BIODIVERSITY AND ETHNOGRAPHY OF TEA MANAGEMENT SYSTEMS IN YUNNAN, CHINA

by

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ABSTRACT

This study investigates biodiversity and cultural practices associated with tea (*Camellia sinensis* (L.) O. Kuntze; Theaceae) management systems in Yunnan Province of southwestern China. Surveys were conducted in smallholder communities of six sociolinguistic groups (Akha, Bulang, Han, Hmong, Lahu, and Yao) that manage tea resources in forests, agro-forests, mixed crop fields, and terrace gardens. Interviews were carried out between 2006 – 2010 to identify the influence of socio-economic and policy variables on tea production and consumption patterns. Ecological plot sampling and ethnobotanical inventories were employed to characterize the composition, structure, and uses of tea management systems. Tea leaf samples were randomly selected within each plot for: (1) video morphometrics to measure six shape and size attributes, (2) high performance liquid chromatography (HPLC) to quantify nine catechin and methylxanthine compounds and, (3) amplified fragment length polymorphisms (AFLP) molecular marker analysis to assess genetic diversity. Results indicate a relationship between the perceived value of a commodity and a change of management practices, ecological knowledge, and land use. Findings demonstrate how variable management practices result in the loss, conservation, or enhancement of plant species richness and genetic diversity, and how smallholders variably benefit from diversity in their agro-ecosystems. Plant species richness was found in the order agro-forest edge > forest > agro-forest > mixed crop field > terrace gardens. Statistically significant variation was found in morphological, phytochemical, and genetic characters between the different types of tea management systems. Morphological diversity was found in the order agro-forest > mixed crop field > forest > terrace gardens, whereas genetic diversity was found in the order mixed crop field > agro-forest > forest > terrace gardens. HPLC data show that tea samples from agro-forests and mixed crop fields had greater mean Total Catechin Content (TCC) and mean Total Methylxanthine Content (TMC) compared to forests and terrace gardens. Results further demonstrate that management, processing, and preparation methods are related to the phytochemical profile, anti-oxidant activity, and flavor of tea. This study provides useful baseline data to examine long-term change linked to expanded market integration and an engagement of ecosystem ecology with anthropology.

To my late grandfather, Haroon Ibn Ali,

for inspiring exploration.

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INTRODUCTION

There are many ways in which humans interact with the environment to cultivate useful plants. Human-environment interactions can result in the enhancement, conservation, or loss of biodiversity. The present study investigates human-environment interactions associated with tea (*Camellia sinensis* (L.) O. Kuntze; Theaceae) production in Yunnan Province of southwestern China. Yunnan encompasses the center of diversity and domestication of the tea plant (Chen and Pei 2003), where twelve wild relatives (section *Thea* of *Camellia*) and hundreds of landraces and cultivars are found (Xiao and Li 2002; Long et al. 2003; Ming and Zhang 1996). The Akha, Bulang, Lahu, and Yao, among other socio-linguistic groups, have managed tea in forests and agro-ecosystems in the uplands of Yunnan for hundreds of years or more. The extensive management and utilization history of tea resources in Yunnan, coupled with socio-economic and political change, provides a compelling case study to assess biodiversity and cultural practices. Tea production further provides a relevant case study because of tea's widespread role in global diets as a source of flavonoids with potential benefits to human wellbeing.

BIODIVERSITY AND AGRICULTURE

Biodiversity is broadly defined as the variability among living organisms and the ecological complexes of which they are a part. Some researchers define biodiversity as synonymous with species richness, or the total number of species in a defined space at a given time, and relative species abundance (Hubbel 2001). Biodiversity is fundamental to sustaining life on earth by providing numerous environmental services (Millenium

Ecosystem Assessment 2005; Magurran 2003). For example, biodiversity contributes to nutrient cycling, soil protection, pollination, flood control, and genetic resources. Numerous studies have noted the role of biodiversity in maintaining ecosystems and strengthening their resilience in responding to natural and anthropogenic change (Gunderson and Holling 2001; Walker 1995; Steffen et al. 1996; Chapin et al. 1997; Tilman 1996, 1997 and 1999; Stone et al. 1996).

Biodiversity in agricultural ecosystems is important for the resilience and productivity of farms and farmer livelihoods (Convention on Biological Diversity 2000). Agricultural biodiversity is the product of natural and human selection through interactions among the environment, genetic resources, and farmer management practices. The Conference of the Parties (COP) to the Convention of Biodiversity (CBD) define agricultural biodiversity as "all components of biological diversity of relevance to food and agriculture, and all components of biological diversity that constitute the agricultural ecosystems, also named agro-ecosystems: the variety and variability of animals, plants and micro-organisms, at the genetic, species and ecosystem levels, which are necessary to sustain key functions of the agro-ecosystem, its structure and processes,". The CBD acknowledges the distinct cultural dimensions of agricultural biodiversity that set it apart from other components of biodiversity including human activities and management practices, participatory processes, and local knowledge.

The CBD further notes the challenges of agriculture in relation with biodiversity. This includes the challenge of increasing agricultural production to meet the needs of a growing population on the one hand, while sustaining the biodiversity necessary for agricultural production on the other. Agriculture has contributed to increased food and livelihood security, and to the conservation of biodiversity. Concurrently, agriculture is identified as a major driver of biodiversity loss through land-use conversion, intensification of production, excessive water use, chemical input, and introduction of non-native species.

Given the essential function of agricultural biodiversity to satisfy human needs for food and livelihood security, farmers have been recognized as having vested interest in ways to manage the biodiversity of their agro-ecosystems including its conservation and sustainable use (Jarvis et al. 2007). A growing body of evidence suggests that smallholder agro-ecosystems are valuable models for the conservation of biodiversity (Brush and Meng 1998; Schroth et al. 2004; Peng 2000). Numerous studies have found that agro-forests, home gardens, and other smallholder production systems contribute to environmental services, plant species conservation, economic risk reduction, food security, and human health (Padoch and Peters 1993; Potvin et al. 2005; Moguel et al. 1999; Belcher et al. 2005; Zimmerer and Douches 1991; Harlan 1975; Jose 2009). However, political, economic, and social dynamics are altering human-environment relationships. These local and global processes are placing pressures on smallholder agrarian systems (Koohafkan 2002) and on associated biodiversity across the globe, some of which is unknown. Understanding the causes and consequences of the loss of species abundance is of central importance in conservation biology (Hubbell 2001).

Interdisciplinary case-study research is needed to evaluate the multiple dimensions of biodiversity associated with various modes of agricultural production and related forest resources, identify factors that influence biodiversity, and document how production systems are responding to political, economic, and social change. Comparative, quantitative case-study data is especially necessary to refute or support patterns identified in the literature regarding the conservation, promotion, or loss of biodiversity resulting from variable modes of production. This research should document the knowledge, cultural practices, and participatory processes that farmers have employed in order to enhance the resilience and productivity of their farms. Such data is valuable to monitor biodiversity and may provide lessons towards improved agricultural production on a global scale. It may also be valuable to inform the integration and management of the agricultural systems in conservation policy. Biodiversity conservation in agrarian landscapes is particularly germane given that over one third of the earth's surface is dedicated to agricultural activities, and that this area is expected increase to fulfill the caloric needs of a growing population. Tilman et al. (2001) project one billion hectares of ecosystems will transform into modern agricultural landscapes by 2050.

PROJECT DESCRIPTION

This study explores the multiple dimensions of biodiversity associated with smallholder tea (*Camellia sinensis* (L.) O. Kuntze; Theaceae) management systems in southern Yunnan, China and their responses to socio-economic and political influence. I conducted research in four types of tea management systems, including forest populations, agro-forests, mixed crop fields, and terrace gardens. I employed an ethnobiological approach that integrates social and natural sciences research methods across cultural, socio-economic, and environmental dimensions.

Forest tea includes tea trees that are wild, sparsely planted in forests, or those once cultivated and have become feral. Tea trees may grow to 15m or higher and live for over one hundred years in a forest environment (Xiao and Li 2002). Tea agro-forests and mixed crop fields are referred to in Yunnan as "ancient forest tea gardens" / *gushu cha yuen*). Tea agro-forests are forest areas thinned for tea cultivation or swidden areas where plants are regenerated. Tea trees in agro-forests are generally pruned to spread their branching formation and are maintained between 2 to 8 m. Farmers manage tea agro-forests to maintain a multi-storied vegetative structure, i.e. high canopy level, mid-level tree layer and herbaceous ground layer (Long and Wang 1996). The vegetative structure and composition of these systems mimic some of the environmental services provided by forests including soil fertility, watershed, and pests and disease control (Jose 2009; Schroth et al. 2004; Montagnini 2006). Mixed crop tea fields are created in tea agro-forests by replacing associated woody plants with grain production. Tea trees are pruned to increase sun exposure for heightened yields. In contrast, terrace tea (*taidi cha /* "tableland tea") gardens are open fields most often managed for uniformity, high-yield, and efficiency where tea plants are cultivated in compact rows and pruned to waist-high shrubs. This management model usually relies on input of agrochemicals.

Study Area

Research was carried out in Xishuangbanna, Lincang, and Honge Prefectures of southern Yunnan Province, southwestern China (Figure 1). Yunnan was selected as a study site for examining tea management systems because it encompasses the center of diversity and domestication of tea resources. Yunnan's extraordinary biodiversity is threatened by dramatic economic and political change (Fox 2009). The province is home to twenty-six state-designated socio-linguistic groups and at least 18,000 vascular plant species (Li and Walker 1986). It includes two global biodiversity hotspots (Dijk et al. 1999), the Indo-Burma and Mountains of Southwest China hotspots, and is located between two Vavilov centers of crop domestication (Turrill 1926). Yunnan is notable as an ancient crossroads of migration and regional trade between Southeast Asia, India and Tibet (Yang 2004). It is also part of the Southeast Asian region termed *Zomia* (Schendel 2001) that is characterized by highland cultures that historically fled state organized societies and maintained deliberate stateless structures (Scott 2009).

A large portion of Yunnan's population is composed of rural households that rely on the biodiversity of their surroundings for food, fodder, medicine, and other natural resources. Traditional livelihoods and land use are increasingly vulnerable to rapid development driven by globalization of natural resource markets, policy reforms, agricultural intensification, and infrastructure development (Fox 2009). Over the past five decades, vast areas of southern Yunnan's sub-tropical forests and traditional agriculture have been transformed into monocultures of native and non-native cash crops such as tea (*Camellia sinensis*, Theaceae) and rubber (*Hevea brasiliensis*, Euphorbiaceae) as rural

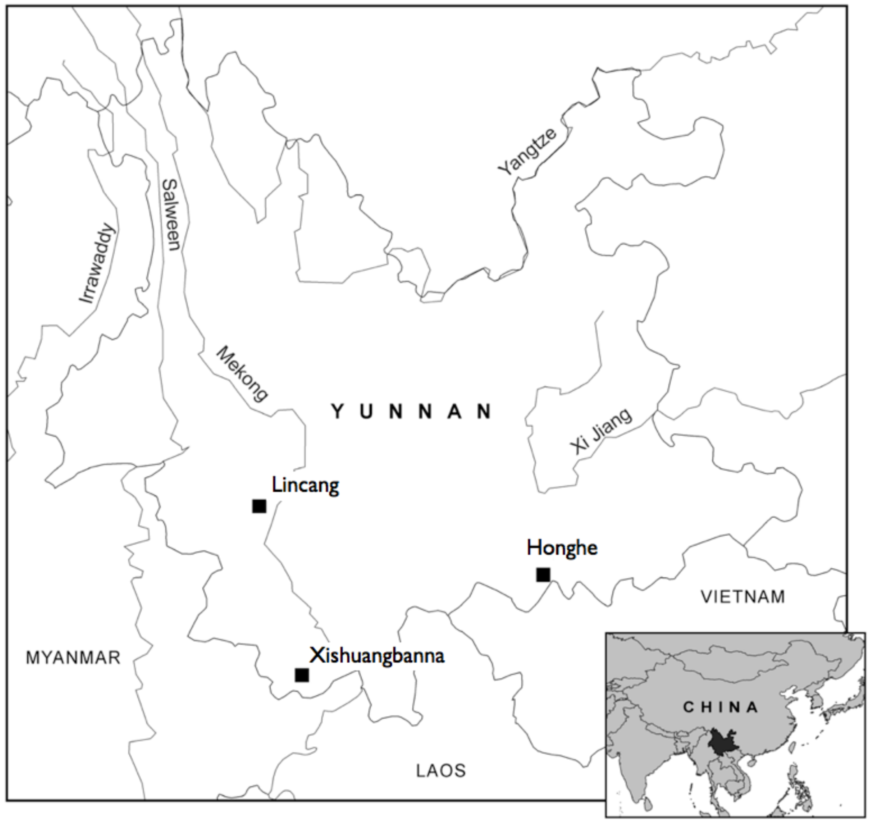


Figure 1.1 Map of study sites in Xishuangbanna, Lincang, and Honge Prefectures of southern Yunnan Province, southwestern China.

households increasingly participate in global trade (Zeigler et al. 2009).

The proliferation of monocultures in Yunnan has been driven by expanding markets for cash crops coinciding with the opening of China's economy and national development efforts emphasizing modern modes of production. Rubber plantations alone have replaced approximately 500,000 ha of forest and traditional smallholder agro-ecosystems in southern Yunnan and neighboring Southeast Asia over the past five decades (Zeigler et al. 2009). Intensified land use in this region is expected to increase to 1.0 - 1.5 million ha by 2050 (Zeigler et al. 2009). These major land-cover and land-use changes have notable consequences for climate change, biodiversity, and ecosystem services (Fox 2009). The ability of biotic resources in this area to sustain human needs may thus be in compromise. Meeting the challenge of balancing land-use practices for biodiversity conservation, livelihoods and agriculture requires effective ways of measuring biodiversity and understanding interactions between biological and socio-economic dynamics.

Objectives, Research Questions, and Hypotheses

The objectives of this study were to:

(1) Compare multiple dimensions of biodiversity associated with various tea management systems, including forests, agro-forests, mixed crop field, and terrace gardens. Identify the underlying elements that influence the loss, conservation, or enhancement of this diversity. Diversity will be assessed at the floristic, morphological, phytochemical, and genetic levels.

(2) Examine the interactions between smallholder tea management practices and market integration, consumption patterns, policy, and socio-economic dynamics.

The research questions of this study at the field sites in Yunnan were:

(1) How does biodiversity associated with various tea management systems (forests, agro-forests, mixed crop fields, and terrace gardens) vary at the floristic, morphological, phytochemical, and genetic levels?

(2) How are practices, knowledge, and decision-making associated with tea management systems responding to consumption patterns, policy, and socio-economic change?

The hypotheses of this study were:

(1) Yunnan's increased market integration, agricultural expansion, and development policy have influenced tea management systems through a decline of: (i) plant species richness and evenness, (ii) complexity of vegetative structure, (iii) morphological, phytochemical, and genetic diversity and, (iv) ecological knowledge of tea varieties.

(2) Increased market demand of tea from "ancient tea gardens" (agro-forests and mixed crop fields) has resulted in their increased valuation in livelihoods and land use, and to expanded area dedicated to tea production.

Study Overview

A total of 14 months of fieldwork were conducted in Yunnan Province, China. Permits for fieldwork in Yunnan were provided by the Kunming Institute of Botany, Chinese Academy of Sciences. The Graduate Center IRB of the City University of New York granted approval for the participation of human subjects in this study (IRB # 07-04-1258). Permits for field interviews and plant inventories in Yunnan were granted by the Kunming Institute of Botany of the Chinese Academy of Sciences.

Fieldwork consisted of 12 months of surveys in tea production communities and markets. This research focused on documenting biodiversity and cultural practices associated with tea management systems of Akha, Lahu, Yao, Yi, Hmong and Han socio-linguistic groups. Tea market surveys assessed consumption patterns and commodity chains. Based on preliminary survey findings, further research was conducted in an Akha upland community in Xishuangbanna Prefecture that manages tea plants in agro-forests.

This fieldwork focused on assessing the impact of market demands and socio-economic and political change on land use values, decision-making, and ecological knowledge.

An additional two months of fieldwork was carried out in Tibetan communities in northwest Yunnan where tea was historically relied on in medical and dietary systems. This component of the project sought to assess the influence of expanded markets of tea in southern Yunnan on exchange and consumption patterns in Northern Yunnan. It further sought to understand local perceptions of the relationship of tea consumption to community health. Fieldwork for this study was grounded in the disciplines of ecology, botany, and cultural anthropology. Methodologies used included plot sampling, ethnobotanical inventories, plant morphology, participant observation, questionnaires, semi-structured and unstructured interviews, 24-hour food recall surveys, and community mapping.

Interviews were conducted with the assistance of field scientists from the Kunming Institute of Botany that translated from Mandarin to English. Field assistants were selected on the basis of their field research experience, training in anthropology and ethnobotany methods, and their proficiency in English. In addition, community members at each study site assisted with translating from the language of the study site to Mandarin.

A total of 16 months of laboratory work was conducted to characterize the phytochemical profiles and genetic diversity of tea leaf samples collected from fieldwork.

Phytochemical analysis consisted of identification of catechin and methylxanthine compounds using high performance liquid chromatography (HPLC) and measurement of antioxidant activity through a reagent-based assay. Genetic diversity of tea leaf samples was assessed using amplified fragment length polymorphism (AFLP) molecular markers. Data was organized in spreadsheets and statistically analyzed.

Study Presentation and Chapter Overview

This study is presented in three main parts. Part I sets the context for subsequent chapters. It is composed of three chapters that provide a literature review on biological, social, and theoretical context of the study. Chapter One gives background on tea botany, genetic diversity, and chemistry. Chapter Two introduces the socio-ecological context of the study setting in Yunnan. Chapter Three reviews the theoretical context that informed the research design. The subsequent chapters present the original research of this study.

Part II explores the practices and multiple dimensions of biodiversity of tea management systems. It starts with an examination of the natural resource management practices of tea production systems in Chapter Four. Chapter Five investigates the floristic diversity of tea agro-ecosystems through ecological and ethnobotanical sampling approaches. Chapter Six measures the diversity of tea based on morphological, phytochemical, and genetic variation.

Part III focuses on the dynamic markets, land use, and consumption patterns associated with tea. It starts in Chapter Seven with an exploration of the pu-erh tea market in Yunnan in order to understand how social constructs and demand of "ecological" pu-erh influence production systems. Chapter Eight investigates how market expansion of tea resources influences decision-making, ecological knowledge of tea varieties, and the place of tea agro-forests in the land use of an Akha community. Chapter Nine examines the practice of tea tasting in Yunnan in order to understand the relationship between sensory perceptions, phytochemical composition, and antioxidant activity. Chapter Ten surveys the persistence of traditional tea consumption systems in rural Tibetan communities in northern Yunnan. It further investigates perceptions on the relationship of food intake with community health. A synthesis of findings and implications for conservation, agriculture, and human health is presented in the Conclusions. This work concludes with recommendations for future studies and research questions arising from this study.

PART I

BACKGROUND

The following three chapters provide a literature review on the biological, social, and theoretical context of the study. Chapter One provides background on tea botany, genetics and chemistry. Chapter Two introduces the socio-ecological context of the study setting in Yunnan. Chapter Three reviews the theoretical context that informed the research design. This context provides a foundation for the original research chapters in Part Two and Part Three.

Chapter One

REVIEW OF TEA BOTANY, GENETIC DIVERSITY, AND CHEMISTRY

TEA BOTANICAL PROFILE

The tea plant was first taxonomically described in 1753 in Linnaeus's *Species Plantarum* where it was referred to as *Thea sinensis*. Linnaeus later distinguished the species into black tea (*Thea bohea*) and green tea (*Thea viridis*). By the early 1900s, taxonomists recognized that black tea and green tea are from the same species, *Camellia sinensis* (L.) O. Kuntze (Theaceae).

Theaceae

The Theaceae (Mirb. ex Ker Gawl.) is part of the order Ericales (Bercht. & J.Presl) in the Asterid branch of eudicots (Angiosperm Phylogeny Group III 2009). This family includes approximately 600 species grouped into seven to forty genera, depending on the taxonomic circumscription, that are distributed in tropical and subtropical Asia, Africa, southeast North America, and the Pacific Islands (Cronquist 1981; Takhtajan 1997; Tsou 1998). The greatest diversity of Theaceae species is found in tropical and subtropical South China and adjacent South East Asia (Min and Bartholomew 2010).

Members of the Theaceae are generally evergreen trees or shrubs that are occasionally deciduous. They are usually bisexual, lack stipules, and have simple, glossy, and serrated leaves that are alternate, spiral, or distichious. Their flowers are generally large, showy, solitary or in clusters or racemes, and axillary or subterminal (Prince and Parks 2001). Their corolla is white, red, or yellow. They have numerous stamens in one to six whorls. Seeds are globose, semiglobose, compressed oblong, ovoid, or reniform. They can be winged or wingless. The characteristics used to identify Theaceae are not unique to the family and are likely to be pleisiomorphic. Similar features can be found in the Actinidiacea, Symplocaceae, and Tetrameristaceae including the spiral arrangement of perianth parts, series of numerous stamens, and involucral bracts that often grade into sepals. The only autapomorphy determined for the Theaceae is a specialized pseudopollen (Tsou 1998).

Camellia sinensis: Varieties and Distribution

Camellia sinensis is an evergreen tree or shrub. It has yellow-white flowers and long serrated leaves. Flowers are axillary, solitary, or up to three in a cluster. They are 2.5-3.5 cm in diameter and have six to eight petals. The outer petals are sepaloid and the inner petals are obovate to broadly obovate. There are numerous stamens 0.8-1.3 cm in length. Young leaves have short white hairs on their underside and young branches are grayish yellow and glabrous. Current year branchlets are purplish red. Terminal buds are silvery gray and sericeous. Petioles are 4-7 mm in length, pubescent, and glabrescent. Leaf blades are elliptic, oblong-elliptic, or oblong. Seeds are brown, subglobose, and 1-1.4 cm in diameter. Flowering of *C. sinensis* occurs from October through February and fruiting occurs from August to October (Min and Bartholomew 2010).

There are four varieties of *C. sinensis* including C. *sinensis* var. *assamica*, C. *sinensis* var. *sinensis*, C. *sinensis* var. *dehungensis*, and C. *sinensis* var. *pubilimba.* Commercial tea is most often produced from *C. sinensis* var. *assamica*, or the broad-leaf variety of the tea plant, and *C. sinensis* var. *sinensis*, or the small-leaf variety of the tea plant. Both these species are found in wild and cultivated systems. Individuals of *C. sinensis* var. *assamica* are characterized as quickly growing plants suitable for warm tropical environments whereas *C. sinensis* var. *sinensis* is more suitable for colder climates (Banerjee 1992). Individuals of *C. sinensis* var. *assamica* grow as either tree or bush forms and *C. sinensis* var. *sinensis* individuals grow as shrubs or dwarf plant forms. Plants of *C. sinensis* var. *assamica* generally grow into a tree if left undisturbed. Differentiation between the two commercial *C. sinensis* varieties is further defined by *matK* and *rbcL* nucleotide sequence polymorphisms of the chloroplast locus (Katoh et al. 2003).

C. sinensis is distributed in evergreen broad-leaved forests at altitudes from 100 - 2,200 m. It grows in a range of soils and climates worldwide. The native tea growing area, posited here as the "tea belt", encompasses southwestern China (Yunnan, Sichuan, Guangxi and Guizhou provinces), northern Laos, northern Vietnam, Myanmar, Cambodia, and northeastern India. The natural habitat of the tea plant is in the undergrowth of tropical and subtropical forests. Outside of the tea belt, the tea plant is primarily found in terraced landscapes, but some tea is found growing in forests in eastern China (Anhui, Fujian, Guangdong, Hainan, Henan, Hubei, Hunan, Jiangsu, Jiangxi, Shaanxi, and Zhejiang Provinces), Japan, southern Korea, Thailand, and Taiwan. Tea has been introduced for cultivation in tropical and subtropical regions globally that receive at least 127 cm (50 inches) of rainfall a year including Sri Lanka, Indonesia, central Africa, Turkey, and Argentina. It is considered to grow favorably in areas where annual average temperatures range between 18-20 ˚C and do not drop below 12 ˚C or exceed 30 ˚C (Williges 2004).

The center of diversity of *C. sinensis* is in the Upper Mekong River Region of Yunnan Province (Chen and Pei 2003; Chen et al. 2005). The Mekong River has played a pivotal function in the dispersal of tea seeds from the Yunnan-Guizhou Plateau towards Southeast Asia. This waterway passes through the Indo-Burma and the Mountains of Southwest China hotspots of biodiversity. Along with natural dispersal, various socio-linguistic groups have journeyed and migrated along the Mekong River, carrying tea seeds and associated cultural knowledge and practices. The Yunnan-Guizhou Plateau is also the center of differentiation of the two main commercial *C. sinensis* varieties. South of 25 degrees north in the Yunnan-Guizhou Plateau, *C. sinensis* differentiated as *C. sinensis* var. *assamica*, while in the north it differentiated as *C. sinensis* var. *sinensis*. The broad-leaf variety is prevalent across the tea belt while the small-leaf variety prevails in Eastern China, Taiwan, Japan, India's Darjeeling, and tea-growing countries outside of Asia (Ming 1992).

The biogeographic distribution of the *C. sinensis* varieties is a function of adaptation and cultivation history. As the practice of tea cultivation spread from southwestern China to eastern China, Taiwan, and Japan, *C. sinensis* var. *sinensis* was the selected introduced variety due to its suitability to the colder and non-tropical environment (Banerjee 1992). Tea drinkers' preference also influenced this cultivation pattern. *C. sinensis* var. *sinensis* has a sweeter taste than *C. sinensis* var. *assamica*. It was generally chosen for cultivation in eastern China, Taiwan, and Japan to produce green and whites teas as well as in India's Darjeeling region to produce delicate black teas. *C. sinensis* var. *assamica* is generally used in western China, Myanmar, and Assam in making black, green, and pu-erh teas. However, both varieties can be used to produce green, black, white, yellow, red and pu-erh teas and both varieties can be found across these regions. Hybridization occurs where the *C. sinensis* varieties overlap. Wild and cultivated tea is highly heterogeneous in terms of taste, morphological, phytochemical, and genetic variation (Takeda 1990). Its extensive cultivation has made it difficult to determine whether specific *C. sinensis* individuals are wild, cultivated, or escaped. There are hundreds of tea cultivars developed by introgression and there are considered to be few "pure" *C. sinensis* var. *assamica* or *C. sinensis* var. *sinensis* individuals in cultivated systems.

The distribution and naming of *C. sinensis* var. *assamica* and *C. sinensis* var. *sinensis* is linked to British relationships with China and India. Tea became popular with Europeans after their arrival in Eastern China in the 17^{th} century. At that time China was the global supplier of tea and the Dutch and East India Companies monopolized its shipping and distribution to Europe. The British looked for alternative sources of tea and when Chinese tea became inaccessible during the Opium wars in the mid 19^{th} century, they were forced to find other sources of tea to fulfill demand.

While India historically did not commercially produce tea, Scottish major Robert Bruce observed indigenous communities of Assam in 1823 preparing tea from a local plant resembling *C. sinensis*. He collected samples for identification and experimentation at the Calcutta Botanical Gardens. In 1831, Lieutenant Charlton also observed indigenous communities of Assam preparing tea from a local plant resembling *C. sinensis*. Several years later in 1834, Robert Bruce's brother, Charles Alexandra Bruce, was able to have the tea from Assam identified as *C. sinensis.* The tea plants from Assam were distinguished from tea plants collected from eastern China as a separate variety, respectively termed *C. sinensis* var. *assamica* and *C. sinensis* var. *sinensis*. However, *C. sinensis* var. *assamica* was later found not to be limited to Assam but also growing in forests and traditional agro-ecosystems in southwestern China where its center of diversity has been identified, thus suggesting a China center of origin.

The British East India Company was active in exploring tea cultivation and processing in China so they could transfer tea germplasm and technology to India for commercial production (Murray 1852). In 1848, they sent the Scottish botanist Robert Fortune to smuggle and transport tea from China to India (Fortune 1853). Fortune used Wardian cases, transportable greenhouses invented by Nathaniel Bagshaw Ward, to transport 20,000 tea seeds and seedlings from eastern China to India's Darjeeling. The British East India Company also brought trained tea farmers and producers from China to India to transfer knowledge on tea cultivation and processing. Forest tracts were cleared across Darjeeling and Assam for tea plantations where both *C. sinensis* var. *assamica* and *C. sinensis* var. *sinensis* were cultivated.

The decision of which variety of tea to plant often depended on what was available, and in some cases the two varieties were intercropped. This resulted in hybrid tea with increased variability and suitability for certain environments as compared to pure varieties. However, *C. sinensis* var. *sinensis* plants were found to cope poorly in India's tropical areas of Assam whereas *C. sinensis* var. *assamica* had difficulty thriving in the cooler high-altitude areas of Darjeeling. Tea plants in Assam and Darjeeling were appropriately replaced on the basis of this realization of differing environmental suitability. While the introduced variety from China did not thrive in all regions in India, the knowledge and practices of tea cultivation that were transferred from China to India are responsible for spurring the tea industry in India.

Wild Tea (*Camellia*: Section *Thea*)

Wild tea refers to the closest relatives of cultivated *Camellia sinensis*, including wild *Camellia sinensis*, and other species in section *Thea* of *Camellia* (Theaceae; Long et al. 2003). *Camellia* encompasses around 100 species in subgenera *Camellia*, *Protocamellia*, *Thea*, and *Metacamellia* (Chang and Bartholomew 1984). Chang and Bartholomew's (1984) circumscription for the subgenus *Thea* consists of eight sections, including section *Thea* that has twelve species. Eleven of the twelve species of section *Thea* are distributed in the Yunnan-Guizhou Plateau with Yunnan being the center of diversity (Ming 1992; Ming and Zheng 1996; Chang and Bartholomew 1984; Ming 2000). All species are endemic to China (Table 1.1; Long et al. 2003).

Table 1.1 Species and distribution in Section *Thea* of *Camellia*. These species are regarded wild tea. This table is adapted from Long et al. 2003.

Species Name	Distribution Area	Altitude (m) and Habitat
C. costata	China: SE Guizhou, NW Guangdong, N and E Guangxi	700-1100, evergreen broadleaf forest
C. crassicolumna		
var. crassicolumna	China: SE Yunnan	1300-2300, evergreen broadleaf forest
var. multiplex	China: SE Yunnan	1900-2210, evergreen broadleaf forest
var. shangbaensis	China: S Yunnan	2450, evergreen broadleaf forest
C. fangchengensis	China: S Guangxi	320, evergreen broadleaf forest
C. grandibracteata	China: W Yunan	1750-1850, evergreen broadleaf forest
C. gymnogyma		
var. *gymnogyma*	China: SE Yunnan, SW Guangxi	1000-1600, broadleaf forest or scrub
var. *remotiserrata*	China: NE Yunnan, N Guizhou, S Sichuan	920-1350, China fir forest or broadleaf
C. kwangsiensis		
var. *kwangnanensis*	China: SE Yunnan	1550-1850, broadleaf
var. *kwangsiensis*	China: SE Yunnan, W Guangxi	1500-1900, broadleaf
C. leptophylla	China: S Guangxi	220-850, scrub
C. petilophylla	China: Guangdong, S Hunan	270-480, sparse forest or scrub
C. purpurea	China: SE Yunnan	1500-2200, evergreen broadleaf forest
C. sinensis		
var. *assamica*	China: Yunnan, Guizhou, Guangxi, Hainan; Vietnam; Laos; Thailand; Myanmar; NE India	100-1500, evergreen broadleaf forest
var. *dehungensis*	China: S Yunnan, SW Yunnan	1000-1600, under forest or scrub
var. *pubilimba*	China: SE Yunnan, W Guangxi, W Guangdong, Hainan	240-1450, broadleaf forest
var. *sinensis*	China: S China, SE Tibet; S Japan; N Myanmar	130-200, sparse forest or scrub
C. tachangensis	China: E Yunnan, SW Guizhou W Guangxi	1500-2250, evergreen broadleaf forest
C. taliensis	China: W Yunnan	1300-2700, sparse forest/scrub

Wild tea species vary in morphology, secondary metabolites, and use. Several wild tea species are used as food, beverages, and medicine in the uplands of southwest China and neighboring areas of Southeast Asia (Wachira et al. 1997; Zhen 2002). The wild tea species used to prepare tea beverages include *C. taliensis*, *C. grandibractiata*, *C. kwangsiensis*, *C. gymnogyna*, *C. crassicolumna*, *C. tachangensis*, *C. ptilophylla* and *C. irrawadiensis* (Wachira et al. 1997). Wild tea species are sometimes used instead of cultivated *C. sinensis* due to accessibility, personal taste preferences, and select medicinal properties. Some wild tea species have a more bitter taste than cultivated tea and offer different medicinal values. Further research is needed to understand people's knowledge, practices and classification of wild tea species and to evaluate the commercial development potential of these resources. *In situ* and *ex situ* conservation approaches are also necessary for the sustainability of wild tea species that face pressures of excessive harvesting (Long and Wang 1996).

Wild tea species are important sources of germplasm for tea agro-ecosystems. Introgression (Wilkes and Wilkes 1972) occurs relatively freely within members of genus *Camellia* through natural and horticultural processes (Wachira et al. 1997). Introgression can benefit cultivated species by providing the genetic base for increased yield, disease and drought resistance, and resilience (Tuxill and Nabhan 2001). The ease of inter-specific introgression within members of genus *Camellia* (Wachira et al. 1997) allows managers of tea resources to intentionally encourage introgression and exploit the wide range of germplasm of *Camellia* species. This has resulted in hundreds of tea landraces with unique phytogenetic traits. Yunnan in particular has high diversity of tea landraces because of genetic exchange and diversified management by various socio-linguistic groups, coupled with a geographic location that has variable landforms and microclimates (Zeng et al. 2001).

TEA GENETIC DIVERSITY

Notable variation occurs among cultivated and wild tea species. For example, Chen (2005) documented variable leaf, flower, caffeine and polyphenolic profiles among 87 accessions of *C. sinesis* var. *sinensis*, *C. sinensis var. assamica, C. sinensis var. dehungensis*, *C. talinensis*, and *C. crassicolumna*. However, most vegetative characteristics of the tea plant are influenced by environmental factors, and molecular techniques have proven beneficial to identify discrete groups and genetic variability among tea plants (Wickramaratne 1981; Wachira et al. 1995; Wachira et al. 1996; Wachira et al. 2001). For example, Paul et al. (1997) employed amplified fragment length polymorphism (AFLP) markers in tea to detect diversity and genetic differentiation of 32 clones of Chinese, Assam, and Cambod types growing in India and Kenya. They found that the Chinese types had the greatest diversity among sample groups and that Assam clones from India and Kenya clustered closely. Similarly, Balasaravanan et al's (2003) genetic diversity assessment among 49 tea cultivars from South India distinguished samples into Assam, China and Cambod tea types with the Chinese types showing the greatest genetic diversity. Additionally, they found greater genetic distance between Assam and Cambod types than between Assam and China types. Rajashekaran's (1997) AFLP analysis of 42 tea clones sourced from South India and Kenya revealed the success of AFLP for developing markers related to resistance against blister blight disease.

In some cases, selection for desirable traits of tea plants has led to genetic erosion in cultivated systems as represented by a decrease of heterozygosity compared to the nearest wild relatives (Kaundun and Matsumoto 2003). However, the heterozygosity (H) of some cultivated *C. sinensis* var. *assamica* populations have been found comparable to other wild tea species (Chen et al. 2005). These populations of *C. sinensis* var. *assamica* seem to be under human selection on the basis of their increased leaf area, plucking shoot weight, and caffeine and polyphenolic content compared to other cultivated and wild tea species (Chen et al. 2005). The varying outcomes in the literature on the influence of human selection on genetic diversity of tea resources warrants further study to understand the conditions under which each outcome holds. These findings would be useful to inform breeding and germplasm conservation programs (Chen et al. 2005).

PHYTOCHEMICAL CONSTITUENTS AND HEALTH-RELATED CLAIMS OF TEA

Tea is a globally significant source of dietary polyphenols, a group of phytochemicals that are inversely associated with the incidence of chronic disease (Bolling et al. 2009). Tea polyphenols comprise approximately 30% of dried leaf extract and include the flavonols, flavandiols, flavonoids, and phenolic acids (Lin et al. 2003). Catechins, a group of polyphenolic flavan-3-ol monomers and their gallate derivatives, are the primary polyphenols responsible for the health-related claims of unfermented tea (Zhen 2002) while the methylxanthine compound caffeine contributes to tea's stimulant properties. Caffeine and catechins are secondary metabolites that serve as defense compounds in plants. They provide protection against pathogens and predators (Ames et al. 1990), oxidative stress, and other environmental variables. Other compounds in unfermented tea include the methylxanthines theobromine and theophylline, amino acids and their derivatives such as theanine, proanthocyanidins, gallic acid, quinic esters of gallic, coumaric and caffeic acids, and free sugars (Del Rio et al. 2004).

Catechins are colorless compounds found throughout the plant kingdom, particularly in higher woody plants (Robinson 1991). They are products of the phenylpropanoid pathway that are derived from the amino acid L-phenylalanine via deamination by L-phenylalanine ammonia-lyase. There are three classes of catechins that are differentiated based on the number of hydroxyl groups in ring B: catechin, gallocatechin, and afzelechin. Catechin compounds have two chiral carbon atoms and four possible isomers (Robinson 1991). The major catechins in tea are (+)-catechin (C), (-)-epicatechin (EC), (-)-epigallocatechin (EGC), (-)-epicatechin 3-gallate (ECG), (-)-gallocatechin (GC), (-)-catechin 3-gallate (CG), and (-)-epigallocatechin 3-gallate (EGCG). Epigallocatechin 3-gallate (EGCG) is the most bioactive constituent in tea and has been the focus of research on its' potential health attributes (Moyers et al. 2004).

Variation occurs in the catechin level of tea depending on genetic, environmental, and processing factors. At the genetic level, three genes in the phenylpropanoid pathway regulate the synthesis of catechins: phenylalanine ammonia-lyase (PAL), chalcone synthase (CHS) and dihydroflavonol 4-reductase (DFR) (Kaundun and Matsumoto 2003). PAL is involved in initiating phenylpropanoid metabolism and linking primary and secondary metabolism by catalyzing the conversion of L-phenylalanaline into cinnamic acid, the first substrate of the phenylpropanoid pathway (Kaundun and Matsumoto 2003). CHS plays a pivotal role in the biosynthesis of flavonoid antimicrobial phytoalexins and anthocyanin pigments in plants (Ferrer et al. 1999). It is responsible for producing the aromatic ketone chalcone by condensing one *p*-coumaroyl- and three malonyl-coenzyme A thioesters into a polyketide reaction intermediate (Ferrer et al. 1999). Chalcones are key intermediaries in the biosynthesis of flavonoids that have antibacterial, antifungal, anti-tumor, and anti-inflammatory properties. DFR participates in the phenylpropanoid pathway before the synthesis of catechin. It plays a dominant role in the formation of anthocyanin-colored pigments and tannins (Johnson et al. 2001).

Catechins are recognized to serve as signal molecules in plant development and defense by protecting against microbial attack and infection (Dixon et al. 2002). Their amounts thus vary depending on environmental conditions (Chung et al. 1998) in addition to genetic factors and processing. A series of changes occur in tea's chemical composition during the processing from raw leaves to processed white, green, oolong, black, and pu-erh teas. Polyphenol content decreases approximately 15% during the processing of green tea that typically involves steaming, rolling, and drying of tea leaves (Chen 2002). Enzymes in the cytoplasm are released during the processing of black tea by crushing the leaves. This processing step initiates an oxidation process where the monomeric flavan-3-ols undergo polyphenol oxidase polymerization, thereby leading to oxidation of catechins and the formation the oxidized high molecular components bisflavanol, theaflavin and thearubigin (Zhen 2002). Statins, a class of fermentation-derived drugs used to reduce cholesterol, are further produced during the microbial fermentation process of certain post-fermented tea types, such as black pu-erh (Jeng et al. 2007).

Numerous studies have hypothesized an inverse relationship of tea consumption to the risk of various health conditions (Iwasaki et al. 2010). Many *in vitro* and animal studies have supported this hypothesis by demonstrating a range protective effects and cellular mechanisms of tea constituents that have anti-oxidative, anti-inflammatory, neuro-protective, anti-cancer, immune enhancing, anti-microbial, anti-viral, anti-diabetic, anti-estrogenic, and anti-atherosclerotic activities (Schneider and Segre 2009; Clement 2009; Zhen 2002; Lin et al. 2003; Finger et al. 1992; Cooper et al. 2005). In addition, studies suggest that these biological activities may be relevant in the prevention and treatment of various forms of autoimmune and cardiovascular diseases, bone and skin health, inflammation, oxidative stress, cancer, neurodegenerative condition, and the metabolic syndrome diabetes (Table 1.2 provides a list of references on the different health-related claims attributed to tea). Some of the chemoprotective mechanisms of action of tea catechins have been identified as: (1) inducting apoptosis in various cancer cell lines, (2) inhibiting metallo- and serine- proteases involved in tumor invasion and metastasis, (3) activating specific cell cycle inhibitors such as p21 and p27, (4) inhibiting transcription factor-activated protein 1 leading to cell growth inhibition, (5) degrading heterocyclic amines and preventing their damage to DNA and cancer initiation, (6) inhibiting angiogenesis in tumors by suppressing vascular endothelial growth factor transcription, (7) inducing CYP genes that destroy carcinogens, and (8) inhibiting the transcription factor nuclear factor-kappa B and thus inhibiting its activation by DNA-damaging agents (Moyers et al 2004; Hanson 2005).

Table 1.2 References for health-related claims attributed to tea (*C. sinensis*).

Health Condition	References
Atherosclerosis	Sueoka et al. 2001; Vinson 2000; Hirano-Ohmori et al. 2005; Lill et al. 2003; Tokunaga et al. 2002; Bursill et al. 2006
Autoimmune Diseases	Hsu 2006; Varilek et al. 2001
Bone Health	Vali et al. 2006
Cancer	Yang et al. 2009; Yang et al. 2002
Bladder Cancer	Chen et al. 2004
Breast Cancer	Shrubsole 2009; Rosengren 2003; Thangapazham et al. 2007
Cervical Cancer	Ahn 2003
Colorectal Cancer	Orner et al. 2003; Tamura et al. 2000
Esophageal Cancer	Hasan et al. 2000
Lung Cancer	Hasan and Nihal 2001; Fujimoto et al. 2002
Osteosarcoma	Roomi et al. 2005
Pancreatic Cancer	Takada et al. 2003
Prostate Cancer	Liao et al. 1995
Skin Cancer	Katiyar and Mukhtar 2001
Stomach Cancer	Hibasami et al. 1998
Leukemia	Lee at al. 2004
Candida albicans	Martinez et al. 2006
Diabetes	Waltner-Law et al.; McKay et al.; Koyama et al.; Anderson and Polansky 2002
Hair Loss	Esfandiar 2005
Human Immunodeficiency Virus	Nance and Shearer 2003
Inflammation	Cao et al. 2007
Inflammatory Bowel Disease	Matsuoka et al. 2002
Influenza Virus	Song et al. 2005
Iron-Overload	Srichairatanakool et al. 2006
Liver Disease	Kuo and Lin 2003
Obesity	Westerterp-Plantenga et al. 2005; Yung-His et al. 2000
Oxidative Stress	Ho et al. 1992
Neurodegenerative Diseases	Levites et al. 2001; Melzig et al. 2003
Skin Problems	Hsu et al. 2003

Despite the extensive research on tea, epidemiological and clinical studies examining the association between tea consumption and risk of chronic disease are inconclusive (Iwasaki et al. 2010; Shrubsole et al. 2009; Zhang et al. 2007; Wu et al. 2003; Inoue et al. 2008; Ogunleye et al. 2010). However, clinical studies have substantiated green tea extracts as the source of the only botanical prescription drug approved by the United States Food and Drug Administration (FDA) (Chen et al. 2008). This prescription drug is known as Veregen®, which is an ointment of catechin extracts, and is prescribed for topical treatment of genital and perianal warts (*Condylomata acuminata*) in immunocompetent patients (Tatti et al. 2008).

Chapter Two

HISTORICAL AND CULTURAL CONTEXT OF TEA PRODUCTION AND CONSUMPTION IN UPLAND YUNNAN

This chapter begins with a discussion of tea cultivation, utilization, and trade in historical perspective. It focuses on the role of tea as a key commodity in China's state-controlled trade and the expansion of tea cultivation for exchange with Tibetan communities. The geographical and cultural context of Yunnan is then reviewed with an emphasis on the upland socio-linguistic groups investigated in this study: the Akha, Bulang, Lahu, Yi, and Yao. The literature review of this chapter primarily draws from the historical and ethnographic accounts of Ceresea (1996), Rossabi (1980), Yang (2004 and 2009), Michaud (2006), Hansen (2004), Scott (2009), Alting von Geusau (2000 and 2003), Hill (1989), and Olson (1998).

TEA IN HISTORICAL PERSPECTIVE

Tea (*Camellia sinensis* (L.) O. Kuntze; Theaceae) is thought to have developed from a medicine that was sourced from forests to a food and beverage harvested from domesticated plants. The domestication process of *C. sinensis* most likely changed its' phytochemical and genetic characteristics depending on interactions between human selection and environmental variables. The earliest known documentation of tea is in the third and fourth centuries, when the poet Liu Kun mentioned the medicinal use of tea in Jiangsu Province of China (Ceresea 1996). Tea consumption was also mentioned during this period in Sichuan Province where it was taken in the form of gruel. The Pu, an ancestral people of the Bulang, Wa and De'ang, are considered the first cultivators of the tea plant (Huang 2005). Tea cultivation in southwestern China is estimated to date over 1,700 years (Xiao and Li 2002). Lu Yu's *Chajing* ("Tea Canon") of the 7th century is the first monograph on tea resources. It opens with the statement, "Tea comes from an extraordinary tree of the South." Lu Yu continues with a description of a huge tea tree on a mountain in Xiachuan (Sichuan), "whose girth is one that requires two men to embrace it". While the presence of tea and the habit of drinking tea have long been well documented in China, the original birthplace of the tea plant remains a debate. The present study assumes that tea is native to the area posited here as the tea belt where tea plants have been found in forests and where wild tea species in section *Thea* of *Camellia* are distributed. This includes southwest China and contiguous parts of Laos, Myanmar, Cambodia, northeastern India, and Vietnam.

Buddhist monks helped disseminate the practice of tea consumption throughout China, southeast Asia, and Japan. They cultivated tea plants in their monastery gardens and used it as an aid for extended meditation. Monks also prepared tea as a tonic to treat a range of health conditions of local communities, including improving circulation, reducing inflammation, and detoxifying blood. Today there are over one hundred traditional wellbeing functions attributed to tea to strengthen, balance, and cleanse the body and prevent illness. Tea cultivation spread where climatic conditions allowed, while the practice of drinking tea reached far beyond. By the end of the Tang Dynasty (618 – 907), Tibetans and nomadic groups north and west of the Chinese border had adopted the practice of drinking tea (Ceresea 1996). As will be discussed in Chapter Nine, the habit of tea drinking in extreme altitude areas may be regarded as adaptation to environmental conditions and pastoralist livelihoods that limit access to fruits and vegetables. Tea provides energy for livelihood activities, protects against environmental stress and illness, and helps compensate for dietary deficiencies.

Tea cultivation further spread in China because tea was utilized as a commodity and political tool to negotiate treaties and build empire. Rossabi (1980) describes how China's dynastic courts exchanged tea to procure warhorses from neighboring territories to the north and west. Dynastic courts desired strong horses for mobility against invaders and to maintain control over the empire. Intensive agrarian practices left limited land for breeding horses. In addition, China lacked trained breeders. The trade of tea became the major dependable source of procuring horses for the survival of the state. Consequently, tea production was tightly knit with government affairs. Soldiers were ordered to cultivate, pack, and transport tea during the Sung (Song) Dynasty (A.D. 960 – 1279) when an extensive state-controlled tea-horse trade developed. Merchants became prominent in the exchange of tea as political relations between China and its neighbors shifted.

Tea developed as a key commodity during the Ming Dynasty (1368-1744) on the caravan network known as the Southwest Silk Road (*Xi'nan Sichou-zhilu*), or Southern Silk Road (*Nanfang Sichou-zhilu*), that connected Yunnan, Southeast Asia, India, and Tibet (Yang 2004). Yunnan, previously the Nanzhao Kingdom, maintained close relationships with these regions before it became a province of China in the mid-thirteenth century. Yang (2009) emphasized that Yunnan held trans-regional importance in commodity and cultural exchange based on its central location as a land bridge between Southeast Asia, China, and Tibet. Abundant natural resources were exchanged on the various branches of the Southwest Silk Road over the course of two millennia. Tea and horses eventually fueled traffic on the branch linking Yunnan to Tibet and northeastern India, known variously as the *Cha-ma Dao* (Tea-Horse Road), *Cha-ma Gu-dao* (Tea-Horse Ancient Road), the Old Stone Road, *Drelan* (Mule Road), and *Gyalam* (Wide Road).

The Southwest Silk Road historically linked to the maritime Silk Road and the Northern Overland Silk Route, creating an immense and integrated network between the East and the West. Tea reaching India from Yunnan further made its way on a trade network extending through Eurasia. The Yunnanese dominated long distance trade on the Southwest Silk Road because of the richness of products procured from Yunnan, as well as the ability to traverse mountainous areas that to others were unfamiliar (Hill 1989). The earliest textual record of the Southwest Silk Road is found in the Han envoy Zhang Qian's exploration in the western regions in the late 2nd century BCE where he mentioned a trade route other than the Silk Road connecting southwest China with India (Yang 2004).

YUNNAN AND THE UPLANDS

Geographically and culturally, Yunnan (Mandarin: "South of the Clouds") lies at the heart of the mainland Southeast Asian massif (Michaud 2006). It is the southwestern most province of China and shares international borders with Vietnam, Laos, and

Myanmar, as well as provincial borders with Tibet, Sichuan, Guizhou, and Guangxi. Yunnan was acquired as a province of the Chinese empire in the mid-thirteenth century after the conquest of the Mongols. Prior to this invasion, Yunnan was part of the Nanzhao Kingdom and was more closely linked with Southeast Asia, India, and Tibet than it was to the Chinese Empire (Yang 2009).

