euphorbiaceae	epiphyte & vine	+	+
43	*Cryptolepis buchananii*	Asclepiadaceae	epiphyte & vine	-	+
44	*Cucurbita moschata*	Cucurbitaceae	epiphyte & vine	+	-
45	*Cucurbitaceae sp.*	Cucurbitaceae	epiphyte & vine	+	-
46	*Cyathula prostrata*	Amaranthaceae	epiphyte & vine	-	+
47	*Cyclea hainanensis*	Menispermaceae	epiphyte & vine	-	+
48	*Davallia cylindrica*	Davalliaceae	epiphyte & vine	+	+
49	*Dendrobium bellatulum*	Orchidaceae	epiphyte & vine	+	-
50	*Dendrobium capilipes*	Orchidaceae	epiphyte & vine	+	+
51	*Dendrobium chrysotoxum*	Orchidaceae	epiphyte & vine	+	+
52	*Dendrobium fimbriatum*	Orchidaceae	epiphyte & vine	+	-
53	*Dendrobium gibsonii*	Orchidaceae	epiphyte & vine	+	-
54	*Dendrobium minutiflorum*	Orchidaceae	epiphyte & vine	-	+
55	*Dendrobium pendulum*	Orchidaceae	epiphyte & vine	+	-
56	*Dendrobium primulinum*	Orchidaceae	epiphyte & vine	-	+
57	*Dendrobium salaccense*	Orchidaceae	epiphyte & vine	+	-
58	*Dendrobium sp.*	Orchidaceae	epiphyte & vine	+	+
59	*Derris marginata*	Leguminosae	epiphyte & vine	+	-
60	*Derris sp.*	Leguminosae	epiphyte & vine	-	+
61	*Desmodium sp.*	Leguminosae	epiphyte & vine	+	+
62	*Dioscorea sp.*	Dioscoreaceae	epiphyte & vine	+	+
63	*Diploclisia glaucescens*	Menispermaceae	epiphyte & vine	+	-
64	*Dischidia chinensis*	Apocynaceae	epiphyte & vine	-	+
65	*Dischidia minor*	Apocynaceae	epiphyte & vine	-	+
66	*Drymaria cordata*	Caryophyllaceae	epiphyte & vine	+	+
67	*Drynaria sp.*	Drynariaceae	epiphyte & vine	+	+

Appendix III Continued (17)