China gradually expanded its empire from its original base at the bend of the Yellow River as it incorporated greater territory and rule (Rossabi 2004). As the Chinese State expanded, local groups were either absorbed or fled, sometimes after revolt. The socio-linguistic groups that China incorporated contributed cultural and linguistic traits to the dominant Han Chinese population and presented variable challenges for the State. Some socio-linguistic groups differ in cultural practices from the Han Chinese but consider themselves part of the State. Others perceive themselves as distinct from the Han Chinese but have assimilated after lengthy exposure to Chinese rule and culture. Still others maintain a strong identity, cultural traditions, and institutions and have rejected integration with China (Rossabi 2004). This cultural resilience is particularly notable in the uplands of Yunnan that are among the least developed areas in China, partially because their biophysical environment makes them difficult to access. The ethnocentric concept of a culturally superior China surrounded by less sophisticated people developed in the Han (206 B.C.E – C.E. 220) and Tang (618-907) dynasties where Yunnan was viewed as “backwards” (Hansen 2004).

Biological and Cultural Diversity of Yunnan

Yunnan is part of the Indo-Burma and the Mountains of Southwest China biodiversity hotspots (Dijk et al. 1999). It has the greatest species richness in China, which ranks first in the northern hemisphere and eighth in the world for species richness (National Environment Protection Agency of China 1998). Yunnan is home to around 13,000 species of angiosperms (~250,000 worldwide), 7,000 fungi (~74,079 worldwide), 1,500 fern species (10,000 worldwide), 107 gymnosperms (~640 worldwide), 793 bird species (~9,040 worldwide), 141 reptile species (~6,300 worldwide), and 102 amphibian species (~4,010 worldwide) (Zhao et al. 1990). This richness in flora, fauna, and microorganisms is partly a result of geophysical complexity created by variation of altitude, soil, climate, and microhabitat. Montane areas cover 94% of Yunnan's total area of 383,000 km^2, encouraging pockets of speciation (Pu et al. 2007). Elevations range from 6,740 meters in the northwest to 76 meters in the southeast. Six rivers emerge and flow through Yunnan to Southeast Asia and inland China, including the Lancangjiang (Mekong River), Nujiang (Salween River), Jinshajiang (Yangtze River), Honghejiang (Red River), Nanpanjiang (Pearl River), and Dulong (Irrawaddy).

In addition to hosting the greatest richness of flora and fauna, Yunnan is also the most culturally diverse province of China with twenty-six of the nation's fifty-six officially recognized ethnic groups, or *minzu*, including the majority Han Chinese. However, local concepts of ethnic boundaries include many more ethnic groups than are officially recognized. For example, two hundred and sixty groups in Yunnan officially requested to be recognized as minzu in the 1950s. Minority groups constitute ~ 33% (~

8 million people) of Yunnan’s population and make up 8% of China’s population. Some minority groups have inhabited the area for thousands of years while others migrated from inland China and neighboring lands primarily during the Yuan, Ming and Qing dynasties.

Yunnan’s socio-linguistic groups can be classified into three linguistic families including: (1) Tibeto-Burman (Yi, Hani, Akha, Jingpo, Lisu, Lahu, Nu, Dulong, Pumi, and Jinuo), (2) Mon-Khmer (Wa, Bulang, and De’ang), and (3) Miao-Yao. These groups are further classified into a complex system based on dialects, distinctive socio-economic systems, and belief systems and practice. The main belief systems in Yunnan include animism, shamanism, ancestor worship, geomancy, Buddhism, Confucianism, Islam, Christianity, and Taoism.

The co-existence of natural biodiversity and cultural history in Yunnan has contributed to its importance as a center of plant domestication. Yunnan is located between two Vavilov centers of crop domestication (Turrill 1926). Its’ socio-linguistic groups have relied on crops and other natural resources in domestic and international trade for hundreds of years. Many of these commodities were plants or plant products such as aromatic woods, medicinal plants, resins, latex, tea, tobacco, opium, and pepper. Many other commodities were animal products such as feathers, edible birds’ nests, honey, and beeswax. More bulky and perishable commodities were exchanged on regional markets including rattan, bamboo, timber, cattle, hides, cotton, wild fruits, and root crops.

The Uplands, Fixed Field Agriculture, and the State

Yunnan's uplands are home to notable cultural diversity with unique social structures and relations to lowland state centers as complex zones of refuge. Minority socio-linguistic groups in Yunnan often settled in montane areas to evade state-making projects, control of politically dominant groups, slavery, taxes, epidemics, and warfare of lowland state centers. In the uplands, communities resisting state incorporation lived as a relatively stateless population. They primarily subsisted by foraging, farming, and hunting. Upland communities did, however, remain linked to the lowlands through trade, and in some cases, they have provided most of the natural resources valued in global commerce. Despite the exchange of people, goods, and cultures between the uplands and lowlands, there remains a stark cultural divide between the two. People of the state have often perceived the ungoverned upland communities as uncivilized and wild. From a lowland perspective, the "backwardness" of upland inhabitants could be seen as a function of altitude: the higher the altitude of a community, the greater its backwardness. (Scott 2009)

Yunnan's upland communities are regionally linked with dispersed montane communities of mainland Southeast Asia, referred collectively as *Zomia* (derived from "highlander" in several Tibeto-Burman languages) by some political ecology scholars (Schendel 2001). Challenging conventional geographic notions of "region", Zomia is an area united by social structures of indigenous communities that have elected to resist inclusion by the politically dominant lowland cultures and rule. The region of Zomia has a complex and little-known history that is characterized by its heterogeneity of language, dress, settlement pattern, ethnic identification, economic activity, and religious practices that differ from the lowland valley state (Michaud 2006). Zomia's relative isolation at the periphery of lowland state centers has enabled relative isolation and autonomy. This relative isolation, coupled with geophysical and biological complexity of the uplands, appears to have encouraged a kind of "speciation" of cultural practices (Scott 2009).

While highly diverse, the communities of Zomia are characterized by their: (1) location at the periphery of the state, (2) physical mobility, (3) swidden agriculture and other cropping practices that enhance mobility, (4) religious heterodoxy, (5) egalitarianism, and, (6) non-literate, oral cultures. Escapist social structures have enabled upland communities to have mobility and flexibility to abandon their fields and houses to create new communities elsewhere. The lack of written language further contributes to a flexible social structure, where their oral history has the plasticity to be reinvented. Scott (2009) hypothesizes that the characteristics that unite, and sometimes stigmatize, the diverse upland socio-linguistic groups of this region are political adaptations to evade state capture and formation. The communities of Zomia can thus be viewed as zones of political resistance and cultural refusal.

Before the founding of agrarian states, historical social landscapes predominately consisted of elementary, self-governing, kinship units that in some cases cooperated in trading, hunting, skirmishing, and peacemaking. The founding of agrarian states created a distinction between self-governed people and a settled, state-governed population. Fixed-field grain agriculture has historically been the foundation of state power and has thus been promoted by nation building projects. This agrarian model generally fosters social, cultural, and environmental uniformity. It allows tax surveyors to measure fields and harvests in a straightforward way. States have thus attempted to oblige mobile, swidden cultivators to settle in permanent villages in order to ensure their economic activity was legible, taxable, and able to be confiscated. In this context, the diverse and mobile agricultural practices of upland communities - foraging, hunting, shifting cultivation, fishing, and pastoralism - can be viewed as adaptations to remain stateless. These modes of subsistence are relatively difficult to control and were viewed as economically unproductive by the State.

Social, Political, and Environmental Issues

Yunnan's minority areas have undergone significant change over the past 25 years. The opening of trade and economic reforms present new opportunities and challenges for the area's inhabitants. Yunnan's minority groups face the consequences of unequal development, exploitation of natural resources, new policies of environmental protection, mass immigration, and tourism. Serious side effects of development have arisen over the past two decades including drug smuggling, drug abuse, prostitution, and HIV (Hansen 2004).

Communist policies have effectively encouraged Han migration to the hinterlands of Yunnan since the founding of the People's Republic of China in 1949. The government promoted migrations between the 1950s and 1970s to impose greater control through Han leadership, and to offer work to unemployed Han workers (Rossabi 2004).

Communist policies have further sought to acculturate minorities through policy changes impacting education, language, and religion. For example, the state has implemented a standardized education system that does not acknowledge local languages and cultural practices. Fundamental to this system is the spreading of a standard Chinese national language and teaching of Communist ideology. (Hansen 2004)

Since the 1950s, state-led efforts have cleared large tracts of forests and patches of traditional agrarian systems such as tea agro-forests to procure timber and minerals, cultivate rubber, and promote the industrial development of the country. The main periods of forest decline and transformation of traditional agricultural systems in Yunnan were: (1) the Great Leap Forward (1958-1961) when social and economic plans aimed to transform China from an agrarian nation to a modern communist society and extracted timber to meet charcoal demands for industry, (2) State policies in the 1960s and 1970s when rural communities were forced to open up forested land for grain production as a form of taxes and, (3) the early 1980s following land reforms when many forested areas were not well managed. (Hansen 2004)

Socio-Linguistic Groups

Following is an ethnographic introduction to the socio-linguistic groups involved in this study that manage tea production systems. This ethnographic introduction provides the context to view tea as a cultural product. The information that follows draws from Olson (1998) with a few exceptions that are cited as appropriate. The Akha, Bulang, Lahu, Yao, and Yi socio-linguistic groups included in this study have a historical pattern of migration into the uplands where they were able to maintain societies away from Dai, Han Chinese, and other politically dominant groups in the lowlands. Particular social-linguistic groups often settled in the uplands within a narrow range of altitudes to exploit the agro-economic possibilities of that particular niche ecosystem. Such communities sometimes brought plant germplasm with them as they moved to new surroundings.

Akha

The Akha (Ahka, Aini, Aka, Ak'a, Akaza, Ake) are a Tibeto-Burman socio-linguistic group customarily inhabiting montane areas in China, Myanmar, Laos, Thailand, and Vietnam. They speak Akadaw, a tonal language that is classified as a branch of the Southern Loloish group of the Lolo-Burmese cluster of Sino-Tibetan languages. Akadaw is further sub-grouped into several dialects that are somewhat mutually intelligible. The Akha do not have an indigenous written language and transfer accumulated knowledge and experiences through oral history. Christian missionaries created an Akha script in the 20^{th} century based on Roman and Thai alphabets.

The origin of the Akha is hypothesized to be either the Qinghai-Tibetan Plateau or southern and eastern Yunnan. This group is thought to have migrated from their native habitat to the Mekong River Region of Xishuangbanna, Myanmar, Laos and Thailand. The Akha are closely related to the Hani of the Red River area of Yunnan and northern Vietnam and are officially grouped as Hani in China (Alting von Geusau 2003). Historically, the Han Chinese considered the Akha to be Wuman, an ethnonym denoting non-Sinicized "barbarians" with whom they were occasionally in conflict (Alting von Geusau 2003).

The Akha are among the smaller socio-linguistic groups in China. There are around 450,000 Akha living in Yunnan and Southeast Asia, of which over one third inhabit the highlands of southern Yunnan. Akha settlements are customarily in montane villages comprising of one hundred to one thousand inhabitants. Traditional homes are typically elevated constructions of timber, bamboo, and thatch. In the 1980s, hand-made clay tiles began to replace thatch roofs, and more recently, industrial tile roofs have replaced hand-made clay roofs. Cement homes modeled after lowland homes are also arising in Akha settlements.

Akha livelihoods were customarily based on subsistence agriculture coupled with some commercial production. The Akha diet integrates cultivated foods and livestock with foraging of wild food plants, hunting (wild boar, deer, and bamboo gopher), and fishing. The historical mode of food production was based on the cultivation of upland rice in mixed swidden systems of pumpkin, maize, beans, and green vegetables. Some Akha communities adapted irrigated terraced rice cultivation where geography, water sources, and politics permitted. Their livestock practices include raising chickens, hogs, ducks, goats, cattle, and water buffalo. The early transition of Akha communities into commercial economies involved the production of opium poppies, corn, cotton, chili, and soybeans.

The Akha social system is based on patrilineal descent and is embedded with egalitarian values. Polygyny was sometimes practiced. The Akha follow an animist faith that respects the spirits of deceased ancestors and a supreme being from who they inherited their moral code. Deceased ancestors are called upon during annual rituals to sustain fertility and provide protection and wellbeing. They also honor a Rice Mother to provide good harvests.

Bulang

The Bulang (Blang) are a Mon-Khmer socio-linguistic group. They primarily inhabit Menghai County in southwest Xishuangbanna Prefecture of Yunnan, near the border of Myanmar. Several thousand Bulang also live in Northeastern Myanmar. They are among the smaller socio-linguistic groups of China, with a population around 90,000. Bulang settlements tend to be situated at higher montane altitudes, between 4,500 and 6,500 feet. These settlements typically consist of up to 100 households.

Most Bulang converted from an animist religion to Theravada Buddhism in the tenth century based on encouragement by the more politically dominant Dai group. Elements of the traditional Bulang religion remain integrated in Buddhist practices such as the annual harvest and worship ceremony in old tea agro-forests. Some Bulang also converted to the Methodist and Presbyterian denominations of Christianity with the arrival of British missionaries in the late 1930s.

The Bulang customarily live in elevated bamboo houses where they use the ground floor for their livestock. They farm upland rice, maize, and beans are their dietary staples. Their transition into market economies was based on the cultivation of tea, cotton, and sugarcane. The Bulang traditionally raise chickens, ducks, cattle, pigs, and water buffalo.

Lahu

The Lahu (Kucongs, Co Sung, Co Xung, Guozhou, Kha Quy, Khu Xung, Kwi, Laho, Lahuna, Lahupu, Lahuxi, and Mussur) are part of the central Loloish branch of the Lolo-Burmese subgroup of the Tibeto-Burman language family. They inhabit southwestern Yunnan, the Shan State in Myanmar, northwestern Laos, northern Thailand, and northwestern Vietnam. There are around 650,000 Lahu, of which an estimated 420,000 live in China. Most Lahu villages are situated in the high montane levels, above the Tai, Wa, Akha, and Bulang. Lahu settlements in Yunnan consist of 200 to 1,000 people, but typically on the small village size. They typically construct earthen homes with thatch or wood plank roofs.

The Lahu speak a language closely related to Lisu. Their language is divided into two major dialects, Lahu Na (Black Lahu or Muhsur) and Lahu Shi (Yellow Lahu), which are further divided into the sub-dialects of Lahuna, Nu, Shehleh, Lahu and Lahoshi. Approximately two-thirds of the Lahu population speaks the Lahu Na dialect and the other third speaks Lahu Shi. The Lahu do not have a written language. Protestant and Catholic missionaries have developed scripts for the Lahu.

The Lahu are descendents of the ancient Qiang people of the Qianghai-Tibetan plateau. They migrated southwards from the Qianghai-Tibetan plateau to areas around Dali, Yunnan during the third and fifth centuries. They became known as the Kun or Kunming people around this period. In the tenth century, the Lahu Na migrated south and westwards and the Lahu Shi settled south and eastwards. The Lahu have a marked history of political domination by Tai and Han administrators. They unsuccessfully rebelled against Han control during the 18^{th} – 20^{th} centuries. Many Lahu communities fled into remote areas in Yunnan to escape Han control and other communities fled further south into Thailand, Laos, and Vietnam.

Lahu farming activities and diets are based on upland swidden rice. The Lahu have adapted the cultivation of irrigated terraced rice in Sinicized areas. Fruit tree silviculture, tea cultivation, mixed crop swidden agriculture, and the raising of pigs, cattle, and water buffalo further characterizes Lahu farming.

The Lahu have an egalitarian social system. Community status is largely based on age, rather than gender, wealth, or fertility. Village headmen have historically formed alliances with Tai leaders, the one of the dominant socio-linguistic groups in the lowlands, for formal recognition in what resembles a feudal system. They have in return provided goods, labor, and allegiance. The Lahu practice an animist faith based on spiritual entities known as *ne*. Community shamans known as *maw-pa* perform annual offerings to appease the *ne*. They also respect a powerful diety known as the *G'ui-sha* ("Sky Ghost"). The current Lahu faith often reflects elements of the Christianity, Buddhism, and Marxist ideology. Missionaries brought the Protestant doctrine and Christian rituals to some Lahu communities in the late 19th to early 20th century. Further, Lahu communities adopted aspects of Mahayana Buddhist from Han Chinese, Theravada Buddhism from Tai, and traces of Marxist ideology from post-1949 Chinese Communists.

Yao

The Yao (Pai Yao, Iu Mein, Kim Mien, Kim Mun, Lingnam Yao, Man, and Yu Mien) are part of the Hmong-Yao linguistic family. They are often classified into four main sub-groups: the Byau Min Yao, the Kim Mun Yao, the Mien Yao, and the Yao Mins. Their three main languages are Myen (spoken by ~ 44% of Yao people), Punu (~ 33%), and Lakkya (23%). Some ethnolinguists classify Lakkya as Kham, a Tibetan language. Chinese scholars believe the Yao emerged from a process of ethnogenesis that included widespread intermarriage among Han, Zhuang, Dong, and various Miao peoples.

The Yao form communities in the uplands of Guangxi, Hunan, Guangdong, Jiangxi, Guizhou, and Yunnan Provinces. There are an estimated 2,400,000 Yao people (Olson 1998). The majority of Yao live in Guangxi Province. Their social system is based on patrilineal descent. Historically they practiced swidden farming and this persists to present in some communities. The majority of Yao cultivate rice in paddies. Those living around forested areas hunt, most often in organized communal groups. Foraging supplements the Yao diet and livelihoods.

Yi

The Yi (Lolo) are a Tibeto-Burman socio-linguistic group. They are sub-grouped into the Ahis, Axis, Hei-Is, Hei-Kus, Ichias, Is, Ku Tous, Leisus, Lokqueis, Lolos, Luoluos, Luquans, Manchias, Mantuzus, Misabas, Mosus, Nasus, Neisus, Ngosus, Nos, Norsus, Nosus, Pei-Is, Sanis, and Tous. The Yi are among China's largest minority groups. Most Yi communities inhabit slopes and valleys of the Greater and Lesser Liangshan mountain ranges. There are around 7 million Yi in China, of which 3 million live in Yunnan.

Yi society was customarily characterized by a caste social structure sub-divided into three hierarchical groups: Black Yi, White Yi, and captured slaves. The Black Yi (Black Bone Yi) represented the aristocracy at the top of the caste system and dominated social, political, and economic life. The White Yi followed the hierarchy. They had a population relative to the Black Yi of over ten to one. White Yi were the descendents of Han Chinese taken in Yi slave raids, but who had over the centuries acquired certain property rights and transcended the status of slaves. Captured Han slaves were at the bottom of the social structure. The establishment of the People's Republic of China government in 1949 led to the abolishment of slavery in China and the Yi caste system. However, the Yi are generally still aware of their caste origins.

The Yi descend from the ancient Tusan people native to the Kunming, Yunnan and Chengdu, Sichaun. In the seventh century, six Yi tribes united and formed the Nanchao Kingdom, which survived for more than six hundred years and ruled the

Yunnan area. Yi have fought Han expansionism for over two thousand years. The adaptation to their rugged environment in the Liangshan Mountains allowed them to control mountain passes and harm Han armies. Mongol armies conquered the Yi in 1253 and integrated in the Yi region until the Ming Dynasty invasion in 1368. At this time, the Chinese imperial court governed in the area through a civil service system. This began the acculturation of Yi culture that continues to the present.

Yi economy was traditionally agricultural. Chickens and pigs were common. The Yi typically produced maize, potatoes, buckwheat, and oats as staples at lower elevations. In the highlands, they raised cattle, sheep, goats, and horses. Less integrated Yi communities supplemented their diet with foraging, fishing, and hunting. Opium was an important cash crop at the turn of the 20th century until the Chinese government outlawed its production in the 1930s. Today, most Yi settlements consist of about 20 households made of wood and earth. Cattle and sheep sleep indoors with family members. Yi homes are increasingly being built of brick and tile, resembling Han families. The Yi practice a mix of Daoism, Buddhism, ancestor worship, and animism. Thousands of Yi converted to Christianity in the 1920s and 1930s during an active missionary period.

Chapter Three

THEORETICAL CONTEXT

The present chapter reviews the theory and concepts that informed the research design of this study. The theory reviewed here draws from the fields of ethnobiology and environmental anthropology. Concepts and themes covered include biocultural diversity, socio-ecological systems, ecological knowledge, forest management, human selection, and plant domestication. These concepts are applied in the following data chapters.

BIOLOGICAL AND CULTURAL DIVERSITY

Cultural diversity refers to the wealth and variation of knowledge, perceptions, and practices that exist between people. Article One of the UNESCO Universal Declaration on Cultural Diversity (2001) recognizes cultural diversity as a source of innovation, exchange and creativity that is as necessary for humankind as biodiversity is for nature. In this sense, like biodiversity, cultural diversity is the common heritage of humanity (UNESCO Universal Declaration on Cultural Diversity 2001).

The integration of biological and cultural diversity, or biocultural diversity, is the interrelated diversity of life in all its manifestations. Biocultural diversity recognizes the historical processes of co-evolution between humans and the environment (Norgaard 1994). It links socio-cultural systems with biophysical systems. It also acknowledges the role of ecological knowledge, perceptions, and practices in natural resource management and resilience of socio-ecological systems (Mclvor et al. 2008).

The interrelationship between biological and cultural diversity has been identified by studies that document positive correlations between the geographic distribution of high species richness and languages as proxy measures (Harmon 1996; Stepp et al. 2004; Stepp et al. 2005; Toledo 1994). For example, the world's biodiversity hotspots have also been found to encompass among the most linguistically diverse areas. Other studies have suggested examining ontological communities rather than ethnolinguistic groups as a more comprehensive proxy for cultural diversity, taking the position that reducing all cultural facets to languages is overly simplistic (Mathez-Stiefel 2005). Adoption of an ontological approach allows for understanding the heterogeneity of practices within homogenous linguistic groups.

The hypotheses to explain the correlation of biological and cultural diversity range from deterministic (Collard and Foley 2002) to cultural-symbolic perspectives (Posey 1999). For example, deterministic explanations on the overlap of biological and cultural diversity argue that higher levels of biodiversity allow for the isolation of cultural groups and thus higher levels of cultural diversity (Nettle 1996). Alternatively, cultural-symbolic explanations argue that indigenous and traditional people maintain high levels of biodiversity based on their cosmo-visions and knowledge systems (Posey 1999). While previous work has established and promoted the link between biological and cultural diversity (Posey 1988; Harmon 1996; Loh and Harmon 2005), conservation plans and agricultural policy often neglect to address the interaction between these dimensions.

SOCIO-ECOLOGICAL SYSTEMS

Ecological systems, or ecosystems, are defined by the total complex of interacting organisms present in an ecological unit and their associated habitat and inorganic factors (Tansley 1935), along with their input and output environments (Patten 1978). Ecosystems are variously characterized and of different scales, including being any size "so long as organisms, physical environment, and interactions can exist within it," (Pickett and Cadenasso 2002). Aspects of ecological theory stem from Ludwig von Bertalanffy's theory of general systems (Ellen 1982).

The concept of ecosystem is useful in rejecting the treatment of culture and environment as separate entities (Ellen 1982). Socio-ecological systems refer to integrated ecosystems where human-environment interactions create dynamic feedback loops in which humans impact and are impacted by ecosystem processes (Levin 1999). Such systems, also known as human ecosystems, are set apart from non-human ecosystems by the information-processing capability of humans (Stepp et al. 2003). Human actions towards the environment are an expression of dynamic cultural constructs resulting and mediated by ontology, epistemology, value systems, knowledge, practices, and historical contexts (Mathez-Stiefel et al. 2005).

The concept of resilience is increasingly used to understand the impact of change and stress on socio-ecological systems (Folke et al. 2004; Janssen et al. 2006; Anderies et al. 2006). Resilience is the ability of a system to be influenced by disturbance while retaining its structure, function, feedback and identity (Holling 1973). The more resilient a system is, the greater capacity it has to absorb shocks and gradual stress without collapsing or shifting to an alternate regime (Walker et al. 2006). Resilience within a system may increase or decrease as economic, ecological, social, and evolutionary variables gradually and episodically change at the local and global levels.

The theories of resilience and adaptive change contradict predictions that degradation and wide change will necessarily result in the collapse of socio-ecological systems. These theories acknowledge that change and extreme transformation are part of humanity's evolutionary history. Rather then collapse, there is the possibility that human enterprise and innovation can restore and revitalize systems towards paths that sustain natural diversity and create opportunity (Gunderson and Holling 2001). For example, a community may organize itself to correct for external disturbance, and not only persist passively, but to create and innovate when limits are reached. Such a sustainable system has the capacity to create, experiment, and maintain adaptive capability.

The management of ecosystems, such as natural resource management systems, requires active management of both the human and non-human components (Abel and Stepp 2003). Natural resource management systems refer to the technical and social arrangements and decisions involved in the protection and maintenance of resources for specific purposes, their harvesting and their distribution. The resilience of resource management systems is proposed to be a function of biotic factors coupled with the decisions of their managers (Walker et al. 2006). Some of the social factors recognized to promote resilience of natural resource management systems include: (1) social networks,

(2) collective management, (3) adaptive cultural memory, (4) accumulated knowledge and, (5) beliefs and values (Abel et al. 2006).

While economic rationality is a key factor in determining human interactions with the environment, the growing body of case studies provides evidence of epistemological orientations and cultural history in determining natural resource management (Atran et al. 1999; Bang et al. 2007). Epistemological orientations are based on cultural heritage, personal experiences, and responses to external stimuli and these influence behavior and the way individuals understand their world (Tuan 1974). Atran et al. (1999) show that native and immigrant populations living in the same habitat can have differing environmental impacts because of differing cultural contexts and conceptions of nature.

Each individual has unique cognitive and social organizing principles by which they evaluate their biophysical and cultural surroundings, or landscapes (Menzies 1997). The varying ways that individuals and groups see their environment has varying implications for ecological interactions (Ellen 1982). Landscapes are constructed and perceived through the interaction of the mind and the biophysical world within the framework of cultural practices and knowledge (Hood 1996). Place is ultimately the construction of an individual, and individual perceptions of place influence the formation of personal and social identities (Basso 1996). An individual's sense of place contributes to the cumulative constructions a community creates and juxtaposes on its' surrounding landscape. There are commonalities and differences in individual landscape perceptions within and between communities. These landscape perceptions feedback in interactions communities have with their surrounding environment, such as through their natural resource management systems.

Natural resource management systems vary enormously because of different environments that populations find themselves in, and because of differing social structures, perceptions and behavior. Human ecosystems may be classified based on the degree to which a particular population has manipulated the ecosystem (Ellen 1982). Manipulation of ecosystems involves land-use alternation, genetic engineering, application of chemical input, and shifting of resources. On the one extreme of the continuum are “pristine” ecosystems with minimal human manipulation. On the other extreme there are “artificial” ecosystems that can only be maintained by constant human manipulation. In the middle of the continuum are partially altered ecosystems that are sustained through temporary and periodic manipulation. According to this scheme, the continuum generally progresses from high species diversity and biomass with low entropy towards low biomass and species diversity with high entropy. This change results from human manipulation of ecosystems to encourage certain species at the expense of others, from a generalized to a specialized system. However, this is a general scheme with considerable variation on a case-specific basis. For example, some “artificial” systems maintain or even increase the species-diversity index compared to less altered systems. (Ellen 1982)

ECOLOGICAL KNOWLEDGE

Ecological knowledge, and the associated terms “indigenous knowledge”, “local knowledge”, “traditional knowledge”, and “environmental knowledge”, are variously defined and conceptualized in the literature. Ecological knowledge as used in this study is adapted from the various characteristics found in the literature, as comprehensively reviewed by Ellen and Harris (2000). These characteristics include: (1) ecological knowledge is generated by the experience, experimentation, and reasoning of people living in a particular landscape, (2) ecological knowledge is embedded in a cultural context, (3) ecological knowledge is transmitted through observation and communication within and across generations and, (4) ecological knowledge is dynamic; it is constantly being produced and reproduced, discovered and lost.

Negotiation is central to the concept of ecological knowledge (Hunn 1993). There is a general trend in the literature on the loss of ecological knowledge in the face of agricultural modernization. However, some studies find results that are counter-intuitive to this trend. For example, Soemarwoto (2007) presents the process of identification and cultural validation of new rice landraces under the influence of agricultural modernization. Iskandar and Ellen (2007) demonstrate how new ecological knowledge is generated through a synthesis of existing generic knowledge of the local ecology coupled with other socio-ecological considerations.

Ecological knowledge has often been documented as it relates to famine foods. Such foods are differentiated from other foods as being utilized only at times of production crises because of their high costs, low nutrition, unpleasant taste, or low status (Ellen 2007). The concept of ecological knowledge of famine foods is considered particularly relevant to agrarian groups because of the risks of production failure, which may explain why agricultural populations report more names for plants than non-agricultural peoples (Ellen 2007).

FOREST MANAGEMENT AND PLANT DOMESTICATION

Forest management and plant domestication offer rich models of the co-evolution of people and plants. Humans have an extensive history of influencing the landscape in order to increase the benefits they derive for subsistence use and to obtain commercial products. Paleobotanical evidence in New Guinea indicates that people were manipulating the forest in the late Pleistocene, some 30,000-40,000 years ago, by trimming, thinning and ring-barking in order to increase the natural stands of taro, bananas and yams (Hladik et al.1993). Forest products, such as gums and resins, have been document in trade in Southeast Asia as early as the fifth century AD with forest management practices to regulate their production (Dunn 1975; Dove 1994). In addition to forest management practices to secure material needs, many societies have protected certain forest areas for cultural and religious reasons (Dooruewaard 1992). These examples emphasize that forests have historically been manipulated and that assumptions of dichotomies between a natural forest area and a domesticated landscape are often not appropriate. Rather, many societies have transformed forests into environments that are enriched by useful resources. This has resulted in the evolution of habitats along a nature-culture continuum (McKey et al. 1993; Dove 1994).

Natural variation of plant characteristics occurs due to biogeography, season, time of day, age of leaf, plant-insect interactions, predators, soil type, hybridization and other variables. Cultural groups with a long history of interacting with plant resources in their surroundings may know how particular plant characteristics vary over space and time and use this ecological knowledge to select and manage for their preferences. This anthropogenic selection may consequently drive the evolutionary process of plant populations and impact their genetic and secondary metabolite profiles and subsequent fitness level, wellbeing properties, and conservation status.

Domestication is an evolutionary process where human interactions with plants function as an evolutionary force that may drive distinctive changes in morphology, physiology, phenology, life cycles, and reproductive systems of plants (Casas et al. 1996). These changes, collectively or individually, distinguish domesticated plants from their wild relatives (Hancock 2005). Domesticated plants are generally classified as those growing in anthropogenic habitats and are dependent on humans for their reproduction and survival in most cases (Casas et al. 1996). Plant domestication is regarded as one of the most influential technological innovations in human history. This evolutionary process spurred the transition of hunter-gatherers to sedentary agriculture 13,000 to 10,000 years ago and is considered to have independently arisen in 24 regions around the world (Puruggagan 2009).

Sauer (1969) postulated that cultivating wild food trees is the first step in the evolution of a domesticated landscape. Such cultivation probably began when harvesting caused micro-environment changes that favored rejuvenation of the collected species and the growth of plants from leftovers of products that harvesters used. Unconscious manipulation was gradually replaced by more conscious activities including the deliberate planting of certain species through vegetative propagation and seeding (Wiersum 1997). Harris (1989) developed a model of agricultural development where plant-exploiting activities and associated ecological effects were arranged sequentially along a gradient of increasing input of human energy per unit of exploited land. He postulated a gradual transformation of the natural ecosystem into an agro-ecosystem along this continuum on the basis of people-plant interactions. Harris identifies various socio-economic trends resulting in the progressively closer interaction between people and forest resources as natural forests transition into agro-ecosystems. These include increasing sedentarization, greater population density, and a gradual shift from a subsistence economy to commercialization.

Harris' model was further developed by Weirsum (1997) to incorporate forest resource exploitation and management activities. According to this model, the transformation from a unmanaged forest system to a managed forest system and agro-ecosystem involves a shift from the uncontrolled procurement of wild tree products to controlled procurement through social transactions and decision making of user rights. Resource rules and regulations change from common property rights to private land and tree tenure rights. The shift also involves purposeful regeneration of valuable tree species. As the input of human energy per unit of exploited land increases, the reproductive biology of desired species intensifies. Another major transformation involves a shift from minimal tillage of land and to systematic tillage. Eventually, selection and breeding practices of specific genotypes and phenotypes result in a domesticated landscape.

Much domestication of plants can be viewed as efforts to maximize the biomass available for human consumption (Ellen 1982). Since the advent of plant domestication, humans have taken advantage of plant variation by selecting for desired qualities such as higher yields, increased nutritional value, improved appearance, stress tolerance, and other factors that changed the genetic constitution of cultivated species (Simpson and Ogorzaly 2001). In some cases, traits once present are inadvertently lost, while in other cases plant resources have been enhanced. The spread of crops globally and their domination in landscapes demonstrate the increased fitness of domesticated taxa versus wild relatives in certain contexts, and suggests the mutual benefits of people-plant interactions. Domestication ultimately gave rise to food surpluses and this promoted specialization, art, social hierarchies, writing, urbanization, and the formation of government structures (Diamond 2002). In contrast to conscious pressures in cultivated environments, subconscious anthropogenic influences, such as human preference for large-sized individuals of a wild medicinal plant, may result in unintentional selection against the preferred trait (Law and Salick 2005).

Plant resource managers may use hybridization to obtain or introgress desired traits (Collins 2000). The ecological performance and evolutionary fates of hybrids is dependent on their ability to survive the abiotic and biotic conditions present in parental or nonparental habitats including their resistance to herbivores and pathogens (Orians

2000). Hybrids in parental habitats typically express parental secondary metabolites, but sometimes these compounds may be missing or expressed at different concentrations, or novel compounds may be present (Buschmann and Spring 1995). Novelty or loss of secondary metabolite traits occurs by obstruction of the biosynthetic pathway that results in the loss of end products, pathway elaboration, or disruption of regulatory genes showing a shift where the chemical is produced. Secondary metabolite concentrations of hybrids also vary across habitats depending on costs of production and potential fitness (Coley and Barone 2001). Little attention has been directed at the effects of hybridization on secondary metabolite production and the subsequent ecological performance and evolutionary fate of hybrids. In addition, there is little research on the impact of mode of agricultural production on the secondary metabolite profiles of plant resources. Research is needed in tea production systems to document ecological knowledge and practices associated with tea resources and the resulting variation in secondary metabolite patterns.

PART II

CULTURAL PRACTICES AND DIVERSITY OF TEA MANAGEMENT SYSTEMS IN YUNNAN

The following three chapters explore the management practices and diversity of tea forests, agro-forests, mixed crop fields, and terrace gardens (Figure II.1). Chapter Four assesses practices of the various tea management systems. These management systems are evaluated in Chapter Five on the basis of floristic diversity and in Chapter Six on the basis of morphological, phytochemical, and genetic variation.

a. b. c. d.

Figure II.1 The four tea management systems including (a) forest, (b) agro-forest, (c) mixed crop fields and, (d) terrace gardens.

Chapter Four

COMMUNITY PRACTICES IN TEA MANAGEMENT SYSTEMS

Tea plants grow in variable environments in Yunnan that can be broadly classified along a continuum on the basis of their human manipulation. On the one extreme of the continuum are forest tea populations, and on the other extreme are terrace tea (*taidi cha*) gardens. In the middle of this continuum are tea agro-forests and mixed crop fields, which are both referred to as "ancient forest tea gardens" (*gushu cha yuen*) in Yunnan. The tea agro-forests and mixed crop fields of Yunnan have been managed for hundreds of years or more by several socio-linguistic groups including the Bulang, Akha and Lahu. This chapter explores community practices in tea management systems in the uplands of southern Yunnan through participant observation and interviews with smallholders.

Community management of forest resources and agro-ecosystems includes the interests, norms, social interactions and decisions regarding the use and conservation of resources within an area. While numerous studies have systematically compared practices of various management systems of commodities, such as coffee agro-forests versus sun-grown coffee plantations (Soto-Pinto et al. 2000; Vaast and Harmand 2002; Perfecto et al. 2005), research is lacking on systematic comparisons between various tea management systems. This chapter seeks to address this gap by providing data to identify patterns distinguishing forest tea populations, agro-forests, mixed crop fields, and terrace gardens based on management practices. This descriptive data can form the basis for future systematic quantitative research.

STUDY AREA

Research was conducted in Yao, Akha, and Lahu communities that respectively manage tea in forest populations, agro-forests, and mixed crop fields in Honghe, Xishuangbanna, and Lincang Prefectures of southern Yunnan Province, China (Figure 1.1 in Introduction). Surveys were further carried out in nearby communities of various socio-linguistic groups including Yi, Hmong, Bulang and Han settlements. Comparisons were made with terrace tea gardens managed by Akha, Lahu, Bulang and Han smallholders in neighboring areas to the agro-forest and mixed crop fields, labeled here as terrace site I and site II. Table 4.1 summarizes the tea management system at each study site with the corresponding socio-linguistic groups and sample sizes of informants.

The field sites were selected during a preliminary survey based on visual assessment and brief semi-structured interviews. All study sites are located in evergreen broadleaf montane forests between 1,600 – 1,800 meters. The population of each study site is 400-500 inhabitants in family units of 70-85 households that consist of two to four generations. Local livelihoods rely on surrounding forests, fields, and home gardens for subsistence. Income is primarily secured through on-farm production for exchange in national and global markets.

Table 4.1. Management system of tea resources at each study location with corresponding socio-linguistic groups and sample sizes of informants (n=80).

Study Site Location (Prefecture)	Management System	Socio-linguistic Groups Inhabiting Study Area	Primary Socio-linguistic Group Interviewed	Sample Size of Informants
Honghe	Forest	Yao, Yi, and Hmong	Yao	20
Xishuangbanna	Agro-forest	Akha and Bulang	Akha	20
Lincang	Mixed Crop	Lahu, Bulang and Han	Lahu	20
Xishuangbanna	Terrace (Site I)	Akha	Akha	10
Lincang	Terrace (Site II)	Lahu, Bulang and Han	Lahu	10

The forest populations included in this study are part of the Fengshuiling National Nature Reserve in Jinhe Township, Jingping County of Honghe Prefecture. The Yao, Yi, and Hmong communities that harvest from these tea populations were re-settled from their homes inside the reserve with the establishment of the protected area in the 1950s. They live in communities outside the reserve and manage farming land around their settlements that they lease from the government. The state grants these relocated communities limited rights to harvest within the reserve. Their livelihoods are primarily based on foraging, farming of cropland, raising livestock, and managing home gardens. The main farming activity is terrace rice cultivation using local and introduced varieties. Middle and younger aged males of some households earn supplemental income through off-farm labor from infrastructure construction jobs such as road building and repair.

The agro-forests, mixed crop fields, and terrace gardens included in this study are chiefly maintained by family labor and are integrated in a larger system of resource use.

Bulang, Akha, and Lahu communities have managed the agro-forests and mixed crop fields for hundreds of years or more as part of landscape mosaics of varied agricultural land interspersed with secondary forests. Historically, land-use in these communities was predominantly based on swidden cultivation where forests were cleared for crop production and then regenerated back into forests during a fallow period to replenish soil fertility.

Traditional land-use was altered during China's collective period (1958-1982) when agricultural land was communally managed. New state demarcations were imposed following policy reforms of 1982-1983 and communal agricultural and forestlands were contracted to households. Current land tenure at the study sites combines local systems negotiated with state policy. Family members inherit tea production systems and other land use as leased land from the government. Sections of forestlands are demarcated as household, community, and state forest based on state policy. Communities further differentiate forests as watershed, burial, and primary forest based on local systems. Before the collective period, some smallholders cyclically transitioned tea production systems between forests, agro-forests, and mixed crop fields through fallow and thinning practices.

The smallholder terrace tea gardens surveyed were created as part of state-supported economic and political reforms starting in the 1970s including the national Grain for Green campaign of 2002. Under the Grain for Green policy, smallholders were offered grain subsidies in exchange for replacing grain fields with permanent cash cropping classified as forest or “green cover”. Rubber and terrace tea plantations fit as “green cover” and have been promoted to replace shifting cultivation in southern Yunnan because they conform to the state’s dual environmental and development priorities (Sturgeon 2005a; Sturgeon 2005b; Fox 2009). These environmental priorities stem from the state’s response to the Yangtze River flood damage in 1998 and attribution of blame to farmer practices (Sturgeon 2007). Consequently, the state reclaimed forests from communities and discouraged shifting cultivation while encouraging fixed field farming. The state’s promotion of fixed field agriculture includes facilitating the sublease of land previously managed as swidden areas by upland communities to private enterprises for the cultivation of terrace tea plantations.

METHODS

Participant observation, oral histories, and semi-structured interviews (Bernard 2005) were conducted to collect qualitative data to compare management practices of tea forests, agro-forests, mixed crop fields, and terrace gardens. A household interview guide was created after preliminary surveys at the study sites. It included questions on management practices, types of tea cultivated and harvested in the community, preferences and yield of tea landraces, harvest schedule and quantity, knowledge of ecosystem services, and transmission of knowledge. In addition, informant walks were conducted around the various land-use systems of each community. For each management system surveyed, twenty adults of different age classes were selected at random for interviews to understand management practices. Interview responses were coded in order to identify themes (Ryan and Bernard 2003), tabulate responses, and evaluate variation within and among communities.

RESULTS

Management Calendar

The management calendar of surveyed tea production systems is based on the availability of young terminal buds and adjacent leaves of tea plants. These are the parts used for processing tea products and sprout during three continuous seasons from spring to autumn. Spring is regarded as the main harvest season. It starts in early to mid March and runs through mid May. Some informants at each of the study sites reported that the tea harvest season has started earlier each year over the past decade. They attribute this trend to increased solar radiation and temperatures in their tea systems associated with loss of forest cover. The rainy season proceeds the spring season and runs through August, followed by the "rice flower season" that lasts till early to mid November. Farmers continuously collect leaves from tea plants during the three harvest seasons.

Once harvested, households process tea leaves into dried and shaped products. Processed leaves are used for household consumption and are sold to middlemen, entrepreneurs, and processing factories. Informants reserve the winter season from late November to February primarily for non-harvesting activities such as weeding, fertilization, and pruning. Occasional harvesting of old leaves from tea plants is also carried out during the winter season for preparing tonics.

Forest Populations

Participant observation and interviews found that the primary management activities in tea forests include protection of woody plant species and selective harvesting under the regulations of national nature reserve forestry policy. Table 4.2 summarizes the practices in each tea management system. Communities that harvest from the forest tea populations at the study site are regulated by national forestry policy in managing tea and other plant species in the Fengshuiling National Nature Reserve. Local Yao, Yi, and Hmong communities protect and tolerate plants in the reserve and restrict their harvest of these resources.

Informants consider most of the tea plants in the forest populations surveyed as wild, while some tea plants are regarded to be enhancement plantings from their ancestors that lived in the National Nature Reserve before communities were moved out of this protected area. Farmers distinguish between wild and domesticated tea trees based on shape characteristics. Wild trees grow straight with a narrow crown that reaches up to 15-20 meters in height. Informants distinguish trees cultivated by humans based on a large crown resulting from opening up of the branches through pruning activities.

Policy of the Fengshuiling National Nature Reserve restricts harvesting within the reserve to communities that once lived in the reserve and limits their harvest. Harvesting of most plant species, including wild tea plants, for commercial purposes is prohibited. Based on these regulations, households surveyed occasionally harvest tea leaves along with other plants. Older informants reported that they historically followed a community

Table 4.2. Summary of management practices associated with tea production in forests, agro-forests, mixed crop fields, and terrace systems (site I and site II) at the case study sites. Practices are marked for each management system if 90% or more of the interview responses and observations at the study sites indicated a particular practice.

Management Practice	Forest	Agro-forest	Mixed Crop Field	Terrace Site I	Terrace Site II
Tolerance of woody plant species	x	x			
Observation of national nature reserve forestry policy	x				
Prohibition of commercial harvesting of wild tea	x				
Enrichment planting of tea from seed and seedling		x	x		x
Enrichment planting of tea from cuttings				x	
Enrichment planting of associated woody species		x			
Introduction of tea seeds and seedlings from forest populations		x	x		
Removal of moss, ferns and epiphytes growing on tea plants		x			
Tolerance of specific pests		x	x		
Manual weeding		x	x		
Fertilizing using weedy vegetation		x	x		
Pruning of tea plants		x	x		
Shade management		x			
Removal of canopy coverage		x	x		
Maintenance of wind breaks		x			
Thinning of woody plants species		x	x		
Selective harvesting by hand	x	x	x		x
Non-selective harvesting with clippers				x	
Maintenance of tea plants as trees		x	x		
Maintenance of tea plants as shrubs			x		
Maintenace of distance between plants		x	x		
Application of pesticides and herbicides				x	x
Application of hormones				x	
Application of atificial fertilizers				x	x
Purchase of seedlings			x		x

system of user rights of trees and sections of the forest before they were moved off the reserve. At present they do not have a local system of harvesting rights other than the regulations of the reserve. Households harvest between 20 to 300 kilos of fresh tea leaf (or 5 to 75 kilos of dried tea leaf) annually with an average of 200 kilos of fresh leaf (40 kilos dried tea leaf). They pluck tea leaves by hand and harvest the young terminal buds and adjacent leaves for processing tea products. Farmers harvest older leaves of the tea plant for use in tonics and for fodder. The variable size and age of tea plants in forests results in variable total yields of leaf. Informants estimated that most large tea trees yield over 400 kilos of leaf material of which 100-150 kilos consist of the of the young bud and leaf material used for processing tea. However, since informants do no harvest such large quantities from a single plant, these numbers are difficult to derive.

Forest tea harvesters discerned a total and an average of five tea types. These tea types were identified as *Camellia sinensis* var. *assamica*, *Camella tsaii*, *Camellia caudata* and *Camellia crassicolumna.* Taxonomically, *Camellia tsaii* and *Camellia caudata* are not classified as wild tea as they are not in section *Thea* of *Camellia*. However, local communities perceive these as tea types that are related to *Camellia sinensis* var. *assamica* and may be used similarly. Yao harvesters discern tea plants based on leaf qualities including taste, medicinal properties, use, tree shape, color and size. *Camella tsaii* is discerned from other tea types locally for its sour taste, small leaf size, and reddish leaf petioles. It is locally called “little red tea” and is used for pig fodder. *Camellia caudata* is associated with a bitter taste and is used as a medicinal tonic, particularly to strengthen the immune system against flu-like symptoms. Table 4.3

summarizes the number of tea types managed per community and average number of tea types managed by households at each study site and their taxonomic identification.

Once harvested, tea leaves are processed through pan-frying, hand rolling, and sun drying on bamboo mats. Informants reported that they learnt to process tea from trial and error and from other communities. For example, one farmer shared that they previously would only pan-fry leaves and not roll them before drying. These processed leaves would turn brown if they weren't consumed within several days. Farmers reported that rolling leaves prevents them from turning brown and that pan-frying and sun-drying leaves enhances flavor. Processed tea is mainly consumed for household use as a tonic to strengthen the immune system. Some informants reported that processed tea was historically not consumed daily by communities as a beverage because of its medicinal and weight loss properties.

A few household sell fresh or processed leaves to middlemen that have started to increasingly visit their communities since 2005. However, most households do not sell tea for income as it is prohibited and they face fines by forestry officials that monitor the reserve and communities. Those farmers that did sell tea products during the study period earned 4.50-9.10 USD (30-60 CNY) per kilo of dry tea between 2006 and 2008 and approximately 300 USD annually per household. Table 4.4 summarizes the yields, income, and area harvested for each tea management system compared.

Table 4.3 Number of tea types managed per community and average number of tea types managed by households at each study site and their taxonomic identification.

Management System	No. of Tea Types Managed Per Community	Average No. of Tea Types Managed Per Household	Taxonomic Identification of Tea Types
Forest	5	5	*Camellia sinensis* var. *assamica, Camella tsaii*, *Camellia crassicaluma*, *Camellia caudatta*
Agro-forest	15	6	*Camellia sinensis* var. *assamica*
Mixed Crop Field	16	5	*Camellia sinensis* var. *assamica, Camellia taliensis*
Terrace Site I	2	2	*Camellia sinensis* var. *assamica*
Terrace Site II	4	4	*Camellia sinensis* var. *assamica*

Over the past decade, some households in the Yi community surveyed are starting to create agro-forests in land leased from the government in order to legally be able to sell tea products. The state offers 1 mu (1 mu = 0.067ha) of land for household or community management for 40 USD (270 CNY) annually. Farmers have cultivated tea plants in these plots along with tree species that provide suitable timber for home construction. Informants reported they would like to lease additional land in the future and expand the size of the agro-forests and tea plants in these systems in order to be able to sell greater quantities of tea products.

Table 4.4 Summary of tea yields, harvest area, and income associated with tea production in forests, agro-forests, mixed crop fields, and terrace systems (site I and site II) at the case study sites. Values represent averages and ranges at each study site during 2007-2008.

Management Practice	Forest	Agro-forest	Mixed Crop Field	Terrace Site I	Terrace Site II
Number of tea plants per ha	200	350	900	8,000	4,000
Annual yield (kg) of fresh leaf per big tea plant (>2m) used for tea production	100-150	80-110	60-100	N/A	N/A
Annual yield (kg) of fresh leaf per small tea plant (<2m) used for tea production	10	10	10	8	4
Annual yield (kg) of fresh tea leaf per ha used for tea production	6,000	13,500	18,000	64,000	16,000
Size of tea agro-ecosystem	N/A	0.5-1.4 ha	0.1-0.4 ha	0.5-1ha	0.15-0.7 ha
Total area of tea agro-ecosystem managed per household	N/A	0.8-1.5 ha	0.3-0.7 ha	0.5-1ha	0.3-0.7 ha
Anuual harvest (kg) of fresh leaf per household	200	3,200	3,000-5,000	6,000-40,000	4,800-11,200
Annual harvest of dried leaf per household	50	1,250 - 3,750	1,250 - 3,250	1,500 - 10,000	1,200-2,800
Income receievd per kilo of dried tea	$4.50 - $9.10	$38.76 - $203.92	$4.53-$37.76	$1.51	$4.53
Annual income from tea production per household	$300	$7,000 - $150,000	$2,000 - $36,000	$1,500 - $10,500	$1,000 - $10,000
Annual cost of purchasing agro-chemicals	N/A	N/A	N/A	$75.53	$45.00
Annual cost of purchasing tea seeds and seedlings	N/A	N/A	$75.52	N/A	$151.71

Agro-forests

The agro-forests surveyed were 0.5-1.4 ha in size. Households manage 0.8 – 1.5 ha of agro-forests depending on household size. A household's agro-forests are generally distributed around the community and are not adjacent to one another. Approximately 350 tea plants grow in 1 ha of agro-forest and are irregularly distributed with several meters of distance between plants. Farmers maintain tea plants as trees 3-9 meters tall.

Surveyed agro-forests were surrounded by woody plant species and some woody species were distributed among tea plants. Tea plants within the surveyed agro-forests were variable ages. The oldest tea agro-forests at the study sites were created over 70 years ago and farmers regarded the oldest tea trees in their systems to be 150 years of age or more. The younger tea agro-forests in the community were created approximately 15 - 40 years ago. Some households were creating new agro-forests during the study period.

Male and female adults of all age classes participate in management activities of agro-forests. Participant observation and interviews documented that the activities in tea agro-forests include: (1) protection and tolerance of tea and associated woody plant species, (2) enrichment planting of tea and other species, (2) selective thinning of woody plants species, (3) introduction of tea seeds and seedlings from forest populations, (4) removal of moss, ferns and epiphytes growing on tea plants, (5) tolerance of specific pests, (6) manual weeding, (7) fertilizing using weedy vegetation, (8) shade management, (9) pruning of tea plants, and (10) harvesting. Findings indicated the dynamic nature of management strategies as farmers altered their practices in response to increased market demand and prices of tea sourced from ancient forest tea gardens.

Farmers rely on environmental services of the multi-storied vegetative structure and floristic composition in and around their agro-forests, coupled with manual weeding and compost activities. They do not apply pesticides, herbicides, artificial fertilizers, hormones, or other agrochemicals. Informants reported that they maintain woody species in and around agro-forests for pest and disease control, shade, reducing temperatures, windbreak, soil fertility, prevention of landslides, and to harvest food, medicinal, ritual and other useful plants. Smallholders particularly maintain the forest cover at the edge of agro-forests as ecological buffers and as a windbreak. Farmers source seeds and seedlings of tea and other species from areas within and surrounding the community, including by transplanting vegetative material from forest populations. They also source seed through exchange with other communities. They select to grow tea plants from seed and seedling rather than cuttings in order to benefit from the extensive taproot to protect against soil erosion. Informants reported that tea plants grown from cuttings do not have a deep taproot as that of tea plants from seed.

The choice of woody species to cultivate in agro-forests is based on plant knowledge and preferences of useful plants that grow well with tea plants. For example, Akha informants reported that pine trees in tea systems dry the soil while many fruit species enrich the soil. They prefer to maintain fruit trees, eaten by humans or animals, that won't crowd out the agro-ecosystems with numerous seeds. Informants reported that the root system of tea plants is extensive and requires several meters of space from other plants for proper growth. Farmers thus try to keep a distance of approximately five meters between plants when transplanting new vegetative material. However, informants reported that the space between tea trees has reduced over the past decade as farmers planted more tea trees to benefit from increased market prices and demand for tea sourced from ancient forest tea gardens.

Farmers adjust the canopy coverage of agro-forests through protection, enrichment, and thinning activities for a desirable level of shade and sunshine. Informants reported that the amount of shade and sunshine influences the growth, yield, and taste of tea plants. Increasing canopy coverage is considered to reduce temperature, slow the development of leaf shoots, increase the size of leaves, and improve the taste of tea products. On the other hand, increased sunshine is regarded to result in increase temperature and result in higher yield, faster-developing leaf shoots, and smaller leaves. Shade coverage is promoted to nurture the development of seedlings and young tea plants that are one to five years of age.

An Akha informant reported, "Shade in tea gardens makes for tea leaves that are larger and juicer. Without shade the leaves age quickly and are small. But too much shade results in a small amount of tea. There must be the correct amount of sun and shade for a good harvest and good tea". Some informants reported that maintaining shade makes it easier to harvest tea because of cooler temperatures with less solar radiation. Informants reported that until the past five years, the agro-forests were more densely shaded. Farmers have since opened the canopy of their tea systems to increase yields. This has resulted in large variations in shade within an agro-forest and among plots of different households.

Farmers manipulate the form, branching pattern and size of tea plants for greater yields and harvesting accessibility. They maintain tea plants between 3–9 meters and use ladders to harvest the leaves growing on taller trees. Bamboo ladders are generally stationed beside the trunk of tall tea trees. Farmers prune trees to encourage lateral growth and open the branching pattern. This practice increases the crown size of trees that are valued by farmers for greater yield of leaves that are more accessible for harvesting. Informants have started to prune tea plants more frequently since the increased demand of tea from agro-forests.

Farmers' cultivate tea plants in agro-forests as trees rather than pruning them into shrubs so they can have low material costs by taking advantage of the environmental services of a forest-like environment. In addition, informants perceive that greater height of tea trees results in tea products with improved taste. Farmers also maintain tea plants as trees rather than shrubs to meet recent market opportunities of higher prices for tea sourced from trees rather than shrubs. Informants reported that tea plants were historically cultivated as trees within agro-forests rather than shrubs because their community did not have time for pruning in their farming schedules due to a greater focus on rice production. Historically, communities often migrated after a few decades and thus did not invest in extensive cultivation activities in tea agro-ecosystems.

Akha at the study site reported that the maintenance of forest cover serves as a windbreak for a high-quality tea product and protection against malevolent spirits. Low wind is regarded suitable for producing good quality tea. Local Akha believe that malevolent spirits are carried by the wind. They fear these spirits and protect themselves by maintaining windbreaks around their community, fields, and gardens. Older informants noted that their ancestors encouraged the growth of windbreaks around the tea systems when they moved to the community approximately 150 years ago. At that time, the agro-forests were surrounded by open fields, and have since been regenerated through fallow and enrichment planting.

Agro-forest managers reported their community historically did not use pesticides, herbicides, artificial fertilizers, or other agrochemicals because of the inaccessibility and cost of these inputs. Agricultural extension agents have promoted the use of agrochemicals since the 1980s at the study sites. Some smallholders have experimented with these inputs in their crop systems. The majority of informants reported that they found the application of agrochemicals destroys soil fertility and the integrity of plants. In addition, many informants agreed that agrochemicals negatively influence the taste and healing properties of plants and have adverse effects for human health. They found that they needed to apply greater amounts of agrochemicals each year and incurred higher costs while natural pest resistance and soil fertility declined. Informants reported that soil characteristics are one of the most influential factors in determining the quality of tea products. Farmers at the main agro-forest study site classified five types of soil in the community that they discern based on color including black, red, brown, yellow, and white soils. Black and red soils were reported as producing the best quality tea products.

Social norms and regulations have developed within the study sites to prohibit the use of agrochemicals in tea agro-forests. The main agro-forest study site has formed a community group to monitor management practices and ensure certain practices are being met. Informants reported that households that go against these practices would be encouraged to follow community norms or would otherwise be socially condemned. These local regulations have been strengthened by market demand for tea grown without the use of agrochemicals.

Agro-forest farmers manually weed and fertilize their tea systems during the winter and rainy seasons for periods of 1 – 3 weeks. They use a machete and their hands to cut and remove weedy vegetation. Removed weeds are used are fertilizer in tea agro their systems through a compost practice (known as *wa cha* in Mandarin) of turning over the weedy under-story below tea plants. This vegetation is cut with a machete and turned over with a garden spade or by hand. Informants reported that weeds have increased in their tea systems with greater removal of associated woody plants and thinning of canopy coverage. They further reported that weeds have increased in their systems with land-use changes in surrounding areas, particularly decreased forest cover, and with the introduction of invasive species. Farmers have thus started to weed their tea systems more frequently.

Some farmers try to extend the life span of tea trees by removing moss, ferns, fungi and epiphytes growing on the trunk and branches of tea plants. Informants reported that the bark of tea trees rots when covered with moss and fungi. Select insect species found on tea plants are also removed. These practices started five years ago when market prices of tea products from ancient tea gardens increased. However, some smallholders maintain epiphytic orchids on their tea plants to impart a desired fragrance and taste to the leaves. Smallholders may also tolerate certain caterpillar species on their tea trees for use in the local ethno-medical system. Several informants reported that the presence of these caterpillar species on tea plants enriches the medicinal properties of tea.

Another practice that has increased in recent years in agro-forests is the removal of flowers from tea trees. Farmers that follow this practice reported they remove flowers so that “the plant will not waste energy in growing flowers and will use it for growing leaves.” Households occasionally harvest flowers from the tea plant for consumption in salad or prepared with other foods. Some farmers have started to experiment with incorporating flowers in creating tea products. Most often, flowers are removed from tea plants are left on the ground as compost.

Farmers of agro-forests hand-pluck the young terminal buds and adjacent leaves of tea plants during the spring, summer, and autumn harvest seasons for processing into tea products. Households occasionally harvest old leaves from tea plants during the winter season for subsistence use in tonics to strengthen the body and protect against colds and coughs. They dedicate six days to tea collection activities per week during the harvest season. Households divide harvesting areas among household members so that each member is harvesting from a different garden or part of a garden. Farmers harvest from an individual tree plant every one to two weeks depending on the development of young terminal buds and leaves that are influenced by the local microclimate. Most farmers reported that the morning is the best time to pluck tea when the leaves are covered with morning dew, as this is perceived to result in a processed tea with good taste. Despite preferences of harvest times during a day, farmers harvest tea from the morning through the evening in order to meet market opportunities.

Managers of tea agro-forests discerned 3-15 tea types, with an average of six types. These tea types are all taxonomically identified as *Camellia sinensis* var. *assamica.* Chapter Eight discusses the variation of folk taxonomy of tea cultivars among the main agro-forest study site. Tea types are variably valued among the community based on their perceived quality such as taste characteristics. In addition to type of tea, informants reported that variability in habitat impacts the quality of tea. The environmental characteristics that most influence tea leaf characteristics are soil, shade, slope, elevation, nearness to a river, and the particular other species in the agro-ecosystem.

Tea plants in agro-forests are harvested after they are approximately nine years of age. Individuals harvest approximately 4-6 kilos of fresh tea buds and leaves per day during the harvest seasons (1 kilo of dried tea leaf = 4 kilos fresh tea leaf material). Total harvest for households depends on household size, which further influences the ability of households to hire off farm laborers to help harvest. Depending on size, tea plants in agro-forests yield approximately 10-110 of fresh young buds and leaves used for tea production. Informants reported that yields vary on the basis of the size of the tea plant and shade exposure. Since 2008, some households have started to hire off-farm laborers from the lowlands to help harvest tea along with household members to further benefit from market opportunities. These laborers are paid 7.55 USD (50 CNY) per day and are usually hired during the spring season when market demand is the highest. Hired laborers are Dai farmers as well as Akha that migrated to lowland towns and no longer have their own tea gardens.

Farmers process the leaves they harvest at the end of each day by pan-frying the leaves in woks, hand-rolling the leaves, and drying them overnight on bamboo mats. Households process leaf till 10 -11 pm during high-points of the harvest season. Observation during the study period indicated that farmers have started to use bigger woks and construct processing spaces in the homes as they harvest greater quantities of tea. Fuel wood is a significant input in tea production. Households use approximately 1 kilo of fuel wood per kilo of dried processed tea (4 kilos of fresh tea leaf).

Processed leaf is usually sold to middlemen that visit the community. Since 2009, farmers are increasingly leaving the community to sell their product in lowland towns in Xishuangbanna including Menghai and Jinghong. They are also traveling to other tea centers in Xishuangbanna such as Eiwu. Farmers most often sell their tea leaves as a processed product but occasionally sell fresh unprocessed leaves to middlemen looking to process the leaves in lowland factories. Over the study period, tea from the community fluctuated between 37.76 – 203.92 USD (250-1,350 CNY) per kilo of dried tea leaf. Figure 4.1 illustrates the average price per kilo of dried tea leaf over a decade at the main agro-forest study site and depicts the seasonal variation of prices between the spring and summer harvest. Agro-forest managers received an annual income of 7,000 - 150,000 USD during the study period. Variations in income among households in a given

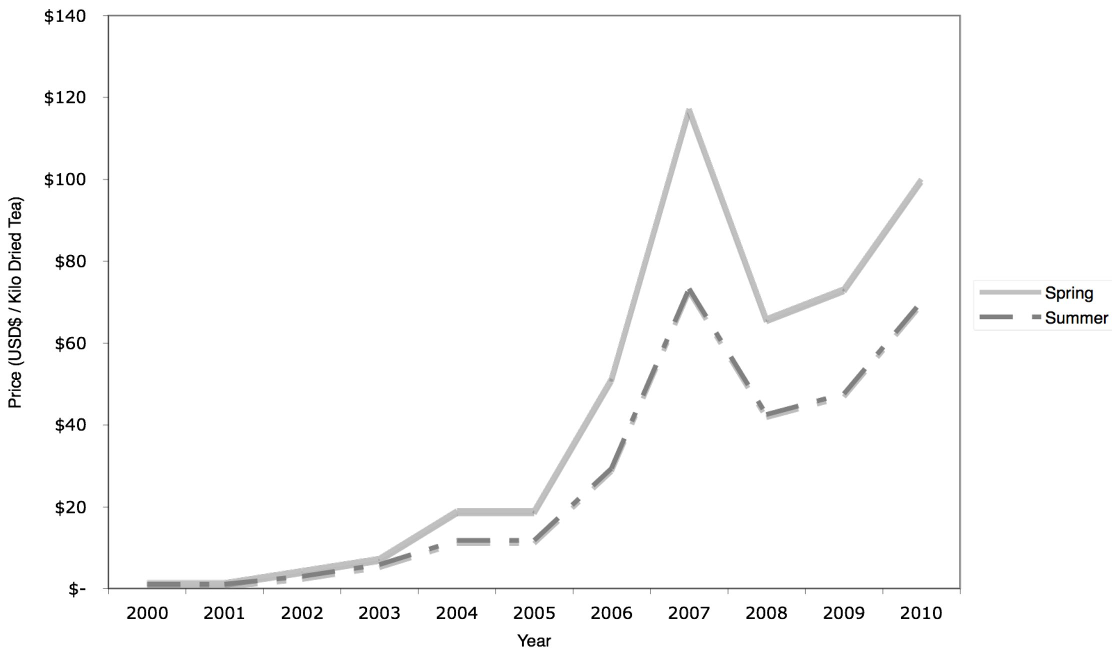


Figure 4.1 Average price of dried tea (US$ / Kilo) between 2000 – 2010 during the spring and summer season received by smallholders at the main agro-forest study site in Xishuangbanna, Yunnan.

year varied on the basis of household size and market connections.

Some communities managing agro-forests honor the spring tea harvest with ceremonial ritual. Bulang managers of agro-forests practice a spring harvest ceremony that integrates their pre-Buddhist animist traditions with Theravada Buddhism. In some Bulang communities managing agro-forests, the community constructs an altar in a selected tea agro-forest regarded as sacred where all community members gather. The spiritual advisor of the community reads texts in Dai scripts to thank their ancestral founder for gifting tea trees to support the Bulang forever. This is accompanied by music, dance, and ritual offerings at the altar. In other Bulang communities managing agro-forests, the spring tea harvest is honored in a smaller ceremony with a few community leaders. The community's spiritual leader hosts a ceremony on a selected day in the spring where he ties a red thread around an old sacred tea tree and connects it to himself. The leader then encircles the tea tree reciting prayers, thanking the ancestors for tea plants, and requesting protection for the community and a good harvest. Informants reported that this practice represents the connection that tea plants have to the lifeblood of the community.

Akha informants at the main agro-forest study site reported that they learnt about managing tea systems from their elders, relatives and friends, other communities, tea entrepreneurs, and through continual experimentation in their gardens. They reported they particularly learnt from the nearby Bulang community. Local Akha regard the Bulang to be their "older brothers" as the oldest living settlers on the mountain. Community members start harvesting tea at the age of around eleven or twelve by assisting their parents or other family members. They learn about management through observation, instruction, experimentation, and social exchange with others.

Mixed Crop Fields

Farmers of mixed crop tea fields practice some similar practices as managers of agro-forests including: (1) enrichment planting of tea, (2) transplantation and introduction of tea seeds and seedlings from nearby forest populations and communities, (3) manual weeding and fertilizing, (4) pruning of tea plants, and (5) harvesting. Their activities are distinguished from agro-forests with their focus on grain production along with tea.

Farmers eliminate woody species in their tea systems and intercrop corn and other crops with tea plants. While farmers did not mention tolerance of associated woody plants in or around their mixed crop fields during preliminary interviews, participant observation found several *Pinus* sp. individuals in these systems. Further interviews inquiring about these species indicated that farmers maintain these species as timber sources for construction material.

The mixed crop fields surveyed were 0.1-0.4 ha in size and were surrounded mostly by open crop fields of corn and rice. Households manage -.3 – 0.7 ha of mixed crop fields depending on household size. An approximate of 900 tea plants grow in 1 ha of mixed crop field and are irregularly distributed, usually with at least 2 m distance between plants. Farmers maintain tea plants as dwarf trees or shrubs. Informants reported the tea plants within the mixed crop fields were 40 – 80 years of age. They prune tea plants into dwarf trees or shrubs in order to increase solar radiation for greater crop yields. Farmers try to maintain at least 2 meters of distance between tea plants because of the extensive root system that requires space for proper plant growth. However, as in the agro-forest study sites, informants reported that the distance between tea plants has become less with increased market opportunities.

Informants do not directly apply pesticides, herbicides, hormones, or other agrochemicals to their tea fields because these inputs are perceived to degrade soil quality. A community group has formed at the main mixed crop study site to monitor management practices within the community and work towards certifying the community's tea products for green marketing. However, farmers do apply pesticides, herbicides, and artificial fertilizers to the open grain fields that surround their tea fields as they regard the use of these agrochemicals necessary for improved crop yields. Some informants noted that run-off from neighboring fields carry agrochemicals into tea fields.

Another problem that farmers noted that are associated with the open fields is the issue of landslides. Informants noted that landslides in the community have increasingly become a problem since the open fields in the community expanded. Some farmers reported that the extensive and strong root system of tea plants is able to protect against soil erosion and damage of other crops during landslides. They have thus started to cultivate tea plants at the edges of crop fields to prevent landslides from destroying their other crops.

Farmers plant tea throughout the year. Over the past decade, they have started to source seedlings from lowland nurseries. Nursery entrepreneurs source seeds from the community and surrounding communities and sell seedlings back to these communities for 3.02 USD (20 CNY) per seedling. This has resulted in households being unable to find enough seeds in their communities to cultivate tea plants. However, informants reported that the success rate of seed to seedling is greater in the lowlands than it is in their upland environment and are therefore willing to purchase seedlings. The nursery differentiates its seedlings based on the mountain where the seeds were sourced. Farmers are most often unable to differentiate between tea types at the seedling stage and are able to discern tea plants several years after they have been planted in their fields. Participant observation and interviews found that farmers remove individual tea plants whose characteristics they do not like. Seedling exchange between communities is also common. Historically, the mixed crop study sites surveyed participated in an annual seed exchange fair where farmers of different mountain communities gathered with seeds of various crops. Farmers exchanged tea seeds for grain or tea products for grains.

As in the other tea production systems, managers of mixed crop fields harvest tea during the spring, summer, and autumn seasons. Tea plants in mixed crop fields are harvested after they are three or four years of age. Households hand pluck tea leaves 5-7 days per week during the harvest season depending on their other activities and the weather. Household members each harvest approximately 5-7 kilos of fresh tea buds and leaves per day. Farmers collect leaves from an individual tea plant about every 4 days. Individual tea plants in mixed crop fields yield variable yields depending on the size, ranging from 10 to 100 kilos the young buds and leaves used for processing tea. Tea prices fluctuated 4.53-37.76 USD (30-250 CNY) for one kilo of dried tea leaf during the study period and smallholders received an annual income of 2,000 – 36,000 USD with an average of 7,000 USD in the community.

Informants reported that variation in tea plant characteristics result from type of propagation material, variety, plant density within agro-ecosystems, age of plants, and years after pruning. Farmers of mixed crop tea fields discerned 2-16 tea types and an average of five types. Figure 4.2 shows leaf shapes and sizes of tea cultivars recognized as folk varieties by a Lahu farmer managing a mixed crop tea field. Most of these tea types were identified as *Camellia sinensis* var. *assamica*. *Hei taio zi cha* ("black stripe tea") and *dou mi cha* ("gent bean tea") were identified as *Camellia taliensis*.

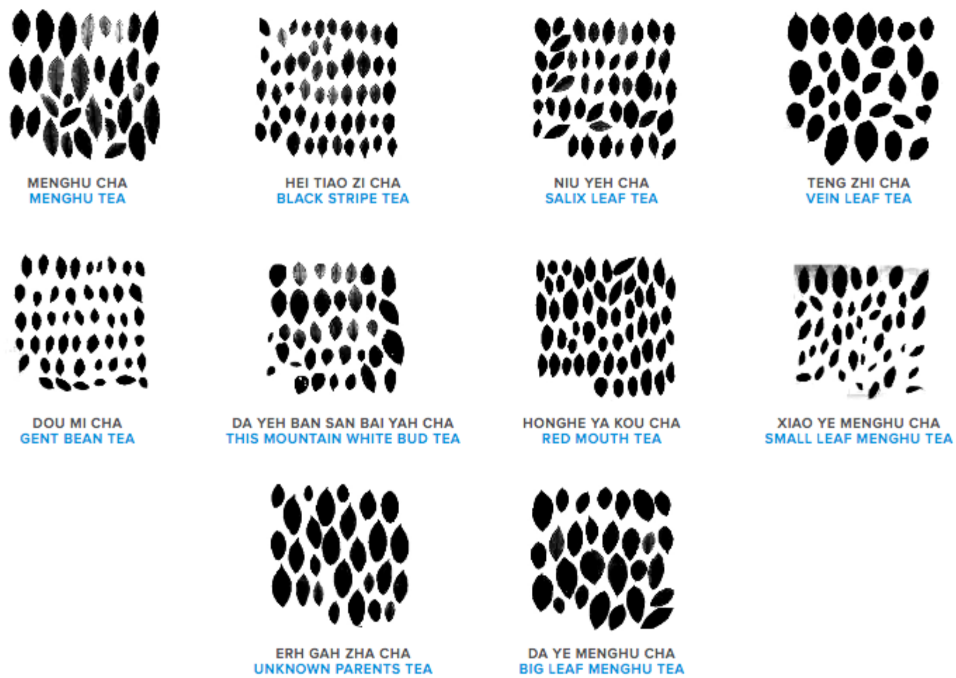


Figure 4.2 Example of a Lahu smallholder's classification system of tea types cultivated in a community that manages tea plants in mixed crop fields. Images are of tea leaves of each tea type discerned by the smallholder. Local names and translations are below the leaf images. The leaf images are relative scale to each other.

Once harvested, tea leaves are processed by households through pan-frying, rolling, and drying. At the main mixed crop study site, households pan-fry leaves on woks in their homes then roll leaves using the community's mechanical roller that was purchased through joint household funds. Households use 1-3 kilos of fuel wood to process one kilo of dried processed tea. During the rainy season, leaves are dried in large smoke baskets that lit with charcoal fires at the base to dry the leaves. Leaves are dried on racks of bamboo mats under a shaded open-air workspace.

Terrace Gardens

Activities in terrace tea gardens are distinguished from forests, agro-forests and mixed crop fields through a management focus on modern agricultural practices. Since the 1970s, state-supported tea research institutes and extension agents have trained rural smallholders in southern Yunnan on “improved” tea cultivation based on uniformity, high-yield, and efficiency by planting clonal propagules in compact hedge rows and maintaining them as shrubs of 0.75 -1.5 meters tall. These systems rely on chemical inputs for management of soil fertility, pests, and disease because they lack the structure and function of forests to provide these ecosystem services. The smallholder terrace tea gardens surveyed at the two study sites, terrace site I and terrace site II, variably follow management practices encouraged by state-supported tea research institutes and extension agents.

The terraces at site I were created by joint efforts of the state-supported tea research institute and by local Akha farmers that previously managed tea in agro-forests. These terraces serve as experimental plots for the tea institute and a primary source of livelihood for locals. Lahu and Han farmers created the terraces at site II following training by extension agents over the past decade. Some farmers have expanded the area of terraces in response to increased market demand while others are increasing the area of the mixed crop fields they previously managed because of greater price premiums from these latter systems.

Terraces at study site I were 0.5-1 ha in size and were 0.15-0.7 ha at site II. Individual terrace gardens are situated adjacent to other terrace tea gardens, resulting in an area of terraces of approximately 60 ha at terrace site I, and 25 ha at terrace site II. Farmers periodically cut young tea plants in terraces to encourage the formation of a bush rather than allowing the tea plant to grow as a tree. They prune branches several times a year to maintain a standard hedge size. Informants at the study sites reported that maintaining tea plants in a hedge results in ease of harvest and allows them to harvest more leaves within a time period. Informants at terrace site I also reported that maintaining uniform size tea shrubs helps to decrease variability of product. Farmers at terrace site I use mechanical clippers to prune tea plants and most farmers at terrace site II prune tea plants using manual clippers. Extensive pruning occurs every three to four years to encourage fresh growth of branches. Farmers at terrace I reported that new tea shrubs will need to be cultivated in their terraces when individual plants reach about 60 years of age.

A major difference between the terrace tea gardens at the two study sites was the use of clonal propagules at site I and the use of seedlings at site II. Informants at site I manage two types of clonal propagules in their terraces from material received from the state-supported tea institute. Farmers were encouraged to use select clonal varieties by the state-supported tea institute because of their high-yield potential, predictable characteristics, and stress resistance. Informants at site II created their terrace gardens using seedlings from lowland nurseries that source seed from mixed crop agro-ecosystems in the surrounding mountain areas. They discern four tea types growing in their terraces. Seeds are generally raised in nurseries for 1-3 years before being planted in terraces. Farmers at site II reported that they cultivate their terraces using seed rather than clonal propagules encouraged by extension agents because they prefer the taste and quality of local tea types sourced from surrounding mountain areas. Most of the tea types sourced from the nursery are regarded to be more suitable for the local environment than the varieties introduced by extension agents. Market preferences for large leaves have also encouraged farmers to grow tea types that yield large leaves. Most of the varieties introduced by extension agents yield small leaves. In addition, informants reported that tea plants from seeds have deeper root system than plants generated from cuttings and are able to protect against soil erosion. Soil erosion and landslides were reported to be major problems at the study sites. Some farmers have introduced narrow hedges of trees for soil protection.

Farmers at both terrace tea sites apply fertilizer, pesticides, and herbicides to manage for pests and disease. Households at site I also apply hormones for better growth. Herbicides and fertilizers are applied to increase yields. Informants reported that they use pesticides to prevent leaves from looking damaged by pest attack in order to be desirable for sales. They shared that without the application of pesticides, tea leaves are eaten by beetles, spider mites and caterpillars. Tea plants are also vulnerable to blister blight leaf disease. Some farmers reported that managing their systems for increased solar radiation serves to decrease moisture levels that promote infection by blister blight. Farmers at site I shared that they apply several kilos of fertilizer annually in their terraces because of high nutrient requirements from the high-yielding varieties they cultivate. Agrochemicals are purchased from state-supported agricultural extension stores or private enterprises in the lowlands. There is no irrigation in these systems due to abundant rainfall.

During the harvest season, farmers at site I use mechanized clippers to cut leaves on the upper branches of tea shrubs. They harvest approximately 50 kilos of plant material per day that contains about 20 kilos of leaf material used for preparing tea products. Alternatively, smallholders at site II hand pluck the young terminal sprouts and adjacent leaves of tea plants. They harvest approximately 10 kilos of fresh tea buds per day during the harvest seasons. Terrace gardens with the high-yielding clonal propagules annually yield an average of 64,000 kilos of buds and leaves used for tea processing per hectare and those cultivated from seed yield an average of 16,000 kilos. Farmers at the terrace sites received 1,000-10,500 USD during the study period.

DISCUSSION

This chapter demonstrated that farmers at the study sites are deliberately managing tea resource systems on the basis of multiple factors including knowledge, cultural beliefs and customs, utilitarian needs, economic opportunities, preferences, and goals. Farmers variably account for these factors and their associated cost to benefit values in making management decisions. Results indicated that each tea management is associated with a few distinct benefits and costs and that these cost to benefit ratios are shifting with market opportunities. Participant observation and interviews emphasized the dynamic nature of management of tea resource systems as farmers continuously evaluate shifting cost to benefit ratios underlying various management options. Findings further revealed the trade-offs that farmers make in their management decisions as they select to carry out management activities that they consider have adverse effects on the environment and tea quality.

This case study contributes to the literature documenting the co-evolution of natural and cultural processes in resource management systems (McKey et al. 1993; Leach and Fairhead 1993; Dove 1994 and 1995) and to the literature documenting the management practices in indigenous communities (Posey 1985; Anderson 1990; Gomez-Pompa 1991; Gomez-Pompa and Kaus 1990; Campbell et al.1993). Findings provide descriptive data on practices to differentiate various tea management systems and contribute to the development of a classification system on these various systems. Such classification can be used for systematic comparisons for further quantitative research on tea management systems that has been lacking in the literature.

Assessing tea forests, agro-forests, mixed-crop fields, and terrace gardens based on a continuum from low input to high input reveals certain trends consistent with the literature on the evolution from a forest environment to a domesticated landscape (Verheij 1991). The transition from forests to different management modes of agro-ecosystems is associated with ecological, technical, and institutional changes. This includes an increase in the presence and productivity of the desired species, in this case tea plants, in increasingly specialized agro-ecosystems. Farmers favor the useful species by removing less desirable species. Uncontrolled harvesting is replaced by a system of controlled rights over specific trees or areas. These user rights are eventually replaced by private ownership. The system eventually changes from a forest environment to open-field conditions. The vegetation structure becomes increasingly systematized, with randomly distributed trees of various ages giving way to even spacing of trees of the same age and the propagation methods change from the use of seeds to clonal propagules. (Verheij 1991)

While this transition model indicates general evolutionary trends from forests to various intensities of agro-ecosystems, the transition from one management system to another are not always irreversible. Historically, some farmers at the study sites cyclically transitioned and regenerated tea systems as forests, agro-forests and mixed crop fields. Previous research has documented similar trends. For example, Fairhead and Leach (1994) describe a process of de-intensification rather than intensification in forest management in West Africa while Baleee (1992) describes the transition from shifting cultivation to forest gathering of several Amerindian tribes in the tropical lowlands of South America.

This study demonstrated that farmers' knowledge at each of the study sites guides many of their management practices. It further indicated that although knowledge is a major factor in farmer decision-making, other factors including preferences, cultural customs, and utilitarian goals also influence decisions and result in variable practices within communities. For example, investigation of farmers' decision making about shade management revealed that they understood that shade influences attributes of tea plants. Farmers of agro-forests articulated that increasing canopy coverage increases leaf size, improves leaf texture, and decreases crown density and yield. Interviews indicated that they had knowledge of tree species that were suitable to cultivate with tea plants and those species that dry soils. Smallholders managing terrace gardens articulated that removing shade from their systems decreases vulnerability to blister blight disease and increases yields. Farmers consistently articulated a conceptual understanding regarding the selection of propagation material. Many farmers reported that select to grow tea from seeds and seedling rather than cuttings in order to take advantage of the strong root to prevent against landslides. Those that use cuttings reported that they have a more consistent product with high yields than if they used seeds. Findings emphasizing the ecological function, utilitarian goals and cultural customs involved in natural resource management are consistent with the literature (Anderson 1996; Schmink et al. 1992; Weidelt 1993).

Results revealed the various ways in which communities are actively managing natural resources and are protecting some of these resources based on local regulations and customs. Informants harvesting from forest populations are primarily guided by national reserve policy to protect and tolerate plant species, whereas local communities managing agro-forests have developed community norms to protect forest cover around their agro-forests. Maintenance of forest cover around agro-forests in the Akha study site serves the utilitarian purpose for communities to source food, medicinal and other useful plants for household consumption and income generation. It provides ecological functions of pest and disease control, windbreak, protection of water resources, soil fertility and erosion control. Maintenance of forest cover around agro-forests also plays a role in the local belief system and fits within the community's larger cosmology by protecting the Akha from malevolent spirits carried by the wind. Previous studies have supported that while protection of forest cover may primarily be based on religious values rather than ecological concerns, they nevertheless function as a conservation strategy (Wiersum 1997). In addition, interviews indicated that farmers at the agro-forest and mixed crop study site conserve and experiment with tea cultivars. The knowledge articulated by farmers is valuable for developing conservation programs integrating agriculture and for the conservation of tea genetic resources.

Interviews and participant observation revealed the dynamic nature of management. Farmers have altered their management practices in response to changes in ecological, cultural, socio-economic, technological, and political conditions. Smallholders of agro-forests are increasingly thinning the woody plants in their systems, decreasing canopy, planting more tea plants, and protecting these resources in response to increased market integration and heightened demand. These actions are consistent with the literature documenting deforestation in response to increased commercialization. However, some farmers are resisting introduction of new agricultural technologies such as agrochemicals, which contradicts numerous studies in the literature (Wiersum 1997).

Results demonstrated that despite the adoption of new agricultural technologies by some communities, farmers are selectively adapting practices. For example, farmers at terrace site II have created terraces after training from extension agents, but continue to propagate with local seeds rather than the introduced clonal propagules because of leaf preferences and an understanding of strategies to prevent against soil erosion. The variation of management between the two terrace study sites highlights that not all terrace gardens are the same and warrants further study of tea resource systems with larger sample sizes.

Findings revealed that market opportunities may result in a situation where farmers carry out management activities that they consider have adverse effects on the environment and tea quality. For example, increasing solar radiation was perceived by agro-forest farmers to increase yields while decreasing the quality of tea products. The occurrence of such practices highlights the trade-offs that farmers have to make and their continuous cost-benefit assessment. However, some farmers at the agro-forest study site indicated that they resist trade-offs that have adverse effects for long-term sustainability such as utilization of agrochemicals. Thus, while they have intensified the planting of tea trees and increased thinning activities, they have avoided the use of agrochemicals to increase yields.

Understanding management practices are of economic importance because high-quality products often depend on management practices coupled with environmental conditions, post-harvest processing, and genetic resources (Bosselmann et al. 2009). The effect of certain management on tea product quality has been poorly documented, such as shade management, and calls for further study. Previous studies have found shade to influence the yields and sensory qualities of other agronomic products. For example, increased shade in coffee production systems at low altitudes was associated with increased yield and sensory properties of some coffee varieties (Beer 1987; DaMatta 2004; Muschler 2001; Vaast et al. 2005). Alternatively, increased shade above 50% resulted in decreased coffee bean yields (Soto-Pinto et al. 2000) while increased at high altitudes resulted in decreased sensory attributes. These findings emphasize that optimal agronomic shade management is related to site conditions and varietals and that recommendations regarding management should consider site-specific conditions.

Other areas that warrant further study based on farmer interviews are soil analysis and fuel wood use associated with tea processing. Farmers emphasized the importance of soils for the quality of tea products and shared their classification system of soils. However, this study did not investigate soil properties. Future studies should analyze soil organic matter content, pH, and texture within tea resource systems and assess the relationship of local soil classification with quality of tea products. This study also found considerable fuel wood usage in processing tea. Future studies should better assess the amount of this use and the sourcing of fuel wood.

Results emphasized that each tea management was associated with different costs and benefits and highlights the tradeoffs that farmers make in their decision-making. For example, while addition of shade species in tea systems can provide protection against erosion, shade is also associated with increased moisture levels that promote the infection of blister blight leaf disease (Banerjee 1994). Some tradeoffs were associated with greater benefits to farmer livelihoods and environmental services than others. For example, farmers of agro-forests and mixed crop fields were found to have lower costs of inputs and lower yields of tea products than farmers of terrace gardens. At the same time, they received greater income from the sale of tea products on the basis of price premiums received for tea sourced from ancient forest tea gardens. Other than market cost of purchasing agrochemicals, terrace gardens may be associated with costs to environmental and human wellbeing. Previous studies have found that poor tea cultivation practices in terrace gardens using agrochemicals sometimes lead to commercial teas with pesticide and heavy metal contamination which have adverse implications for human health (Qin and Chen 2007). Heavy metals in tea primarily come from the uptake of soil contaminated by agrochemicals, industrial processes and from atmospheric deposits. Future study is needed to quantify any agro-chemical residue of tea products at the study sites. Further research is also needed to quantify the yields, uses, and values of other plant products in agro-forests and mixed crop fields. Although farmers of agro-forests and mixed crop fields had lower yields of tea products than terrace gardens per area unit, they harvested other useful plant products in addition to tea.

The adoption of management practices that don't utilize agro-chemicals by other tea growing areas may help farmers differentiate their product in a competitive global market by offering a higher quality-product. Smallholders compete in volatile global markets influenced my climatic events, trends, and large companies. They may gain increased market share and reduce their vulnerability to fluctuating prices by differentiating their product through high-quality product on the basis of accessible management practices. Certification schemes such as organic and fair trade that may help differentiate product are often inaccessible to smallholders.

Incorporating practices from agro-forests and mixed crop fields in the management of terrace tea gardens may be beneficial in protecting against soil erosion, a problematic factor in tea cultivation (Banerjee 1994; Williges 2004). Several practices have already been introduced in terrace gardens in other tea-growing areas to help prevent erosion including alley cropping and adding hedges of tree species at the edge of fields (Banerjee 1994; Williges 2004). Some of these programs have created hedges with utilitarian species that offer farmers additional subsistence and income. For example, in Sri Lanka the government has promoted the addition of hedges and alley cropping in tea terraces in order for soil and environment protection against erosion. They have promoted hedge species that can be used as on-farm food and fodder in order to make their adoption more valuable. The Upper Mahaweli Watershed Management Project in Sri Lanka specifically recommended leguminous species such as *Gliricidia sepium* for hedges because they can be used as valuable fodder to supplement low-protein roughage such as dry grass or rice straw.

CONCLUSION

The present chapter described practices of various tea management systems in Yunnan in order to serve as a basis for further systematic comparisons. Findings revealed that farmer management practices at the study sites are determined based on interactions of underlying knowledge, beliefs, and economic opportunities. Findings highlight the numerous trade-offs involved in management decisions.

The knowledge held by farmers provides valuable lessons and may offer an appropriate basis for designing sustainable farming systems and developing management and policy schemes. Agro-forests and mixed crop fields were found to offer multiple benefits compared to terrace gardens including higher returns to investment, protection against erosion, and an organic product grown without agro-chemicals. On the basis of these benefits, these agro-ecosystems present an attractive alternative management system to the modern terrace garden that dominates tea-growing areas worldwide. Efforts are needed to disseminate farmer knowledge and lessons among communities for more sustainable farming practices. Policy schemes that seek to expand tea cultivation in Yunnan can facilitate the process by drawing from the management practices of agro-forests and mixed crop fields and incorporating community-based management practices in their land-use programs.

Chapter Five

FLORISTIC COMPOSITION AND STRUCTURE OF TEA MANAGEMENT SYSTEMS

The present chapter examines the plant species composition and vegetative structure of tea forest populations, agro-forests, mixed crop fields, and terrace gardens. It expands on characterizing the various tea management systems described in the previous chapter by providing data from ecological plot sampling (Southwood and Henderson 2000). This chapter further provides ethnobotanical inventory data from surveys carried out around tea forest and agro-forest areas on plants that are used and linguistically discerned by smallholders. These systems were selected for ethnobotanical inventories following ecological plot sampling because their management is associated with the tolerance of woody plant species in addition to tea plants.

This research contributes to the body of literature documenting the diversity of plant species in tea management systems in Yunnan (Long and Wang 1996; Qi et al. 2005; Sturgeon 2005). Long et al. (1996) compared the species composition of three plots of 50 m x 100 m in an old agro-forest, a regenerated agro-forest, and a natural forest in a Jinuo community in Jinuo Mountain of southeastern Xishuangbanna Prefecture, Yunnan. Qi et al. (2005) conducted field surveys in 78 plots of 20 m x 20 m in old tea agro-forests in 6 villages in Jingmai Mountain, Lancang County, Yunnan.

METHODS

Ecological Plot Sampling

The tea forest populations, agro-forests and mixed crop fields described in the previous chapter were surveyed through ecological plot sampling. For each of these three management systems, the tea-growing areas managed by five smallholder households were randomly selected for plot sampling. Comparisons were made in two terrace tea gardens near the agro-forests (labeled here as terrace I) and two terraces near the mixed crop fields (labeled here as terrace II). Table 5.1 shows the sample size of plots surveyed for each tea management system at the study sites. A GPS unit was used to map the area of the systems surveyed and a random number generator was employed to select and mark the location of one 20 m x 20 m plot within each system. A 20 m x 10 m plot rather than a 20 m x 20 m plot was marked in two out of the five forest tea areas sampled because these tea populations were situated along narrow trails at the edge of steep mountain slopes and a 20 m x 20 m plot was difficult to sample. In addition, a 20 m x 10 m plot was marked at the edge of the five agro-forests surveyed, as smallholders include the edges of agro-forests in their management practices of tea resources. The total tea management area surveyed was 7,600 m^2.

The floristic composition and spatial pattern of the vegetation in each plot was measured at two levels: (1) all tea trees greater than or equal to 1 m tall and, (2) all associated woody species equal to or greater than 5 cm DBH (diameter breast height; 1.37 m aboveground). Individual plants within the plots were mapped and measured for height and diameter. The local name, use, and taxonomic identification were recorded of

Table 5.1 Sample size of plots surveyed for ecological sampling for each management system at the study sites.

Management System	Study Site Location (Prefecture)	Primary Socio-linguistic Group of Smallholders	Sample Size of 20m x 20m Plots	Sample Size of 20m x 10m Plots	Total Area Surveyed (m^2)
Forest	Honghe	Yao	3	2	1,600
Agro-forest	Xishuangbanna	Akha	5	0	2,000
Agro-forest Edge	Xishuangbanna	Akha	0	5	1,000
Mixed Crop	Lincang	Lahu	5	0	2,000
Terrace (Site I)	Xishuangbanna	Akha	2	0	800
Terrace (Site II)	Lincang	Lahu	2	0	800

each plant species. A horizontal transect of 20 m x 1 m was marked running through the center of each plot to measure canopy coverage using a spherical densiometer.

Ethnobotanical Inventories

Ethnobotanical inventories were conducted around tea forest and agro-forest areas to document the associated plants that are managed, used, and recognized by local communities. At each of these two study sites, three expert informants were selected for transect walks totaling an area of 3 ha. All plants with local names and / or uses were collected and photographed. Local names were voice recorded. Specimens were identified and deposited at the Kunming Institute of Botany.

Data Analysis

Height and DBH of plants tallied in each plot were analyzed statistically using JMP 7.0 software (SAS) to determine mean values. The relationships of height and DBH of plants tallied within plots to management system were determined using Analysis of Variance of pooled means with a significance level of $p \leq 0.05$. Tukey–Kramer HSD was performed to compare all mean pairs. Differences with $p \leq 0.05$ values were considered significant.

Data from plot sampling was further analyzed for Importance Values (IV) and diversity indices. Importance Values rank species within a site on the basis of relative density, relative frequency, and relative dominance (Kent and Cooker 1992). Relative density is the total number of individuals of the species in a given area at the site. Relative frequency is how commonly a species occurs across a site and is a measure of species distribution across the site. This value was determined by tallying the occurrence of a given species in each 10 m x 10 m quadrant of the 20 m x 20 m sample plots. Relative dominance refers to the total basal area occupied by the species in a given area. Basal area measures the cross-sectional area of each tree stem at DBH. For each plot sampled, IV was calculated as the sum of relative frequency, relative density, and relative dominance expressed as a percentage. Plant species diversity of each tea management system was analyzed using Shannon Weiner, Species Evenness, and Species Richness diversity indices (Magurran 2003).

RESULTS

Ecological Plot Sampling

Density and Distribution of Tea Plants

Density of tea plants tallied in the various tea management systems were found to be in the order of terrace site I > terrace site II > mixed crop fields > agro-forest > forest. The average number of tea plants found in each 20 m x 20 m plot surveyed was 20 for forest plots, 43 for agro-forests, 94 for mixed crop fields, 398 for plots at terrace site II, and 930 for tea plants at terrace site I. Figure 5.1 shows the distribution and density of tea plants tallied within one 20 m x 20 m plot sampled for each tea management system. The distribution of tea plants in terrace gardens were regularly spaced in rows while those in the other systems were irregularly positioned within the plots.

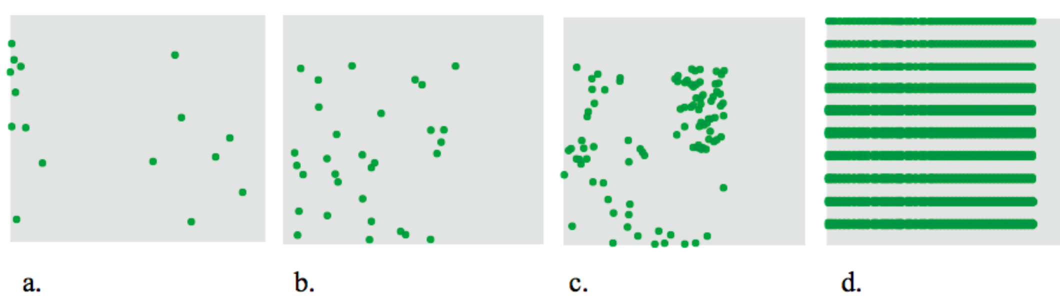


Figure 5.1 Distribution and density of tea plants tallied within one 20 m x 20 m plot sampled in the surveyed tea systems including (a) forest, (b) agro-forest, (c) mixed crop field and (d) terrace gardens. Dots represent tea plants tallied and mapped within the plots.

Height of Plants

Mean height of plants tallied (n=1197) in the various tea management systems were found to be in the order forest > agro-forest > mixed crop fields > terrace site II >

for terrace site I. Results show significant variation in height on the basis of tea management system ($p<0.0001$). Significant variation was further found for means comparisons of height for all pairs of management system ($p<0.0001$) except between terrace site I and terrace site II. Figure 5.2 shows values of height of plants tallied in each tea management system. Plants tallied in forests (n=179) had a mean height of 7.53 m and standard deviation of 4.28. Plants tallied in agro-forest plots (n=243) had a mean height of 3.34 m and standard deviation of 3.93, while those in mixed crop fields (n=501) had a mean of 2.24 m and a standard deviation of 2.12. Plants in terrace gardens had the lowest mean value and standard deviation for height of plants with a mean of 1.02 m and standard deviation of 0.13 for at terrace site I (n=186) and a mean of 0.70 m and standard deviation of 0.39 for terrace site II (n=88).

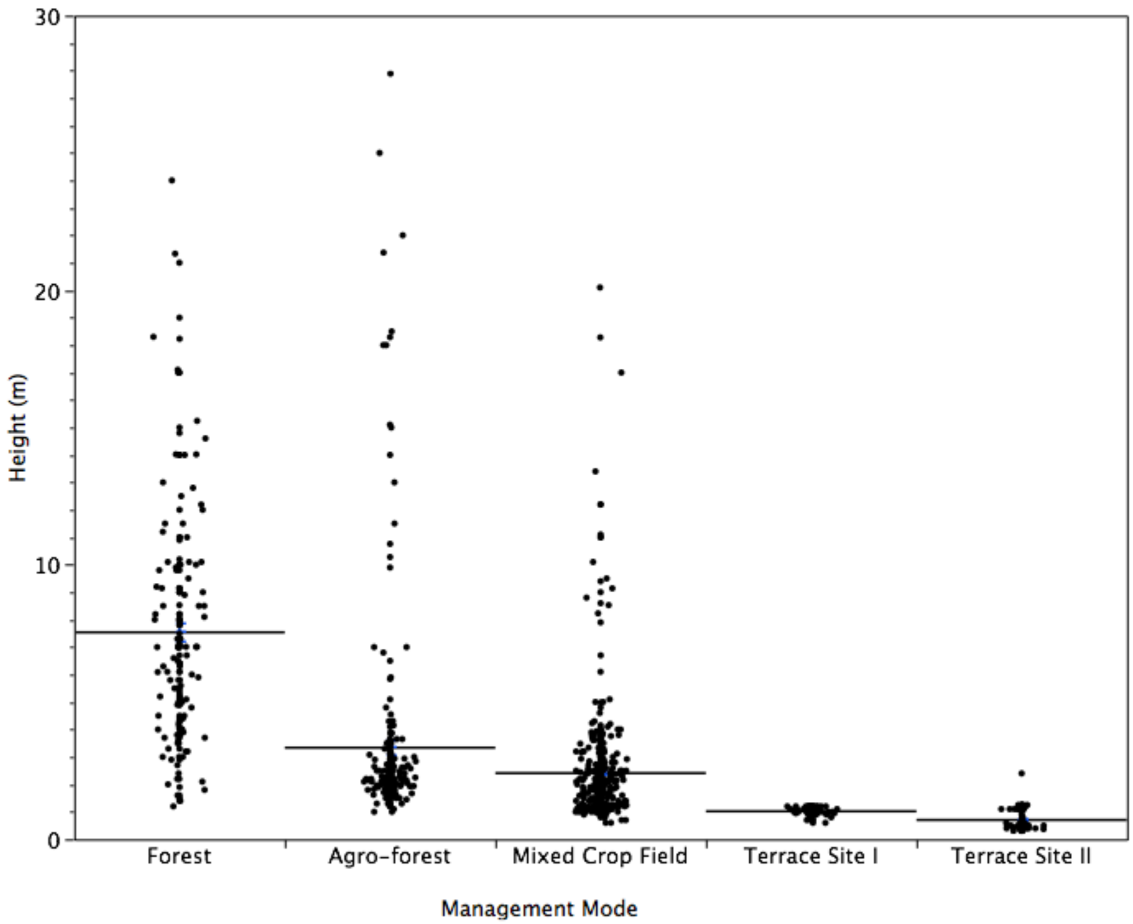


Figure 5.2 Height of plants tallied (n=1197) within sample plots for each management system. Horizontal bar lines represent mean values for each management system. Results show significant variation in height on the basis of management system (*p*<0.0001). Significant variation was further found for means comparisons of height for all pairs of management system (*p*<0.0001) except between terrace site I and terrace site II.

Diameter Breast Height (DBH)

Mean DBH of plants tallied (n=1197) in the tea management systems were found to be in the order forest > agro-forest > mixed crop fields > terrace site I and terrace site II. Results show significant variation in DBH on the basis of management system (*p*<0.0001). Significant variation was further found for means comparisons of DBH for all pairs of management system (*p*<0.0001) except between terrace site I and terrace site

II. Figure 5.3 shows values of DBH of plants tallied in each management system. Plants tallied in forests (n=179) had a mean DBH of 17.75cm and standard deviation of 17.72cm. Plants tallied in agro-forest plots (n=243) had a mean DBH of 13.31cm and standard deviation of 10.02, while those in mixed crop fields (n=501) had a mean of 7.46cm and a standard deviation of 6.70. Plants in terrace gardens did not have DBH values with heights less than 1.37m.

Over-story Density

Over-story density, or canopy coverage, was found to be in the order forest > agro-forest > mixed crop fields > terrace site I and terrace site II. Results show significant variation of over-story density on the basis of management system ($p<0.0001$). Significant variation was further found for means comparisons of over-story density for all pairs of management system ($p<0.0001$) except between terrace site I and terrace site II. Figure 5.4 shows values of over-story density in sample plots for each management system and Figure 5.5 illustrates over-story density within one 20 m x 20 m plot for each management system surveyed. Forest plots had a mean over-story density of 93.01% and standard deviation of 2.16. Agro-forest plots had a mean over-story density of 34.95% and standard deviation of 5.99, while mixed crop fields had a mean of 25.83% and a standard deviation of 17.89. Terrace gardens had no canopy coverage.