68	*Ecdysanthera rosea*	Apocynaceae	epiphyte & vine	-	+
69	*Embelia pulchella*	Myrsinaceae	epiphyte & vine	+	-
70	*Embelia ribes*	Myrsinaceae	epiphyte & vine	+	+
71	*Entada phaseoloides*	Leguminosae	epiphyte & vine	+	-
72	*Epigynum auritum*	Apocynaceae	epiphyte & vine	+	-
73	*Epipremnum pinnatum*	Araceae	epiphyte & vine	+	-
74	*Epithema carnosum*	Gesneriaceae	epiphyte & vine	+	-
75	*Euonymus fortunei*	Celastraceae	epiphyte & vine	-	+
76	*Euonymus vagans*	Celastraceae	epiphyte & vine	-	+
77	*Ficus hederacea*	Moraceae	epiphyte & vine	+	+
78	*Fissistigma polyanthoides*	Annonaceae	epiphyte & vine	+	-
79	*Fissistigma sp.*	Annonaceae	epiphyte & vine	-	+
80	*Flemingia fluminalis*	Papilionaceae	epiphyte & vine	+	+
81	*Garcinia sp.*	Guttiferae	epiphyte & vine	-	+
82	*Garrettia siamensis*	Verbenaceae	epiphyte & vine	+	-
83	*Gelsemiun elegans*	Loganniaceae	epiphyte & vine	+	+
84	*Gesneriaceae sp.*	Gesneriaceae	epiphyte & vine	+	+
85	*Gnetum montanum*	Gnetaceae	epiphyte & vine	+	-
86	*Gynostemma pentaphylla*	Cucurbitaceae	epiphyte & vine	+	+
87	*Hedera rhombea*	Araliaceae	epiphyte & vine	-	+
88	*Hoya lantsangensis*	Asclepiadaceae	epiphyte & vine	+	+
89	*Illigera nervosa*	Hernandiaceae	epiphyte & vine	-	+
90	*Jasminum sp.*	Oleaceae	epiphyte & vine	+	+
91	*Lepisorus sp.*	Polypodiaceae	epiphyte & vine	+	+
92	*Lindera monghaiensis*	Lauraceae	epiphyte & vine	+	-
93	*Liparis sp.*	Orchidaceae	epiphyte & vine	+	+
94	*Liparis viridiflora*	Orchidaceae	epiphyte & vine	+	+
95	*Liparis yunnanensis*	Orchidaceae	epiphyte & vine	+	-
96	*Loeseneriella sp.*	Hippocrateaceae	epiphyte & vine	+	-
97	*Lycopodium serratum*	Lycopodiaceae	epiphyte & vine	-	+
98	*Lygodium flexuosum*	Lygodiaceae	epiphyte & vine	+	-
99	*Lygodium japonicum*	Lygodiaceae	epiphyte & vine	+	+
100	*Lygodium polystachyum*	Lygodiaceae	epiphyte & vine	+	+
101	*Magnoliaceae sp.*	Magnoliaceae	epiphyte & vine	+	-
102	*Melodinus henryi*	Apocynaceae	epiphyte & vine	+	-
103	*Menisperma sp.*	Menispermaceae	epiphyte & vine	+	-
104	*Millettia dielsiana*	Leguminosae	epiphyte & vine	+	+
105	*Millettia lantsangensis*	Leguminosae	epiphyte & vine	+	-
106	*Millettia sp.*	Leguminosae	epiphyte & vine	+	-
107	*Mucuna interrupta*	Leguminosae	epiphyte & vine	+	-
108	*Oberonia iridifolia*	Orchidaceae	epiphyte & vine	+	+
109	*Ophiorrhiza austro-yunnanensis*	Rubiaceae	epiphyte & vine	+	-
110	*Orchidaceae sp.*	Orchidaceae	epiphyte & vine	+	+
111	*Paederia scandens*	Rubiaceae	epiphyte & vine	+	+

Appendix III Continued (18)