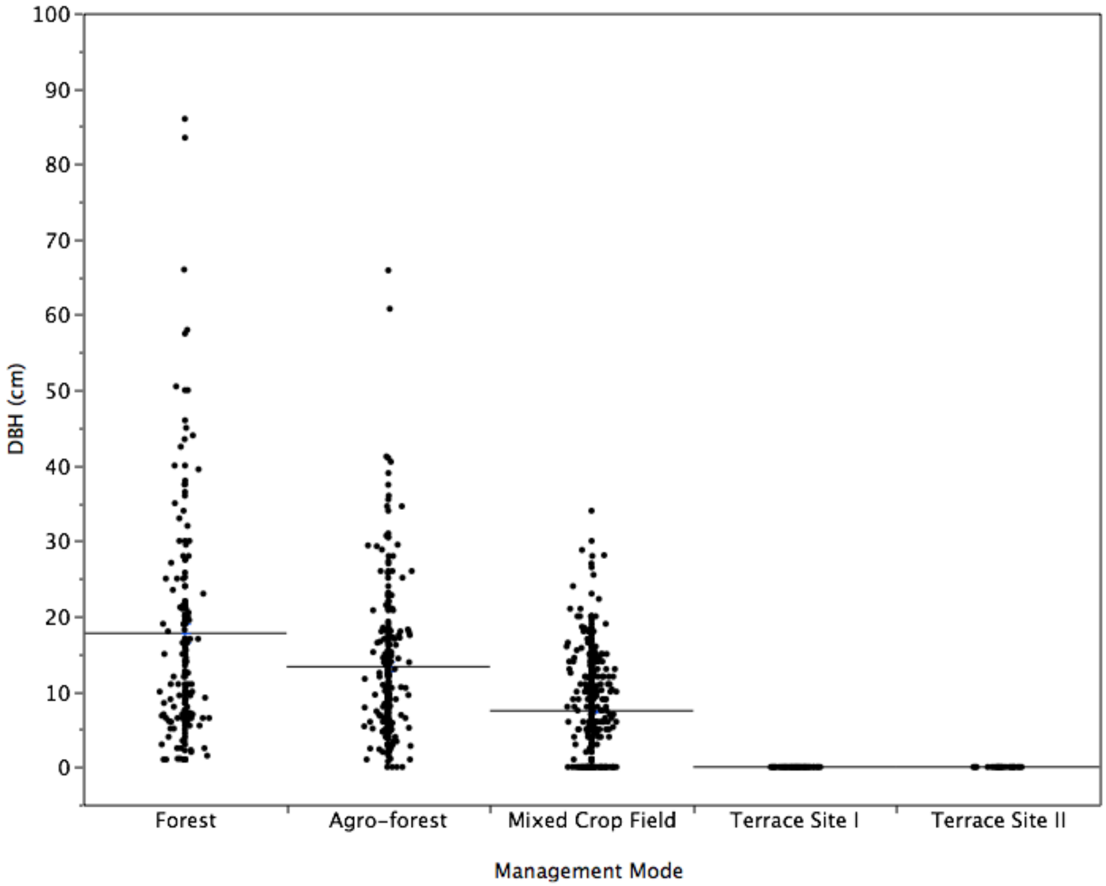


Figure 5.3 Diameter Breast Height (DBH) of plants tallied (n=1197) within sample plots for each management system. Horizontal bar lines represent mean values for each management system. Results show significant variation in height on the basis of management system (p<0.0001). Significant variation was further found for means comparisons of height for all pairs of management systems (p<0.0001) except between terrace site I and terrace site II that had zero values being below the height of DBH.

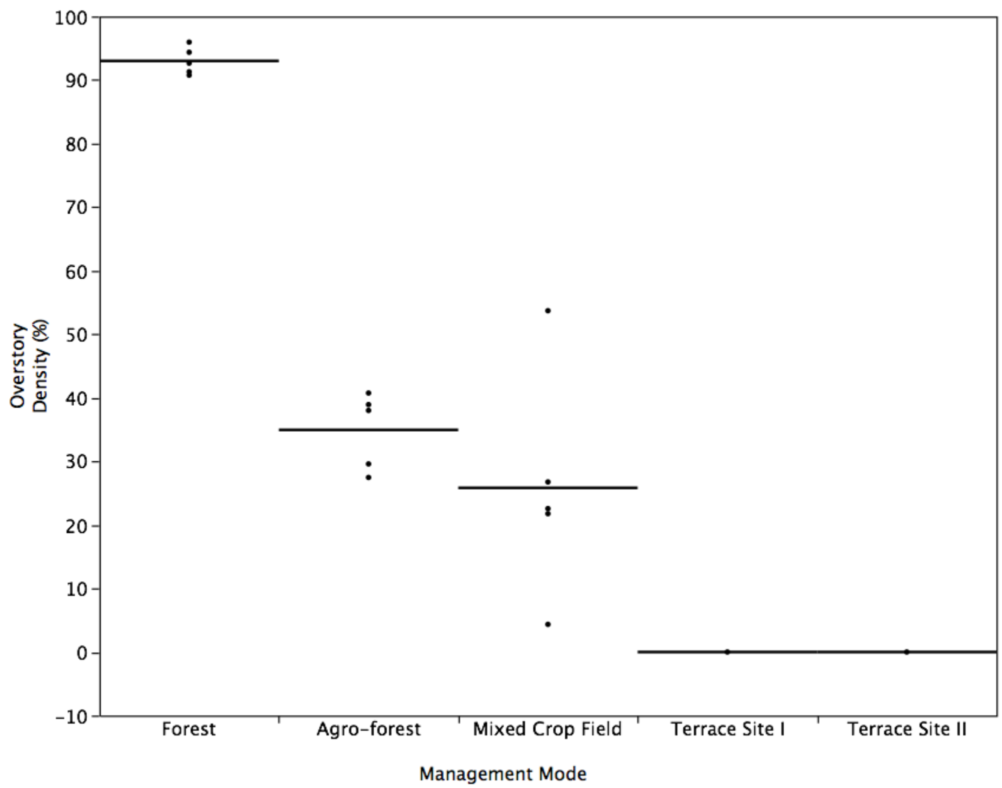


Figure 5.4 Over-story density of plots surveyed for each management system. Results show significant variation of over-story density on the basis management system (p<0.0001) and for means comparisons of over-story density for all pairs of management systems (p<0.0001) except between terrace site I and terrace site II.

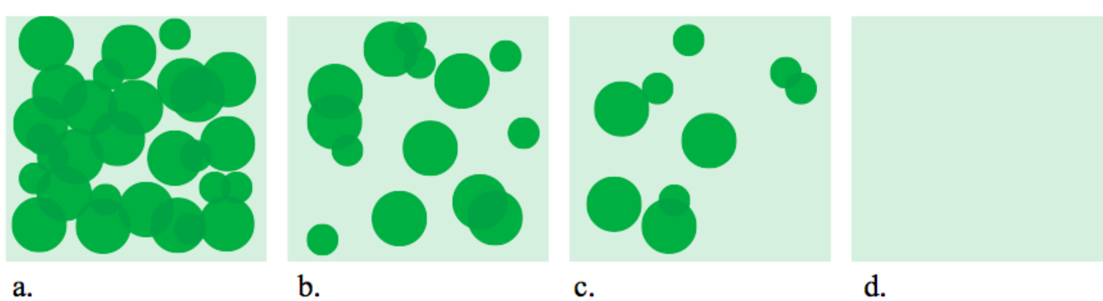


Figure 5.5 Illustration of over-story density within one 20 m x 20 m plot sampled in the surveyed tea systems including (a) forest, (b) agro-forest, (c) mixed crop field and (d) terrace gardens. Dots represent over-story mapped within the plots.

Importance Values

Importance Values (IV) found that *Camellia sinensis* var. *assamica* had the highest IV of all plant species tallied for all agro-forest and terrace garden plots and for four of the mixed crop plots. The IV of *Camellia sinensis* var. *assamica* ranged from 43.96% - 74.67% in agro-forest plots, 43.95% - 100% in mixed crop fields, and was 100% in all terrace plots. *Camellia sinensis* var. *assamica* had the greatest IV of all plant species tallied in two of the five forest plots. Table 5.2 lists the IV of plant species inventoried in surveyed plots.

The forest systems surveyed consist of three species taxonomically classified as wild tea (section *Thea* of *Camellia*): *Camellia crassicolumna*, *Camellia sinensis* var. *assamica,* and *Camellia taliensis*. In addition, individuals of *Camellia tsaii* and *Camellia caudata* were tallied in forest plots. While these species are not classified as wild tea as they are not in section *Thea* of *Camellia*, local communities perceive these as tea types that are related to *Camellia sinensis* var. *assamica* and may be used similarly. The IV of *Camellia sinensis* var. *assamica* ranged from 7.4% - 32.4% in forest plots.

The other species with IV of greater than 10% in the forest plots include *Cyclobalanopsis* sp. (Fagaceae), *Acer* sp. (Aceraceae), *Jacaranda* sp. (Bignoniaceae), *Eurya groffii* (Theaceae), *Castanopsis platyacantha* (Fagaceae), Legumaceae, *Viburnum pyramidatum* (Caprifoliaceae), *Ilex godajam (*Aquifoliaceae), and *Eurya loquiana* (Theaceae). Plants species with IV of greater than 10% in agro-forests include *Calophyllum polyanthum* (Clusiaceae), *Schefflera* sp. (Araliaceae), *Docynia delavayi*

Table 5.2 Importance Values (IV) of plant species tallied in forest, agro-forest, mixed crop fields, and terrace garden plots. All plots were 20m x 20m, except Forest Plots 4 and 5 were 20m x 10m because they were at the edge of steep slopes. Data is provided for the density (D), frequency (F), and basal area (BA) of each species in the study plots. IV was calculated as the sum of relative D, relative F, and relative BA expressed as a percentage.

Species	Family	D	F	BA (m^2)	IV (%)
Forest Plot 1					
Camellia crassicolumna	Theaceae	16	4	0.457	17.03
Cyclobalanopsis sp.	Fagaceae	8	3	0.666	14.62
Acer sp.	Aceraceae	9	4	0.126	9.70
Illicium sp.	Magnoliaceae	7	3	0.180	8.40
Lithocarpus sp.	Fagaceae	1	1	0.581	8.28
Macaranga sp.	Euphorbiaceae	3	3	0.266	7.45
Castanopsis sp.	Fagaceae	5	3	0.111	6.62
Phoebe sp.	Lauraceae	4	2	0.067	4.65
Ilex sp.	Aquifoliaceae	4	1	0.066	3.69
Eurya prunifolia	Theaceae	1	1	0.166	3.40
Milletia sp.	Fabaceae	2	2	0.026	3.19
Eurya groffii	Theaceae	2	2	0.004	2.93
Maesa ramentacea	Myrsinaceae	1	1	0.059	2.14
Manglietia fordiana	Magnoliaceae	1	1	0.043	1.95
Euonymus sp.	Celastraceae	1	1	0.006	1.52
Machilus sp.	Lauraceae	1	1	0.005	1.50
Litsea sp.	Lauraceae	1	1	0.004	1.49
Camellia caudata	Theaceae	1	1	0.000	1.44
Forest Plot 2					
Camellia sinensis var. *assamica*	Theaceae	36	4	0.326	32.40
Viburnum pyramidatum	Caprifoliaceae	17	3	0.447	23.93
Castanopsis sp.	Fagaceae	1	1	0.292	8.93
Viburnum leiocarpum	Caprifoliaceae	2	2	0.174	8.38
Maesa ramentacea	Myrsinaceae	1	1	0.080	4.03
Toxocarpus villosus	Asclepiadaceae	1	1	0.036	3.01
Acer sp.	Aceraceae	1	1	0.032	2.91
Maesa striata	Myrsinaceae	1	1	0.023	2.71
Symplocos anomala	Symplocaceae	1	1	0.011	2.43
Camellia caudata	Theaceae	1	1	0.006	2.31
Grewia glabra	Tiliaceae	1	1	0.005	2.29
Wendlandia scabra	Rubiaceae	1	1	0.004	2.26
Clerodendrum mandarinorum	Verbenaceae	1	1	0.002	2.23
Camellia tsaii	Theaceae	1	1	0.000	2.18
Forest Plot 3					
Castanopsis platyacantha	Fagaceae	3	2	1.299	19.33
Eurya loquiana	Theaceae	11	4	0.288	15.13
Ilex godajam	Aquifoliaceae	4	3	0.409	10.75
Camellia taliensis	Theaceae	5	3	0.092	7.73

Species	Family	D	F	BA (m^2)	IV (%)
Forest Plot 3 *(continued)*					
Camellia pachyandra	Theaceae	7	1	0.151	7.53
Camellia sinensis var. assamica	Theaceae	5	3	0.063	7.40
Acer flabellatum	Aceraceae	4	3	0.080	6.93
Litsea sp.	Lauraceae	2	2	0.050	4.14
Brassaiopsis ciliata	Araliaceae	2	2	0.045	4.08
Manglietia insignis	Magnoliaceae	1	1	0.170	3.75
Rehderodendron kweichowense	Styracaceae	1	1	0.126	3.24
Schefflera sp.	Araliaceae	1	1	0.049	2.35
Daphniphyllum macropodum	Daphniphyllaceae	1	1	0.011	1.91
Ilex chinensis	Aquifoliaceae	1	1	0.009	1.88
Machilus sp.	Lauraceae	1	1	0.009	1.88
Prunus phaeosticta	Rosaceae	1	1	0.017	1.97
Maesa ramentacea	Myrsinaceae	1	1	0.080	4.03
Toxocarpus villosus	Asclepiadaceae	1	1	0.036	3.01
Acer sp.	Aceraceae	1	1	0.032	2.91
Maesa striata	Myrsinaceae	1	1	0.023	2.71
Symplocos anomala	Symplocaceae	1	1	0.011	2.43
Camellia caudata	Theaceae	1	1	0.006	2.31
Grewia glabra	Tiliaceae	1	1	0.005	2.29
Wendlandia scabra	Rubiaceae	1	1	0.004	2.26
Clerodendrum mandarinorum	Verbenaceae	1	1	0.002	2.23
Camellia tsaii	Theaceae	1	1	0.000	2.18
Forest Plot 4					
Cyclobalanopsis sp.	Fagaceae	3		0.071	25.88
Camellia sinensis var. *assamica*	Theaceae	4		0.014	15.01
Legumaceae	Legumaceae	1		0.044	13.49
Jacaranda sp.	Bignonicaceae	1		0.028	9.71
Roseaceae	Roseaceae	2		0.007	7.66
Paralia sp.	Ebencaceae	1		0.018	7.21
Macaranga sp.	Euphorbiaceae	1		0.017	6.88
Mussaenda sp.	Rubiaceae	1		0.004	4.00
Castanopsis sp.	Fagaceae	1		0.002	3.41
Moreaceae	Moreaceae	1		0.002	3.41
Evodia sp.	Rutaceae	1		0.002	3.34
Forest Plot 5					
Camellia sinensis var. *assamica*	Theaceae	11		0.135	31.83
Castanopsis sp.	Fagaceae	1		0.196	22.16
Eurya groffii	Theaceae	5		0.021	10.23
Schefflera sp.	Araliaceae	2		0.049	8.36

Species	Family	D	F	BA (m^2)	IV (%)
Forest Plot 5 *(continued)*					
Grewia glabra	Tiliaceae	2		0.029	6.28
Phoebe sp.	Lauraceae	3		0.013	6.23
Manglietia fordiana	Magnoliaceae	2		0.013	4.59
Litsea sp.	Lauraceae	2		0.010	4.28
Viburnum leiocarpum	Caprifoliaceae	1		0.006	2.21
Eurya prunifolia	Theaceae	1		0.003	1.96
Camellia tsaii	Theaceae	1		0.002	1.86
Agro-forest Plot 1					
Camellia sinensis var. *assamica*	Theaceae	31	4	0.199	74.67
Calophyllum polyanthum	Clusiaceae	1	1	0.094	16.53
Myrica esculenta	Myricaceae	1	1	0.021	8.80
Agro-forest Plot 2					
Camellia sinensis var. *assamica*	Theaceae	46	4	0.574	65.76
Schefflera sp.	Araliaceae	1	1	0.290	14.16
Castanopsis sp.	Fagaceae	1	1	0.133	9.12
Manglietia fordiana	Magnoliaceae	1	1	0.027	5.70
Helicia vestita	Proteaceae	1	1	0.013	5.26
Agro-forest Plot 3					
Camellia sinensis var. *assamica*	Theaceae	30	4	0.098	53.59
Docynia delavayi	Rosaceae	2	1	0.114	15.77
Koelreuteria bipinnata	Sapindaceae	1	1	0.091	12.88
Erythrina indica	Fabaceae	1	1	0.067	10.88
Rhus chinensis	Anacardiaceae	1	1	0.021	6.88
Agro-forest Plot 4					
Camellia sinensis var. *assamica*	Theaceae	50	4	0.094	43.96
Prunus majestica	Rosaceae	3	1	0.495	24.77
Maesa indica	Myrsinaceae	2	1	0.125	9.41
Symplocos anomala	Symplocaceae	4	1	0.034	6.86
Erythrina indica	Fabaceae	1	1	0.053	6.00
Lindera communis	Lauraceae	1	1	0.025	4.87
Rhus chinensis	Anacardiaceae	1	1	0.007	4.14
Agro-forest Plot 5					
Camellia sinensis var. *assamica*	Theaceae	61	4	0.063	56.79
Melia toosendan	Meliaceae	1	1	0.094	18.64
Melia azedarach	Meliaceae	2	1	0.063	14.56
Alangium chinense	Cornaceae	1	1	0.004	5.23
Rhus chinensis	Anacardiaceae	1	1	0.001	4.78

Species	Family	D	F	BA (m^2)	IV (%)
Mixed Crop Plot 1					
Camellia sinensis var. *assamica*	Theaceae	99	4	0.146	100.00
Mixed Crop Plot 2					
Camellia sinensis var. *assamica*	Theaceae	128	4	0.645	100.00
Mixed Crop Plot 3					
Pinus sp.	Pinaceae	9	4	0.237	56.05
Camellia sinensis var. *assamica*	Theaceae	32	4	0.009	43.95
Mixed Crop Plot 4					
Camellia sinensis var. *assamica*	Theaceae	132	4	0.189	100.00
Mixed Crop Plot 5					
Camellia sinensis var. *assamica*	Theaceae	78	4	0.086	52.26
Pinus sp.	Pinaceae	8	4	0.447	47.74
Terrace Site I Plot 1					
Camellia sinensis var. *assamica*	Theaceae	1060	4	0.000	100.00
Terrace Site I Plot 2					
Camellia sinensis var. *assamica*	Theaceae	800	4	0.000	100.00
Terrace Site II Plot 1					
Camellia sinensis var. *assamica*	Theaceae	444	4	0.000	100.00
Terrace Site II Plot 2					
Camellia sinensis var. *assamica*	Theaceae	352	4	0.000	100.00

(Rosaceae), *Koelreuteria bipinnata* (Sapindaceae), *Erythrina indica* (Fabaceae), *Prunus majestica* (Rosaceae). *Pinus* sp. (Pinaceae) had the highest IV in one of the mixed crop plots.

Diversity Indices

Shannon-Wiener Diversity, Species Evenness, and Species Richness values for the tea systems surveyed were found to be in the order of agro-forest edge > forest > agro-forest > mixed crop field > terrace site I and terrace site II. Figure 5.6 shows values for Shannon-Wiener Diversity Index for each management system. Figure 5.7 shows values Species Richness and Species Evenness for each management system.

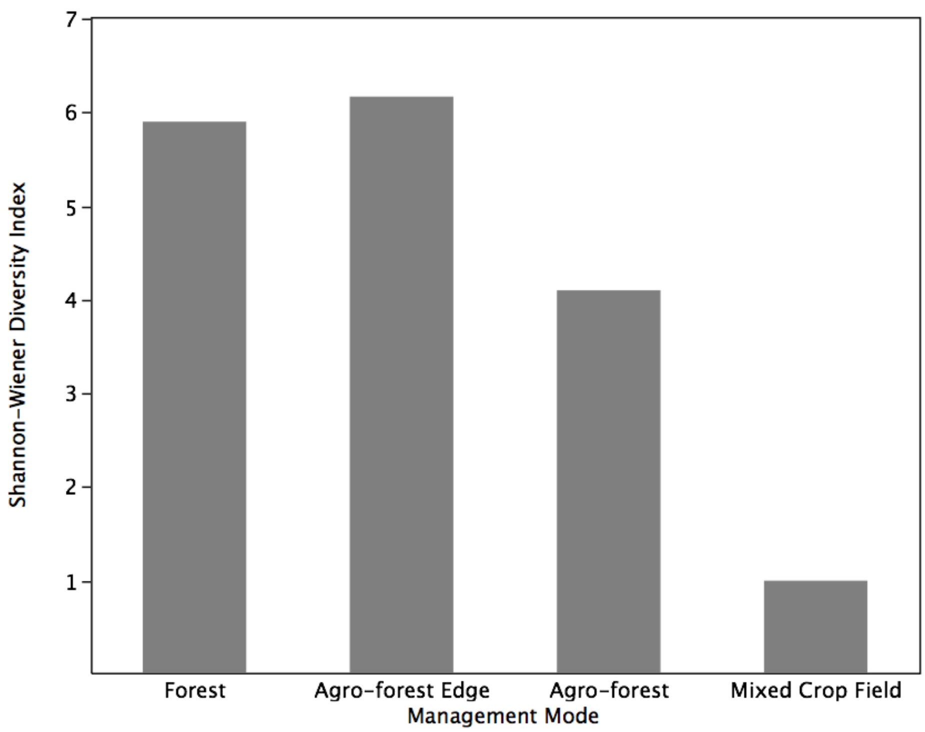
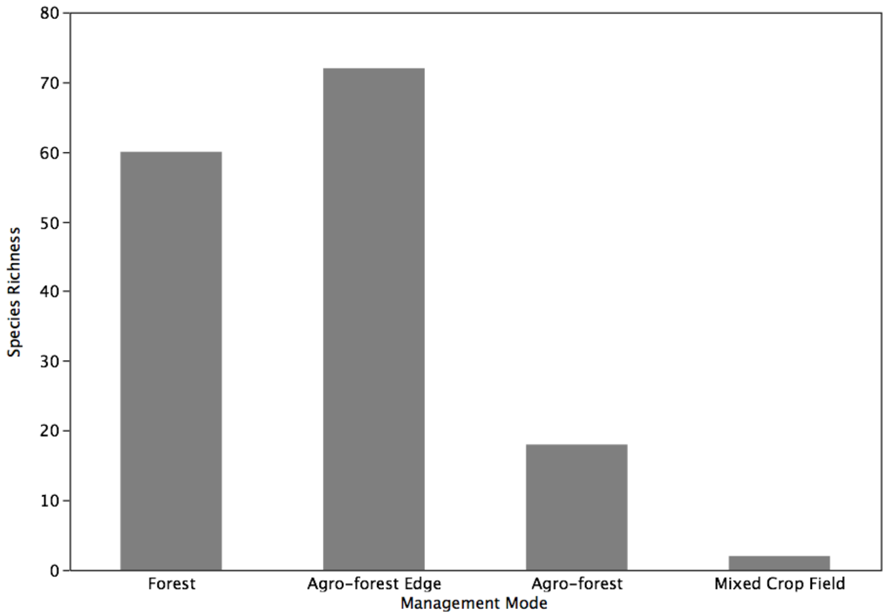
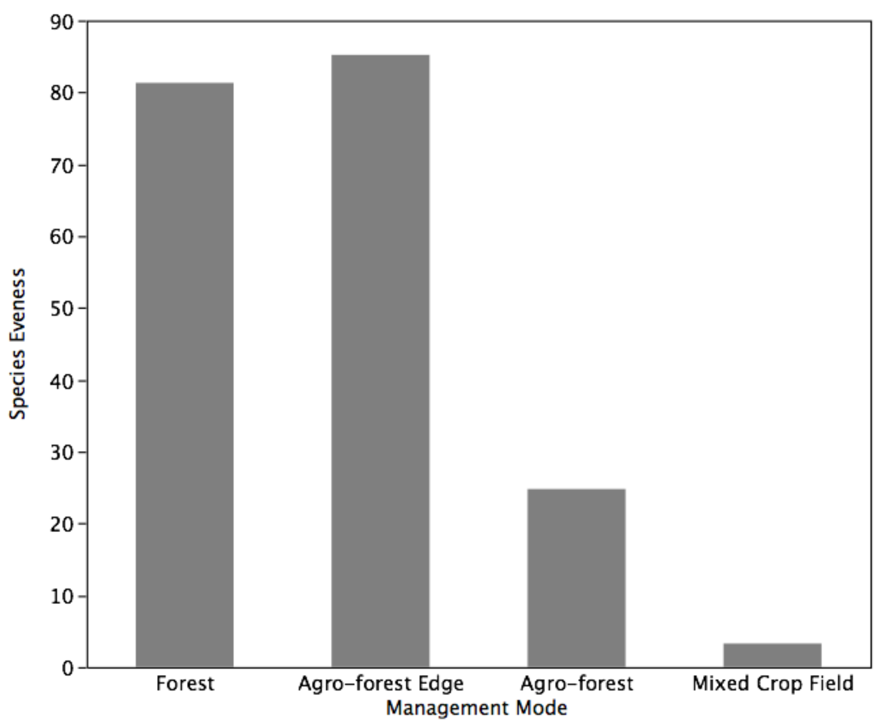


Figure 5.6 Measurements of plant species diversity calculated on the basis of Shannon Weiner Diversity Index for each management system.



a.



b.

Figure 5.7 Measurements of plant species diversity calculated on the basis of (a) Species Richness and (b) Species Evenness for each management system.

Ethnobotanical Inventories

Ethnobotanical inventories documented 121 species that farmers identified with either a local name or use in transects around the forest population surveyed. A total of 256 species with local names and/or uses were identified by smallholders in transects around agro-forests. Table 5.3 shows the plant species that were taxonomically identified from ethnobotanical inventories around tea forest populations and Table 5.4 shows the taxonomic identification of species inventoried around agro-forests.

The species inventoried in the forest transects represent 40 plant families. The most represented plant families surveyed in the forest transects were Theaceae, Fagaceae and Lauraceae, or the tea, beech and laurel families. The Theaceae and Fagaceae each contained nine species and Lauaceae contained seven species. The most represented genera inventoried were *Castanopsis* (Fagaceae) with a total of five species and Camellia (Theaceae) with four speces. Other families that were represented in the inventories with 2-4 species were Acanthaceae, Aceraceae, Aquifoliaceae, Araliaceae, Asparagaceae, Campanulaceae, Caprifoliaceae, Celastraceae, Ericaceae, Lauraceae, Magnoliaceae, Melastomataceae, Myrsinaceae, Plantaginaceae, Primulaceae, Rosaceae, Rubiaceae, Rutaceae, Smilacaceae, and Solanaceae.

The species inventoried in transects around agro-forests represent 46 plant families. The most represented plant families in the agro-forest transects were Lauraceae and Moraceae, or the laurel and fig families, with seven and six species respectively. The

Table 5.3 Plant species documented from ethnobotanical inventories in transects around tea forest populations that smallholders identified with a local name and / or use.

Plant species	Family
Goldfussia sp.	Acanthaceae
Ophiorrhiziphyllon macrobotryum	Acanthaceae
Acer flabellatum	Aceraceae
Acer sp.	Aceraceae
Saurauia napaulensis	Actinidiaceae
Ilex chinensis	Aquifoliaceae
Ilex godajam	Aquifoliaceae
Ilex sp.	Aquifoliaceae
Brassaiopsis fatsiodes	Araliaceae
Trevesia palmata	Araliaceae
Brassaiopsis ciliata	Araliaceae
Schefflera sp.	Araliaceae
Toxocarpus villosus	Asclepiadaceae
Ophiopogon latifolius	Asparagaceae
Ophiopogon peliosanthoides	Asparagaceae
Ophiopogon tonkinensis	Asparagaceae
Jacaranda sp.	Bignonicaceae
Campanumoea javanica	Campanulaceae
Pratia nummularia	Campanulaceae
Leycesteria gracilis	Caprifoliaceae
Viburnum pyramidatum	Caprifoliaceae
Viburnum leiocarpum	Caprifoliaceae
Celastrus sp.	Celastraceae
Euonymus sp.	Celastraceae
Carex baccans	Cyperaceae
Daphniphyllum macropodum	Daphniphyllaceae
Paralia sp.	Ebencaceae
Agapetes rubrobracleata	Ericaceae
Vaccinium sciaphilum	Ericaceae
Macaranga sp.	Euphorbiaceae
Milletia sp.	Fabaceae

Plant species	Family
(continued)	
Lithocarpus echinophorus var. *bidoupensis*	Fagaceae
Castanopsis argyrophylla	Fagaceae
Lithocarpus fenestratus var. *brachycarpus*	Fagaceae
Cyclobalanopsis sp.	Fagaceae
Lithocarpus sp.	Fagaceae
Castanopsis argyrophylla	Fagaceae
Castanopsis platyacantha	Fagaceae
Castanopsis sp.	Fagaceae
Castanopsis megaphylla	Fagaceae
Hydrangea sp.	Hydrangeaceae
Hypericum sp.	Hypericaceae
Elsholtzia blanda	Lamiaceae
Lindera thomsonii	Lauraceae
Phoebe angustifolia	Lauraceae
Phoebe sp.	Lauraceae
Machilus sp.	Lauraceae
Litsea sp.	Lauraceae
Machilus sp.	Lauraceae
Phoebe sp.	Lauraceae
Buddleia macrostachya	Loganiaceae
Parakmeria yunnanensis	Magnoliaceae
Illicium sp.	Magnoliaceae
Manglietia insignis	Magnoliaceae
Manglietia fordiana	Magnoliaceae
Medinilla fengii	Melastomataceae
Oxyspora paniculata	Melastomataceae
Maesa ramentacea	Myrsinaceae
Maesa striata	Myrsinaceae
Jasminum duclouxii	Oleaceae
Oberonia caulescens	Orchidaceae
Plantago asiatica	Plantaginaceae
Hemiphragma heterophyllum	Plantaginaceae

Plant species	Family
(continued)	
Ardisia crispa	Primulaceae
Maesa membranacea	Primulaceae
Cimicifuga sp.	Ranunculaceae
Duchesnea indica	Rosaceae
Potentilla kleiniana	Rosaceae
Rubus alceaefolia	Rosaceae
Prunus phaeosticta	Rosaceae
Rubia sp.	Rubiaceae
Ophiorrhiza macrantha	Rubiaceae
Wendlandia scabra	Rubiaceae
Mussaenda sp.	Rubiaceae
Mycetia gracilis	Rubiaceae
Zanthoxylum sp.	Rutaceae
Evodia sp.	Rutaceae
Smilax polycephala	Smilacaceae
Smilax microphylla	Smilacaceae
Lycianthes biflora	Solanaceae
Gueldenstaedtia sp.	Solanaceae
Rehderodendron kweichowense	Styracaceae
Symplocos anomala	Symplocaceae
Schima wallichii	Theaceae
Camellia caudata	Theaceae
Camellia sinensis var. *assamica*	Theaceae
Camella tsaii	Theaceae
Camellia crassicoluma	Theaceae
Eurya prunifolia	Theaceae
Eurya groffii	Theaceae
Eurya loquiana	Theaceae
Grewia glabra	Tiliaceae
Clerodendrum mandarinorum	Verbenaceae

Table 5.4 Plant species documented from ethnobotanical inventories in transects around tea agro-forests that smallholders identified with a local name and / or use.

Plant species	Family
Agro-forest Inventories	
Pseuderanthemum polyanthum	Acanthaceae
Actinidia sp.	Actinidiaceae
Saurauia napaulensis	Actinidiaceae
Alternanthera sessilis	Amaranthaceae
Amarathus spinosus	Amaranthaceae
Amarathus viridis	Amaranthaceae
Celosia argentea	Amaranthaceae
Rhus chinensis	Anacardiaceae
Heracleum bivittatum	Apiaceae
Amalocalyx microlobus	Apocynaceae
Ecdysanthera rosea	Apocynaceae
Amorphophallus yunnanensis	Araceae
Colocasia fallax	Araceae
Colocasia tonoimo	Araceae
Schefflera venulosa	Araliaceae
Acanthopanax trifoliatus	Araliaceae
Aralia armata	Araliaceae
Trevesia palmata	Araliaceae
Calameae	Arecaceae
Calameae	Arecaceae
Bidens pilosa	Asteraceae
Callipteris esculenta	Athyriaceae
Impatiens sp.	Balsaminaceae
Impatiens duclouxii	Balsaminaceae
Impatiens balansae	Balsaminaceae
Begonia cathayana	Begoniaceae
Begonia sp.	Begoniaceae
Begonia crassirostris	Begoniaceae
Betula alnoides	Betulaceae
Mayodendron igneum	Bignoniaceae
Cassia fistula	Caesalpiniaceae
Tamarindus indica	Caesalpiniaceae
Campanumoea javanica	Campanulaceae

Plant species	Family
(*continued*)	
*Crateva uniloculari*s	Capparidaceae
Viburnum cylindricum	Caprifoliaceae
Viburnum foetidum var. *ceanothoides*	Caprifoliaceae
Chenopodium album	Chenopodiaceae
Crassocephalum crepidioides	Compositae
Enydra flucuans	Compositae
Sonchus oleraceus	Compositae
Dichondra repens	Convulvulaceae
Zehneria maysorensis	Cucurbitaceae
Coccinia grandis	Cucurbitaceae
Momordica cochinchinensis	Cucurbitaceae
Daphniphyllum majus	Daphniphyllaceae
Dioscorea bulbifera or *Dioscorea pseudonitenss*	Dioscoreaceae
Dioscorea persimilis	Dioscoreaceae
Tectaria decurrens	Dryopteridaceae
Elaeocarpus sikkimensis	Elaeocarpaceae
Phyllanthus urinaria	Euphorbiaceae
Euphorbia antiquorum	Euphorbiaceae
Manihot esculenta	Euphorbiaceae
Erythrina subumbruns	Fabaceae
Craspedolobium schochii	Fabaceae
Castanopsis calathiformis	Fagaceae
Quercus sp.	Fagaceae
Lithocarpus fenestratus	Fagaceae
Castanopsis sp.	Fagaceae
Rhynchotechum obovatum	Gesneriaceae
Cymbopogon citratus	Gramineae
Eleusine indica	Gramineae
Dendrocalamus giganteus	Grimineae
Dendrocalamus hamiltonii	Grimineae
Dendrocalamus latiflorus	Grimineae
Pleioblastus amarus	Grimineae
Elsholtzia kachinensis	Labiatae

Plant species	Family
(*continued*)	
Mentha haplocalyx	Labiatae
Cinnamomum bejolghota	Lauraceae
Lindera netcalfiana var. *dictyophylla*	Lauraceae
Litsea cubaba	Lauraceae
Cinnamomum iners	Lauraceae
Iteadaphne caudata	Lauraceae
Cinnamomum porrectum	Lauraceae
Litsea lancifolia var. *ellipsoides*	Lauraceae
Aloe vera var. *chinensis*	Liliaceae
Pratia nummularia	Lobeliaceae
Urena lobata	Malvaceae
Marsilea quadrifolia	Marsileaceae
Medinilla septentrionalia	Melastomataceae
Osbeckia crinita	Melastomataceae
Toona sinensis	Meliaceae
Stephania brachyandra	Menispermaceae
Acacia concinna	Mimosaceae
Acacia pennata	Mimosaceae
Ficus semicordata	Moraceae
Ficus auriculata	Moraceae
Ficus callosa	Moraceae
Ficus racemosa	Moraceae
Ficus vasculosa	Moraceae
Ficus virens var. *sublanceolata*	Moraceae
Musa sp.	Musaceae
Musa acuminata	Musaceae
Myrica esculenta	Myricaceae
Myrica rubra	Myricaceae
Ardisia virens	Myrsinaceae
Embelia ribes	Myrsinaceae
Embelia oblongifolia	Myrsinaceae
Ardisia soanaceae	Myrsinaceae
Decaspermum parviflorum	Myrtaceae
Psidium guajava	Myrtaceae
Oaxlis corniculata	Oxalidaceae

Plant species	Family
(*continued*)	
Passiflora edulis	Passifloraceae
Bambuseae	Poaceae
Bambuseae	Poaceae
Bambuseae	Poaceae
Polygala arillata	Polygalaceae
Polygonum sp.	Polygonaceae
Polygonum sp.	Polygonaceae
Fagopyrum dibotrys	Polygonaceae
Rumex trisetifer	Polygonaceae
Monochoria hastata	Pontederiaceae
Monochoria vaninalis	Pontederiaceae
Monochoria vaninalis var. *korsakowii*	Pontederiaceae
Portulaca oleracea	Portulaceae
Helicia nilagirica	Proteaceae
Pteridium aquilinum	Pteridiaceae
Clematis sp.	Ranunculaceae
Potentilla kleiniana	Rosaceae
Rubus sumatranus	Rosaceae
Rubus multibracteatus	Rosaceae
Mussaenda hossei	Rubiaceae
Lasianthus sikkimensis	Rubiaceae
Mycetia longiflora	Rubiaceae
Toddalia asiatica	Rutaceae
Euodia lepta	Rutaceae
Zanthoxylum planispinum	Rutaceae
Houttuynia cordata	Sauruaceae
Limnophila rugosa	Scrophulariaceae
Scoparia dulcis	Scrophulariaceae
Smilax hypoglauca	Smilacaceae
Smilax china	Smilaceae
Solanum indicum	Solanaceae
Solanum americanum	Solanaceae
Lycianthes neesiana	Solanaceae
Solanum violaceum	Solanaceae

Plant species	Family
(*continued*)	
Cyphomandra betacea	Solanaceae
Solanum coagulans	Solanaceae
Solanum torvum	Solanaceae
Solanum nigrum var. *photeinocarpum*	Solanaceae
Solanum spirale	Solanaceae
Sphenoclea zeylanica	Sphenocleaceae
Camellia sinensis var. *assamica*	Theaceae
Ternstroemia gymnanthera	Theaceae
Eurya grofii	Theaceae
Centella asiatica	Umbelliferae
Eryngium foetidum	Umbelliferae
Hydrocotyle sibthorpiodes	Umbelliferae
Oenanthe javanica	Umbelliferae
Elatostema sp.	Urticaceae
Elatostema albopilsum	Urticaceae
Clendendron colebrookianum	Verbenaceae
Clerodendrum serrutum var. *amplexifolium*	Verbenaceae
Clerodendron chinensis var. *simplex*	Verbenaceae
Tetrastigma sp.	Vitaceae
Tetrastigma planicaulum	Vitaceae
Cayratia japonica	Vitaceae
Tetrastigma obovatum	Vitaceae
Cissus luzoniensis	Vitaceae
Zingiber menghaiense	Zingiberaceae
Globba racemosa	Zingiberaceae
Amomum maximum	Zingiberaceae
Alpina nigra	Zingiberaceae
Costus speciosus	Zingiberaceae
Zingiber fragile	Zingiberaceae
Zingiber orbiculatum	Zingiberaceae
Zingiber zerumbet	Zingiberaceae

most represented genus inventoried was *Ficus* (Moraceae) with a total of six species. Other families that were represented in the inventories with 2-4 species were Actinidiaceae, Amaranthaceae, Araliaceae, Apocynaceae, Araceae, Arecaeae, Balsaminaceae, Begoniaceae, Caesalpiniaceae, Caprifoliaceae, Compositae, Cucurbitaceae, Dioscoreaceae, Euphorbiaceae, Fabaceae, Fagaceae, Gramineae, Grimineae, Labiatae, Melastomataceae, Mimosaceae, Moraceae, Myrsinaceae, Musacea, Myricaceae, and Myrtaceae.

Species inventoried in transects around forests and agro-forests had multiple uses including for medicine, food, construction material, dye, fodder, fuel wood, ritual, and tools. Table 5.5 lists the number of plant species inventoried for each plant use documented from forest and agro-forest areas. The plant uses that were most documented by smallholders in the forest area surveyed were for medicine and food. A total of 29 species were reported to have medicinal purposes in forests and 30 plants were documented as food plants. The plant use that was most documented by smallholders in the agro-forest area surveyed was food followed by medicine. A total of 97 species were reported to be edible plants and 37 species were documented as medicinal plants. The most reported medicinal use in both forest and agro-forest areas were plants for immune support. Other notable uses in forests and agro-forests were plants used for fodder. Plants used for construction material, furniture, and fuel wood were also prominent in ethnobotanical inventories around agro-forests.

Table 5.5 Number of plant species inventoried for each plant use documented from ethnobotanical inventories in transects around tea agro-forests that smallholders identified with a local name and / or use.

Plant Use		No. Species inventoried in Forests	No. Species inventoried in Agro-forests
Medicine		29	37
	Anti-microbial	3	2
	Broken bone treatment	0	2
	Burn treatment	0	2
	Cough remedy	3	1
	Detoxification	0	2
	Diarreah remedy	0	2
	Digestive aid	2	3
	Female health condition	2	2
	Immune support	11	6
	Joint pain	2	0
	Malaria cure	0	1
	Male health condition	0	1
	Medicinal bath	2	3
	Skin condition	0	3
	Stomachache	0	2
	Urinary tract infection	0	0
	Other	4	5
Food		30	97
	Fruit	16	44
	Nut	2	2
	Spice	3	3
	Wild vegetable	9	48
Other		33	52
	Construction and furniture	3	9
	Dye	2	4
	Fodder	7	9
	Fragrance	2	0
	Fuel wood	5	8
	Ornamental	4	5
	Poison	2	1
	Ritual	2	5
	Tool	1	3
	Toy	0	3
	Other	5	5

DISCUSSION

Comparison of measures of floristic composition and structure for the forest, agro-forest, mixed crop field and terrace garden plots demonstrates the variation within management systems. Results from plot sampling and ethnobotanical inventories support that increased human manipulation of management systems does not necessarily result in a linear trend of decreasing plant species diversity. Findings on the diversity of plant species in tea management systems of Yunnan are consistent with previous studies (Long and Wang 1996; Qi et al. 2005) and contribute to the literature of diversity of agrarian landscapes (Jarvis et al. 2007).

Data on plant species maintained in agro-forests from plot sampling and ethnobotanical inventories are consistent with the literature on the presence of associated woody plant species in smallholder tea agro-ecosystems in the uplands of Yunnan (Long and Wang 1996; Qi et al. 2005). Long et al. (1996) found 283 higher plant species in a tea agro-forest area of approximately 3 ha managed by a Jinuo community in Jinuo Mountain of southeastern Xishuangbanna Prefecture, Yunnan. Qi et al. (2005) found 244 plant species in an area of 1,600 m^2 of old tea agro-forests in Bulang communities in Jingmai Mountain, Lancang County, Yunnan. Their surveys showed a species richness of 3.03 based on the Shannon-Wiener diversity index.

The higher diversity index values for plots sampled at the edges of tea agro-forests compared to forest plots refutes simplistic notions of ecological simplification with increased human management. Local communities maintain the edges of tea agro-forests as strategies to buffer the system from pests, disease, and wind. The edges of the agro-forests surveyed are not primary forest but are fallow areas that were dedicated to swidden agriculture around 75 years ago. The transition from swidden fields to forested areas reinforces the cyclic nature of traditional land use in some upland communities of Yunnan where forests can grow into fields, and fields into forests. Smallholders at the study sites reported that if these systems are converted into terrace gardens, it maybe more difficult to regenerate them into forests because of the loss of soil fertility. However, this study did not measure soil fertility of the various management systems and this topic warrants further study.

Ethnobotanical inventories demonstrated the importance of tea forest and agro-forest areas for local livelihoods beyond the procurement of tea resources. Smallholders rely on forests and agro-forests for food, medicine, construction material, fuel wood and other livelihood needs. The multiple uses associated with plants maintained in agro-forests and their role in livelihood strategies points to the survival basis for plant species conservation in these management systems. The greater number of plants inventoried in agro-forests compared to forests highlights the variation of knowledge and practices of the local ethnobotanical systems as well as suggests the influence of national forest policy. As discussed in the previous chapter, the forest populations surveyed are located in a national forest protected area. Communities that once lived within the reserve boundaries were moved off the reserve and were granted limited user rights of forest resources. Their reliance on forest resources and associated cultural practices subsequently changed as communities were relegated a minor role in the management of resources and lost many of their land-use rights.

CONCLUSION

This chapter demonstrated the variation of plant species diversity associated with different tea management systems. Such case-study data is valuable to refute or support patterns identified in the literature regarding the conservation, promotion, or loss of biodiversity associated with variable agricultural management systems. It is also valuable to inform the integration and management of the agricultural matrix in conservation policy.

The conservation of biodiversity in management systems is associated with both costs and benefits to local communities. Findings showed that many of the plants that are conserved around agro-forests have a utilitarian function for the community for the procurement of food, medicine, fuel wood, construction material and other uses. Agro-forests provide a management model that fosters biodiversity under specific circumstances. However, if livelihood strategies change for these communities, the diversity associated with local land use is also predicted to change.

Chapter Six

MORPHOLOGICAL, PHYTOCHEMICAL, AND GENETIC DIVERSITY OF TEA

The present chapter compares the morphological, phytochemical, and genetic variability of tea leaves sampled from the forests, agro-forests, mixed crop fields, and terrace garden plots surveyed in the previous two chapters. This research seeks to address the influence of variable management on tea resources. In addition to random sampling of leaf material, an ethnobotanical sampling approach that incorporates farmer perceptions was employed to characterize genetic diversity.

METHODS

Plant Material

Random Sampling Approach and Leaf Morphology

Preliminary analysis of tea leaf morphology was carried out in order to determine a sample size for assessing morphological and phytochemical variation. A total of 250 leaves were collected from ten tea plants in agro-forests and photographed infield on a light box. Figure 6.1 shows a sample of leaves collected from forests, agro-forests, mixed crop fields, and terrace gardens. Images of leaves were processed with SigmaScan video-morphometric software configured for nine shape and size characteristics: (1) perimeter (length), (2) area, (3) compactness (perimeter squared divided by the area; a circle has a compactness of 1), (4) major axis, (5) minor axis, (6) major length, (7) minor length, (8) feret diameter (diameter of the leaf if it were converted to a circle, ratio of feret diameter

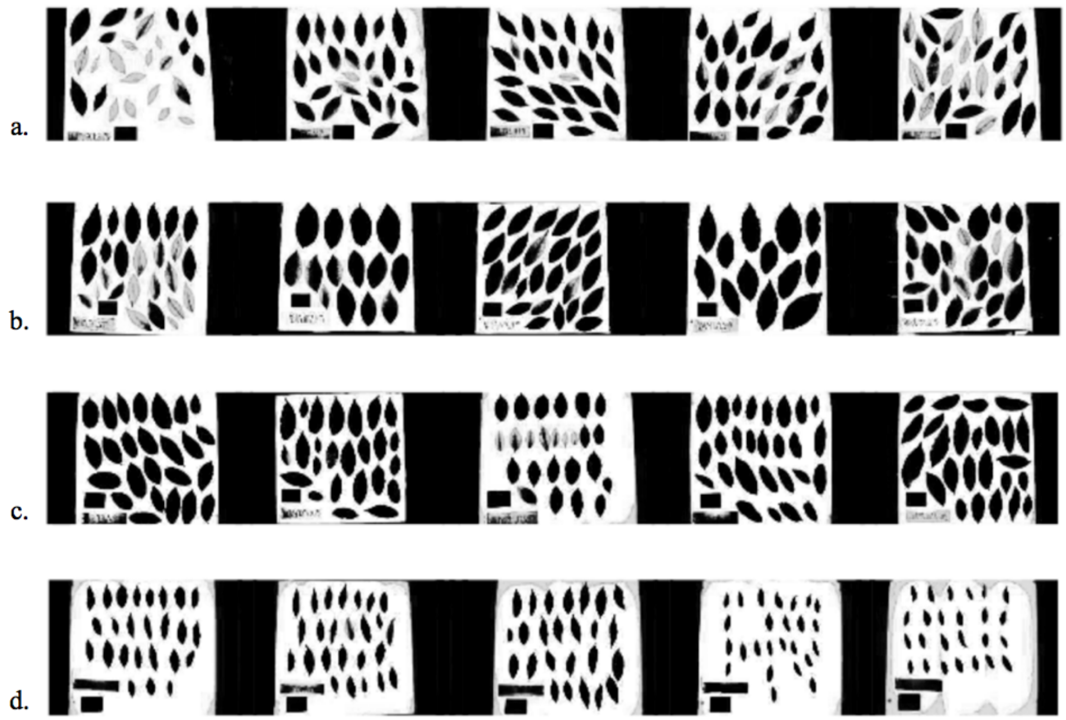


Figure 6.1 Example of tea leaves collected from (a) forest, (b) agro-forest, (c) mixed crop field, and terrace gardens. Images are in relative scale to each other. The black rectangular marker in the lower left of each image is 3.3 inches by 2.4 inches in size.

to major axis is a unique shape descriptor) and, (9) shape factor ((4 pi * area) / perimeter squared; shape factor of a circle = 1; shape factor of a line = 0). Preliminary analysis indicated that a sample of 50 -100 leaves is required for consistently reliable estimates of the standard deviation of leaf asymmetry and that this sample size has a similar standard deviation to larger sample sizes (Figure 6.2). The median of this range, 75, was selected as a sample size of tea leaves per tree.

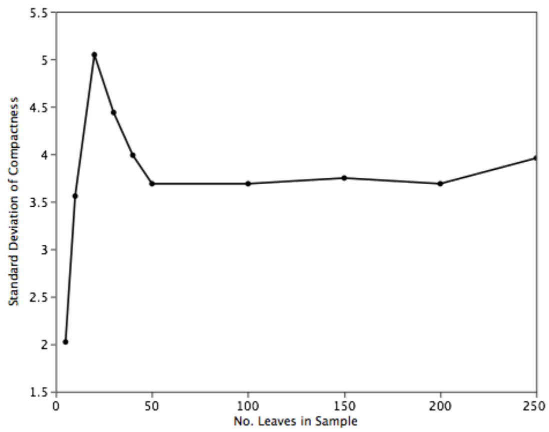
A random number generator was used to select five tea plants from each of the forest, agro-forest, and mixed crop field plots assessed for ecological sampling described in Chapter Five. Three tea plants were selected from each of the sample plots at terrace site I and terrace site II. Seventy-five leaves on each tea plant surveyed were collected from random positions for morphological and phytochemical analyses. Three young leaves were further collected from each tea plant for genetic studies. Leaves collected for morphological and phytochemical analyses were photographed infield and were then dried under the shade for laboratory phytochemical analysis. Images were processed for leaf morphology as described above. Samples for genetic analysis were dried infield with silica until laboratory analysis. Table 6.1 lists the sample size of leaves surveyed for morphological, phytochemical, and genetic analysis.

Ethnobotanical Sampling Approach

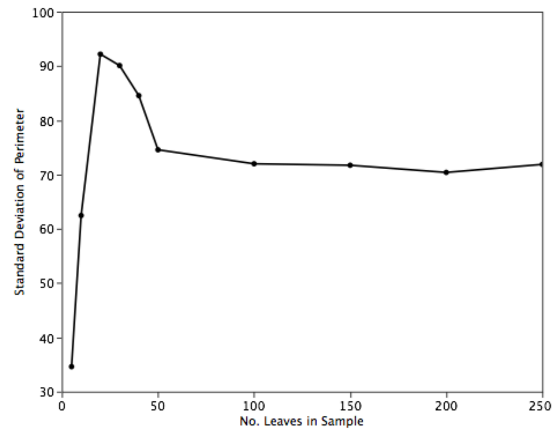
An ethnobotanical sampling approach was further used to assess genetic variation of farmer cultivars. A smallholder from each household managing the tea systems surveyed (n=19) was requested to identify the different tea cultivars in their tea systems as described in Chapter Three. Local name, use, and characteristics of each cultivar were documented. Leaves were collected from each cultivar as described above.

Phytochemical Profiles

Leaves from each of the tea plants sampled for morphological variation were dried in field under the shade and analyzed in the laboratory for variation of secondary metabolite profiles. High Performance Liquid Chromatography (HPLC) was performed to quantify twelve catechin and methylxanthine compounds responsible for the health-related claims, stimulant properties, and taste of tea as described and validated by



a.



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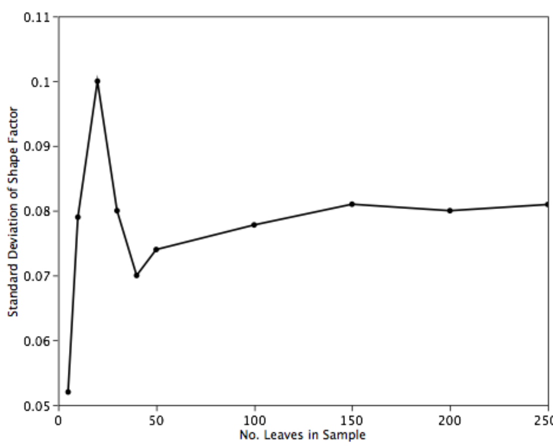

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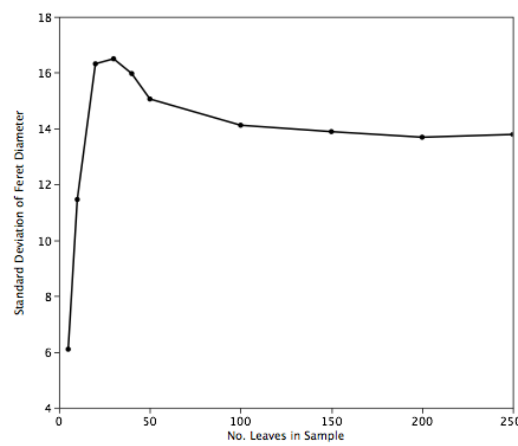
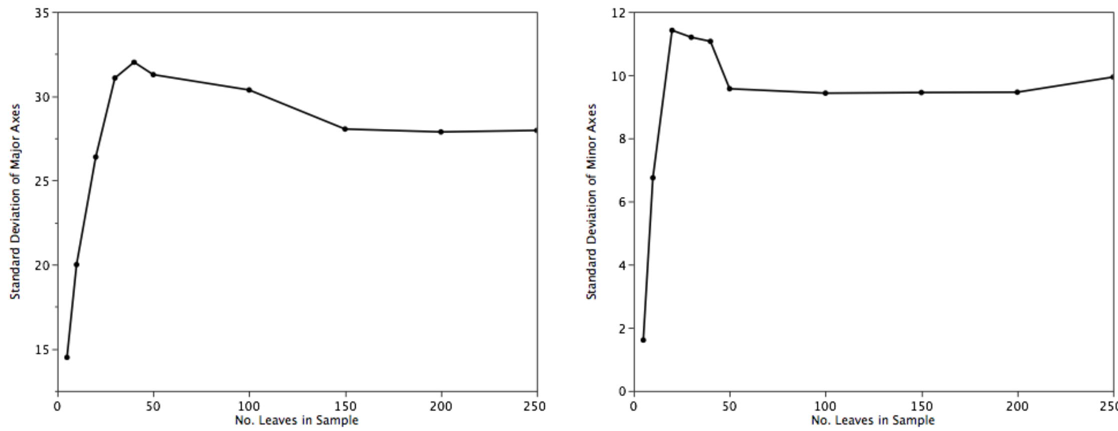


d.

Figure 6.2 Sample size was determined by analyzing the standard deviation of leaf asymmetry (y-axis) of six morphological characteristics versus number of leaves in the sample (x-axis). The characteristics assessed included: (a) compactness, (b) perimeter, (c) shape factor, (d) feret diameter, (e) major axis and (f) minor axis. Results indicated that that a sample of 50-100 leaves is required for consistently reliable estimates of the standard deviation of asymmetry. This sample size had a similar standard deviation to larger sample sizes.



e. f.

Figure 6.2 (*continued*) Sample size was determined by analyzing the standard deviation of leaf asymmetry (y-axis) of six morphological characteristics versus number of leaves in the sample (x-axis). The characteristics assessed included: (a) compactness, (b) perimeter, (c) shape factor, (d) feret diameter, (e) major axis and (f) minor axis. Results indicated that that a sample of 50-100 leaves is required for consistently reliable estimates of the standard deviation of asymmetry. This sample size had a similar standard deviation to larger sample sizes.

Unachukwu et al. (2010). These 12 study analytes include (-)-epigallocatechin 3-gallate (EGCG), (-)-epigallocatechin (EGC), (+)-catechin (C), (-)-epicatechin (EC), (-)-epicatechin 3-gallate (ECG), (-)-gallocatechin 3-gallate (GCG), (-)-gallocatechin (GC), (-)-catechin 3-gallate (CG), caffeine, theobromine, theophylline, and gallic acid. Ground tea leaves were extracted with 80% aqueous methanol in a ratio of 1 g : 10 mL solvent (w/v) using a sonicator for 30 min. The supernatant was filtered under vacuum with Whatman No. 5 filter paper and evaporated under reduced pressure. The remaining aqueous filtrate was frozen overnight and dried in a lyophilizer. Ten mg of dried extract was reconstituted in 1 ml 80% aqueous methanol, centrifuged samples at 15000 rpm for 15 min, and filtered samples through a 0.45 μm nylon membrane filter.

Table 6.1 Sample size of leaves surveyed for morphological, phytochemical, and genetic analysis.

Management System	Study Site Location (Prefecture)	Sample Size of Trees Per Plot	Total Sample Size of Trees Per Management System	Sample Size of Leaves Per Tree	Total Sample Size of Leaves Per Management System
Forest	Honghe	5	25	75	1875
Agro-forest	Xishuangbanna	5	25	75	1875
Mixed Crop	Lincang	5	25	75	1875
Terrace (Site I)	Xishuangbanna	3	6	75	450
Terrace (Site II)	Lincang	3	6	75	450
Total			87		6525

Compounds were separated on a Waters 2695 HPLC (Milford, MA) module equipped with a 996 photodiode array detector and a Synergi Fusion C-18 reversed-phase column (4 µm, 250 mm × 4.6 mm; Phenomenex, Torrance, CA). Column temperature was set at 30 ˚C and sample temperature was maintained at 4˚C. The mobile phase gradient system was established as 0.05% (v/v) trifluoroacetic acid in distilled water for Mobile Phase A (MPA) and acetonitrile for Mobile Phase B (MPB) at a flow rate of 1.0 ml/min for 35 min. Samples were run using a gradient profile set as 0–25 min from 12-21% MPB and 25 – 30 min from 21–25% MPB. Forty microliters (µL) of each of the 100 infusions was run in triple injections for HPLC analysis. Peaks representing the 12 study analytes were detected at 280 nm and were identified based on their characteristic absorbance spectra and retention time.

Genetic Diversity

Each tea tree sampled for morphological and secondary metabolite diversity was assessed for genetic diversity. Amplified fragment length polymorphism (AFLP) polymerase chain reaction (PCR) based DNA fingerprinting technique (Vos et al. 1995; Mueller and WolfenBarger 1999) was employed to detect genetic differentiation of tea resources within management systems. DNA of dried leaf samples was extracted and purified as described in Appendix Two. The AFLP PCR protocol was adapted from Vos et al. (1995) and is presented in Appendix Three. Briefly, genomic DNA samples were digested with Mse I and Eco RI restriction endonucleases and were ligated to Eco RI and Mse I adapters with T4 DNA ligase in a restriction mixture consisting of ATP, BSA, and buffer. PCR was performed in a pre-selective and a selective reaction with six primer pairs (525 AGT, 525 GTG, 526 AGT, 526 GTG, 527 ATG, 527 GTG). Genomic DNA was amplified in the pre-selective reaction using an AFLP primer pair with one selective nucleotide and Taq polymerase. The pre-selective PCR amplification was confirmed by gel electrophoresis and was used as a template for the selective amplification. Selective PCR was carried out separately for each primer pair. The selective product was sequenced, and the sequence data was processed using GeneMarker Software (Softgenetics).

Data Analyses

Morphometric, phytochemical, and genetic data were analyzed statistically using JMP 7.0 software (SAS) to assess patterns within the management systems. Total Catechin Content (TCC; expressed as mg/g dry tea) was determined for HPLC results by the addition of the individual amounts of catechins quantified (EGCG, ECG, EGC, GCG, CG, GC, EC, and C). Similarly, Total Methylxanthine Content (TMC; expressed as mg/g dry tea) was determined by the addition of the individual methylxanthine compounds quantified from HPLC results (CAF, TB, TP). The relationship of management system to morphological characteristics, TCC, TMC, and polymorphisms were determined using Analysis of Variance of pooled means with a significance level of $\alpha = 0.05\%$. Tukey-Kramer HSD was performed to compare all mean pairs. Differences with $P \leq 0.05$ values were considered significant. Principal Components Analysis, Manhattan Distance, K-means clustering were applied to visualize patterns within the various management systems.

RESULTS

Leaf Morphology

Analysis of Variance (ANOVA) of the nine shape and size characteristics of leaves collected through random sampling indicated significant variation of means ($P < 0.0001$) for seven characteristics within samples from each management system (Figure 6.3). This included significant variation of means for the characteristics of compactness ($P < 0.0001$), shape factor ($P < 0.0001$), feret diameter ($P < 0.0001$), major length ($P < 0.0001$), minor length ($P < 0.0001$), area, and major axis ($P < 0.0001$). Tukey-Kramer pairwise comparison of all pairs of agro-ecosystem modes showed significant variation for these seven characteristics between: (1) forests and agro-forests, (2) agro-forests and mixed crop fields, (3) agro-forests and terrace gardens, (4) mixed crop fields and terrace gardens, and (5) forests and terrace gardens. Samples within agro-forest plots had the greatest variance of morphological characteristics relative to all the agro-ecosystems assessed. ANOVA

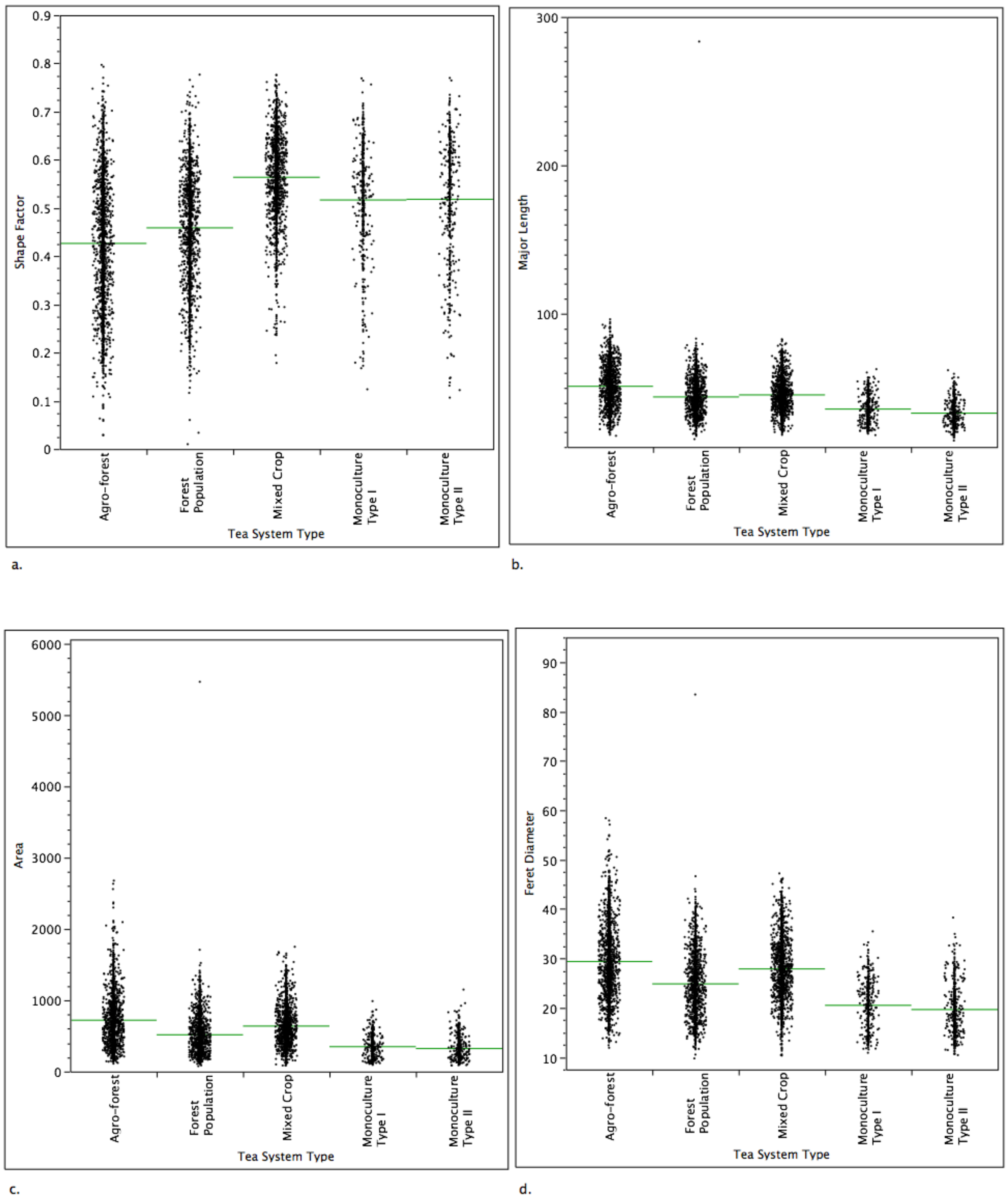


Figure 6.3 Analysis of Variance (ANOVA) of the nine shape and size characteristics indicated significant variation ($P < 0.0001$) for (a) shape, (b) major length, (c) area, and

(d) feret diameter within samples from forests, agro-forests, mixed crop fields, and terrace gardens.

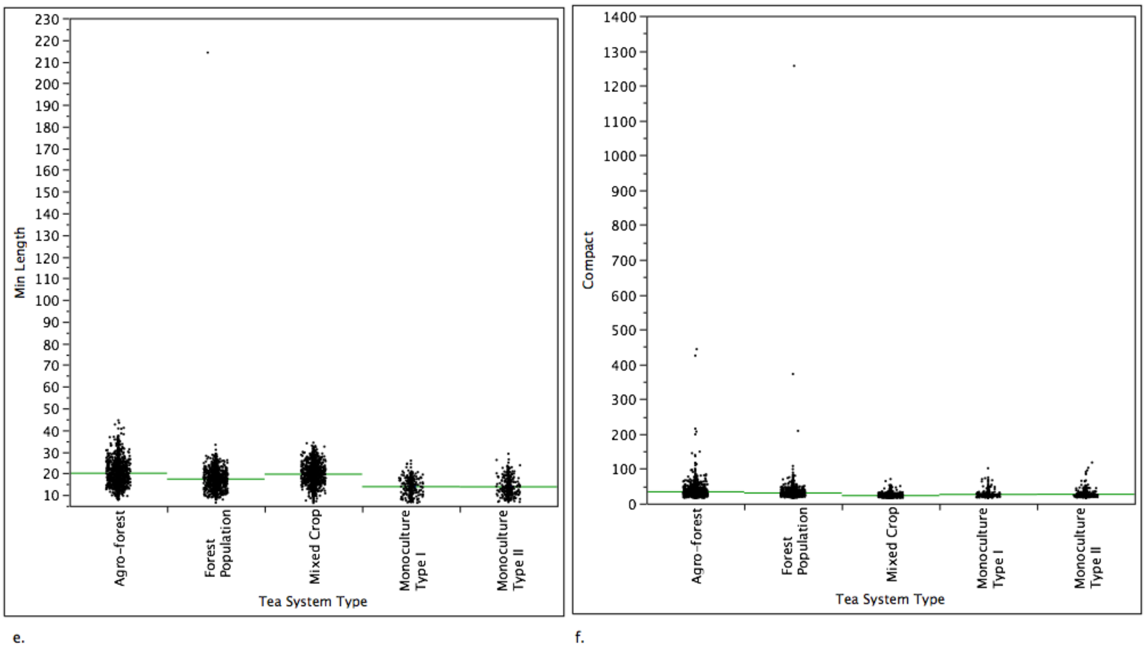


Figure 6.3 (*Continued*) Analysis of Variance (ANOVA) of the nine shape and size characteristics indicated significant variation ($P < 0.0001$) for (e) minimum length and, (f) compactness.

indicated within tea system diversity for agro-forests showed statistical significance ($P < 0.05$) for all nine characteristics measured (Figure 6.4). There were significant differences in leaf characters within different plots of mixed crop fields. Means of all characteristics showed statistical significance of $P < 0.0001$ except perimeter and major length had significant variation of $P < 0.007$ and $P < 0.0433$ respectively. Forest populations showed significant variation of means within plots of $P < 0.0001$ for all morphological characteristics except for compactness, which was not significantly variant at $P < 0.1415$. Terrace gardens showed significant variation ($P < 0.001$) for four out of seven characteristics. Perimeter, major length, and max were not statistically significant for tree plants between plots in monocultures with $P < 0.6968$, $P < 0.4546$, and $P < 0.5905$ respectively. Morphological diversity is further evidenced in ANOVA of within plot diversity. Within plot diversity of each of the trees in agro-forests showed significant variation of $P < 0.001$ for all of the plots surveyed.

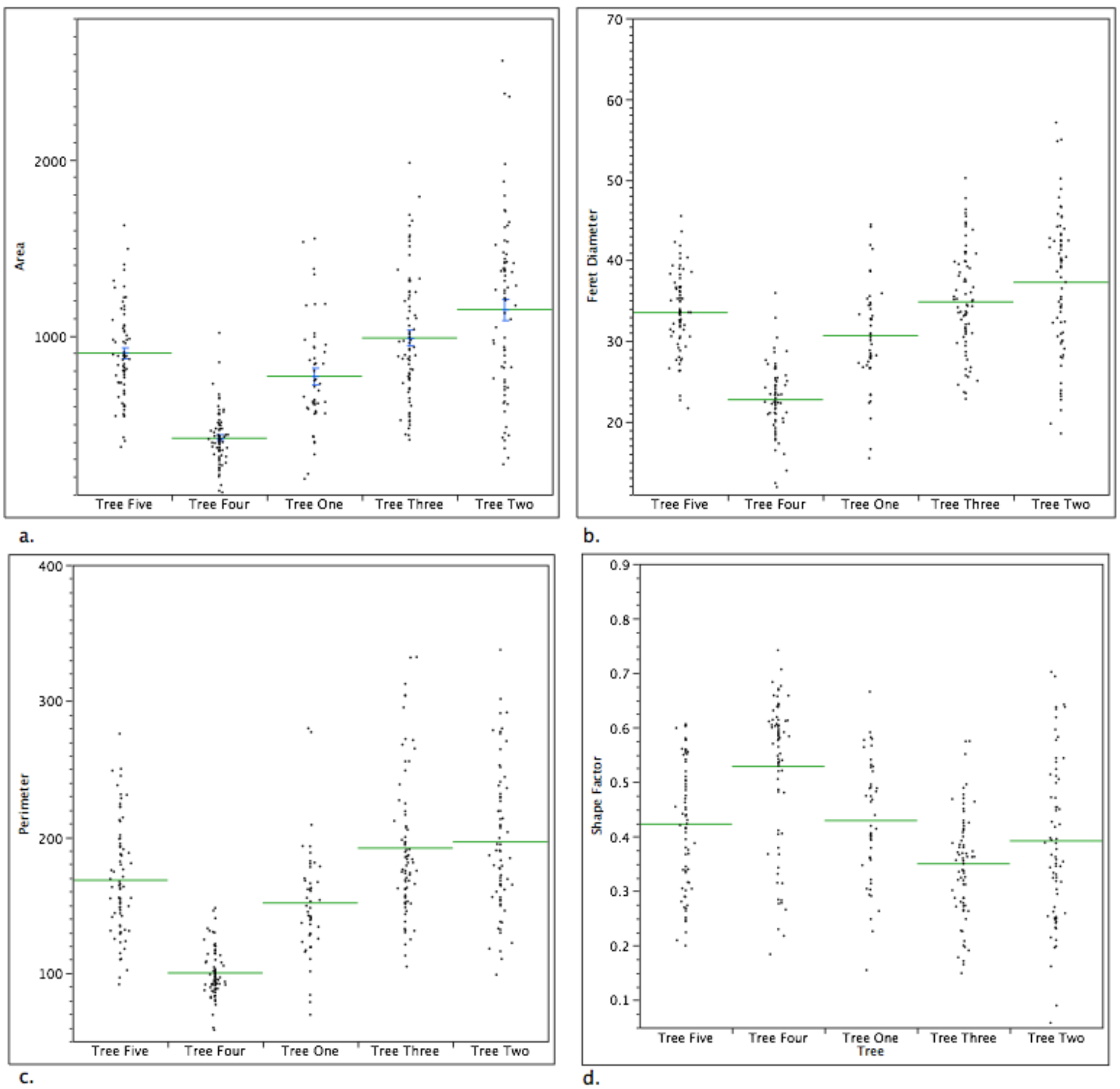


Figure 6.4 Analysis of Variance (ANOVA) of the nine shape and size characteristics between the five agro-forest plots surveyed indicated significant variation ($P < 0.0001$) for (a) area, (b) feret diameter, (c) perimeter, and (d) shape factor.

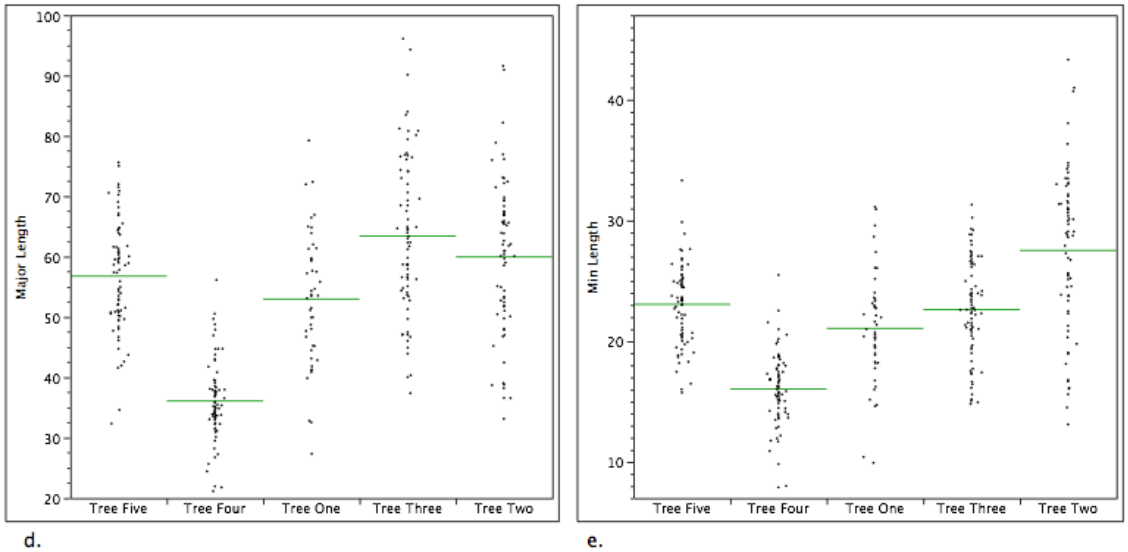


Figure 6.4 (*Continued*) Analysis of Variance (ANOVA) of the nine shape and size characteristics between the five agro-forest plots surveyed indicated significant variation ($P < 0.0001$) for (d) major length, and (e) minimum length.

Principal Component Analysis (PCA) to identify morphological characteristics that most reflect variability in tea agro-ecosystems was conducted on the 6357 X 9 autoscaled data matrix followed by an orthogonal rotation. Three principal components (PC), PC1, PC2, and PC3, were identified with initial eigenvalues >1 that explained 97.03% of the total variability of the data set and 65.80, 19.75, and 11.45% respective percent variances. PC1 was mainly characterized by area, Feret diameter, major length and minimum length with significant loadings of 0.982, 0.990, 0.92 and 0.904. Exemplary 2-dimensional analysis was carried out on PC1 and PC2 as they both accounted for 85.6% of the total variance. Figure 6.5 shows a score plot of leaf morphological characteristics clustered based on the different mode of tea agro-ecosystem. PC1 distinctly separated samples cultivated by terrace gardens site II from those cultivated from agro-forests and forests. Majority of the outliers of the 95% confidence ellipse belong to the agro-forest group indicating the varied nature of leaf size in this group. The derived leaf volume dimensions and the leaf compact morphological characteristics accounted for by PC2 clearly distinguished leaves cultivated using mixed cropping from the rest of the group, provided an indicator marker for this group of leaves.

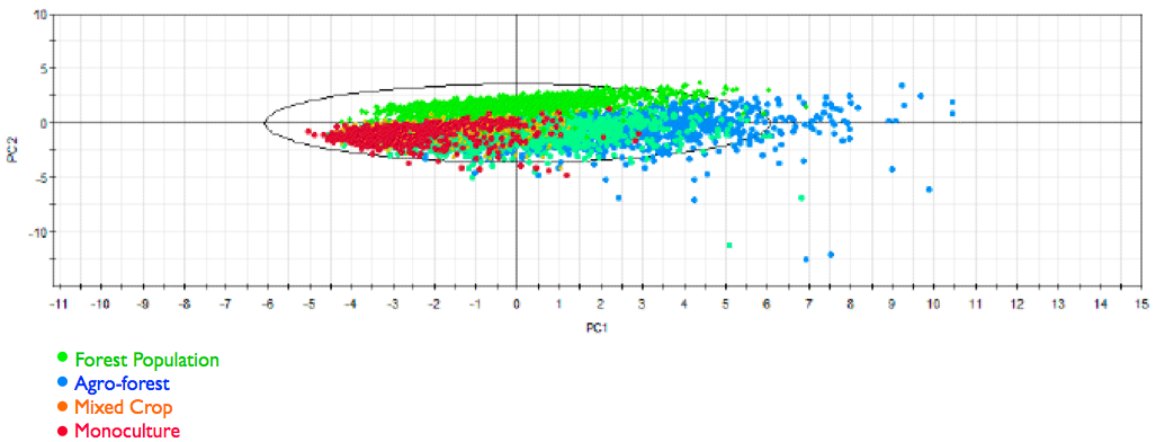


Figure 6.5 Score plot of leaf morphological characteristics clustered based on the different mode of tea agro-ecosystem. PC1 distinctly separated samples cultivated by terrace garden site II from those cultivated from agro-forests and forests. Majority of the outliers of the 95% confidence ellipse belong to the agro-forest group indicating the varied nature of leaf size in this group.

Phytochemical Profiles

Qualitative analysis of HPLC chromatograms showed that tea from forests had the greatest number of peaks. A total of 18 peaks were identified in samples from forests, 13 peaks were identified from samples from agro-forests, 14 peaks were identified from samples from mixed crop fields, and 11 peaks were identified from terrace gardens. Quantitative analysis of HPLC data of leaves collected through random sampling showed that samples from agro-forests and mixed crop fields had greater Total Catechin Content (TCC) (Figure 6.6) and Total Methylxanthine Content (TMC) (Figure 6.7) compared to tea samples from forests and terrace gardens. ANOVA of mean TCC and TMC showed statistical significance (P<0.0001) of means within each agro-ecosystem mode.

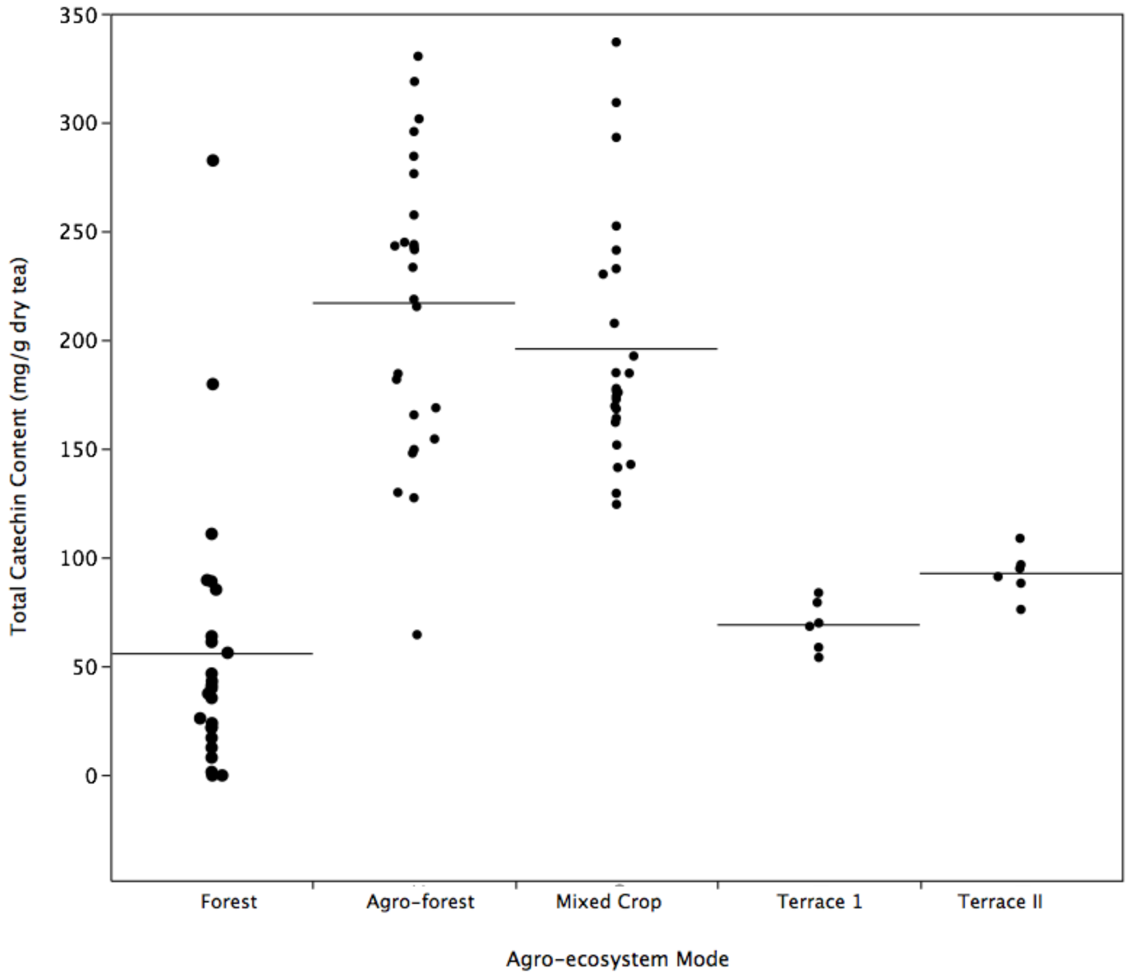


Figure 6.6 Mean values of Total Catechin Content (TCC) between the different types of management systems showed significant variation of $P < 0.0001$.

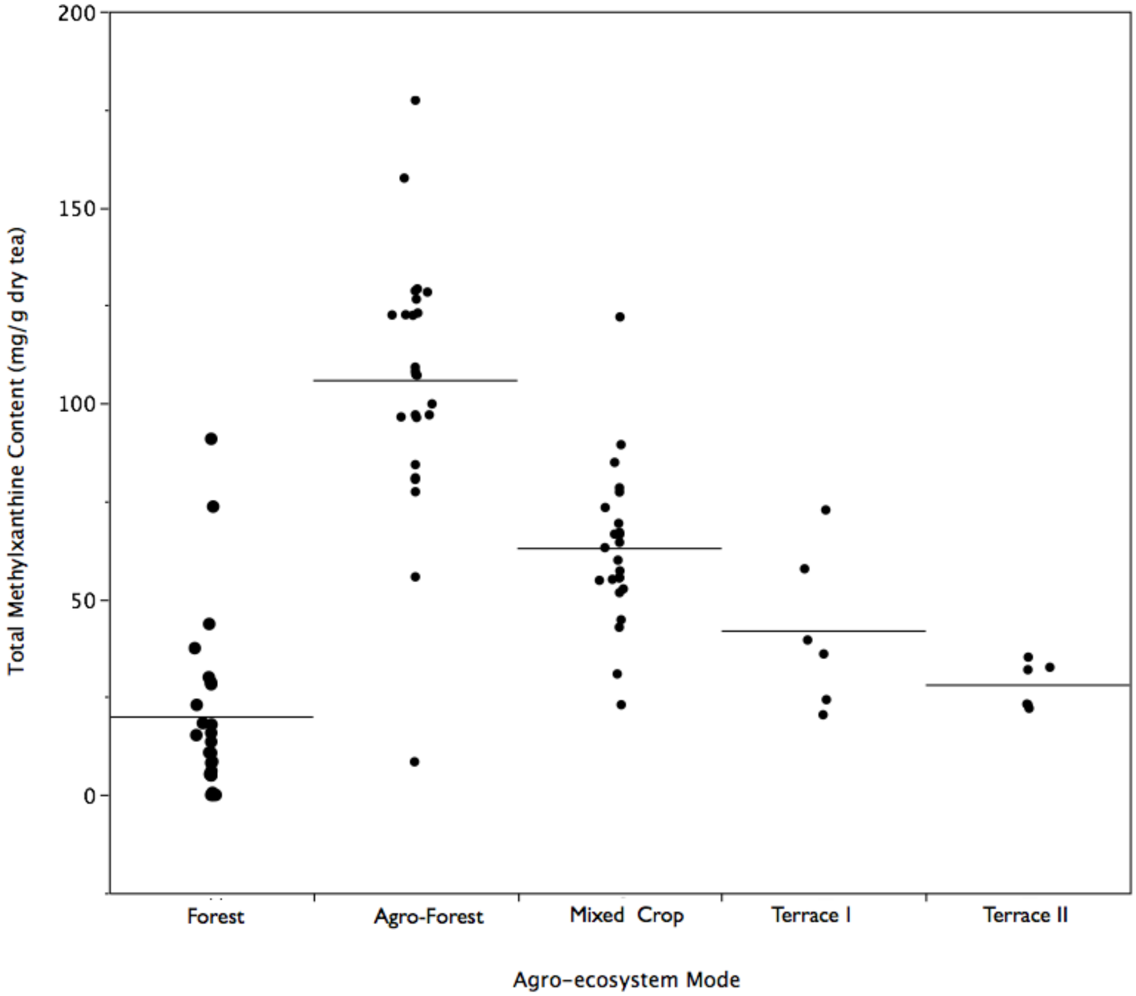


Figure 6.7 Mean values for Total Methylxanthine Content (TMC) between the different types of management systems showed significant variation of $P < 0.0001$.

Tukey-Kramer pairwise comparison of each pair of tea agro-ecosystems for mean TCC found statistical significance between: (1) forests and agro-forests, (2) forests and mixed crop plots, (3) forests and terrace gardens, (4) agro-forests and mixed crop plots, (5) agro-forests and terrace gardens, and (6) mixed crop plots and terrace gardens. Figure 6.8 shows the mean quantities of individual analytes for each type of management system. Caffeine, epi-catechin, and catechin gallate were the most prevalent analytes in all samples. Theophylline was the least prevalent analyte and was not found in most samples.

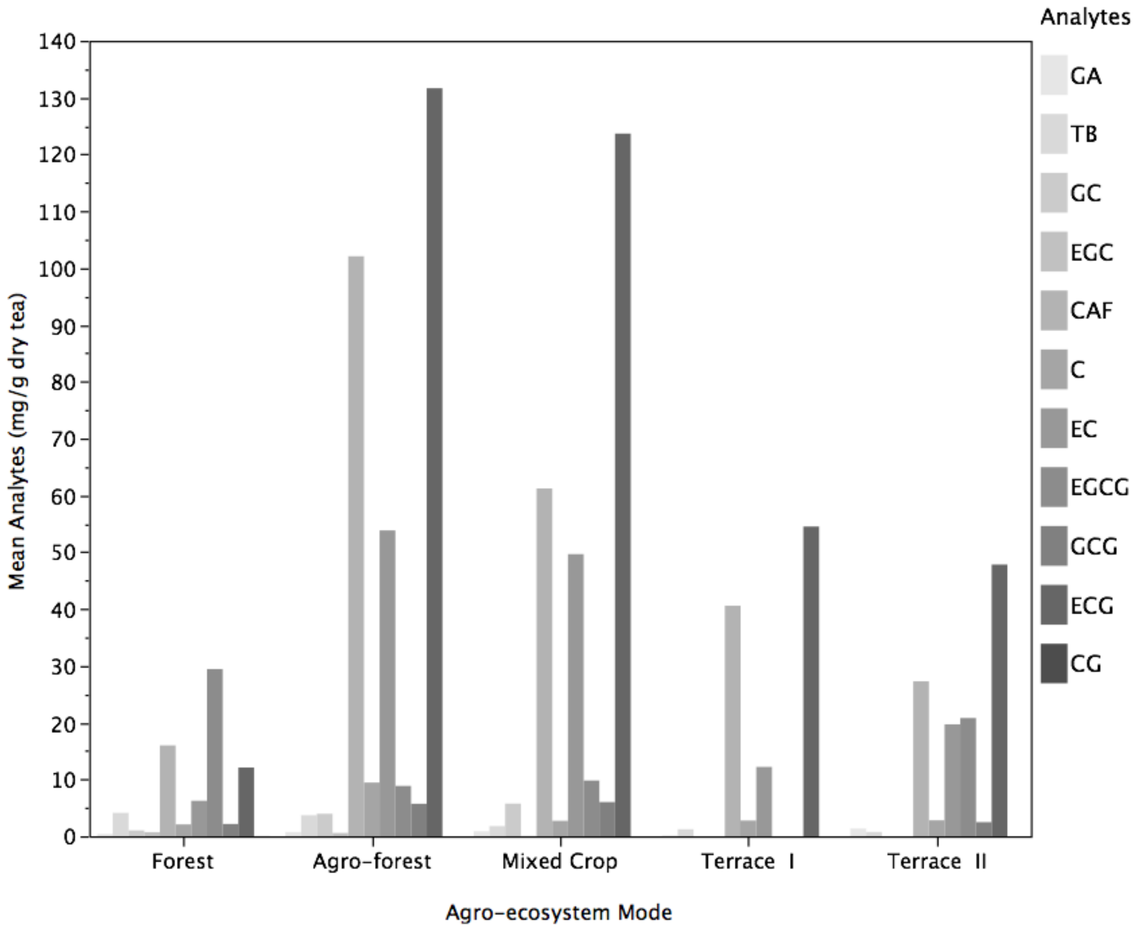


Figure 6.8 Mean quantities of individual analytes by agro-ecosystem mode. Analytes include: (1) gallic acid (GA), (2) theobromine (TB), (3) gallo catechin (GC), (4) epi-gallo catechin (EGC), (5) caffeine (CAF), (6) catechin (C), (7) epi-catechin (EC), (8) epi-gallo catechin gallate (EGCG), (9) gallo-catechin gallate (GCG), (10) epi-catechin gallate (ECG) and, (11) catechin gallate (CG).

Genetic Diversity

AFLP markers employed to detect differentiation within tea populations growing in different management systems showed greater diversity within populations than between populations. Dendrograms constructed on the basis of band sharing of tea samples randomly collected did not distinctly cluster populations. K-means cluster plot constructed of the randomly collected tea samples distinctly separated mixed crop and terrace garden samples around their means, and showed an overlap between forest and agro-forest samples (Figure 6.9). Mixed crop samples were the most dispersed on the K-Means cluster plot, which is an indication of wider genetic diversity based on polymorphisms compared to the other populations. Terrace garden samples depicted the least dispersion on the K-Means cluster plot. The means of samples from mixed crop plots and terrace garden samples showed the greatest distance, based on greatest dispersion of points plotted, which suggests most genetic differentiation between these samples compared to other samples.

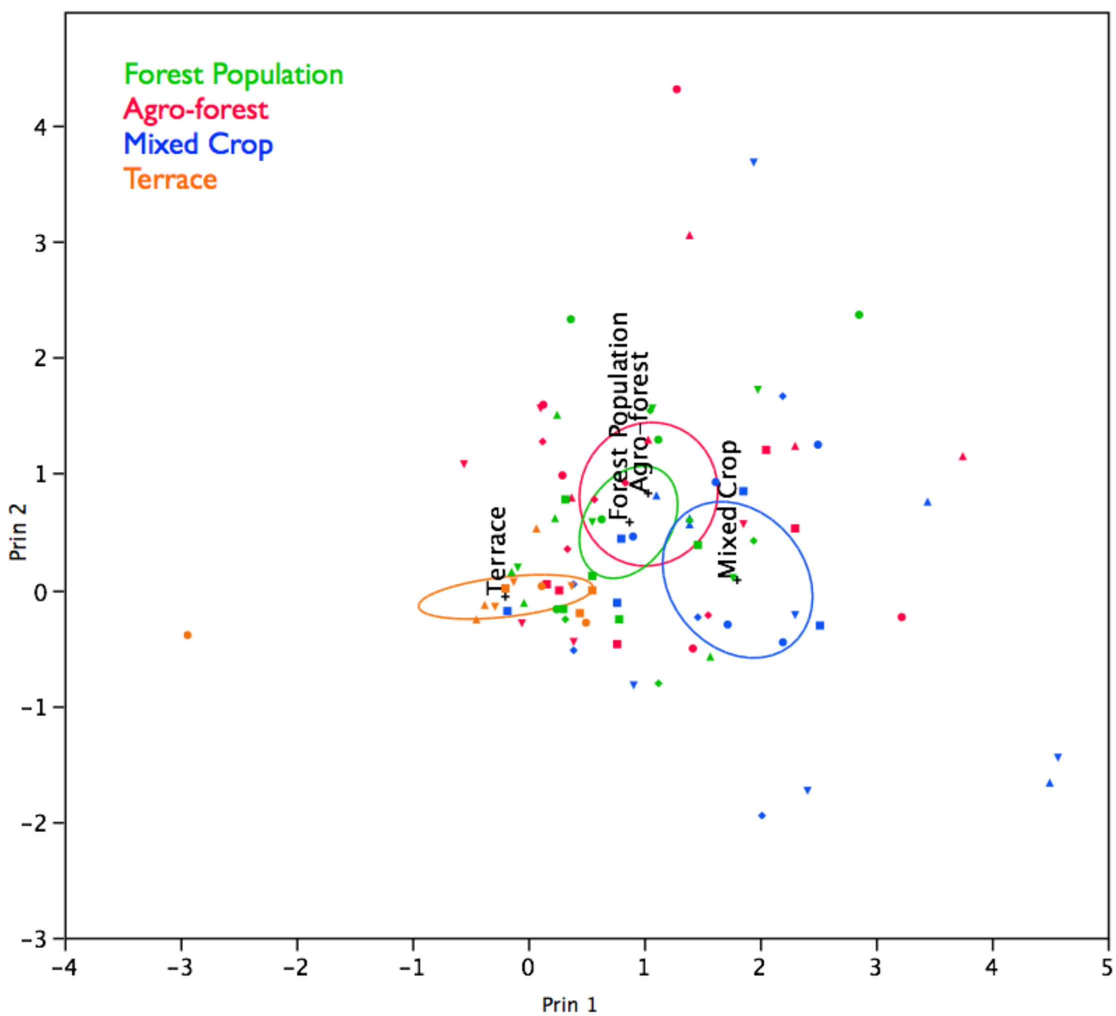


Figure 6.9 K-cluster means plot of AFLP data matrices for samples from forests, agro-forests, mixed crop fields, and terrace gardens. The distance between two points indicates genetic relatedness based on polymorphisms.

AFLP markers employed to detect differentiation within tea samples collected through an ethnobotanical approach showed wider dispersion of samples from agro-forests compared to forests. Figure 6.10 shows a Manhattan Distance plot of cultivars managed within one smallholder tea agro-forest that is 0.50 ha in size compared to samples from a nearby forest population.

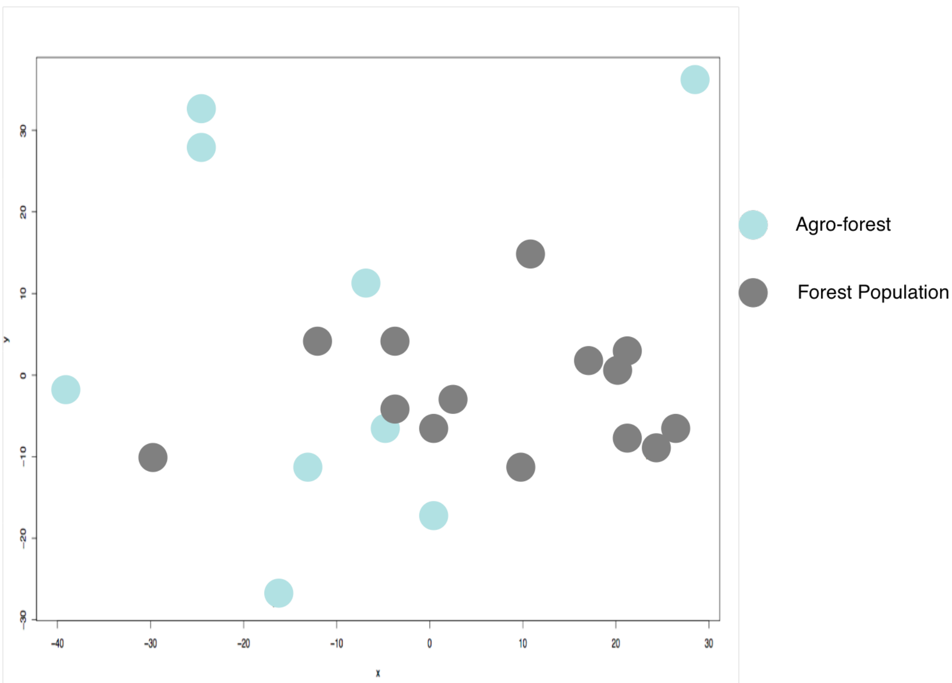


Figure 6.10 Manhattan Distance plot of AFLP data matrices for samples agro-forests and forests collected through an ethnobotanical approach. The distance between two points indicates genetic relatedness based on polymorphisms.

DISCUSSION

Leaf Morphology

Variation of morphological characteristics within tea management systems suggests the role of environmental and cultural influences. The greater variation of morphological characters in the two traditional agro-ecosystems, agro-forests and mixed crop plots, compared to more unmanaged forests suggests the role of humans in enhancing leaf diversity. It also supports the practice of farmers in selecting desirable phenotypes of tea. The smaller variation of morphological characters in terrace gardens compared to agro-forests and mixed crop plots concur with the desire for standardized market product by managers of the former agro-ecosystems. Terrace gardens have the greatest market integration of the agro-ecosystems assessed. The data also shows that smallholders who manage agro-forests select and prefer tea plants with large leaves, and cultivate them in a shade-grown environment that fosters the development of large leaves. The data supports that farmers of terrace gardens select tea plants with small leaves and cultivate them under high sun-intensity. Managers of terrace gardens prefer to cultivate small leaves because all the foliage on the plant has greater resemblance to young new leaves, which are demanded by the market. Processed old leaves can then falsified and sold in the market as new leaves.

Phytochemical Profiles

The greater TCC and TMC content found in agro-forests and mixed crop plots compared to forests and terrace gardens may be because these agro-ecosystems present the greatest stress to tea plants. Polyphenolic and methylxanthine compounds are secondary metabolites that are produced by plants as defense against environmental stress. Coley and Barone (2001) hypothesize that these compounds are adaptations that reduce the damage and mortality caused by herbivores and pathogens. The production of secondary metabolites represents a metabolic cost of energy and nutrients, and they only evolve when their benefits outweigh their costs (Coley and Barone 2001).

The lower plant species richness within agro-forests and mixed crop fields coupled with increased solar radiation likely results in increased predation with fewer types of host plants in the system, and increased oxidative stress from solar radiation. Tea plants may respond to this by utilizing their limited metabolic energy to produce greater quantities of specific secondary metabolites. A possible reason that there are fewer of secondary metabolites in terrace gardens compared to agro-forests and mixed crop fields is the use of pesticides and herbicides in the former system. Tea plants may no longer have the ecological cue to produce these compounds and conserve their metabolic energy.

Genetic Diversity

The greater genetic diversity found within plots of a particular management system than between management systems is consistent with previous findings on genetic diversity assessed by AFLP markers (Paul et al. 1997). However, results deviate from studies (Balasaravanan et al. 2003; Rajashekaran's 1997) that sampled from a wider geographic range in other tea growing regions that were able to distinctly cluster tea populations based on dendrograms. This discrepancy may be because the tea samples surveyed for this study were limited to the geographic area of Yunnan and did not compare tea samples to other areas. In addition, it may be because of the greater genetic diversity of tea samples in Yunnan compared to the other studies that were able to distinctly cluster commercial varieties sampled from a broader geographic range. The results are consistent with previous studies evaluating genetic relatedness of tea in Yunnan that used isozymes (Chen et al. 2005) and found greater diversity within populations than between populations of cultivated *Camellia sinensis* var. *assamica* and wild tea in section *Thea* of Camellia.

Comparison of genetic data from random sampling and ethnobotanical sampling found inconsistencies in genetic distance within agro-forest samples and forest samples. Greater genetic distance was found within samples from agro-forests than forests through the ethnobotanical sampling approach while similar distance was found through a random sampling approach. This highlights the value of incorporating farmer knowledge and perceptions in genetic sampling to understand agro-diversity.