112	*Palhinhaea cernua*	Lycopodiaceae	epiphyte & vine	+	-
113	*Passiflora caerulea*	Passifloraceae	epiphyte & vine	+	+
114	*Peperomia dindygulensis*	Piperaceae	epiphyte & vine	+	-
115	*Peperomia heyneana*	Piperaceae	epiphyte & vine	+	+
116	*Peperomia pallucida*	Piperaceae	epiphyte & vine	+	+
117	*Peperomia tetraphylla*	Piperaceae	epiphyte & vine	+	+
118	*Pericampylus sp.*	Menispermaceae	epiphyte & vine	+	+
119	*Pharbitis discifera*	Convolvulaceae	epiphyte & vine	+	-
120	*Pharbitis spectabilis*	Convolvulaceae	epiphyte & vine	+	-
121	*Phylacium sp.*	Papilionaceae	epiphyte & vine	+	+
122	*Piper sp.*	Piperaceae	epiphyte & vine	+	+
123	*Pothos chinensis*	Araceae	epiphyte & vine	+	+
124	*Pothos scandens*	Araceae	epiphyte & vine	+	+
125	*Premna sp.*	Verbenaceae	epiphyte & vine	+	-
126	*Pseudodrynaria coronans*	Drynariaceae	epiphyte & vine	+	+
127	*Pueraria alopecuroides*	Papilionaceae	epiphyte & vine	+	+
128	*Pueraria lobata*	Papilionaceae	epiphyte & vine	+	-
129	*Pueraria phaseoloides*	Leguminosae	epiphyte & vine	+	+
130	*Pyrrosia adnascens*	Polypodiaceae	epiphyte & vine	+	+
131	*Pyrrosia subfurfuracea*	Polypodiaceae	epiphyte & vine	+	+
132	*Pyrrosla sp.*	Polypodiaceae	epiphyte & vine	-	+
133	*Remusatia sp.*	Araceae	epiphyte & vine	+	-
134	*Rhaphidophora hongkongensis*	Lamiaceae	epiphyte & vine	+	-
135	*Rourea microphylia*	Anacardiaceae	epiphyte & vine	+	+
136	*Sageretia hamosa var. trichoclada*	Rhamnaceae	epiphyte & vine	+	-
137	*Salacia polysperma*	Hippocrateaceae	epiphyte & vine	+	+
138	*Schefflera fengii*	Araliaceae	epiphyte & vine	-	+
139	*Scurrula chingii var. yunnanensis*	Loranthaceae	epiphyte & vine	+	+
140	*Scurrula sp.*	Loranthaceae	epiphyte & vine	+	+
141	*Shuteria vestifa*	Leguminosae	epiphyte & vine	+	+
142	*Smilax bockii*	Smilacaceae	epiphyte & vine	-	+
143	*Smilax corbularia*	Smilacaceae	epiphyte & vine	+	+
144	*Smilax hayatae*	Smilacaceae	epiphyte & vine	-	+
145	*Smilax hypoglauca*	Smilacaceae	epiphyte & vine	+	+
146	*Smilax indica*	Smilacaceae	epiphyte & vine	+	+
147	*Smilax ocreata*	Smilacaceae	epiphyte & vine	+	+
148	*Smilax perfoliata*	Smilacaceae	epiphyte & vine	-	+
149	*Smilax sp.*	Smilacaceae	epiphyte & vine	+	+
150	*Spatholobus varians*	Leguminosae	epiphyte & vine	+	-
151	*Stemona tuberosa*	Stemonaceae	epiphyte & vine	+	+
152	*Stephania cepharantha*	Menispermaceae	epiphyte & vine	+	-
153	*Stephania delavayi*	Menispermaceae	epiphyte & vine	+	+
154	*Tetrastigma formosanum*	Vitaceae	epiphyte & vine	-	+
155	*Tetrastigma planicaule*	Vitaceae	epiphyte & vine	+	-

Appendix III Continued (19)

156	*Thladiantha cordifolia*	Cucurbitaceae	epiphyte & vine	+	-
157	*Thunbergia coccinea*	Acanthaceae	epiphyte & vine	+	-
158	*Thunbergia fragrans*	Acanthaceae	epiphyte & vine	+	+
159	*Thunbergia sp.*	Acanthaceae	epiphyte & vine	+	+
160	*Toddalia asiatica*	Rutaceae	epiphyte & vine	+	-
161	*Trevesia palmata*	Araliaceae	epiphyte & vine	+	-
162	*Trichosanthes sp.*	Cucurbitaceae	epiphyte & vine	+	+
163	*Tylophora atrofolliculata*	Asclepidaceae	epiphyte & vine	+	+
164	*Vanda clenisoniana*	Orchidaceae	epiphyte & vine	+	+
165	*Vanda coerulescens*	Orchidaceae	epiphyte & vine	+	+
166	*Vanda sp.*	Orchidaceae	epiphyte & vine	+	+
167	*Vanda tere*	Orchidaceae	epiphyte & vine	+	+
168	*Vandopsis gigantea*	Orchidaceae	epiphyte & vine	+	+
169	*Viscum articulatum*	Loranthaceae	epiphyte & vine	+	+
170	*Vitis piasezkii*	Vitaceae	epiphyte & vine	-	+
171	*Whitfordiodendron filipes*	Papilionaceae	epiphyte & vine	-	+
172	*Zehneria sp.*	Cucurbitaceae	epiphyte & vine	+	-
173	*Zeuxine sp.*	Orchidaceae	epiphyte & vine	+	+