The greater genetic distance of samples from mixed crop fields than forest populations suggests the role of tea farmers in enhancing germplasm diversity. The creation of genetic diversity in mixed crop fields systems is partly a result of farmer selection practices for desired properties, experimentation, and germplasm exchange between different communities. For example, farmers of the mixed crop field systems have an annual seed fair where tea seeds are exchanged between communities.

The greater genetic diversity in mixed crop fields than in agro-forests reflects the management practices of smallholders of each agro-ecosystem mode. Whereas tea plants in agro-forests are maintained to grow as trees, smallholders of mixed crop plots prune their tea plants into shrub-like trees and often remove individual tea plants from their fields in order to plant other tea plants based on preferences and for experimentation. While smallholders of agro-forests also experiment with tea germplasm, their focus on maintaining tea plants as trees has resulted in system with less dynamic germplasm. In addition, the mixed crop field community introduces tea seedlings from low land markets that source germplasm from several mountains. This has contributed to increasing the genetic diversity of smallholder tea fields at this study site.

The least differentiation within samples from terrace gardens at site I reflects the utilization of clonal varieties for uniformity of product. However, terrace tea gardens are relatively diverse compared to other crop monocultures. There are 56 nationally recognized tea cultivars in China and approximately 1,400 tea cultivars used by different tea enterprises. Future studies should examine the diversity of tea through a sampling strategy that incorporates a wider geographic area than Yunnan to assess this variation. While the diversity between terrace tea gardens is notable when compared to other crops, the diversity within a terrace garden is significantly less than traditional smallholder agrarian models because of the use of clones by the former.

Results demonstrated that the different modes of tea agro-ecosystems showed differentiation based on morphological, phytochemical, and genetic data. However, comparison between morphological, phytochemical, and genetic results revealed incongruent clustering schemes. Morphological and phytochemical characteristics of tea plants are influenced by environmental variables and do not necessarily reflect genetic relatedness. Morphological and phytochemical data clustered more distinctly than genetic data for type of management system. There was greater genetic variation found within plots of each type of management system than within systems. However, there was greater morphological and phytochemical variation found between the different types of management systems than within management systems. The discrepancy between morphological and genetic data is consistent with previous studies that have highlighted the role of environmental influences in morphological variation (Venkatesha et al. 2010).

Findings are further consistent with studies that have emphasized the role of the environment in chemical defenses of plants (Coley and Barone 2001). Agro-forests and mixed crop fields are forms of ecological agriculture that rely on ecosystem services rather than external inputs. Findings suggest that these systems rely on chemical defenses to against tea pests. The main tea pests are the short-hole borer *Xyleborus fornicatus*, a beetle in the family of Scolytidae. It is widely distributed in tea areas between elevations of 150 to 1,300 meters and causes severe damage of plant frames at lower elevations. Spider mites also eat tea. There are a number of naturally occurring predators such as coccinellid and staphylinid larvae, lace-wing larvae and other mites such as Typhlodromus and Phytoseius that prey on tea mites.

CONCLUSION

Variation of tea leaf characteristics within the various management systems contributes to the literature on domestication as an ongoing process. Findings suggest that morphological and phytochemical characteristics of tea plants are influenced by environmental variables and are not correlated to genotypic relatedness. This research provides evidence that communities may not only utilize biotic diversity, but they may also play an active role in maintaining or even creating diversity. The data also suggest that tea resources are influenced by farmer selection and exchange that has resulted in greater genetic diversity within management systems than between systems. The genetic diversity found in agro-forests, forests, and mixed crop fields may serve to buffer disease and is an important seed bank for commercial tea production.

PART III

SOCIO-ECONOMIC DYNAMICS OF TEA PRODUCTION AND CONSUMPTION IN YUNNAN

Part III of this study focuses on markets, land use, and consumption associated with tea. Chapter Six explores the pu-erh tea market to understand how social constructs and demand of "ecological" pu-erh influence production systems and farmer decisions. Chapter Seven examines the influence of increased market integration of pu-erh tea on land-use valuation and folk taxonomy of tea varietals in an Akha upland community in Southern Yunnan. Chapter Eight assesses how variable tea production practices affect drinkers' perceptions, phytochemical profiles, and anti-oxidant activity. It suggests how consumer preferences feedback to influence tea production. Chapter Nine moves away from a focus on tea production in southern Yunnan to examine traditional tea consumption in northern Yunnan. Specifically, it investigates the persistence of tea consumption in Tibetan communities in northern Yunnan who have historically relied on tea as a dietary staple. Tea demanded by Tibetan communities contributed to the expanse of tea production in China for over 1,000 years (Yang 2004).

Chapter Seven

INCREASED MARKET INTEGRATION OF PU-ERH TEA

The present chapter explores the recent expansion of the pu-erh (or *pu'er*) tea market in Yunnan in order to understand the influence of market variables on tea production and consumption practices. The chapter begins with an introduction to place Yunnan's pu-erh production within a global context. It provides a market context for the chapters that follow towards understanding the impact of increased market integration on land use, ecological knowledge, and consumption. Surveys were conducted in tea production communities and tea markets in Yunnan in order to understand: (1) actors in the pu-erh market, (2) prices and sources of pu-erh, (3) marketing mechanisms, (4) tea taste and associated production variables and, (5) perceived sustainability of the market.

Global Tea Production Area and Quantity

China, followed by India, is the largest tea producer in the world. In 2008 China dedicated 1,215,174 ha of agricultural land to producing over 1,200,000 tons of tea, an area that constituted 43% of the global tea production area of 2,806,443 ha (FAO 2010). Total area dedicated to tea production expanded over 300% in China and 43% in India since 1961 when both countries had comparable tea production areas of 331,229 ha and 354,979 ha respectively. The other leading tea producing countries are Japan, Laos, Myanmar, Nepal, Sri Lanka, Thailand, Turkey, and Vietnam.

Within China, Fujian Province is the largest tea producer, contributing to approximately 20% of national tea production (China National Product Statistics 2007).

Following Fujian, Zhejiang (16%), Yunnan (13%), and Sichuan (11%) provinces lead China's in tea production. Yunnan is distinguished from other tea producing areas of China as being the primary source of pu-erh tea while the other provinces produce primarily green, oolong, black, and white teas. Pu-erh refers to processed leaves and buds from the broad-leaf variety of the tea plant (*Camellia sinensis* var. *assamica* (L.) O. Kuntze; Theaceae) native to the Upper Mekong River Region of China's Yunnan Province (Ming and Zhang 1996) and contiguous parts of China, Laos, Vietnam, Myanmar, and India. Pu-erh is most often processed as a compressed tea of various brick, cake, log, nest, and gourd shapes. Dali Prefecture produces the most tea in Yunnan (25%) followed by Lincang (20%), Simao (17%), and Xishuangbanna (13%) (Yunnan Provincial Data 2009).

Customary Use of Pu-erh

Numerous socio-linguistic groups in Yunnan Province, including the Bulang (Blang), Wa, Akha (Hani), Lahu, Yao, Hmong (Miao), Jinuo, De'ang, Dai, and Han, have produced pu-erh for centuries. They consume tea as a medicine, tonic, beverage, and food for energy and wellbeing. Pu-erh is also consumed as a social beverage and for continuation of cultural traditions. Some of the health-related claims attributed to pu-erh include strengthening the immune system, balancing the body's hot and cold levels, detoxifying blood, treating rheumatism and stones, remedying headaches, and reducing swelling. Pu-erh has several health-related claims associated to mental wellbeing including invigorating the mind and relieving stress. Additionally, pu-erh is valued for providing nutrition, aiding digestion, and preventing obesity.

A few socio-linguistic groups in Yunnan prepare pu-erh as a food. For example, upland Bulang communities ferment pu-erh in underground pits for several weeks to years and eat the leaves as an accompaniment or salad. The Bulang also eat fresh tea with *nanmi* (a condiment made of several spices) and elder Bulang women chew tea leaves with a mixture of betel nut (*Areca catechu* L.; Arecaceae), lime, and other plants. Fresh and fermented tea leaves are particularly eaten during celebrations such as the annual harvest and nature worship ceremony in tea agro-forests. The Jinuo roast tea leaves that are mixed with spices and wrapped in banana leaves.

Processing of Pu-erh

Following harvest, tea leaves are processed as a type of loose green tea (*san cha* or "scattered tea"), which is the raw material for pressed green pu-erh (*sheng bing* or "raw cake"), aged pressed green pu-erh (*lao bing* or "old cake"), and pressed black pu-erh (*shu bing* or "cooked cake"). The processing of loose green pu-erh starts with withering and heat fixing leaves by pan-frying them on a wok to lower the moisture content and deactivate oxidative enzymes, i.e. polyphenol oxidase, catalase, peroxidase and ascorbic acid oxidase (Zhen 2002). Pan-fried leaves are rolled by hand or by mechanical grinders in order to disrupt the cell walls to remove additional moisture and shape the plant material. Kneaded leaves are spread out, typically on bamboo mats, and sun-dried to prevent spoiling and to capture the "taste of the sun" (*tai yang wei*). These processing steps are similar to that of other green teas and function to prevent oxidation of phytochemical constituents (Zhen 2002). However the deactivation of enzymes is not as complete for pu-erh. Consequently, pu-erh has a distinct oxidizing process and develops a smooth taste with age.

Pressed green pu-erh is prepared by steaming loose green pu-erh and compressing the supple leaves into desired shapes using bamboo or stone molds. The compressed tea is then sun dried. Historically, pressed green pu-erh was a main commodity on the caravan trade routes from Yunnan and Sichuan provinces to Tibet, Nepal, India, and Myanmar. These trade paths are now collectively known as the Southwest Silk Road (*Xi'nan Sichouzhilu*), Southern Silk Road (*Nanfang Sichouzhilu*), Tea-Horse Road (*Chama Dao*), and Tea-Horse Ancient Road (*Chama Gudao*). Sections of the Southern Silk Road are estimated to date over 1,000 years (Yang 2004). Pressed green pu-erh oxidized and fermented during the trade journey over months and years as it interacted with ambient moisture and temperature fluctuations, and its flavor transformed from bitter to mellow. Such tea can be classified as aged green pu-erh.

Today, connoisseurs store pressed green pu-erh in clay jars, bamboo wrapping and baskets, caves, and underground pits in attempt to optimally age tea and transform its flavor to aged-green pu-erh. The characteristics of aged green pu-erh can artificially be imparted by a microbial food-processing technology (*hou fa jiao*, "post-fermentation", "cooking," or "ripening") that was developed in the 1970s. The resultant black pu-erh differs from green pu-erh and aged-green pu-erh in that it involves oxidizing and heap-fermenting leaves for several hours to days following the rolling process of loose green pu-erh. Temperatures and moisture are often adjusted for controlled post-fermentation and leaves may be intentionally inoculated with selected microorganisms such as *Aspergillus* sp. (Trichocomaceae) (Ku et al. 2010). The oxidized and fermented leaves are then steamed, compressed, and dried. Black pu-erh is categorized as a post-fermented tea. The microorganisms in black pu-erh oxidize polyphenol compounds more completely than the enzymatic oxidation of other black teas (Xie et al. 2009), and create fermentation-derived compounds known as statins.

Market Expansion of Pu-erh

Tea developed in the Ming Dynasty (1368-1744) as a key commodity traded from Yunnan to Tibet on Tea-Horse Road, a trade route part of the extensive caravan network connecting Southwest China, Tibet, Southeast Asia, and South Asia (Yang 2004). During the Qing Dynasty (1644-1912) districts such as the "Six Great Tea Mountains" (*Liu da cha shan*) of Xishuangbanna (Sipsongpanna) were promoted because of their excellent tea-growing environment. The tea trade in southern Yunnan appears to have increased until around the time of the War of Resistance (1937-45) against the Japanese (Hill 1998). With the establishment of the People's Republic of China in 1949, the state promoted tea production by developing tea factories and research institutes, and by demarcation of tea districts.

Yunnan's tea products experienced heightened market integration during a recent boom cycle (2002 – 2008) when producers and traders revitalized Yunnan's longstanding tea trade, bringing it up-to-date with the sensibilities and desires of modern consumers. This boom was a response to China's emerging free-market economy and state promotion of tea (Sturgeon 2005). Toleno (2006) suggests that this boom was further a consequence of demand from tea consumers in China, Taiwan, Singapore, Hong Kong, Japan, and Korea in response to rising health concerns and taste attributes of tea contaminated with chemical-residue. Several studies between 1998-2005 found tea samples from eastern China contained agricultural chemical residues and heavy metal in excess of safety standards (Han et al. 2006; Wang 2005). Reports noted rising anxiety by consumers in East Asia who fear death by acute poisoning and health issues from chronic poisoning by contaminated foodstuffs (Jiang 2003). Yunnan's tea producers and traders met the market opportunity presented by such studies with efforts to distinguish their tea from other areas. This spurred a bull market of tea from pu-erh, which is the focus of the present chapter.

METHODS

One hundred interviews using questionnaires were conducted with tea producers (n=30), traders (n=20), vendors (n=20), consumers (n=20), and masters (tea experts; n=10) in Yunnan Province, China between 2006-2009. All informants gave prior informed consent to volunteer in this study. Interviews with tea producers were carried out in upland Bulang, Ahka, Yao, Lahu, and Yi ethnic communities in Xishuangbanna, Honghe, and Lincang prefectures of southern Yunnan. Interviews with tea traders, consumers, and experts were administered in tea markets, tearooms, and tea processing factories in urban centers and rural areas in Yunnan. Interviews with vendors, consumers and experts were primarily conducted in the urban centers of Kunming, Jinghong, Menghai, and Lincang City. Some interviews were also conducted in tea factories near tea-growing mountains. Interviews with traders were conducted in tea-growing areas, factories, and markets. A questionnaire (Appendix One) was administered on tea prices, sources, production quantities, preferences, and dynamics. Responses from interviews were coded and were compared between tea producers and vendor. A market inventory was also conducted in 30 tea shops in Kunming to document prices, sources, and marketing themes. Additional inventories were carried out in tea shops in Jinghong, Menghai and Lincang City of Yunnan as well as in tea shops in Beijing and New York.

RESULTS AND DISCUSSION

The Pu-erh Boom and Bust Cycle

Yunnan's tea producers and traders met the market opportunity presented by the demand for tea free of agro-chemicals by marketing pu-erh tea from agro-forests, forests, and mixed crop fields under the name *sheng tai cha* ("ecological tea" or "natural tea"). Increased demand for pu-erh and "ecological tea," followed by hype by consumers in Asia, spurred a bull market for tea from Yunnan.

As prices escalated, income of producers and traders increased over 100-fold and new actors entered the supply chain. Smallholder communities that produce tea witnessed the return of off-farm laborers. Tea terraces became a dominant land use in southern Yunnan and products from these plantations were often falsely represented as sourced from "ecological" systems such as agro-forests. Industrial processors took advantage of fermentation technologies to impart the smooth taste characteristics of aged pu-erh, which allowed some unscrupulous processors to misrepresent production dates. A short-term focus and the lack of regulatory frameworks compromised the quality of Yunnan's tea production. A study at the peak of the pu-erh boom found Yunnan tea followed Anhui in exceeding lead concentrations compared to some other provinces (Qin and Chen 2007). Consumer knowledge and speculation of adulteration and oversupply of low-quality tea led to the market collapse in 2008. Producers experienced variable repercussions. Communities that converted their lands to tea terraces struggled to fulfill subsistence needs. At the same time, those that maintained "ecological" or organic tea production and innovated with processing were afforded a competitive market edge (Menzies 2008) as traders and consumers remained willing to pay price premiums for tea they recognize as sourced from agro-forests and mixed crop fields. Traders gained the ability to identify tea as "ecological" from agro-forests and mixed crop fields by increasingly visiting the tea production communities and buying directly at the source. Figure 4.1 in Chapter Four demonstrates how the pu-erh market rebounded for a smallholder Akha community that maintained tea production in agro-forests.

Actors in the Pu-erh Market

Increased market integration of pu-erh tea has been accompanied by a longer and more complex commodity chain within Yunnan and to markets in major cities in China. At the cultivation level, the market chain comprises of smallholders the different tea management systems and field laborers hired by smallholders or private enterprises. Suppliers of seeds, seedlings, fertilizer, pesticides, herbicides, hormones, and mechanized harvest equipment also participate in tea cultivation. These inputs are particularly used by terrace tea plantations. Agronomists, forestry officials, and extension agents are additionally involved in tea cultivation. Policy makers are linked to this segment of the commodity chain through promotion of tea production in southern Yunnan as a means to alleviate rural poverty and develop commerce.

Smallholders, tea enterprises, and factory workers participate in the processing segment of the pu-erh commodity chain. The kind of enterprises participating in tea processing, i.e. pharmaceutical companies, has diversified as a result of the pu-erh market. Suppliers of processing equipment are also involved in this market segment. New marketing methods and actors participate in the promotion of pu-erh. For example, the media and graphic designers increasingly brand pu-erh. Tea-performance artists hired by teahouses and festivals prepare tea through exhibitory methods to encourage interest in pu-erh. Local and provincial governments are further linked to marketing through numerous initiatives to promote the pu-erh industry for economic development. Local governments offer quality certificates of production and support technology and product innovation.

Consumers influence the pu-erh marketing chain through preferences and demands. The consumers of pu-erh have expanded from rural areas and historical trade destinations, such as Tibetan communities, to urban centers. Interviews revealed that the greatest demand of pu-erh comes from Kunming and China’s major urban centers including Beijing, Shanghai, Fuzhou, Guangzhou, and Jinan. Traders in these areas further serve as middlemen to supply pu-erh demand from Hong Kong, Taiwan, Korea, and Malaysia. The pu-erh boom cycle has also been accompanied by increased pu-erh consumption in western countries. However, consumers in Asian countries that have a long history of tea consumption are willing to pay higher premiums for “ecological” pu-erh than western countries. Asian countries are thus the primary end consumers of high quality pu-erh.

Marketing of Pu-erh

Yunnan’s urban areas have experienced a surge in marketing materials over the past five years due to increased public awareness and interest in pu-erh. The media has been involved in this process through television, advertisements, books, magazines, journals, and internet websites dedicated to pu-erh. Private enterprises in Yunnan and Chinese cities promote pu-erh by offering tea tastings. Several social organizations and tea festivals have arisen in Kunming, Lincang City, Jinghong, and Menghai to exchange and disperse information on pu-erh. This includes cultural promotion centers, internet networks, product fairs, competitions, and clubs. Provincial and prefecture governments participate in marketing through designations such as the re-naming of Simao Prefecture as Pu’er.

Pu-erh is branded for diverse characteristics that highlight its habitat, associated cultural practices, age, health properties, and social and historical values. The most prevalent themes to market pu-erh are that it is sourced from “ancient” and “big tea trees” that grow in “ecological”, “natural” and forest tea systems on famous tea mountains. The age of tea is another prevalent theme to market pu-erh. Table 7.1 lists the frequency of marketing themes recorded during an inventory of the Kunming tea market. While the branding of pu-erh emphasizes sourcing from ancient and big tree teas, interviews and observation suggest this label is most often falsified as there is more product with this label on the market than there are old and big tree tea plants in Yunnan. Additionally, there is little consistency in the way different informants understand the term “ecological”. Table 7.2 demonstrates the variability with which the pu-erh market constructs “ecological” tea. Despite the prevalence of products marketed as “ecological” tea, some traders and salesmen are not familiar with the meaning of this term. *Terroir*, or the environment and location in which tea is produced, is another common theme in branding pu-erh. Tea market interviews found that the mountains and areas most represented on the labels of pu-erh products include: Ailao, Bada, Banzhang Baoshan, Bulangshan, Dehong, Gedeng, Honghe, Jingmai, Lincang, Manchang, Mangong, Mansa, Manzhuang, Menghai, Menghu, Mengsong, Nannuo, Simao, Wuliang, Yibang, Yiwu, Youle, Yushou and Xiding. All of these mountains have tea agro-forests and mixed crop fields some of them are areas were sources of tea send to the Chinese emperors and royalty.

Interviews revealed the dynamic nature of marketing of pu-erh. As the Yunnan pu-erh market transitioned from a boom to a bust period, tea salesmen began to focus on different and fewer marketing strategies. During the boom in 2007, many vendors focused on the marketing of pu-erh as a luxury item. They branded tea with themes that invoked sophistication and fashion and promoted its purchase as a collectible or gift. By 2009, several months after the bust of the pu-erh, vendors began to increasingly market pu-erh as a staple necessary to maintain human health.

Table 7.1 Themes used to market pu-erh tea recorded during a 2007 market inventory of 30 tea shops in the urban center of Kunming, Yunnan.

Frequency (%)	Marketing Theme	Frequency (%)	Marketing Theme
64	Ancient	28	Environmental conservation
63	Big trees / tree tea	27	Cultural revitalization and preservation
62	Vintage	27	Weight loss / reduction of blood fat
56	Ecological	25	Improving rural livelihoods
66	Famous tea mountain / Geographic location	24	Big buds
66	Wild / forest tea	23	Celebration
47	Health	19	Etiquette
44	Symbol of Chinese culture	19	Hygiene
43	Organic / green food	19	Thirst quencher
42	Yunnan identity / symbol of Yunnan's ethnic culture	17	Hangover remedy
41	Collectible	17	Social exchange
41	First flush / spring tea / snow buds	16	Nutrition
41	Gift / souvenior	15	Stimulation
37	Tea-Horse caravan trade	12	Polyphenols
34	Yunnan big leaf	11	China's wealth and Yunnan's development
33	Free of pollution	11	Fashion
33	Investment	9	Intellectual value
31	Number of possible infusions	6	Worship
29	Emperor tea / tribute tea		

Table 7.2 Market concepts of "ecological" tea elicited during semi-structured interviews with tea vendors in 2007.

(%)	Concepts of "Ecological" Tea
38	Big trees
37	Old trees
34	Tea that grows in the forest / wild / "original" habitat
33	No chemical input (pesticides, herbicides, hormones, fertilizers)
31	Tea that doesn't grow in terraces / less managed
29	Tea not bred by modern experiments
27	Tea grown in an environment without pollution
15	Diverse environment able to manage pests and disease
14	Not familiar with the meaning of "ecological tea"
12	Tea plants from seed (not clones / not grafted)
9	Abandoned tea trees once managed by people
6	Green in color

Tea Taste and Associated Production Variables

Informants used multiple taste and physiological descriptors to capture the sensory experience of pu-erh tea tasting. The most prevalent taste terms used by informants to describe the different types of pu-erh tea (loose green pu-erh, pressed green pu-erh, aged-green pu-erh, and black pu-erh) included bitter (58%), bitter with a sweet aftertaste (57%), and sweet (54%). Table 7.3 lists the taste terms used by informants to describe pu-erh. A total of 73% of informants said that bitter or bitter-sweet taste indicates medicinal properties of tea. Informants perceived tea with a bitter and bitter-sweet taste to be grown in a forest, "ecological",

Table 7.3 Most prevalent taste terms mentioned during interviews to describe different types of pu-erh.

Taste Term	Frequency (%)
Bitter	58
Bitter with a sweet aftertaste	57
Sweet	54
Sour	39
Salty	34
Astringent	33
Acidic	33
Floral	31
Smoky	34
Fruity	27
Smooth	26
Mellow	23
Full	22
Fishy	22
Moldy	21
Earthy	21
Metallic	19
Acrid	17
Vegetal	12
Burnt	2

"natural" or "healthy cultivation environment". Urban informants referred to bitter pu-erh from forest and agro-forests as "bitter tea" (*ku cha*), "ecological tea" or "natural tea" (*sheng tai cha*), "big tree tea" (*da shu cha*), or "ancient tree tea". The experience of the pu-erh tea tasting is additionally described based on physiological sensations (physiologically and mentally uplifting, mouth-watering, throat drying, calming), fragrance (sweet, floral, citrus), color (golden, amber, red), and clarity (clear, dusty, cloudy). Informants recognized numerous factors associated with production environment to impact the taste of pu-erh, including harvest time, season, location, plant height and age, cultivar or landrace, altitude, fog, slope, temperature, canopy cover, soil, rain fall, and humidity. Table 7.4 shows the production variables that informants report influence the taste of tea. Comparisons between tea producers and tea vendors and traders indicate that tea producers attribute greater habitat variables as influences on the taste of pu-erh. Alternatively, tea vendors and traders attribute processing factors as influences.

Perceived Sustainability of the Pu-erh Market

Interviews conducted at the peak of the pu-erh tea boom cycle in 2007 revealed the majority of respondants felt that the pu-erh market was unsustainable. Informants considered the lack of quality control and standardization, falsification of product, and knowledge gaps to be the greatest problems contributing to the lack of sustainability of the pu-erh market. Additionally, they considered the greater demand than supply for "ancient" and "ecological" tea than supply as limiting the growth of the pu-erh tea market. The infiltration of newcomers in the commodity chain, opportunism, short-term focus, and poor processing technology were reported as major weaknesses of the pu-erh market. Informants further noted the failure to meet international standards, lack of consensus on how pu-erh should be grown, processed, marketed, labeled, prepared, and consumed, and poor management as hindering market sustainability. Some informants considered poorly processed tea from unknown sources to pose health risks. They link the use of agro-chemicals and microorganism technology for the production of fermented pu-erh to this risk. A few informants noted that wild tea relatives that are increasingly

Table 7.4 Informant perceptions of production variables that influence the taste of pu-erh tea recorded during semi-structured interviews in Yunnan in 2007.

Frequency of Tea Producer Responses (%)	Frequency of Tea Vendor Responses (%)	Production Variables
		Tea Trees
46	57	Age
36	43	Height
21	16	Unpruned vs. pruned
8	0	Time of flowering
		Habitat
66	39	Shade level vs. sun level
64	61	Agro-chemical Input
59	66	Elevation
53	19	Denseness of Forest
47	24	Climate
43	49	Pollution of Surroundings
42	2	Wind Level
36	8	Soil Type
33	19	Direction of Mountain Faces
28	7	Presence of Rivers and Streams
24	17	Cloudiness
21	18	Slope and Shape of Mountain
19	3	Presence of Orchids, Moss, and Epiphytes in System
14	46	Geographic Location (Latitude; Watersheds)
		Production System
66	63	Forest, Agro-forest, Mixed Crop, and Monoculture
		Varieties
51	11	Local Landraces vs. Introduced Cultivars
		Season
65	72	Spring, Summer, Fall
48	71	First Flush
		Leaves
47	2	Age
39	23	Amount and Length of Young Hairs
32	7	Level of Water Retention
29	8	Length of Petioles
23	14	Shape
23	14	Color
21	9	Thickness of Leaf
13	9	Pattern of Leaf Serration
		Processing
38	39	Pan Fried, Baked, Steamed
43	47	Drying Method (Sun, Shade, Baking, Smoking)
41	49	Wilting of Leaves
34	12	Color of Processed Leaf
31	56	Vintage
21	38	Hand Processed vs. Machine Processed
19	38	Mixed Origin vs. Single Origin
18	33	Pure Leaf vs. Mixed Leaf wiith Stems
18	48	Storage (Temperature and Humdity)
7	2[illegible]	Type and Quantity of Microorganisms

Table 7.5 Perceptions of market problems elicited during interviews with tea vendors during the peak of the pu-erh cycle in 2007 in Yunnan.

Frequency (%)	Problems
53	Lack of quality control
45	Lack of standardization
44	Falsification of product
42	Lack of knowledge
39	Greater demand for forest and ancient tea than supply
39	Lack of scientific research
34	Infiltration of newcomers
32	Lack of processing equipment
31	Greater supply of monoculture tea than demand
31	Short-term focus
31	Lack of processing skills
29	Opportunistic actors
27	Too much emphasis on marketing w/o supporting knowledge
26	Failure to meet international standards
23	Lack of technological support
21	Lack of agreement
14	Disease-causing toxins
14	Poor management of tea enterprises
9	Lack of understanding of wild tea - maybe beneficial or poisonous

being commercialized may contain unknown poisonous compounds if consumed in large amounts. Table 7.5 presents the prevalence of market problems from informant responses.

DISCUSSION AND CONCLUSION

The results here illustrate the dynamic nature of markets. The expansion of pu-erh tea commercialization has resulted in a more complex market chain coupled with heightened efforts to increase public awareness and interest in pu-erh. In some aspects the pu-erh commodity chain has increased in length as new actors have entered. In other aspects, the commodity chain has shortened as increasing number of traders and vendors from major cities in China are buying pu-erh directly from tea mountains. The dynamic nature of markets was evidenced in the branding of pu-erh over the recent boom and bust years. Pu-erh is branded for diverse characteristics that highlight its habitat, associated cultural practices, age, health properties, and social and historical values. The emphasis on branding themes changed as the pu-erh market fluctuated. Pu-erh was branded as a luxury item during the boom period, but quickly was re-branded as a dietary staple necessary for wellbeing during the market bust period.

Results also point to the divergent perceptions of producers versus market vendors regarding the production variables that influence the taste and quality of pu-erh. This is significant as these perceptions influence pu-erh production and processing in a variety of ways. The increased presence of market actors in the tea production mountains is likely to further influence production practices and presents interesting questions for future research.

Chapter Eight

LAND-USE SIMPLIFICATION AND DEVELOPMENT OF FOLK TAXONOMY OF TEA CULTIVARS

The present chapter examines how land-use, valuation, and ecological knowledge respond to increased market integration of pu-erh tea in Yunnan. Research was conducted in an Akha community in mid-elevation montane southern Yunnan over a 4-year period (2006 – 2010) corresponding to a tea market boom cycle. The Akha community manages tea in agro-forests. Surveys were carried out with smallholders to measure socio-cultural valuation of land use. In addition, smallholders' folk taxonomies (Berlin 1992) of tea varietals were compared as a measure of ecological knowledge (Rocha 2005). The objectives of these surveys were to understand land-use decision-making from the perspective of rural households as they transform from subsistence economies of regional trade to participants in globalization.

STUDY AREA

Research was conducted in Baljalpuxeevq, a smallholder Akha community in the Bulang Mountains, Menghai County, Xishuangbanna Dai Autonomous Prefecture, Yunnan, China. Baljalpuxeevq is in the border area near Myanmar at 1,800 meters in evergreen broadleaf montane forest within the Indo-Burma biodiversity hotspot (Dijk et al. 1999). Baljalpuxeevq was chosen as a study site because its remote location has historically limited interaction with the market and state compared with many other communities in Xishuangbanna. The tea trade in Xishuangbanna began primarily in areas to the northeast of the Mekong River because of greater accessibility than communities to the southwest of the Mekong River (Hill 1998) such as Baljalpuxeevq. During the early 20th century

Baljalpuxeevq's inhabitants traded opium and tea for salt and rice with Tai (Tai-Lue or Dai) in Myanmar and occasionally in Xishuangbanna's lowlands. Even after Menghai, to the southwest of the Mekong, developed as a tea-processing center, Baljalpuxeevq was slower to expand its tea trade than other more accessible areas (Toleno 2006). The study site's mid-level montane location above the altitude where rubber can grow (1,100 m) allowed it to avoid state-promoted rubber projects. However, with the recent tea boom, Baljalpuxeevq's agro-forests have become one of the most sought after sources for "ecological" pu-erh.

In 2008, 427 Akha inhabited Baljalpuxeevq in family units of 88 households. The Akha arrived to the Bulang Mountains in the mid-nineteenth century from a nearby area. The Bulang previously inhabited Baljalpuxeevq, and created many of the agro-ecosystems that the Akha now steward, including tea agro-forests. Local households are organized in a nuclear structure with a portfolio of land use surrounding the settlement. The nearest market town is six-hours by foot or 1.5 hours by automobile (45 kilometers) on unpaved roads developed by the state in the 1960s. Historically, agriculture was predominantly based on swidden cultivation where forests are cleared for crop production and then regenerated back into forests during a fallow period to replenish soil fertility. Agricultural land was communally managed in Baljalpuxeevq during China's collective period (1958-1982). New state demarcations were imposed following policy reforms of 1982-1983 when communal agricultural and forest lands were distributed to households under the *liangshanyidi* policy, as in other rural communities in the region (Xu et al. 1999). Current land tenure combines locals systems negotiated with state policy. Sections of forestlands are demarcated as household, community, and state forest. Since 2006, the provincial government has facilitated commercial tea enterprises to sublease land from communities in the Bulang Mountains previously managed for swidden cultivation for the creation of terrace tea plantations. These enterprises hire migrant workers and have created laborer settlements in land contracted from Baljalpuxeevq and neighboring communities. For further information about the study site, Appendix Five presents the oral history of Akha of Baljalpuxeevq.

METHODS

Land-use valuation and folk taxonomy surveys were conducted in 2008 to understand variability of value and knowledge systems within the community and how these dimensions are responding to increased market integration. Land-use results were compared with 2005 data collected by Toleno (2006). Folk taxonomy surveys were adapted from agro-ecological knowledge surveys presented in Rocha (2005). Surveys started with free listing interviews (Weller and Romney 1988) to define the domains “types of land use” and “types of tea” around the community. Fifteen households were randomly selected for free listing interviews of land-use types and 30 households were selected for free listing interviews of tea types. Informants were asked about all the types of land use and tea in the community. This was supplemented with informant walks around the community and open-ended interviews. Land-use categories were photographed and names were recorded in Akha, Mandarin, and English. The most frequently reported land uses were incorporated in weighted ranking valuation interviews. Expert informants were selected to identify tea types for use in specimen sorting interviews to measure agro-ecological knowledge.

Thirty informants of equal age classes were randomly selected from 22 households to rank land-use photographs. Age classes were set as youngest (< 35 years old), middle aged (35 – 50 years old), and elders (> 50 years old). Informants were requested to score photographs with a set of one hundred markers to indicate the relative importance of each land-use category based on personal meanings of importance. Semi-structured interviews followed to understand ranking schemata and informants' personal meanings of importance. Thirty additional informants of equal age and gender groups were selected to sort tea types. Informants were presented with a pile of specimens and requested to sort (Weller and Romney 1988), name, and describe the samples and share their preferences.

The number of markers assigned to each land use was expressed as a Land-Use Importance Value (LIV) percentage and the number of tea types linguistically marked by each informant relative to total tea types was expressed as an Ecological Knowledge Score (EKS). A coded-valuation schemata modified from Kellert and Wilson (1993) was applied to informant responses. Bivariate regression, analysis of variance, means comparisons using Tukey-Kramer HSD, and principal components analysis were employed to assess consensus and variation of LIVs and EKSs among age and gender groups.

RESULTS

Surveys on Smallholders' Land-Use Valuation

Research conducted in 2005 during the early phase of the Yunnan tea boom documented 34 land use categories (Table 8.1; Toleno 2006). Wet rice paddy, upland dry rice fields, and wet rice terraces were the three most significant land-use categories based on informant consensus. Since 2005, local Akha have stopped managing upland dry rice fields and upland wet rice terraces in response to state discouragement of shifting cultivation and opportunities presented by tea markets. Other significant land uses in 2005 included tea fields (tea agro-forests), cardamom plantings (*cal kol yal / Amomum tsaoko*; Zingiberaceae), pastures, school, corn fields, sweet bamboo stands, and peanut fields. Research conducted in 2008 following the peak of the Yunnan tea boom documented 29 land uses with 14 significant categories. Table 8.1 compares land uses reported by informants between the 2005 and 2008 study periods. Old tea agro-forests, wet rice paddy, and forests were the most important land uses in 2008 (Table 8.2) and are the primary contributors of household income, dietary subsistence, and other natural resources. Informants report that they choose to manage wet rice paddy over their customary upland rice because the labor demands are seasonal rather than constant throughout the year. Banana stand, fallow, grazing fields, and tobacco plots were the least valued land uses.

Local smallholders have expanded tea cultivation area for future generations and intensified management of existing tea agro-forests to increase production. From 1984 to 2009, total tea cultivation area managed by Baljalpuxeevq's Akha expanded from 267 ha to 467 ha by planting tea in forests and swidden fields. Smallholders have intensified management in existing tea agro-forests through selective girdling of associated woody plant species to cultivate more tea. Intensification of tea agro-forests has thinned the canopy, increased sunlight, and stimulated the growth of invasive weedy species. At the same time, locals are transforming some swidden fields previously managed for upland rice into tea agro-forests. Thus, while plant biomass decreases in forests and agro-forests, it is being enhanced in previously active swidden areas that are being transformed to tea agro-forests.

Table 8.1 Comparison of land-use categories documented in 2005 (Toleno 2006) and 2008 surveys in Baljalpuxveeq through free-list interviews and community walks.

Land-Use Categories (Akha)		Survey Year 2005	2008
Al baol dev mil caq	A type of forest	x	x
Al du yal	Corn field / mixed crop land	x	x
Al haq yal	Type of bamboo stand	x	x
Al siq yal	Fruit orchard	x	x
Cal kol yal	Cardamon (*Amomum tsako*) land	x	x
Dal hml / al neiq yal / ha qil yal	Rattan stand	x	x
Dei ma	Wet rice paddy	x	x
Haq geeq yal	Type of bamboo thicket	x	x
Hhaoq niyul yal (1)	Seasonal forest vegetable garden	x	x
Hhaoq niyul yal (2)	Home vegetable garden	x	x
Jiefang cao (Mandarin)	*Ageratina adenophora* / weed fields	x	x
Laol baoq yul	Old tea field / tea agro-forest	x	x
Laol baoq xeevq	New tea field / new tea agro-forest	x	x
Li hhei (yal saq) / dal piav yal	New fallow / barren or bracken land	x	x
Mal dao xeel	Canna edulis / *Bajiaoyu* plot	x	x
Neev paoq yal	Peanut field	x	x
Neev piav yal / al neev yal	Soybean / bean field	x	x
Nga beiv yal	Banana stand	x	x
Nioq hyuv / dal deq yal / li hhei (yal saq)	Grazing pasture	x	x
Saoq hav / al baol saoq hav	Old forest / dense forest area	x	x
Ssavq peel yal	Type of bamboo stand	x	x
Uq jil yal	Thatch grass field / type of fallow	x	x
Ya haoq yal	Tobacco land	x	x
Yao ssavq yeiq mil caq	Unfrequented place (Watershed forest)	x	x
Yaq il yal	Potato land	x	x
Ziq yal / yuf maf yal	Hemp field	x	
Qeil yal	Upland dry-rice field	x	
Dei ma do siq	Wet rice cultivated in a hillside terrace	x	
Mal dei yal	Pumpkin patch	x	
Xuexiao (Mandarin)	The village school	x	
Meq	Lowlands (not local land use)	x	
Lav beeq pu	Han village (not local land use)	x	
Laol baq	River or stream (as food source)	x	
Saq soq yal	Mountain pine (not local land use)	x	
Diq xeel (jaoq)	Where things do not grow well	x	
Hhavq laoq / il quvq	Narrow valley floor with standing water	x	
Paol qeil yal	Sugarcane fields (not local land use)	x	
Saq keq	Land where trees are returning	x	
Guoyou [senlin] (Mandarin)	State forest		x
Fengjing lin (Mandarin)	View forest		x
Gaoq jaoq hhal	Burial forest		x

Table 8.2 Mean Land-use Importance Values (LIVs) by informant gender and age-class surveyed in Buljalpuxeevq in 2008 during photo-elicitation weighted ranking interviews.

Land-Use Categories	LIV Mean Total	LIV Mean Male	LIV Mean Female	LIV Mean Ages < 35 Years	LIV Mean Ages 35 - 49 Years	LIV Mean Ages = > 50
1. Old tea field / tea agro-forest	11.91%	12.05%	11.68%	12.67%	12.51%	10.81%
2. Wet rice paddy	11.47%	11.52%	11.38%	11.31%	11.14%	11.85%
3. Forest (national & community forest)	11.13%	11.31%	10.84%	10.47%	11.49%	11.31%
4. New tea field / new tea agro-forest	9.56%	9.92%	8.96%	9.97%	10.42%	8.68%
5. Home vegetable garden	7.84%	7.92%	7.71%	8.77%	8.26%	6.72%
6. Cardamon (*Amomum tsako*) land	7.51%	7.51%	7.50%	6.90%	7.98%	7.81%
7. Corn field / mixed crop land	6.54%	6.37%	6.83%	6.54%	6.48%	6.68%
8. Rattan stand	6.53%	6.98%	5.76%	6.22%	6.45%	6.64%
9. Bamboo stand	6.17%	5.80%	6.79%	6.28%	5.06%	6.67%
10. Seasonal forest vegetable garden	5.62%	5.71%	5.46%	4.85%	5.73%	6.40%
11. Banana stand	4.64%	3.67%	6.31%	4.74%	4.06%	5.34%
12. New fallow / barren or bracken land	4.05%	4.06%	4.03%	4.36%	3.81%	3.93%
13. Grazing pasture	3.77%	3.63%	3.99%	5.16%	2.77%	3.28%

Tea production has changed from being an occasional activity for women to a key livelihood for the entire adult community. Before the 1980s, local people intermittently visited their agro-forests to harvest tea. With the increased market value of agro-forest tea, local Akha have restructured their livelihood activities to dedicate five to six days per week from the start of the spring harvest in March through the end of the fall harvest in October. Baljalpuxeevq's middle-aged men have tapped into customary resources and developed social networks with tea industry agents to take advantage of market opportunities. These customary resources include local institutions of natural resource management and associated ecological knowledge, experience with self-organization, and experimentation with plants and land use. Locals have also started a community group adapted from customary institutions to unite individual household management, processing, and marketing of tea towards creating brand recognition for the community. This new resource institution functions to ensure production without agro-chemicals, set a minimum price, prohibit tea grown outside the community from being sold in the village, share knowledge, and experiment with tea processing. The group has refined tea-processing techniques to better preserve taste and have revived products such as pressed tea in bamboo.

Income received by local farmers for agro-forest tea has increased from USD $1.18 per kilo of dried leaf in 2000 to a high of USD $220 per kilo. Tea contributes up to 99% of household cash income and has replaced cardamom (*Amomum tsako*; Zingiberaceae), introduced to the community in 1987, as the primary source of income. Annual tea income varies depending on household size and social networks. Despite the collapse of the regional pu-erh market, connoisseurs remain willing to pay premiums for high-quality product from Baljalpuxeevq's old agro-forests. With this new wealth, many local households have moved from below the poverty line to middle-class entrepreneurs. They have utilized profits from tea sales for household items such as vehicles, meat, clothes, snack foods, and electronic products. They have also used profits for building new homes, roads, and community facilities. In addition, income from tea is used for hiring external labor for harvesting tea and for construction. This is the first time that Baljalpuxeevq's Akha have employed external labor, including members of the historically dominant Dai socio-linguistic group.

Despite recent tea wealth, locals continue to rely on subsistence agriculture, home gardening, and foraging as risk management and because of restricted accessibility to lowland markets during the rainy season. In addition, they continue subsistence farming because of preferences for locally-grown food. Informants emphasize that the tea market is unpredictable and they should not abandon other farming activities. Coded land-use valuation (Table 8.3) suggests that local Akha have a multidimensional value system. Value attributed to un-utilized land for its past and potential use highlights a long-term perspective. In view of the greater proportion of subsistence values attributed to land uses by elder informants versus the middle and youngest generations, it appears that land value systems are being reoriented towards a cash economy.

Bivariate fit analysis of Land-Use Importance Values (LIVs) by informant age further supports the reorientation of local value systems towards market economics. An increase in informant age is significantly associated with increasing valuation of wet rice paddy ($P < .0001$), ginger plots ($P < .0001$), corn / mixed-crop land ($P < .0001$), rattan stand ($P < .0004$), bamboo stand ($P < .0001$), forest vegetable garden ($P < .0060$), and banana stand ($P < .0132$). With the exception of cardamon plots, these land uses represent subsistence strategies. An increase in informant age is significantly associated with a trend of decreasing valuation of tea agro-forests, forest, home gardens, fallow, and pastures. Home gardens are a relatively new land use in the community, and forests are increasingly perceived as a limited resource.

Principle-components analysis (PCA) of land-use valuation matrices suggests variability in the community among gender and age. PCA found the first eigenvalue to account for 24.34% of variance for total value ranking schemes. Results of gender and age-class comparisons support that within-group agreement is greater than total group agreement. The first eigenvalue accounts for 32% of variance among female land use schemata, 26% for males,

Table 8.3 Coded valuation of the proportion of informants that indicated a particular value orientation towards land-use categories during photo-elicitation weighted ranking interviews in Buljalpuxeevq in 2008.

Land-Use Categories	Holistic (%)	Spiritual (%)	Traditional (%)	Survival Skills (%)	Moralistic (%)	Abstract Liking (%)	Utility (%)	Income (%)	Ecological (%)	Health (%)	Social (%)	Aesthetic (%)	Destructive / Negative Value (%)
Old tea field / tea agro-forest	3	3	14	-	-	14	3	5	-	8	6	-	-
Rice paddy	-	-	16	25	-	9	36	-	9	9	-	-	-
Forest	24	5	12	-	3	1	26	8	24	4	2	6	-
New tea field / tea agro-forest	8	-	25	-	8	8	-	33	-	-	-	-	-
Home vegetable garden	14	-	-	-	-	-	71	-	-	14	-	-	-
Cardamon (*Amomum tsako)* land	-	-	-	-	-	-	-	64	9	27	-	-	-
Corn field / mixed crop land	-	-	-	-	-	14	43	-	-	-	-	-	43
Rattan stand	17	-	6	6	-	11	28	-	11	-	22	-	-
Bamboo stand	16	-	-	-	-	-	83	-	-	-	-	-	-
Seasonal forest vegetable garden	-	-	-	-	-	-	5	-	-	-	-	-	5
Banana stand	-	-	-	-	-	57	29	-	14	-	-	-	-
New fallow / barren or bracken land	32	-	5	5	5		16	5	32	-	-	-	-

41% for the youngest, 30% for the middle-aged, and 36% for the eldest.

Other land-use changes over the study period since 2005 is that buffalo are no longer in pastures and that some land previously managed for swidden cultivation has been subleased to private tea enterprises through state facilitation. The decision to no longer raise buffalo is a function of state policy discouraging pasture management because of the potential for environmental degradation and because motorized tractors have replaced buffalo for plowing fields. Local diets increasingly include meat purchased from lowland markets. Lands previously managed as pasture are valued for their potential to be transferred to other uses with increasing concerns of land shortage. This concern has risen as new policies prohibit resettlement, the population grows, and outside commercial enterprises sublease land that was previously managed by locals for swidden cultivation.

Surveys on Folk Taxonomy of Tea Varietals

Results suggest that local Akha maintain diverse tea varietals (types or landraces) in agro-forests because of varying personal preferences and as a risk management strategy. Social exchange and experimentation of plant germplasm are customary practice in Baljalpuxveeq while discernment of tea varietals has become more rigorous in response to increased market integration and value of tea. Locals source tea germplasm from surrounding forests, other communities, and occasionally experiment with cultivars introduced by extension agents. Lowland tea varietals are generally considered unsuitable for upland environments and vice versa.

Local tea classification includes 3 - 15 tea varietals based on leaf characteristics (color, shape, taste, texture, thickness), taste (bitter, bitter with a sweet aftertaste, sweet, sour, salty, acrid), type of production system (agro-forest, forest, terrace), ecological attributes (shade cover, soil types, associated woody species), origin (local versus introduced), tree form and yield. Origin is the primary character used in selecting tea varietals, which locals differentiate as “Akha people’s tea” versus “Han terrace tea”. Leaf color and size are the key characters in local tea nomenclature. *Pavq mngl laol baoq* (“long leaf tea”), *pavq qavl laol baoq* (“slender leaf tea”) *laol baoq bawneh* (“red tea”), and *Han taidi cha* (“Han terrace tea”) have the greatest agreement between informants’ classification schemes. The former two types are more broadly classified as “Akha people’s tea”. Figure 8.1 shows one example of a local tea classification scheme.

Figure 8.1 Example of local classification of tea cultivars in Baljalpuxveeq within agro-forests. All cultivars are *Camellia sinensis* var. *assamica*.

Local tea types have the greatest frequency in the community's tea agro-forests and are preferred by all informants while state-introduced cultivars occur in lowest frequency and are least preferred. The oldest tea agro-forests, over 70 years old, are dominated by two local tea varietals and middle-aged tea agro-forests consist of four to fourteen tea varietals and a mean of seven. Only a few individuals of introduced cultivars are found in tea agro-forests, but comprise 100% of systems created under the state's Grain for Green campaign. Forty percent of informants participate in this program by managing terrace tea on previous swidden land in exchange for grain subsidies. However, locals generally do not harvest this tea because of its perceived undesirable taste and because they allocate their limited labor to more profitable tea agro-forests.

Ecological Knowledge Scores (EKS) indicate that knowledge of tea resources is increasing with expanded market integration and is shifting from women to men. Middle-aged men responded to the increased value of tea by utilizing traditional agro-ecological knowledge, increasing interaction with tea resources, and enhancing linguistic discernment of tea types. This has been facilitated through social networks within the community, nearby communities, and with tea industry agents. Middle-aged men hold the greatest knowledge of tea types (91% EKS) followed by youngest men (67% EKS), elder women (63% EKS), youngest women (60% EKS), and middle-age women (53% EKS). Elder men have the lowest ability to discern tea types (27% EKS). Consequently, bivariate analysis of EKS by informant age illustrates a significant trend of decreasing ability to identify tea types with an increase in age ($P < 0.0001$). Comparison of EKSs indicates that the variation between age groups is significant ($P < 0.0171$) as well as between males and females of the middle-aged group ($P < 0.0002$) and the eldest group ($P < 0.0001$). Principal Component Analysis of sorting schemata demonstrates that there is not complete cultural agreement of tea varietals as local classification schemes evolve and group knowledge accumulates; the first eigenvalue accounts for 24.34% of variance for informants, 48.76% for males, and a low eigenvalue for female classification schemes.

DISCUSSION AND CONCLUSION

This study demonstrates that Baljalpuxeevq's Akha have been enterprising in responding to opportunities and limitations provided by the intersection of markets and state policies. Increased market integration and value of "ecological" tea has heightened the role of tea agro-forests in livelihoods and led to a process of decision-making resulting in changes in land use, labor, and ecological knowledge. Local Akha have tapped into customary resource institutions and employed collective action to reconfigure land-use, reorganize labor structures, and share and negotiate information on tea resources to take advantage of emerging market opportunities. Cooperation with tea industry agents—combined with customary strategies of experimentation, risk management, and the transmission and development of knowledge—has provided a competitive market advantage. These factors have resulted in a distinct situation that both corroborates and diverges from previous studies and highlights the complex nature of the impacts of increased market integration and state development efforts.

Land-use simplification during the study period reflects trends of land-use and land-cover change documented in other communities in southern Yunnan and regionally in response to state projects and globalization (Xu et al. 2009; Zeigler et al. 2009; Fox 2009; Sturgeon 2005; Xu et al. 2005). The cultivation of tea plants in previous swidden areas by the community and private enterprises supports a general trend across Southeast Asia of the transformation of former swidden areas (Mertz et al. 2009) to commercial agriculture and tree-farming (Fox et al. 2009). However, in contrast to some other communities in the region that have converted their land use to monocultures of cash crops, Baljalpuxeevq's smallholders have maintained a diversified portfolio of subsistence activities to account for market uncertainties. They are cultivating new tea agro-forests rather then planting monocultures as in some other communities. The divergent patterns witnessed in Baljalpuxeevq are likely a function of its relative inaccessibility that allowed customary practices to persist. Additionally, its upland location above the altitude where rubber can grow (1,100 m) enabled it to avoid state-promoted rubber projects.

Refined folk taxonomy of tea varietals in response to heightened valuation of tea agro-forests and the shift in this agro-ecological knowledge from women to men points to the complexity and difficulty of understanding the impacts of market integration. The generation of agro-ecological knowledge is valuable from a market perspective because an institution's ability to generate knowledge and create new products is recognized as a source of competitive advantage (Grant 1996). The positive trend of ecological knowledge with increased market integration has been previously documented in a fishing community in Ecuador (Guest 2002). However, other studies have found the effects of economic change on traditional ecological knowledge (Godoy et al. 2005) to be negative (Nolan and Robbins 1999; Reyes-Garcia 2001; Benz et al. 2000; Zent 2001; Srithi et al. 2009) or neutral (Zarger and Stepp 2004; Ayantunde et al. 2008). Additionally, as local Akha focus their attention on tea, ecological knowledge of other plants and resources in the community surroundings may be declining.

The increase in agro-ecological knowledge of tea varietals in Baljalpuxeevq can be attributed to the resourcefulness of local Akha in utilizing customary knowledge and social resources while developing new linkages. The role of customary institutions for resource management in Baljalpuxeevq coincides with previous work on the resilience and importance of customary institutions of the Hani / Akha in the uplands of Xishuangbanna (Xu et al. 1999). The emergence of a market-driven institution in Baljalpuxeevq to organize tea production matches the variables recognized to foster the development of community forestry institutions including: resource salience to livelihoods, manageability of the system, and users' prior organizational experience (Ostrom 1999). In the current context, connections forged with tea industry agents have allowed locals access to market information and enabled sales to national and global high-end niche markets for "ecological" tea. Social networks within the community, other communities, and with tea industry agents provide a platform for debate on diverse perspectives, sharing and negotiation of information, and articulation of agreed knowledge on tea resources. Social networks also serve to integrate individual knowledge of tea resources and foster the accumulation of group knowledge. The community's open-mindedness norms, cognitive diversity, and recognition of local experts further assist in the development of group knowledge (Mitchell and Nicholas 2006). The interplay of these customary and market factors has allowed the community to enjoy a level of affluence previously unknown and enabled it to endure the recent pu-erh tea bust. Figure 8.2 highlights the process of the development of ecological knowledge of tea resources in response to increased market integration. The model presented was developed based on field observations during this study in southern Yunnan, coupled with literature research on the development of individual and group knowledge (Mitchell and Nicholas 2006)

The economic benefit of cooperating with tea industry agents is consistent with previous findings in Baljalpuxeevq (Toleno 2006) and more recently in another smallholder community in Xishuangbanna (Menzies 2008). Tea industry agents have had greater success than state programs in integrating consumer demands for high-quality product with local desires to improve livelihoods while maintaining cultural practices and the ecological viability of land use (Toleno 2006). Consumers are willing to pay price premiums for tea from

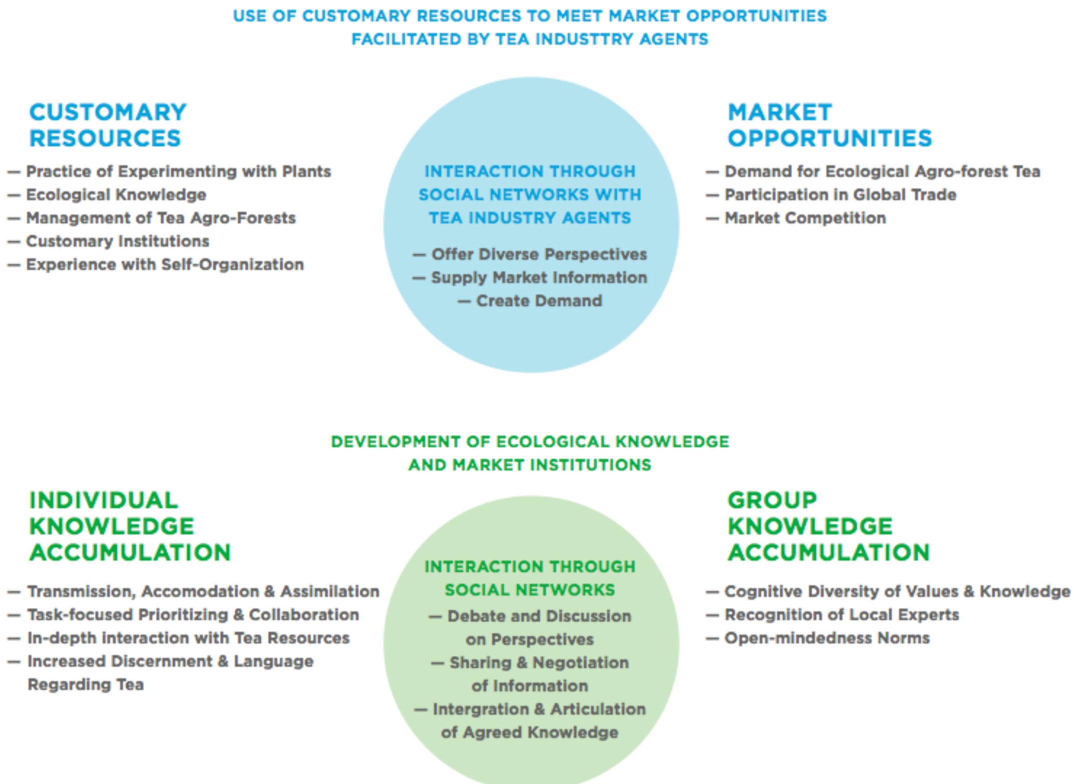


Figure 8.2 Process of ecological knowledge development of tea resources in response increased market integration. This model was developed based on field observations during this study in southern Yunnan, coupled with literature research on the development of individual and group knowledge (Mitchell and Nicholas 2006).

Baljalpuxveeq's agro-forests but not from monocultures created for the Grain for Green campaign.

The increased refinement in classification of tea resources supports Berlin's (1992) hypothesis that only species that come under intense human manipulation are further subdivided into folk varietals. Berlin (1992) shows how the degree of linguistic recognition of sub-generic taxa increases as the level of management of plant systems intensifies. The maintenance of local tea types emphasizes the role of cultural preferences in preserving landraces (Brush and Meng 1998) and contributes to Akha cultural identity, as indicated by tea categorized as “Akha tea” versus “Han terrace tea”. More recently, market demand for “ecological” tea with complex taste profiles contributes to landrace maintenance and is beneficial for cultural continuity and prevention against genetic erosion.

However, as Baljalpuxeevq becomes more accessible with infrastructure development, local value systems and institutions are predicted to continue shifting towards a market orientation. Previous studies on agrarian change suggest potential long-term outcomes of market integration and globalization for rural farming communities, particularly socio-economic differentiation among rural households. Bernstein (2002) for example argues that socio-economic differences between capitalist farmers and landless laborers is the inevitable long-term outcome of the transition of agriculture to capitalism. He supports that “market-friendly” agrarian reforms and other capitalist initiatives do little in the long-term to stimulate agricultural production and reduce rural poverty. Likewise, Li (2007) contends that social dispossession results from growing capitalist economies. She supports that intervention is necessary to maintain growth of capitalist economies, and that such intervention dispossess sections of the population. Rigg (2006) highlights that poverty in rural areas is becoming progressively de-linked from agricultural resources as non-farm opportunities expand and increased mobility leads to the delocalization of livelihoods.

The state-facilitated subleasing of village lands to commercial tea enterprises for the establishment of expansive terrace tea plantations is expected to further influence local values and may have adverse environmental and health implications. Run-off from fertilizers, pesticides, and insecticides used by commercial tea enterprises may have negative consequences to surrounding land use, particularly to the village paddy rice fields in the valleys immediately below the new tea terraces and to aquatic fauna in the stream below the village. The tea clones introduced to the uplands by commercial enterprises poses the risk of genetic pollution (Alteiri 2003) to the reservoir of tea diversity managed by local communities. The new tea enterprises are able to benefit from the environment that upland groups have managed for hundreds of years, and from the esteemed "ecological" labels and terroir of the Bulang Mountains that locals have branded. The influx of hundreds of lowland migrant laborers presents additional socio-economic and environmental implications. These laborers are generally not familiar with local ecology and developed their conceptions of nature elsewhere. Atran et al. (1999) showed how the cognitive models of ecological relationships held by immigrant populations arriving in a new habitat may be inappropriate to understanding the ecology of their new habitat and result in environmental degradation. The environmental consequences of lowland migrant laborers working in the new upland tea enterprises may ultimately damage the "ecological" branding of Bulang Mountain tea.

Chapter Nine

PU-ERH TEA TASTING: CORRELATION OF PERCEPTIONS TO PHYTOCHEMISTRY

This chapter examines how variable production and preparation practices of pu-erh tea affect drinkers' perceptions, phytochemical profiles, and anti-oxidant activity. The *gong fu cha dao* ("way of tea" with "effort," "work," or "skill") method of brewing tea through multiple infusions was employed to evaluate green, aged, and black pu-erh samples from smallholder agro-forests (or *gushu cha yuan* / "old tree tea gardens") and terrace plantations. An overall aim of this chapter is to inform studies on human selection of medicinal plants.

BACKGROUND

Pu-erh tea tasting is a social practice that emphasizes shared sensory experience, wellbeing, and alertness. The diverse environments and cultural practices involved in tea production by Yunnan's multiple socio-linguistic groups contribute to tea with wide-ranging sensory profiles. Tea, as a botanical with multiple markets, functions, and cultural uses, appeals to varied tastes (Purdue 2008). The desire for varied sensory experiences among pu-erh tea drinkers provides feedback that helps to maintain and enhance the diversity associated with tea production. Pu-erh tea tasting has developed prominence over the past two decades in response to expanded market integration of pu-erh tea from Yunnan. Consequently, historical tea production and consumption practices are being revitalized and adapted for the contemporary socio-economic context.

Taste Attributes of Bioactive Constituents of Tea

A combination of catechin, methylxanthine, carbohydrate, and amino acid compounds contribute to the distinctive taste and color of tea (Drewnowski and Gomez-Carneros 2000; Scharbert et al. 2004). Catechins have been documented as bitter, astringent, and bitter with a sweet aftertaste (Yamanishi 1990). Theobromine is described as bitter and metallic (Rouseff 1990), caffeine is bitter (Hall et al. 1975), and the amino acids are sweet and sour (Nelson et al. 2002). Catechins are colorless or light-colored compounds and their oxidative products, the theaflavins and thearubigins, possess the dark brown and orange-red color attributes that are characteristic of black teas (Liang et al. 2003).

Gong Fu Cha Dao Tea Preparation

The *gong fu cha dao* ("way of tea" with "effort," "work," or "skill") method of brewing tea is currently being revitalized and adapted in Yunnan in response to the recent expansion of the pu-erh market. Gongfu cha dao developed in eastern China and draws from earlier tea preparation methods documented in Lu Yu's *Cha Jing* ("Classic of Tea", written around 760-780 CE), considered the first monograph of tea (Lu et al., 1974). The gongfu cha dao method is based on multiple infusions of briefly steeping leaves in a lidded bowl or in an unglazed clay teapot (Figure 9.1). The number of infusions, brewing duration, leaf amount, and water temperature used in preparing pu-erh varies with production and processing variables of tea and drinker preferences. Some pu-erh drinkers interviewed for this study claim that brewing tea through brief and multiple infusions functions to optimally release its aroma, taste, color, and physiological properties, thus providing for a "balanced composition" that brings out nuanced essences.

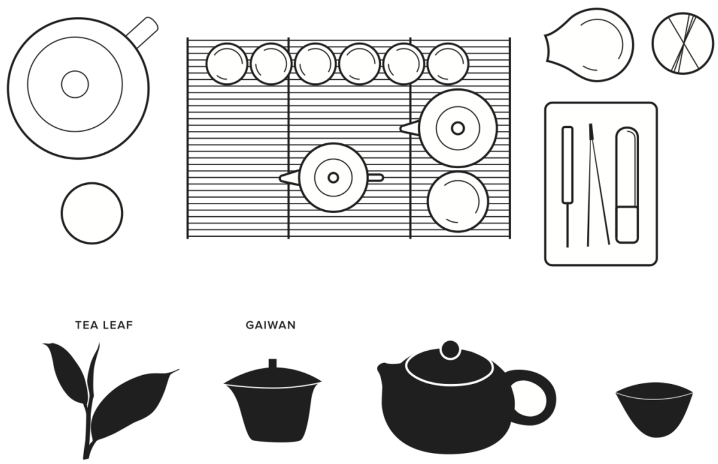


Figure 9.1 Tea setting for the *gong fu cha dao* ("way of tea" with "effort," "work," or "skill") method of brewing tea that is based on multiple infusions of briefly steeping tea leaves in a lidded bowl (*gai wan* or "lid bowl") or in an unglazed clay teapot.

A notable component of pu-erh tea tasting is for drinkers to compare and communicate their sensory perceptions of each infusion and to discern characteristics of how and where the tea was grown and processed. This practice is considered to keep the mind and senses vigilant through focus and communication. The first infusion prepared during the pu-erh tea preparation, and occasionally the second, is poured out in order to open the dried leaves and release their sensory properties for the following infusions. In some Tibetan communities of Yunnan surveyed, pu-erh tea infusions are distributed in a hierarchical order. The most elder or senior drinkers are offered the first serving and the youngest or least senior drinkers receive the last infusions.

Theoretical Framework

Humans have an intrinsic distaste for bitter substances, and the rejection and detoxification of these substances is thought to be an adaptation for survival (Glendenning 1994; Hladik and Simmen 1996). Johns (1990) hypothesized that despite the association of bitter substances with toxicity, some societies may have evolved mechanisms for selecting plants with bitter, astringent, and unpalatable properties for nutritional and pharmacological sources, sensory variety, and cultural identity. The earliest written mentions of tea are found in its documentation as a medicine and gruel in the 3rd and 4th centuries (Ceresa 1996). Early documentation of tea generally describe its taste as bitter (Zhen 2002). Some tea producers and consumers continue to select bitter tea for its potential health benefits. Research on perceptions of the organoleptic properties of plants and their associated medicinal properties is important towards understanding the process of experimentation, discovery, and selection in ethnomedical systems (Casagrande 2000). The taste of plants, particularly bitterness, may guide societies in the search for medicinal plants and beneficial phytochemicals (Etkin 1988; Moerman 1998).

MATERIALS AND METHODS

Interviews on Preparation and Perceptions of Pu-erh

A preparation protocol was developed based on observation of thirty pu-erh tea tastings in Yunnan. Infusion time, water and tea quantity, and brewing temperature were recorded. This protocol was employed for preparing samples for analysis of color, taste, phytochemical, and antioxidant profiles. Five informants were identified as key experts based on semi-structured interviews with tea masters who host pu-erh tastings in teahouses in Yunnan. During regularly scheduled pu-erh tastings, key experts were requested to compare perceptions of production, medicinal properties, taste, and color between tea infusions of ten pu-erh samples. A rating scale methodology was employed to quantify taste and color based on a similar scale and respondent sample size developed by Thorngate and Noble (1995). Key experts were asked to rate the strength of taste for each infusion on a 5-point scale, with 1 being the lowest taste strength and 5 the highest taste strength. Similarly, informants were asked to rate the color intensity for each infusion based on a 4-point category scale, with 1 being lightest and 4 the darkest. Informants were also requested to share their perceptions of production variables of each sample and indicate samples perceived to have the greatest potential health-benefiting properties and stimulant properties.

Plant Material

The 100 tea infusions assessed for this study were derived from 10 pu-erh samples from southwestern Yunnan. Five of the pu-erh samples (or 50 of the tea infusions) were from agro-forests and the other five samples (or 50 of the tea infusions) were from terrace plantations. Samples from each mode of production were processed as green pu-erh (or "raw"/ *sheng*; N = 3), aged green pu-erh (N = 4), and black pu-erh (or "cooked"/ *shu*; N = 4). The green and black pu-erh samples were analyzed within 6 months of their production and the aged green pu-erh samples were all over 10 years from their date of production. Voucher specimens of tea (*Camellia sinensis* var. *assamica* (L.) O. Kuntze; Theaceae) were collected from agro-forests and deposited at the Kunming Institute of Botany, Chinese Academy of Sciences.

Chemicals and Reagents

One hundred tea infusions were prepared in the lab with bottled water (Poland Spring, Wilkes Barre, PA). HPLC-grade acetonitrile (purchased from J.T. Baker, Phillipsburg, NJ), trifluoroacetic acid (Fisher Scientific, Fair Lawn, NJ) and distilled water (Milli-Q system, Millipore Laboratory, Bedford, MA) were used for high performance liquid chromatography to separate and identify study compounds. Gallic acid, ascorbic acid, sodium carbonate, 1-1-diphenyl-2- picrylhydrazyl (Sigma Chemical Co., St. Louis, MO, USA.), and reagent-grade ethanol (Fisher Scientific, Fair Lawn, NJ) were used as solvents and controls to measure free radical scavenging capacity. Pure standards of gallic acid (GA), (+)-catechin (C), caffeine (CAF), (-)- epigallocatechin 3-gallate (EGCG) and (-)-gallocatechin (GC) were purchased from ChromaDex (Santa Ana, CA). Standards of (-)-epicatechin 3-gallate (ECG), (-)-epigallocatechin (EGC), and (-)-catechin 3-gallate (CG) were purchased from Fisher Scientific (Pittsburgh, PA) and standards of theobromine (TB), theophylline (TP), (-)-gallocatechin 3-gallate (GCG) and (-)-epicatechin (EC) were bought from Sigma Chemical Co. (St. Louis, MO).

Sample Extraction

Samples were prepared in the laboratory using a *gong fu cha dao* protocol of multiple infusions developed during participant observation of thirty pu-erh tea tastings. Ten infusions were prepared in a gaiwan using 8 grams of each of the ten samples (100 infusions total). The first infusion of each sample was prepared by steeping 8 grams of dry leaves in 80 ml of spring water at 95 °C for 30 seconds (Figure 9.1). The leaves steeped for the first infusion were re-steeped for the second through tenth infusions using

80 ml of spring water at 95 °C for 20 seconds. The resultant extracts were filtered under vacuum with No. 5 Whatman paper, frozen at -20 °C, lyophilized to obtain dried extracts and weighed. One gram of each extract was re-suspended in 10 ml of water. Aliquots (1.5 ml) of the filtrate were centrifuged at 15000 rpm for 15 min and the supernatant was passed through a 0.45 μm nylon membrane filter prior to HPLC and DPPH analysis.

HPLC for Quantification of Phenolic and Methylxanthine Compounds

HPLC (High-Performance Liquid Chromatography) quantification of samples was performed using a Waters 2695 HPLC (Milford, MA) module equipped with a 996 photodiode array detector (PDA). Sample compounds and standards were separated on a Synergi Fusion, 4 μm, 250 x 4.6 mm ID, C-18 reversed-phase column (Phenomenex, Torrance, CA). Column temperature was maintained at 30 °C and sample temperature was kept at 4 °C. A gradient system was used for the mobile phase elution consisting of 0.05% (v/v) trifluoroacetic acid in distilled water (Solvent A) and in acetonitrile (Solvent B) at a flow rate of 1.0 mL/min for a duration of 35 min. The following gradient profile was used, as previously described by Dalluge et al. (1998): 0-25 min, 12-21% B; 25-30 min, 21-25% B. The column was reconditioned between sample injections by flushing it with100% Solvent B for 10 min and then re-equilibrating the column for 5 min to starting conditions. Forty microliters (μL) of each of the 100 infusions were run in single injections for HPLC analysis. The UV-vis spectra were recorded from 254 to 400 nm and peaks representing the twelve catechin and methylxanthine compounds investigated were detected at 280 nm. Peaks of the study compounds were identified based on their characteristic absorbance spectra and retention time (Figure 9.2). The limit of detection

(LOD) and the limit of quantification (LOQ) of 7 standards, GA, C, CAF, EGCG, ECG, TP, and TB were found to be in the ranges of 0.05 to 1 µg/mL and 0.1 to 5 µg/mL, respectively (Unachukwu et al. 2010).

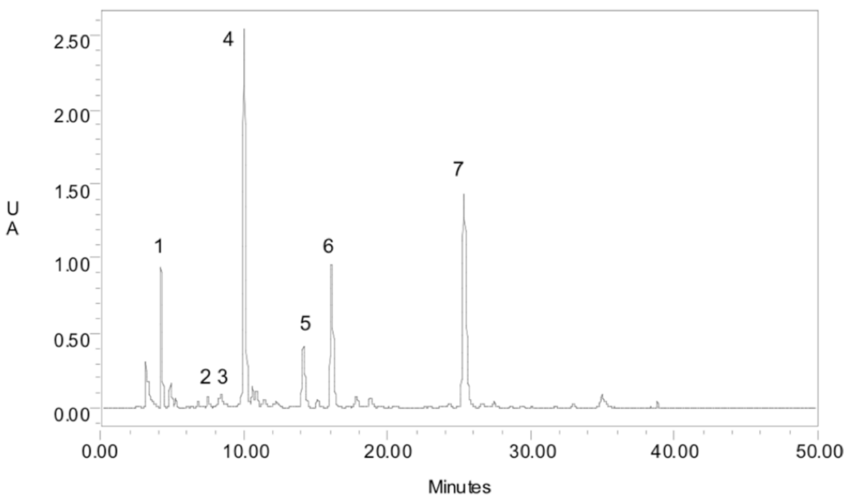


Figure 9.2 Chromatogram of an aged green pu-erh tea sample analyzed using Synergi Fusion C_{18} reverse phase HPLC column 4 µm, 250 × 4.6 mm ID by gradient elution during method development of this study. Detection was carried out with UV at A_{280}. Peak identification are as follows: (1) gallic acid (GA), (2) (-)-epigallocatechin (EGC), (3) (+)-catechin (C), (4) caffeine (CAF), (5) (-)- epigallocatechin 3-gallate (EGCG), (6) (-)-gallocatechin 3-gallate (GCG), and (7) (-)-catechin 3-gallate (CG).

DPPH Analysis of Free Radical Scavenging Capacity

Free radical scavenging capacity was assessed using the 1-1-Diphenyl-2-picrylhydrazyl (DPPH) assay as a measure of anti-oxidant activity as described in Saito et al. (2007). Forty infusions of pu-erh representing each processing method from agro-forests were selected for DPPH analysis. Gallic acid (0.015625 - 0.25 mg/ml) and ascorbic acid (0.03125 – 0.5 mg/ml) were used as positive controls. Fifty µL of extracts and control dilutions were mixed with 150 µL of 400 µM DPPH solution; each mixture was prepared in quadruplicates of five concentrations. The mixtures were incubated for

30 min at 37°C. Absorbance values were measured at 517nm using a Softmax Pro 3.0 microplate reader (Molecular Devices, Sunnyvale, CA). Radical scavenging capacity of each sample was calculated as the percentage of DPPH free radicals inhibited by the sample in comparison to radical inhibition in the negative water control. Values obtained were plotted against concentration (μg/ml) of sample dilutions. Free radical scavenging capacity was expressed as IC_{50} values (concentration of sample required to scavenge 50% of DPPH radicals; the lower the IC_{50} value, the higher the anti-oxidant activity).

Statistical Analysis

The results were analyzed statistically using JMP 7.0 software (SAS) to determine mean values of quantified masses of compounds analyzed by HPLC and IC_{50} values assessed by DPPH. Total Catechin Content (TCC; expressed as mg/g dry tea) was determined by the addition of the individual amounts of catechins quantified from HPLC results (EGCG, ECG, EGC, GCG, CG, GC, EC, and C). Similarly, Total Methylxanthine Content (TMC; expressed as mg/g dry tea) was determined by the addition of the individual methylxanthine compounds quantified from HPLC results (CAF, TB, TP). Aggregate values of analyte quantities for each sample were calculated by the addition of the ten infusions brewed per sample. The relationship of production, processing, color, and taste variables to TCC, TMC, and IC_{50} were determined using Analysis of Variance of pooled means with a significance level of $\alpha = 0.05\%$. Tukey-Kramer HSD was performed to compare all mean pairs. Differences with $P \leq 0.05$ values were considered significant.

RESULTS

Perceptions of Pu-erh Tea Tasting

All key experts rated green pu-erh samples from agro-forests with the strongest taste and described these samples as either bitter or bitter with a sweet aftertaste. Key experts were able to distinguish tea samples from agro-forests and terrace plantations because of the more bitter taste of the former. Green pu-erh samples were also perceived to contain the greatest medicinal and stimulant properties. Key experts rated black pu-erh with the mildest taste and the least caffeine content. They described this tea as smooth and perceived it to contain the least medicinal and stimulant properties. Aggregated informant responses indicated that infusions 4 – 7 had the strongest taste and infusions 1, 9 and 10 were rated with the mildest taste.

Variation of Phytochemical Constituents and Free Radical Scavenging Capacity

Total Catechin Content (TCC) of aggregate infusions of individual pu-erh samples ranged from 1.35 – 238.52 mg/g dry tea with a mean of 71.90 mg/g dry tea. ECG had the highest mean value of all catechins quantified, and was found in greatest quantity in a green pu-erh sample harvested from an agro-forest (91.71 mg/g dry tea for aggregate infusions). Total Methylxanthine Content (TMC) of aggregate infusions of individual samples ranged from 43.83 – 98.27 mg/g dry tea with a mean of 58.67 mg/g dry tea. Caffeine had the highest mean value of all methylxanthine compounds quantified and was most present in a sample of aged green pu-erh from a terrace plantation (94.60 mg/g dry tea for aggregate infusions).

The TCC ($P < 0.0001$) and TMC ($P < 0.0265$) significantly varied between samples from agro-forests and terrace plantations, and (Figure 9.3). Samples from agro-forests had a higher mean TCC than samples from terrace plantations, and samples from terrace plantations had a higher mean TMC than samples from agro-forests. Significant variation was also found among samples based on processing method for TCC ($P < 0.0001$), TMC ($P < 0.0027$), and free radical scavenging capacity ($P < 0.0001$) (Figure 9.4). Mean TCC based on processing method was found to be in the order green pu-erh > aged green pu-erh > black pu-erh, and mean TMC was found as aged green pu-erh > green pu-erh > black pu-erh. Figure 9.5 shows mean analytes per infusion by processing method. Mean free radical scavenging capacity was found in the order green pu-erh > aged green pu-erh > black pu-erh (Figure 9.4; Table 9.1 shows the individual IC_{50} values and standard deviation of the 40 infusions assessed in quadruplicates). Means comparisons of TCC for all pairs of processing methods showed significant variation ($P < 0.007$), while means comparisons of TMC for all pairs of processing methods showed significant variation between green pu-erh and aged green pu-erh ($P < 0.0205$), and between aged green pu-

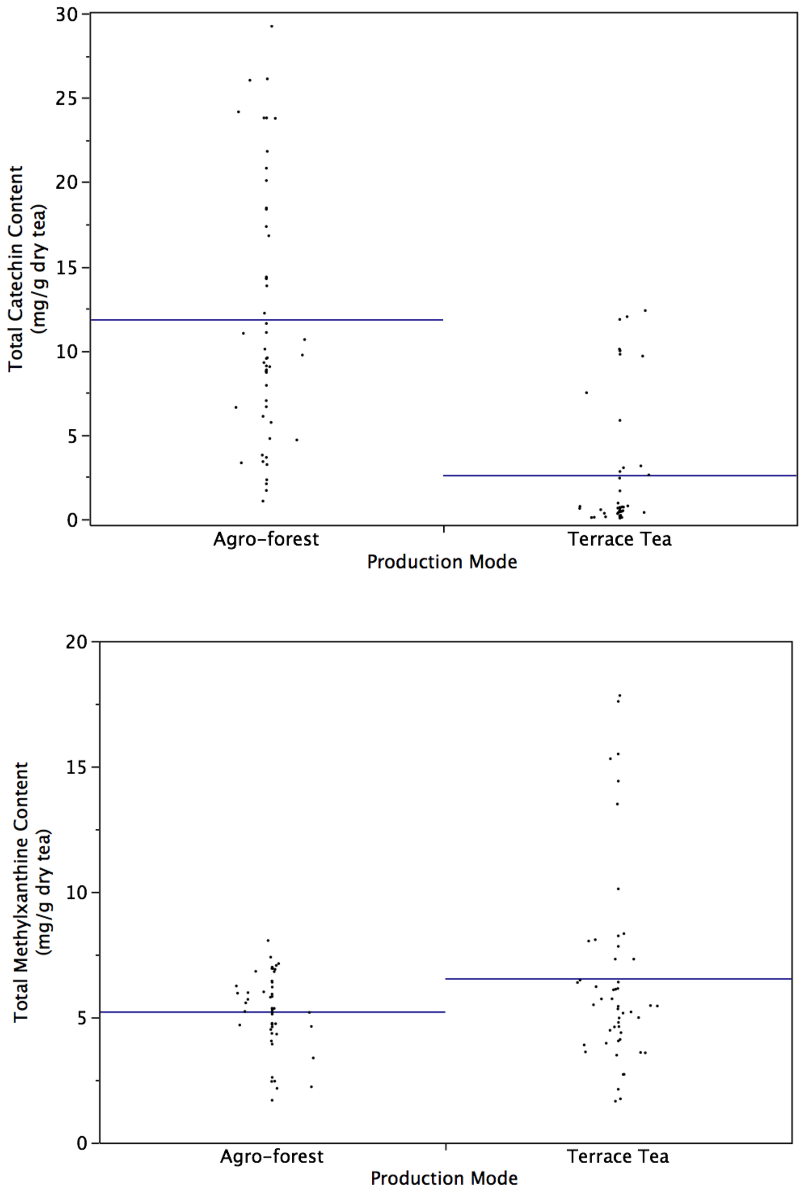


Figure 9.3 Total Catechin Content (TCC; sum of EGCG, ECG, EGC, GCG, CG, GC, EC, and C) and Total Methylxanthine Content (TMC; sum of CAF, TB, and TP) of individual pu-erh infusions by mode of production system: agro-forest versus terrace tea garden. Horizontal lines represent the mean TCC and TMC values.

erh and black pu-erh ($P < 0.0051$). Insignificant variation was found for TMC between green and black pu-erh ($P < 0.8941$). In addition, mean comparisons of IC_{50} values for all pairs of processing methods found significant variation between green and black pu-erh

($P < 0.0001$), and between green and aged green pu-erh ($P < 0.0143$). Insignificant variation was found for IC_{50} between aged green and black pu-erh ($P < 0.1784$).

Aggregate data of all samples found the fourth infusion brewed through the gong fu cha dao method of multiple infusions contained the highest mean TCC, the third infusion contained the highest mean TMC, and the eighth infusion contained the highest mean free radical scavenging capacity (Figure 9.6). However, comparison of infusion sequence only found significant variation for TMC ($P < 0.0013$), and insignificant variation for TCC ($P < 0.9949$) and IC_{50} ($P < 0.4298$). Comparison of all means of the different infusion sequences found insignificant variation between TCC, TMC, and $IC_{50.}$

Relationship of Phytochemical Profiles and Perceptions of Pu-erh Tea Tasting

Infusions rated with the strongest taste (level 5 on the ranking scale) had the highest mean TCC, TMC, and free radical scavenging capacity (indicated by lowest IC50) (Figure 9.7). These infusions were prepared from green pu-erh samples and were perceived by key informants to contain the greatest medicinal properties of samples evaluated. The samples rated with the weakest taste were found to contain the lowest TCC and free radical scavenging capacity. These infusions were prepared from black pu-erh and were perceived to have the least medicinal properties. No correlation was found between informants' perceptions of stimulant properties and TMC. Infusions rated level 3 on the color scale had the highest TMC and infusions rated with the lowest color intensity had the highest free radical scavenging capacity.

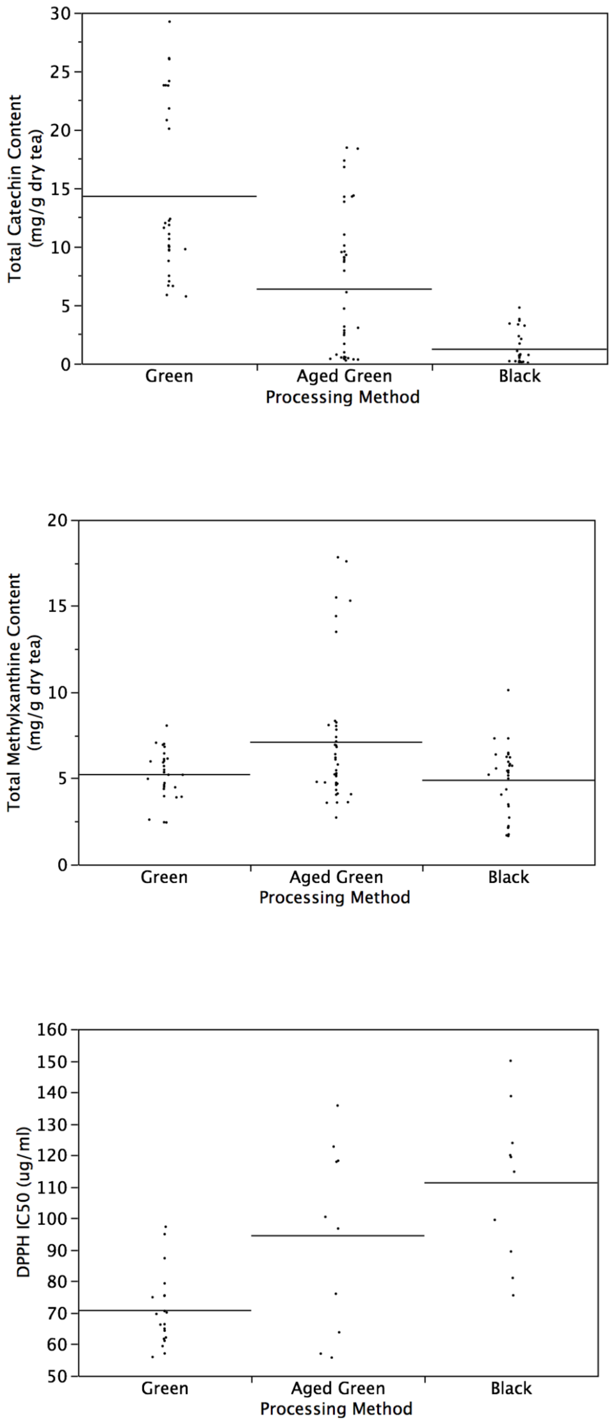


Figure 9.4 TCC (Total Catechin Content), TMC (Total Methylxanthine Content), and DPPH IC_{50} values (measure of free radical scavenging capacity; the lower the IC_{50} value, the higher the free radical scavenging capacity) by processing method. Horizontal lines represent the mean TCC, TMC, and IC_{50} values.

Table 9.1 Free radical scavenging capacity of pu-erh samples from agro-forests measured by IC_{50} values. IC_{50} is the concentration of sample required to scavenge 50% of DPPH radicals (the lower the IC_{50} value, the higher is the free radical scavenging capacity).

Infusion #	IC_{50} Value	Standard Deviation	IC_{50} Value	Standard Deviation
	Green Pu-erh (Loose)		Aged Green Pu-erh	
1	64.31	1.27	96.71	9.88
2	64.94	1.26	118.23	23.74
3	66.36	1.79	100.41	5.54
4	59.41	1.44	135.73	5.02
5	70.08	5.46	117.89	5.26
6	69.62	0.97	122.71	10.09
7	55.95	0.77	76.01	13.21
8	57.07	1.33	63.79	10.57
9	61.10	0.90	55.75	4.42
10	61.72	3.47	57.01	2.39
	Green Pu-erh (Pressed)		Black Pu-erh	
1	97.28	8.25	149.94	8.88
2	74.92	14.46	138.72	20.86
3	87.30	7.79	119.98	5.36
4	70.52	1.96	114.74	5.48
5	66.23	2.03	123.86	8.26
6	75.49	2.09	119.40	10.56
7	79.31	3.28	99.46	6.40
8	62.14	2.70	89.43	24.36
9	94.93	9.13	75.52	15.39
10	75.37	2.37	81.04	5.46

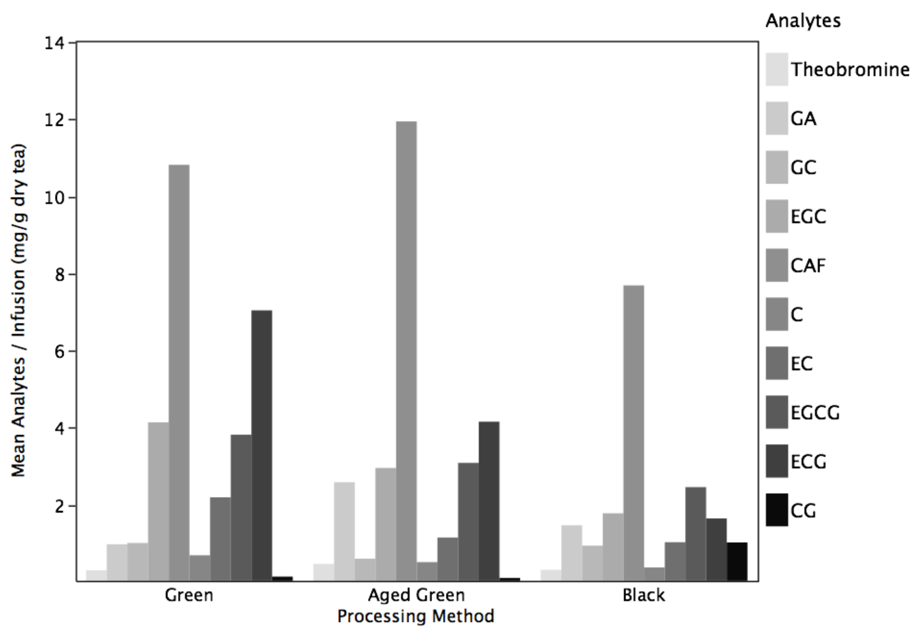


Figure 9.5 Mean quantities of individual analytes quantified by high performance liquid chromatography (HPLC) per infusion by processing method.

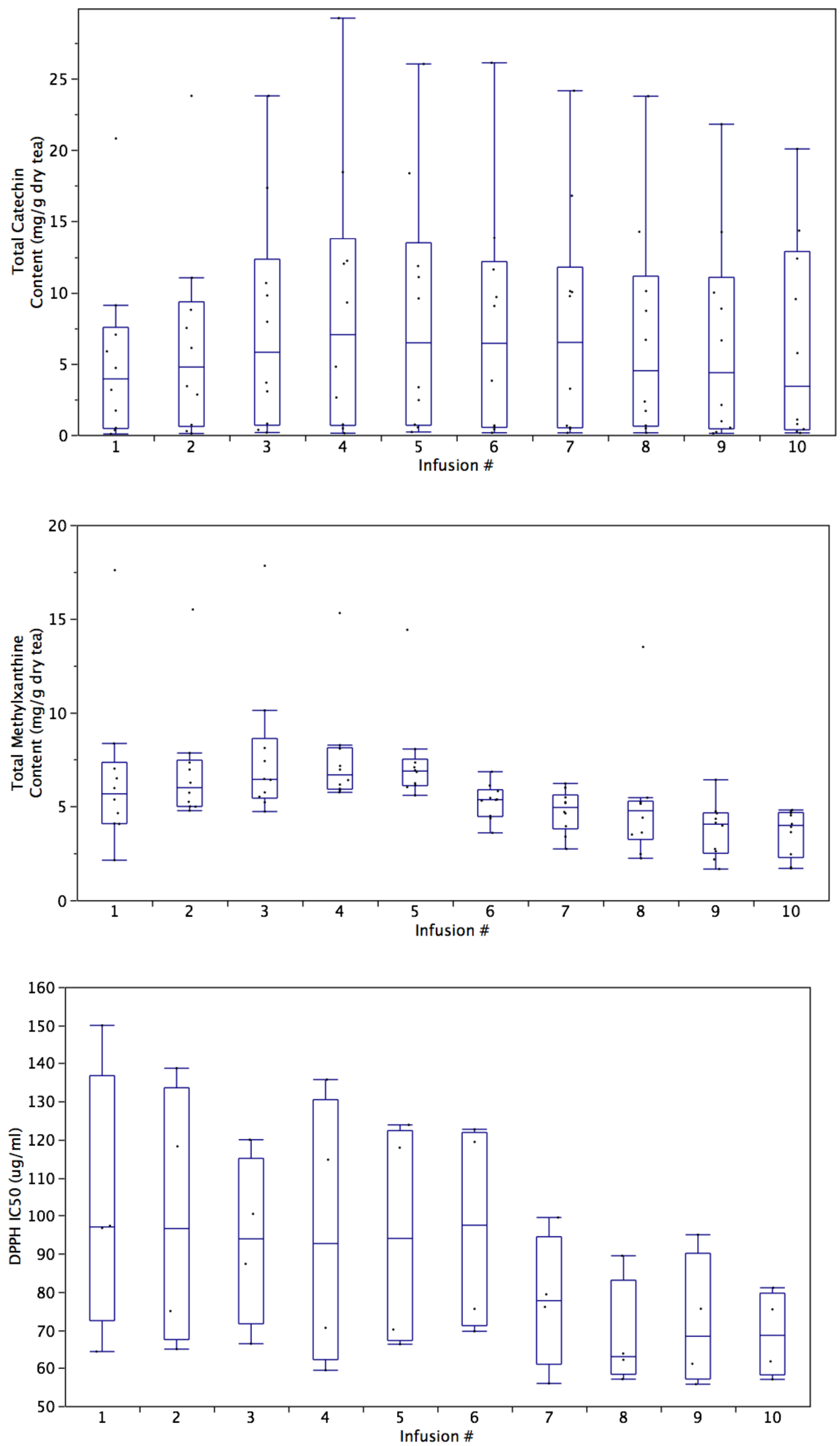


Figure 9.6 Box plots of TCC (Total Catechin Content), TMC (Total Methylxanthine Content), and IC_{50} values (free radical scavenging capacity) by infusion sequence.

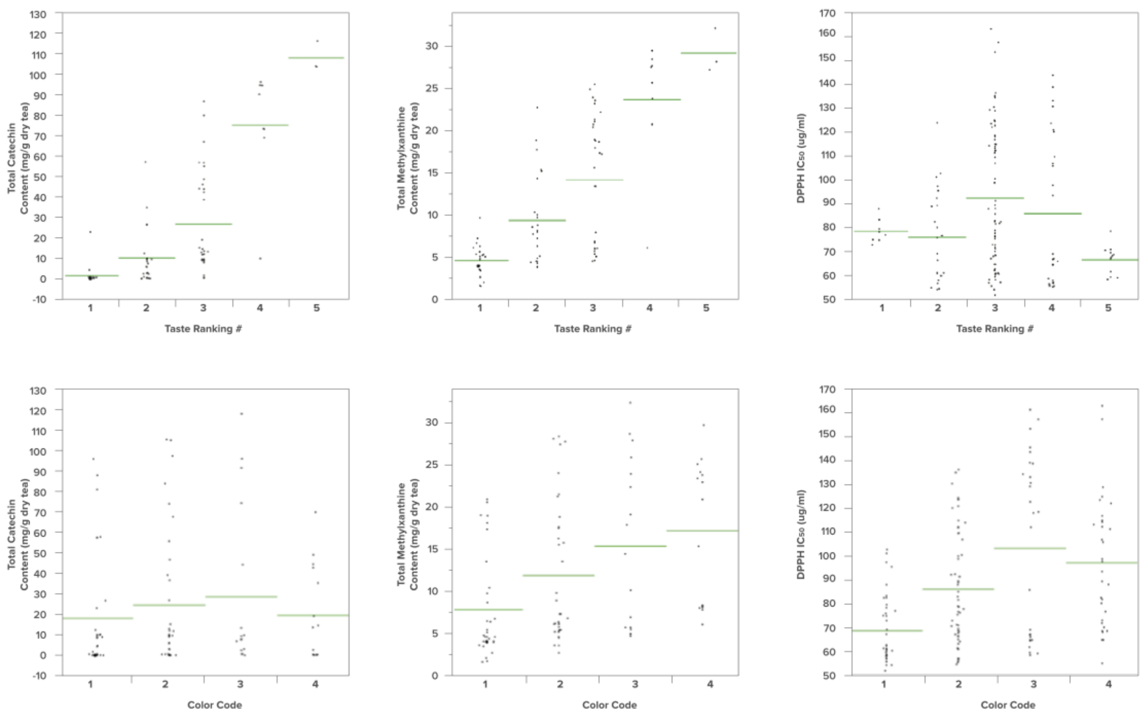


Figure 9.7 Mean of TCC (Total Catechin Content), TMC (Total Methylxanthine Content) and IC_{50} values (free radical scavenging capacity) by taste and color intensity ranking. Horizontal lines represent mean values.

Taste rankings were significantly correlated with TCC ($P < 0.0001$), TMC ($P < 0.0001$), and IC_{50} ($P < 0.0059$). Means comparisons of TCC and TMC for all pairs of taste rankings found significant variations between most taste rankings ($P < 0.01$). The exceptions were between: (1) levels 1 and 2 for TCC ($P < 0.4558$), (2) levels 4 and 5 for TCC ($P < 0.0743$), and (3) levels 5 and 4 for TMC ($P < 0.6347$). Means comparisons of IC_{50} for all pairs of taste rankings only found significant variation between level 3 and level 5 samples. Significant variation was found for color rankings and TMC ($P < 0.0009$) and IC_{50} ($P < 0.0001$), while no significant variation was found for color and TCC ($P < 0.6804$). Means comparisons of TMC for all pairs of color rankings found significant variations between levels 1 and 3 ($P < 0.0018$), and levels 1 and 4 ($P <$

0.0122). Mean comparisons of IC_{50} for all pairs of color rankings were significant except between levels 2 and 4 ($P < 0.2107$), and levels 3 and 4 ($P < 0.7952$).

DISCUSSION

Perceptions of Pu-erh Tea Tasting

The dichotomies of nature and culture, bitter and mellow, and raw and cooked (Levi-Strauss 1997) resonate with informants' perceptions of pu-erh and can be linked with cultural identity and environmental history. Key informants perceived green or "raw" (*sheng*) pu-erh samples to be bitter. "Cooked" (*shu*) pu-erh samples were perceived as smooth tasting. The bitterest tasting green pu-erh samples were discerned as sourced from "ecological", "natural", or forest production environments that lack the input of pesticides, herbicides, and fertilizer. Rural upland communities in southern Yunnan have customarily produced and consumed bitter loose green pu-erh. Alternatively, "cooked" or black pu-erh was consumed in urban areas. Urban tea drinkers developed a palate for artificially-aged pressed black pu-erh tea in the 1970s during China's drive towards modernization, away from the "backwardness" associated with rural mountain cultures. However, the global urban green-food movement and attention to health-centered diets have revitalized a taste for bitter, "ecological" and "natural" pu-erh, now a prized commodity among urban tea drinkers.

Variation of Phytochemical Constituents and Free Radical Scavenging Capacity

This study agrees with previous research that found that variability of production and preparation practices of tea impact TCC, TMC, and antioxidant activity profiles

(Peterson et al. 2004; Unachukwu et al. 2010). The values of TCC and TMC of aggregate infusions of individual samples are in accordance to previous studies on pu-erh that use protocols involving a longer extraction time (Wang et al. 2010). However, the tenth infusion of each sample indicates that the TCC and TMC have not been exhausted and that additional compounds remain to be extracted during additional infusions. These findings help validate the effectiveness of gong fu cha dao preparation in gradually extracting tea compounds. Future studies should employ a preparation protocol of a greater number of infusions.

The higher TCC and free radical scavenging capacity of green pu-erh samples compared to aged green and black pu-erh samples are consistent with previous studies on a decrease in polyphenolic levels and anti-oxidant activity of pu-erh and other teas with an increase in processing and aging (Ku et al. 2010; Wang et al. 2010; Qian et al. 2008). The variability between samples based on production and processing highlights the importance of sampling protocols to include a range of production variables. This study was limited in quantifying 12 analytes and did not account for the oxidative products, polysaccharides, and pigments formed during the processing from green to black teas (Wang et al. 2010). These compounds also have free radical scavenging capacity and may contribute to the greater variation in free radical scavenging capacity of black pu-erh tea samples compared to their TCC.

Relationship of Phytochemical Profiles and Perceptions of Pu-erh Tea Tasting

The significant variation for TCC, TMC, and IC_{50} by taste rankings supports the role of taste in recognizing phytochemical properties of tea. Informants' perceptions that bitter taste profiles of pu-erh indicate medicinal attributes are in accordance with previous studies on the taste of constituents in tea (Drewnowski and Gomez-Carneros 2000; Ding et al. 1992; Rouseff 1990). Key experts' perceptions of medicinal properties of pu-erh coincided with samples that contained the greatest TCC, while perceptions of stimulant properties of pu-erh did not coincide with TMC results. However, key experts' categorization of samples based on taste did show significant mean differences in TMC. Key experts' descriptions of green pu-erh samples as bitter and pressed black pu-er as smooth tasting, coupled with insignificant mean TMC between samples, suggests that the bitter taste of pu-erh tea is more related to catechin than methylxanthine compounds. Casagrande (2000) suggests that bitterness alone may be inadequate for predicting pharmacological properties because human taste reception is not adequate to cognitively link the vast diversity of bitter chemicals with appropriate biological properties.

CONCLUSION

This study demonstrated that production environment, processing methods, and infusion sequence in preparing tea are related to the phytochemical profile, antioxidant activity, and flavor of tea. The findings support previous studies that have suggested that the taste of plants, particularly bitterness, may guide societies in the search for medicinal plants and beneficial phytochemicals. Results showed that the sensory experience of pu-erh tea, as quantified by ranking of taste and color, were correlated to phytochemical profiles and free radical scavenging capacity. Key experts' perceptions of the potential health benefits of tea were related to bitter taste and samples that contained the highest TCC. In addition, findings validated that the gong fu cha dao style of brewing tea through multiple infusions gradually extracts compounds as informants reported.

Nelson et al. (2002) suggest that the ability to recognize and respond to a wide range of chemical constituents is biologically relevant with significant evolutionary implications. As applied to pu-erh, consumer demand for "bitter tea", "ecological tea", and "big tree tea" during pu-erh tea tasting may serve to link human with environmental wellbeing. The samples that had the greatest TCC were perceived by key experts as most biter and were associated with the potential health benefits of tea. Key experts recognized these bitter tasting samples as being sourced from agro-forests rather than terrace plantations. While the potential health-promoting constituents of tea have been widely studied, little attention has been given to the implications of tea from variable agro-ecosystems on human health. Future studies are needed to comprehensively examine how agricultural conditions affect tea flavonoid and methylxanthine profiles and associated bioactivity.

Chapter Ten

PERSISTENCE AND PERCEPTIONS OF BUTTER-TEA DIETS IN THE TIBETAN PLATEAU

The expansion of tea production in Yunnan and other parts of China was largely driven by commodity exchange between China and neighboring territories. This chapter assesses the traditional consumption of tea in Tibetan communities in northern Yunnan because demand from these communities historically drove the production of tea in southern Yunnan. For tea producers, the trade of tea became a means of obtaining natural resources beyond the immediate environment. In particular, China established a state-controlled tea trade to acquire warhorses from across its northern and western frontiers (Rossabi 1980). Tibetan, Mongolian, and other neighboring areas created a significant demand for tea, and thus drove and influenced its production.

The earliest use of tea by Tibetans was as a tonic. When tea became more attainable during the Song Dynasty (A.D. 960 – 1279) (Rossabi 1980), it supplemented diets mostly limited to dairy, meat, and roasted barley flour (*Hordeum vulgare* L.; Poaceae; *tsamba*). The consumption of tea by Tibetans was a dietary adaptation in habitats that limited the cultivation of fruits and vegetables (Owen 2006). Tibetans prepared tea with *ghee* (clarified butter from the *di*, female yak); a combination known as *po cha* (butter tea). However, because of the extreme altitudes and temperatures of the indigenous Tibetan territory, tea had to remain an imported item from tropical and sub-tropical areas. During the Song Dynasty, ancient trade and military routes were revitalized and developed from southern Yunnan and Sichuan to transport tea to Tibet (Yang 2009).

The present chapter explores the persistence of butter-tea diets in rural Tibetan communities in response to socio-economic and political exogenous change. It is posited here that the traditional Tibetan systems of medicine and Buddhist philosophy provided a cultural framework that encouraged the adoption of tea into daily lives as a dietary staple and ritual plant. Given the assumed link between Buddhist philosophy and diet, this study postulates that rural Tibetan households that continue to follow traditional Buddhist practice will have greater adherence to traditional dietary perceptions and practices than Tibetan households with less adherence to Buddhist practice. Butter-tea systems will thus have greater resilience in households that follow daily Buddhist ritual than households that do not. I further hypothesize that the recent Yunnan pu-erh tea boom cycle (2003 – 2008) resulted in the inaccessibility of good-quality tea to rural Tibetan communities. It is assumed that global demand for high-quality pu-erh served to redirect these resources to those willing and able to pay high price premiums. Findings are assessed to suggest implications of butter-tea food systems to community health and to evaluate if they follow patterns of the dietary transition documented globally in developing areas. Lastly, the long-term prospects of butter-tea food systems are discussed.

BACKGROUND

The Dietary Transition

Socio-economic changes that accompany development can serve to decrease the local valuation of previously important traditional foods (Du et al. 2004; Leatherman and Goodman 2005). Concurrently, commercial foods with greater appeal to consumer's taste replace traditional local foods in the diet (Robinson et al. 2007), thereby "delocalizing" the latter (Dickerson et al. 2008). A nutrition transition occurs as diets become increasingly delocalized. This shift generally follows a pattern from traditional diets based on complex carbohydrates and fiber derived primarily from plant foods to diets based on animal-source saturated fats, caloric sweeteners, and refined low-fiber foods (Popkin 1994). Increased caloric intake from fats and sweeteners is recognized to contribute to heightened incidence of obesity and diet-related non-communicable chronic diseases (DR-NCD), particularly cardiovascular disease and adult-onset diabetes (Bonow and Eckel 2003; Popkin 1998; Kokkinos and Moutsatsos 2004). The nutrition transition thus often translates into a situation where developing societies experience a shift from under-nutrition and infectious diseases to obesity and diet-related non-communicable chronic diseases (DR-NCD). Alternatively, development may contribute to increased dietary diversity and micronutrient intake through greater accessibility to a wider range of foods, thereby improving community health (Dickerson et al. 2008).

Tibetan Medicine (*Amchi*)

Tibetan medicine has deep roots in Buddhist philosophy. It was brought to Tibet, concurrently with Buddhism, from India where it derived from the Ayurvedic system of healing (Khangkar 2000). The Buddha spread medical knowledge in his manifestation as the Medicine Buddha. Monks, physician-saints, and lama-doctors carried on this tradition in Tibet and modified it to reflect the habitat and resources of their surrounding landscape, including shamanic pre-Buddhist practices. They continued to develop the system with additional study and exchange with surrounding communities in India, Nepal, Yunnan, Sichuan, and Mongolia. The Dalai Lamas, that emerged as spiritual leaders in Tibet by the 16th century, supported the study and spread of medical healing knowledge through personal study and by creating medical schools. The first medical schools were created in monasteries serviced by monks and lama-doctors. These are regarded as the beginning of the public health system in Tibet (Khnagkar 1990).

The body in Tibetan medicine is conceptualized as composed of three humors, seven physical energies, and three excrements. The three humors (*nyes-pa*) of the body entail the biological representations of the five cosmic energies: earth, fire, air, water, and space. These three humors are vital energy (*rLung*), bile / bodily heat (*mKhrispa*), and phlegm (*Bad-kan*). The seven physical energies are tissue elements that give rise to the structure of the body. These include essential nutrients from ingested food (*Dangs-ma*), blood formed from the essence of absorbed food (*Krag*), muscle formed through the essence of blood (*Sha*), fat formed through the essence of muscle tissue (*Tshil*), bone formed through the essence of bodily fat (*Rus*), marrow formed through the essence of bone (*rKhang*), and regenerative fluid formed through the essence of marrow (*Khuba*). The *Dangs-ma*, or essential nutrients from ingested food, is thus the source of all the other energies of the body that create structure and maintain wellbeing (Khangkar 1990).

Health and wellbeing in the Tibetan medicine are perceived as the balance and interaction of the body's seven energies, three humors, and three excrements. Disease is perceived as the pathological manifestation resulting from excess or weakness in the body's seven energies, three humors, and three excrements. Such an imbalanced state can result from both mental and physiological processes, including physical and spiritual. Disease in Tibetan medicine is classified as either hot or cold. Disease is also classified as: (1) dependent disease caused by past *karma*, (2) imaginary disease caused by demons, (3) absolute disease of the present life and, (4) ostensible disease. Absolute disease of the present life may be caused by improper diet and behavioral patterns.

At the physiological level, essential nutrients from ingested food and beverage is regarded most influential of all the seven substances that may create imbalance of the body's energies, humors, and excrements. Tibetan medicine regards nutrition from food and beverage to ultimately be the source of the blood, muscle, fat, bone, marrow, and regenerative fluid making up the body. Thus, the careful selection of food and their combination is crucial for maintaining wellbeing and preventing illness. The Tibetan medical text *The Four Tantras* contains three chapters that address dietary principles for health maintenance and healing. Tibetan medical practice emphasizes the combination of foods and warns against certain food combinations that are regarded as poisonous. Each food strongly influences the different humors, and may negate the good qualities of each other, or may the combined effect may be deleterious to the body. Excess of particular foods are considered to cause blockage of the vital channels of the body that create circulatory problems. A balanced and moderate diet is viewed as essential in keeping open the body's channels and varies based on an individual's typology. (Khangkar 2000)

STUDY SITES

Research was carried out in three Tibetan communities of Upper Adong, Reshuitang, and Hanpi in the area of the Qinghai-Tibetan Plateau known as Gyalthang by Tibetans. This area is administratively recognized as Diqing Tibetan Autonomous Prefecture in northwest Yunnan, China. Reshuitang and Hanpi are located under near the commercial center of Shangri-La, the capital of Diqing Prefecture. Upper Adong is relatively remote, allowing for a comparative study to assess the influence of market integration. It is located near the road connecting Yunnan to Tibet. The study sites are accessible to Shangri-La on mostly paved roads. The closest market town to Upper Adong is Deqin town, approximately 1.5 hours by automobile. Upper Adong is located approximately a 6 hour automobile ride from Shangri-La. Reshuitang and Hanpi are located 45 minutes and 25 minutes from Shangri-La. Of the three communities, only Hanpi has a monastery, providing the opportunity to compare the influence of Buddhist philosophy on local perceptions and practices.

All three communities are situated at altitudes ranging between 2,700 – 4,000 meters. Such high altitudes are classified as extreme environments that are characterized by cold temperatures, aridity, low biomass, and heightened exposure to ultraviolet radiation and oxidative stress (Owen 2005). Each community is composed of 62-70 households of three to four generations. The majority of households rely on their surrounding landscape for subsistence and income. Households in the case study follow transhumant lifestyles characterized by pastoralist animal husbandry in highlands and management of mixed crop fields around the village settlement. There is usually seasonal division of labor within the household between agricultural activities around the village and pastoral activities in various grazing grounds. Fieldwork was conducted in the permanent village settlements in the lowlands of each community during seasons when community members had returned from harvesting and grazing activities in the high alpine meadows. The majority of households in Reshuitang and Hanpi have at least one family member that receives income from outside labor, including work in construction, carpentry, transportation, or services in the tourism sector of Shangri-La.

METHODS

Household Surveys

Surveys were designed to address two main research questions: (1) What components of traditional butter-tea food system persist and what components are changing? What are the drivers of this change? and, (2) What are the consequences of changes to butter-tea systems for land use and community health? Preliminary research started with participant observation and twenty open-ended interviews in 2008 to gain an overview of dietary, land use, socio-economic, and community health dynamics. Findings from preliminary surveys were used to design a structured questionnaire adapted from Herforth (2010). The questionnaire (Appendix Six) included questions on land use, farm production, income, market acquisitions, perceptions of wellbeing, dietary diversity, community health, ritual, and tea consumption. The questionnaire also included questions to assess Tibetan Buddhist rituals and worldviews and on perception of the quality, caffeine levels, and health properties of various tea samples. These questions were developed after participant observation during preliminary research and through interviews with monks at the Tibetan monastery in Shangri-La. The questionnaire comprised a total of 55 questions including free-listing questions on most prevalent and most serious health conditions in the community and a 24-hour dietary recall.

Eleven households at each study site were interviewed in 2008 using the questionnaire, for a total of 33 households with 95 informants. The sample size represented at least 15% of total households at each study site. Follow-up interviews and participant observation were conducted in 2009 and 2010. Every other house or field encountered while walking around the community was selected for interviews. Informants of each household included any family members that were available and willing to participate in the survey. This usually included one or two family members, but in some cases several generations of both genders participated. Effort was made to ensure the informant sample group consisted of an even representation of gender and age class. Oral history interviews followed the structured questionnaire to understand the historic trade of tea resources. These interviews focused on the participation of elders in the household whom either participated or recollected the tea trade. The interviews on average took 2.5 hours.

Interview responses were coded to assess variation between and among communities. Responses from the 24-hour dietary recall survey were used to tabulate

Food Variety Scores (FVS; Dickerson et al. 2008). FVS is the sum of unique food items consumed during the previous 24 hours regardless of nutritional content and quantity (Dickerson et al. 2008). Foods were than classified into 10 food groups based on a classification system used by Dickerson et al.'s (2008) study on dietary diversity of Tibetan communities.

RESULTS

Butter-Tea Food Systems

Diets at the study sites are centered on butter-tea. The butter-tea system serves to connect land use, procurement of food, medical practice, ritual, family structure, and social networks. The butter-tea system as defined here based on interviews includes: (1) butter tea (water, tea, butter, and salt), (2) grains (barley, wheat, and rice), (3) accompanying foods locally procured and purchased from market (meat, cultivated fruits and vegetables, wild fruits and vegetables, oil), (4) land use (fields, pastures, and home gardens), (5) perceptions of environmental and human wellbeing, (6) associated cultural beliefs and practices, (7) commodity links between tea producers and consumers, (8) perceptions of tea quality, and (9) social networks.

Preparation and Frequency of Butter Tea Consumption

Butter tea is prepared at the study sites using mountain water, salt, pressed brick aged or black pu-erh tea, and yak butter. The water is sourced from local mountains and the butter is from household yaks that graze in surrounding pastures. Salt and tea were historically procured through the trade caravan network extending from southern Yunnan to Tibet. From the Cultural Revolution onwards, tea and salt are purchased from stores in the village.

Four to eight grams of brick tea are infused in 60-80 mL boiling water and heated over the stove for 3-8 minutes, depending on preference. The boiling infusion is churned with four to ten tablespoons of butter and salt (1/4 teaspoon) in a cylindrical wooden mixer (*don*). More recently, electric blenders have replaced the role of traditional wooden churns in some households. The tea leaves are poured from the churn or blender into a earthen tea pot. The tea leaves are used for several infusions depending on the quality of the tea and preference. The ratio of tea to water and butter varies based on taste preference. Elders generally prefer a bitter tasting beverage that is prepared with greater quantities of tea. Households in Reshuitang and Hanpi use 2-3 times the ratio of tea to water than Upper Adong. Some households in Upper Adong serve tea in a hierarchal way depending on age and social status where the first infusions are served to the eldest or most senior (as described in Chapter Nine).

Sixty four percent of surveyed households in Upper Adong used an electric blender for the daily preparation of tea rather than a don. The use of a don continues by all households in Reshuitang and Hanpi, the two communities closest to a commercial center. Informants from the latter communities said they prefer the texture and taste of butter tea from a don compared to from an electric blender. Some informants also regarded churning butter tea with a don as relaxing for the mind and as part of Tibetan identity.

Butter tea consumption is prominent at all study sites with slight variation between sites, but notable variation between generations in a community. Households in Reshuitang and Hanpi eat four meals per day, and households in Upper Adong eat three daily meals. Adults of all households at the study sites consume butter tea for their first two meals. Adults in Reshuitang and Hanpi, who eat four daily meals, also consume butter tea for their third daily meal. At each meal, adults consume on average 3-4 cups of butter tea. The elders at the study site also consume butter tea for dinner. Children are gradually introduced to butter tea and its accompanying foods. Newborns are fed a small amount of butter daily and it is increasingly incorporated in their diet. They drink weak infusions of butter tea as young children.

Accompanying Foods and Shifting Diets

Food Variety Scores (FVS) from dietary recall surveys documented a total of 34 foods in Upper Adong, 36 foods in Hanpi, and 37 foods in Reshuitang (Table 10.1). Informants consumed an average of 12 foods during the 24-hour survey period. The most prevalent foods in the surveys are butter, tea, and salt. The other most common foods reported in 75% of household surveys or more were barley flour, white rice, vegetable oil, lard, cheese, wheat bread, potatoes, and pork.

Middle-aged and younger-aged informants at each study site had a mean Dietary Diversity Score (DDS) of 5 (range 5-7) and elder-aged informants at each study-site had a mean DDS of 3 (range 3-4). The variation in DDS between elders and the younger generations are due to the non-local market foods consumed by the latter that are classified in the following food groups: oil, vegetables, and fruits. Follow-up interviews with elders on diets before China's Collective period starting in 1949 showed a mean DDS of 6 (range 4-6). The higher reported DDS for historic diets are from previously greater consumption of supplementary foods to the main meal of butter tea. Such supplementary foods included wild vegetables, mushrooms, and nuts including: masutake mushroom, *pu ging yin*, *sung*, *you chila*, *biluu*, and *mosau*. These wild vegetables are now harvested infrequently because of the shift to cultivated vegetables from market integration and the introduction of home gardens. In addition, labor has been re-directed at market harvesting activities, specifically collection of *Cordyceps sinensis* (catepillar fungus) and masutake mushrooms.

Table 10.1. Food Variety Scores (FVS) at the study sites of unique food items.

Food		Community		
Food Group	Food Item	Upper Adong	Reshuitang	Hanpi
Cereals / roots / tubers				
	Barley flour	x	x	x
	White rice	x	x	x
	Potatoes	x	x	x
	Wheat bread	x	x	x
	Oats			x
	Buckwheat			x
	Fava beans		x	x
	Instant noodles	x	x	x
Pulses / nuts				
	Walnuts	x		
	Flax seeds	x	x	x
	Peanuts	x	x	x
	Tofu	x	x	
Vegetables / fruits				
	Pumpkin	x		x
	Melon	x	x	x
	Tomatoes	x	x	x
	Onions	x	x	x
	Garlic	x	x	x
	Chives	x	x	
	Radish	x	x	
	Chili peppers	x	x	x
	Corn	x	x	x
	Cucumber			x
	Eggplant		x	x
	Bitter gourd		x	x
	Chinese cabbage	x	x	x
	Mushrooms	x		
	Oranges		x	
	Pears		x	x
	Apples		x	x
Meat / fish / poultry				
	Pork	x	x	x
	Chicken	x	x	x
	Beef		x	
Milk / dairy / eggs				
	Milk	x	x	x
	Yogurt	x	x	x
	Butter	x	x	x
	Cheese	x	x	x
	Chicken eggs	x	x	x
Oils / fat				
	Vegetable oil	x	x	x
	Lard	x	x	x
Other				
	Tea	x	x	x
	Salt	x	x	x
	Sugar	x	x	x
	Seasoning / condiments	x	x	x
	Barley wine	x		
Food Variety Score (FVS)		34	37	36

All adults in Reshuitang and Hanpi consumed *tsamba* for at least one meal and only the elder generation consumed *tsamba* in the remote community. Before the state collectivization period in China (1949-1981), butter tea was primarily consumed with *tsamba*, the traditional grain of Tibetan communities. Locals mix *tsamba* in their bowls of butter tea after they have drunk 4/5 of their cups. The *tsamba* and tea mixture is formed into a paste with the fingers, rolled and formed into a ball, and eaten. The consumption of *tsamba* persists in Reshuitang and Hanpi by all age groups. All generations consume *tsamba* for breakfast. Elders also consume *tsamba* with butter tea for their second and third meals. Alternatively, the middle-aged and younger generations consume butter tea with wheat bread, fried rice, or potatoes for their second and third meals. Milk, cheese, and yogurt occasionally accompany the intake of butter tea during breakfast and lunch. Reshuitang and Hanpi purchase wheat flour and rice from the market, as their local lands aren't conducive to growing these crops. Only elders in Upper Adong eat *tsamba* on a daily basis. Younger generations may eat *tsamba* for festivals or on a seasonal basis in the high alpine pastures. Breakfast and lunch for the middle-aged and younger generations includes butter tea with wheat bread made of grain cultivated in the community's fields. The ability to cultivate wheat in in Upper Adong but not in Reshuitang and Hanpi may explain the reliance on *tsamba* in the latter two communities.

Food intake at dinner reflects the influence of a Chinese Han diet with rice as the staple grain and greater quantities of meat, condiments, store-purchased oil, and cultivated vegetables than previously consumed. Households increasingly purchase ingredients for dinner from the market, particularly in Hanpi and Reshuitang. Rice became the staple grain for dinner at the study sites during the Collective Period when traditional agriculture was discouraged. Households attribute the increased consumption of meat to income opportunities from the expanded commercialization of natural resources, particularly *Cordyceps sinensis* and masutake mushrooms. Off-farm labor activities further contribute to increased income. Historically, meat was primarily consumed during the fall and winter seasons following the annual slaughter that included 2-3 pigs per household. Meat consumption in the summer was rare. Increased income has allowed households to purchase fresh meat throughout the year. This is particularly evident in Reshuitang and Hanpi that have higher meat consumption than Upper Adong. Along with meat, rice is consumed with locally grown or store brought vegetables. Hanpi and Reshuitang purchase more vegetables from market than Upper Adong that primarily relies on vegetables from local fields and home gardens. The most frequent plants in home gardens in Upper Adong are potato, radish, chive, green chili peppers, melon, cabbage, garlic, and pumpkin.

Seasonal variation in diets includes the consumption of wild vegetables and mushrooms. A food exchange system is implemented during the grazing season when several household members harvest and graze their livestock in the high alpine meadows. Family members who remain in the village settlement deliver grain and vegetables to the grazing lands every 2-3 weeks. They bring back milk and milk products to the village settlement. A few informants reported that they adhere to a more traditional diet during grazing that includes greater consumption of *tsamba* and wild vegetables. Several of the young *nemzah* (yak herders) in Upper Adong reported that while they don't eat *tsamba* during periods of sedentary agricultural activities in the village settlement, they eat this traditional grain in the high alpine pastures. They perceive that such a traditional diet provides their body with greater strength and energy for activities at higher elevations. Wild vegetables are also more frequently consumed in the high alpine meadows because of their greater accessibility.

Households noted that wild vegetables and mushrooms have experienced a decline as supplementary foods with changing access to markets, commercial opportunities, and agricultural development. Agricultural productivity has increased at the study sites through collaboration with extension agents. The most notable agricultural technology is the development of cement irrigation canals. Further agricultural extension efforts that have enhanced cultivated yields include the introduction of high-yielding crop seeds, home gardens, and green houses. Income has risen primarily through the sale of *Cordyceps sinensis* and masutake mushrooms. These developments have resulted in the replacement of wild food plant consumption with cultivated crops from local fields, home gardens, and local green house nurseries. Additionally, the increased commercial value of masutake following the market expansion in 1989 has resulted in a shift of this mushroom from home consumption to mostly a source of income. This trend is paralleled by several other food resources that are highly valued by the market. Walnuts, for example, have shifted from being an oil resource for home consumption to a resource reserved for income generation as the market value of walnuts has increased. Households in Upper Adong sell their walnuts and purchase cheaper oil with a less nutritious unsaturated fat profile for home consumption. With access to relatively inexpensive oil, locals consume greater quantities of oil in their diets than before.

The diets of children and the younger generation most notably reflect a dietary transition from traditional diets. Children and teenagers often skip meals at home and chose to eat processed snack foods purchased from the village vendors. They particularly are replacing traditional home meals with instant noodles. Several households reported that village vendors sell processed foods that are expired, which cause food illness for community members.

Role of Butter Tea in Wellbeing and Ritual

Surveys revealed that butter tea plays a multi-functional role in local livelihoods as a source of nutrition, medicine, and stimulant, as well as being a ritual object. There is consensus across study sites on the role of diet in maintaining health, preventing illness, and gaining energy. Butter tea ranked prominently on all survey responses regarding the most valued foods, most important foods in the diet, foods that can treat illness, and foods that can prevent illness. Tea is valued in combination with butter and salt to maintain health and to provide energy to carry out strenuous herding and agricultural activities at high altitudes. Farming and herding activities at high altitudes are recognized as strenuous tasks that creates imbalance to the body's constitution from cold winds, wet ground, and vigorous physical activity. Many informants report that they would not have the mental endurance or physical strength to carry out these daily activities without butter tea. Butter tea is valued to provide the body with *dangs-ma* (essential nutrients) that nourish the vital and physical energies, that in turn create the body's structure and maintain wellbeing. Tea is rarely consumed without butter because households perceive the combination of butter and tea gives greater mind-body balance than either item individually, or other food items. Tea for example is considered to balance the excessive greasiness of butter.

There is consensus across study sites that butter tea hardens the body's constitution and provides structure, "If you don't drink butter tea, your body will be soft." Informants said that the very purpose of their entire land-use system is to source butter and resources with which to procure tea. Surveys indicate that butter tea is further valued in diets for preventing joint pain, high blood pressure, and blood circulation diseases. These conditions are associated with excess "cold" in the body from exposure to strong cold winds and wet ground of the extreme high altitude environment. Joint pain and blood circulation diseases are additionally associated with strenuous grazing and agricultural work that require excessive effort because of the low productivity of the land.

Butter tea may be viewed as meeting the nutritional needs often fulfilled by the consumption of meat and produce. There was agreement among households in Upper Adong and Hanpi that butter can be viewed as a substitute for meat. Additionally, there is consensus among households in Reshuitang and Hanpi that tea can be seen as a substitute for fruits and vegetables. However, many elder informants value butter tea more than meat and produce. They said that butter tea provides the benefits of the latter, but has greater wellbeing properties. Others reported that each substance has its own properties and one substance cannot be viewed as a substitute for another, “everything is unique”. Dietary diversity surveys indicate fruit intake constitutes a minor component of local diets. Most households don’t eat fruit grown in their village surroundings on a regular basis and occasionally purchase fruit from the market, particularly during festivals and ceremonial holidays. The most common fruit purchased are apples and pears.

Monks in Hanpi note the attributes of tea in aiding in meditations. Some informants shared that butter tea is an addictive beverage that results in headaches if not consumed. Local households further value butter tea for its association as a tradition that has been passed for generations in Tibetan communities and that has enabled their survival. They would like to hold on to this practice because it is a gift of their ancestors. Butter is also valued as a social drink and offering of hospitality. Guests are offered bowls of butter tea upon entering a community. An elder in Reshuitang shares, “When you leave your home, you don’t bring your house with you. So you can eat anywhere. You can drink butter tea anywhere. This is the code for our traveling guests.” Guests of high social rank are offered tea in ornate silver-plated bowls that are normally placed at the central altar of each home. Such guests include monks, teachers, doctors, and elders. Historically, a bowl of tea was ceremonially offered at the daily altar as part of an offering of seven bowls of natural resources. Households at the study sites continue this practice daily, however, the seven bowls are now filled with water as representations of the traditional offerings. Tea is also offered during other rituals including the annual visit to the community sacred mountain and the Buddha’s birthday on April 15th.

Adoption of Tea in the Context of Tibetan Medicine and Philosophy

Informants have different understandings of why Tibetans adopted tea into their diets. One prevalent understanding reported during oral history interviews was that as Tibetan communities encountered tea through cultural exchange, tea was found to strengthen the body's blood, flesh, fat, bone, and marrow, and to create energy. The indigenous Tibetan territory had hundreds of endemic medicinal plants of its own. However, tea was selected for daily subsistence because it was able to maintain the body's humors, energies, and excrements in the extreme altitudinal conditions. Tea was not considered to contain the potency of many other medicinal plants growing in Tibetan areas that are regarded to create physiological imbalance if consumed daily. There were a few plants Tibetans had identified with similar properties that they used before the adoption of tea, and was used similarly as tea. These plants however were wild and risked being exhausted if used as a dietary staple. These wild plants were difficult to cultivate because of the restrictive altitudinal conditions that limited agricultural ability and productivity. Some households continued to use these local plants if they did not have adequate resources to exchange for tea. However, tea was still desired because it had an ability to boost energy they found difficult to substitute by other plants. Tea was found especially advisable for bile disorders caused by physical exercise, injury, hot and sour diet, indigestion, anger, and evil spirits. In addition, the attribution of the source of tea to a Buddhist monk, Bodhiharma, promoted its incorporation into daily practice of Tibetan Buddhists.

Perceptions of Health and Community Wellbeing

Free-listing surveys on health conditions revealed insignificant variation across communities. High blood pressure was perceived as the most serious health condition at each study site. It appeared on 64% of total free-lists on the most serious health conditions in the community and ranked first on 36% of the surveys. High blood pressure and cold/coughs were reported as the most prevalent health conditions. Table 10.2 shows the conditions reported on free lists as the most serious health conditions in the community and Table 10.3 shows the health conditions listed as most prevalent in the community.

Informants listed multiple factors that cause the prevalent health imbalances in the community. Change of diets / increased consumption of food purchased from the market was reported as the most prevalent cause of health imbalances in surveys. This factor was listed as the primary cause of community health risks in 63.63% of surveys. Change of diets and increased consumption of food purchased from outside the community is locally perceived to cause diarrhea, stomach pain, high blood pressure, blood clots, liver disease, gallbladder stones, kidney stones, excess cold in the body, excess heat in the body, and irregular heart beat. Elder informants noted that many of these health imbalances were not prevalent before the state collective period when the community followed a traditional butter-tea diet. The community has since witnessed greater frequency of disease and new type of illnesses, particularly among the younger generations who have the greatest change of diet. Households agree that traditional diets were more healthy and

Table 10.2. Frequency of health conditions reported at the study sites as the most serious health conditions during free-listing interviews.

Health Condition	Frequency (%)
High blood pressure	64
Blood clots	45
Brain fluid	42
Joint pain	42
Kidney stones	36
Gallbladder stones	36
Excess cold	33
Liver disease	30
Hemorrhoids	24
Stomach pain	24
Measels	18
Chicken pox	6

Table 10.3. Frequency of health conditions reported at the study sites as the most prevalent health conditions during free-listing interviews.

Health Conditions	Frequency (%)
High blood pressure	73
Colds / coughs	67
Excess cold	55
Diarrhea	52
Stomach pain	45
Joint pain / knee pain	27
Headaches	24
Dizziness	21
Irregular heart beat	18
Excess heat	18
Altitude sickness	12

associated with less illness. Barley, butter, and tea are particularly associated with preventing illnesses and maintaining wellbeing.

Households agree that the shift in diets among children has contributed to increased frequency of diarrhea and stomach pain. There is further consensus that eating snack foods and noodles from the village stores is the primary cause of illness in children and that these diets are not suitable for their wellbeing. The frequency of diarrhea and stomach pain among children is reported to be far greater than before the village vendors began selling snack foods and instant noodles.. The "new" health conditions in the community that are linked to the introduction of processed foods have lower prevalence in the elder generation who attribute this trend to their adherence to a traditional butter tea diet. The middle-aged and younger generations that have adopted a Chinese-style rice meal for dinner are further experiencing obesity, which was not prevalent in the past.

Households link foods from market to health imbalances because of agricultural practices that use hormones, pesticides, herbicides, and chemical fertilizers. Most households believe that food items commercially purchased, including vegetables and meat, likely contain hormones and other substances harmful to health. These foods are perceived not to provide the *dangs-ma* (essential nutrients) that nourish the body's vital and physical energies that are responsible for creating the body's structure and maintain wellbeing. Increased consumption of meat is considered to introduce excessive "oiliness" in the body that causes imbalance of the body's constituents and blocks the body's vital channels. It is also locally linked to obesity. The recent use of spices and condiments purchased from the market in preparing meals is perceived to introduce excess "heat" into the body and to lead to multiple health conditions, particularly stomach problems. In addition, the processed snack foods that children and teenagers consume are considered to contain toxic substances. The excess of sweet foods children eat from village vendors is considered to cause imbalance of the body's constituents. Snack foods sold in the village are noted as most often being stale and sold past the expiry date, providing further toxic substances to the body. The decreased quality of tea available to households is generally perceived to provide lower amounts of energy, strength, mind-body balance, and protection against illness. Some households also perceive the new quality of tea available to contain toxic substances and link these to poor agricultural practices. Households that decide to graze their cattle around village lands rather than in the high alpine pastures recognize that they are receiving less medicinal properties from butter because of the decreased medicinal plant diversity around the community.

Other locally recognized factors regarded as harmful to community health are decreased quality of water and access to clean water, degradation of pastures, inaccessibility of harvesting in state forests, cooking with biomass fuel, and increased strenuous activities in the high alpine lands for cordyceps and masutake harvesting. Elders express that the latter activity should be carried out in moderation, as households previously did before the community's increased market orientation. These activities require harvesters to bend on the ground in the high alpine pasture. Excess contact with the cold and wet ground is perceived to cause multiple health conditions according to the traditional medical system. Decreased access to clean water is regarded as a growing problem in the remote community. This is attributed to population growth and lack of a sanitation system equipped to handle the debris from packaged foods and bottles entering the community.

Health conditions at the study sites are treated at home, the community health clinic, or the township hospital. Previously, the communities had traditional Tibetan doctors. These doctors now practice in Tibetan medical centers in town. Treatment of health conditions at home involves diet modulation and the use of local natural products. The community health clinic and township hospital treats illness through western modalities. Households visit the township hospital for severe health conditions such as blood clots and fluid in the brain. Informants note that individual households have the knowledge to treat some of the community's health conditions, particularly those health conditions that were also prevalent historically.

The most prevalent local natural remedies used by households (mentioned by over 50% of households) are white snow tea (lichen; *Thamnolia vermicularis*), *bai mu* (plant with yellow flowers), Himalayan snow lotus (*Saussurea laniceps*; Asteraceae), *Cordyceps sinensis*, and *sohnee* (described as "plant with white flowers"). These medicines can treat joint pain, colds / coughs, excess cold in the body, excess heat in the body, and high blood pressure. However, changing food consumption patterns have resulted in new types of health conditions in the community that the traditional healthcare is not equipped to treat. Households thus increasingly seek western medicine from community clinics. Some middle-aged and younger-aged informants express that the clinical medicines eliminate pain faster than their traditional remedies, and thus they increasingly seek clinical medicine. Alternatively, some informants report that while western remedies eliminate pain faster, they sometimes cause other health problems.

Increased market orientation has further served to contribute to the trend away from traditional Tibetan remedies as communities elect to sell their mountain medicines with attractive income opportunities from these products.

Persistence of Tibetan Buddhist Ritual

Tibetan Buddhist ritual persists in all households across study sites. All households pray to the sacred mountain of their communities. Male members of all households visit the community's sacred mountain annually on Buddha's birthday (April 15th). All households interviewed have a Buddhist prayer altar in their homes, a room reserved for visiting monks, as well as an incense stupa. Households are further unanimous in their daily offerings of a guiding light to ancestors and Buddhist figures, seven bowls to Buddhist figures, and juniper incense at the stupa. Variation was seen between households in their use of ritual items (tea, butter, barley, rice, marigold flowers, wheat, buckwheat, juniper, bamboo, corn, soy bean, quercus tree, red barley wine, brown sugar, *shogah* incense, *soogeh* incense, *lushoh* incense, *beechee* incense, *jumpoo* incense). All households use barley, marigold flowers, juniper, milk, mountain water, and butter in ritual. Other prevalent ritual items include tea (90.90%), wheat (42.42%), red barley wine (36.36%), brown sugar (27.27%), and bamboo (27.27%). The eldest in the households are generally responsible for carrying out daily ritual.

Acquisition of Butter Tea and Human-Environment Health

Tea was procured through a trade network before China's collective period that extended from tea production communities of southern Yunnan to Tibetan communities in northwestern Yunnan and Tibet. Historically, households at the study sites participated in a feudal system of land use and trade. They supplied field and caravan labor to monastic and aristocratic estates. Several times each year, estates organized caravan teams of local men and horses to journey to tea production centers in Yunnan to procure tea. Caravans at the study sites generally went as far south as Lincang and Dali to collect tea and they transported it as far north as Lhasa. The main purpose was delivery of tea to Lhasa, but many Tibetan communities benefited as the horse caravans passed their towns. Households often traded grass, used for horse fodder by the caravans, in exchange for *tuocha* (pressed pu-erh in the shape of a nest or bowl) when caravans passed the towns of Shangri-La and Deqin. Other families traded butter, charcoal, and crops for tea and salt. Some households performed short-term off-farm labor and were paid in tea. Communities close to monasteries received tea from monks after caravans delivered it. Households left butter outside their homes on designated nights, and monks exchanged the butter for tea by sunrise. Elder informants share that the trade of tea from southern Yunnan to northern Yunnan is at least 1,000 years old, and probably older.

The exchange of tea from producers and traders in southern Yunnan to consumers in the indigenous Tibetan territory was contractual based on quality of tea. The trade contract ensured that tea consumers would obtain good quality product. Concurrently, it supported tea producers, allowing them to grow and process good quality tea for an established market. Horse caravans that transported tea to Tibetan communities could return the tea if consumers found it of poor quality. Growers also risked losing future business from caravans if their quality dropped. These direct links between tea producers and tea consumers resulted in Tibetan communities having access to tea with good color, smell, and taste. Tibetan elders that participated in the horse caravans express they felt a deeper connection to the tea during the days of the caravans because they saw where the tea they were drinking was grown, and how it was produced. Occasionally they met tea producers.

Not all families were wealthy enough to participate in the tea trade. Some families were only able to obtain a small amount of tea while other families could not obtain any tea. These families utilized the plants in their surroundings in their preparation of butter tea. Six plant species were documented as historic substitutes for tea. None of these species are wild tea relatives or in Theaceae.

The tea trade stopped in 1949 when the Chinese government nationalized land and acquired resources of the feudal elite. This state policy directly resulted in the collapse of commodity connections and social networks between northwest and southwest Yunnan. Households purchased tea from the government and later from village stores. At present, the village shops carry 1-2 brands of pressed brick tea from Dali Prefecture in Yunnan and Ya'an Prefecture in Sichuan. While elder men in the village recollect their days traveling to tea production areas, informants of the middle and younger generations have never seen a tea plant. Following 1949, elders noticed a shift in quality of tea. The pressed tea they consume has shifted from *toucha* (nest shaped) to brick tea. Elders express fond memories of the taste of the *toucha* they once consumed. Tea quality further dropped after tea prices began to increase in 2006, before which prices were 50% less. As the price of tea increased, locals perceive the quality of the tea dramatically decreased and that they are now consuming the lowest grade of tea available. They attribute this to this to their reliance on business people who bring tea to sell in the village shop. Many informants support that these businessmen probably bring the tea they can't sell anywhere else. Elders attribute the decline of tea quality to the loss of social networks with centers of tea production. They believe that production practices of tea have changed and that farmers grow more poor quality tea than before in areas of greater pollution. They particularly acknowledge the increased use of pesticides, herbicides, and fertilizers as well as poor factory processes. These changes manifest themselves in a tea product that: (1) has greater stems and older leaves, (2) tastes sour and stale, (3) causes nausea, (4) lacks flavor and fragrance, (5) requires greater amount of leaf in preparation, and, (6) offers less wellbeing and protective properties. Elders particularly perceive that the function of butter tea to strengthen the body is compromised with the drop in quality of tea.

Variability exists between study sites in the amount of tea purchased annually, which depends on preference in tea preparation, or specifically, the amount of tea leaves to water ratio. Households in the monastery / commercial community have the greatest annual expenditure on tea. On average, each houshold purchase five packs of pressed brick tea annually which each contains five tea bricks (250 grams each), or 6,250 grams of tea annually. The total annual expenditure on tea per household is 400 CNY (1 USD = 6.82 CNY at a July 2010 exchange rate). Households in the other commercial community purchase the greatest quantity of tea compared to the other study sites, but purchase a cheaper brand than in the monastery / commercial community. They purchase an average of 12 packs of tea at 20 CNY each, for an annual total of 15,000 grams and expenditure of 240 CNY. Households in the remote community purchase an average of 12 bricks annually, or 3,000 grams. Their annual expenditure ranges between 30-60 CNY depending on the brand they purchase, which ultimately depends on availability in the local store rather than preference. Locals prefer the Yunnan brand (5 CNY / 250 gram tea brick), but most often only find the cheaper Sichaun brand (2.5 CNY / 250 gram tea brick) in the community store.

Perceptions of Tea Quality

Interviews analysis suggests that Tibetan households at the study sites are no longer receiving the same anti-oxidant benefits from tea phytochemical as historically. This is likely due to the lower polyphenolic compounds of teas grown in monocultures and poorly processed. However, Tibetan communities at the study sites are still receiving the stimulant property of tea from caffeine, which is often regarded as the most prominent physiological property of tea.

DISCUSSION

Butter tea consumption persists across the study sites, however components of the butter-tea system have experienced both subtle and significant changes that may threaten community health. Households follow a combination of subsistence and income generating activities that mostly rely on their surrounding landscapes. Opportunities from expanded natural resource markets have served to increase market orientation of households who increasingly re-direct local foods and medicines for market sales. In some aspects, changes in response to exogenous influence have resulted in more comfortable lifestyles. Households now have increased income, greater access to commercial resources, and higher agricultural productivity. At the same time, households are experiencing changes that pose risks to community wellbeing.

Smallholders follow aspects of traditional butter tea diets. The adherence to these diets is linked to low incidence of heart disease, particularly among elders who deviate the least from traditional diets. This follows Fujimoto *et al.*'s findings (in Owen 2005) that Tibetan highlanders have a low incidence of ischemic heart disease despite their saturated-fat-rich diet of butter, low consumption of antioxidant-rich fruits and vegetables, and high-oxidative stress environment. In contrast, middle-aged and younger generations are increasingly selecting new dietary items and abandoning components of butter tea diets. These changes appear to be influenced by: (1) increased access to market items, (2) new cultivated crops, (3) high-yielding seeds and agro-chemicals introduced by agricultural extension efforts, (4) introduction of home gardens and green houses, (5) market opportunities to sell wild foods and nuts previously for home use, and (6) re-allocation of labor resources for commercial harvesting activities and off-farm labor. Dinners prepared by the middle-aged and younger generations at the study site resemble Han Chinese rice diets while elders still adhere to a butter tea diet. New dietary items include white rice, as well as increased meat consumption (particularly pork), sugar, pig fat, instant noodles, cultivated vegetables, and seasonings. Preferences of the younger generation for instant noodles, cakes, and soft drinks purchased from village vendors rather than butter tea diet reflect the changes in taste preference and the gradual shift from butter tea diets.

Elders are concerned that butter tea systems will disappear with the food choices of younger generations. They believe the biggest influence on local diets was China's collective period when rice diets were introduced to the community. The community's market orientation with expanded natural resource commercialization has further resulted in declining consumption of accompanying foods in the butter tea diet, particularly wild vegetables, mushrooms, and walnuts. Households elect to sell traditional foods that historically accompanied their butter-tea diets. Additionally, they re-allocate the labor traditionally dedicated to wild vegetable harvesting to cultivating vegetables in home gardens and greenhouses, as well as to commercial harvesting and off-farm labor.

The dietary transition documented in communities around the world is beginning to be experienced at the study sites. This is evident by the increased prevalence of health conditions reported by households. Households attribute changing diets from the traditional-tea diet to be the principal cause of this trend. The increased prevalence of health conditions in the middle and younger-aged generations compared to the elder generations seem to support this perception. Elders maintain that the new foods are unable to provide the *rLung* (vital energy) and *dangs-ma* (essential nutrients) provided by butter-tea diets.

The partial adherence to traditional butter tea diets at the study sites can be attributed to local preference, cultural identity, accessibility, and adherence to Tibetan Buddhist worldviews and practice. Butter tea is consumed by all households at the study sites. All households practice traditional Tibetan Buddhist rituals and adhere to Buddhist worldviews of health and nutrition. However, the future persistence of Buddhist rituals is uncertain as the elders in the households are the ones responsible for practicing daily rituals. Interviews and observation suggest that the younger generations generally have less of an understanding of the meaning and symbolism of the daily rituals practiced. In addition, these generations are less likely to rely on traditional ethnomedical treatment during times of health conditions, as indicated by their preference to visit the community clinic that administers western medicine. As the Tibetan Buddhist medical and philosophical frameworks that have encouraged the adoption of butter tea diets are increasingly influenced by exogenous change, traditional diets at the study site are likely to decline with shifting worldviews.

Expanded commercial markets for natural resources influence the community in multiple ways. The state's interference of the tea caravan trade in 1949 at the start of the collective period resulted in the loss of commodity links and social networks between tea producers in southern Yunnan and Tibetan tea consumers. This consequently resulted in the decline of quality of tea available to Tibetan communities that once relied on social relations and quality contracts to ensure a good-quality tea product. The recent tea boom for pu-erh from southern Yunnan has further served in lower tea quality and increased tea prices. The tea Tibetans traditionally relied on is being re-directed to urban and global markets that are willing to pay price premiums. Phytochemical analysis confirms that the tea consumed by Tibetan communities at the study sites contains less anti-oxidant compounds than average-quality tea in southern Yunnan. Anti-oxidants from tea have presumably traditionally played an important role for Tibetans as buffering agents in a high-fat butter-tea diet. However, the tea Tibetans now drink on a daily basis may pose risks to wellbeing from poor agricultural practices, including increased pesticides, hormones, fluoride, chemical fertilizers, and herbicides. The older leaves used in brick tea sold to Tibetan communities not only contain fewer polyphenols than the younger leaves previously consumed, but the leaves also contain significantly greater quantities of fluorine than younger leaves that they have accumulated from polluted soil. Studies have found that fluoride levels of pressed tea consumed by some Tibetan communities is 200-300 times higher than other teas and is attributed to result in a high incidence of dental and skeletal fluorosis (Cao et al. 1996).

Increased market integration has clearly impacted diet, nutrition, and wellbeing at the study sites. However, comparative analysis between the three study sites supports that the most significant changes in land use and diets are occurring in the remote community compared to the two commercial communities. Components of the butter-tea system had the greatest change in the remote community compared to the two commercial communities. This includes the re-allocation of traditional barley fields for wheat cultivation. Diets in the remote community were also most altered with abandonment of *tsamba* by the middle and younger-aged generations. The majority of households in the remote community had further replaced the use the wooden *don* to churn butter tea with electric blenders, while traditional churning prevails in the commercial communities. Several village elders in the remote community noted that the changes are because there are no more traditional Tibetan Buddhist leaders in the community to guide them. The monasteries in and near the two commercial communities may thus serve an integral role in the perseverance of traditional Tibetan practice and community health.

CONCLUSIONS

This study provides an example of how worldviews, specifically Tibetan Buddhist medicine and philosophy, influences dietary choices and associated wellbeing. Numerous exogenous variables can serve to influence worldviews, and thus dietary choices and community health. This study provides an example of the integral role of commodity networks in the distribution of quality product. The state's termination of traditional commodity networks during the collective period, coupled with recent expanded commercialization of pu-erh tea, has made good quality tea inaccessible to Tibetan communities. These communities continue to rely on tea on a daily basis for their wellbeing, yet likely procure fewer health protective benefits with poor production processes and use of old leaves with less phytochemicals than the young leaves previously consumed. They likely obtain greater toxic compounds from tea grown in polluted agricultural conditions with agro-chemicals. These findings highlight the potential link between environmental and human wellbeing.

The revitalization of traditional Tibetan healthcare and access to monastic-health centers can play a crucial role in maintaining community health at the study sites. In addition, local health clinics have a positive role to play in dietary health and nutritional outreach, as households increasingly move away from home remedies to seeking treatment from the clinic. Increased income can serve to potentially have positive benefits by addressing some of the historic health conditions recognized in Tibetan communities, such as growth stunting (Harris et al. 2001; Dang et al. 2007). The agricultural extension office that actively promotes crop types in the communities further has the potential to also promote healthful diets. For example, some farmers in Reshuitang have recently started growing linseed oil for cooking. Linseed oil has a more nutritious profile than the oil commercially available. In addition, the revitalization of commodity networks and social relationships between tea producers and tea consumers in Tibetan communities can assist in providing better quality tea to Tibetans. Finally, the recent global economic income that is currently compromising sources of income at the study sites and the subsequent ability to purchase goods from the market may serve to revitalize traditional agricultural and grazing activities as well as traditional butter tea food systems as communities revert to traditional means of livelihoods in their surrounding landscapes.

CONCLUSION

CONCLUSION

The purpose of this study was to understand the biodiversity and cultural practices associated with tea management systems. Surveys were conducted in smallholder communities of six sociolinguistic groups (Akha, Bulang, Han, Hmong, Lahu, and Yao) that manage tea resources in forests, agro-forests, mixed crop fields, and terrace gardens. Interviews were carried out between 2006 – 2010 to identify the influence of socio-economic and policy variables on tea production and consumption patterns. Ecological plot sampling and ethnobotanical inventories were employed to characterize the composition, structure, and uses of tea management systems. Tea leaf samples were randomly selected within each plot for: (1) video morphometrics to measure six shape and size attributes, (2) high performance liquid chromatography (HPLC) to quantify nine catechin and methylxanthine compounds and, (3) amplified fragment length polymorphisms (AFLP) molecular marker analysis to assess genetic diversity. Research sought to assess the influence of socio-economic and political change on these aspects of diversity. This was the first comparative study to measure multiple dimensions of biodiversity associated with various tea management systems in the native tea-growing region of southern Yunnan, China. Findings provide evidence on how farmers manage, maintain, and benefit from biodiversity in agro-ecosystems. The present chapter reviews key findings, synthesizes results in the context of the study hypotheses, and proposes research questions for future studies.

KEY FINDINGS

Variable Smallholder Decision-making and Evaluation of Cost to Benefit Values Associated with Tea Management Systems

Farmers at the study sites are deliberately managing tea resource systems on the basis of multiple factors including knowledge, cultural beliefs and customs, utilitarian needs, economic opportunities, preferences, and goals. Farmers variably account for these factors and their associated cost to benefit values in making management decisions. Results indicated that each tea management is associated with a few distinct benefits and costs and that these cost to benefit ratios are shifting with market opportunities. Participant observation and interviews emphasized the dynamic nature of management of tea resource systems as farmers continuously evaluate shifting cost to benefit ratios underlying various management options. Findings further revealed the trade-offs that farmers make in their management decisions as they select to carry out management activities that they consider have adverse effects on the environment and tea quality.

Diversity and Benefits of Floristic Composition and Structure

This study provides data to characterize the different types of tea management systems based on floristic composition and structure. In comparison to the terrace tea gardens that dominate tea production in Yunnan and worldwide, forests, agro-forests, and mixed crop fields are associated with: (1) lower density of tea plants, (2) greater height of plant species, (3) greater over-story density coverage and, (4) higher plant species evenness and richness. These tea management systems can thus provide models of biodiversity conservation in agricultural systems. However, results from plot sampling and ethnobotanical inventories support that increased human manipulation of management systems does not necessarily result in a linear trend of decreasing plant species diversity. Plant species richness was found in the order agro-forest edge > forest > agro-forest > mixed crop field > terrace gardens. The higher diversity index values for plots sampled at the edges of tea agro-forests compared to forest plots refutes simplistic notions of ecological simplification with increased human management. Local communities maintain the edges of tea agro-forests as strategies to buffer the system from pests, disease, and wind. They also benefit from plant species around their agro-forests for multiple uses including for medicine, food, construction material, dye, fodder, fuel wood, ritual, and tools.

Influence of Plant Selection on Tea Leaf Size

Morphological data found statistically significant variation of tea leaf shape and size characteristics between the different tea management systems and indicated farmer selection of desirable phenotypes of tea. Variation of tea characteristics was found in the order agro-forest > mixed crop field > forest > terrace gardens. Data concur with the plant selection and management practices of agro-forestry managers at the study site in cultivating tea plants with large leaves and managing their tea systems with shade in order to encourage large leaf size. Morphological data further agree with the preference of managers of terrace gardens in cultivating tea plants with small uniform leaves and managing their systems to encourage growth of small and uniform leaves. Managers of terrace gardens prefer to cultivate small leaves because all the foliage on the plant has greater resemblance to young new leaves, which are demanded by the market. Processed old leaves can then falsified and sold in the market as new leaves.

Correlation of Type of Management System to Total Catechin Content

Findings suggest that cultivation practices associated with different types of tea management system influences the phytochemical constituents of tea leaves. Qualitative analyses of HPLC chromatograms found forest tea samples have the greatest diversity of secondary metabolite compounds and that terrace gardens had the lowest diversity of secondary metabolites. Quantitative analyses of 12 catechin and methylxanthine compounds found that tea agro-forests and mixed crop plots are associated with the greatest quantity of the study analytes.

This study posits that the greater Total Catechin Content of tea samples in agro-forests and mixed crop fields compared to forests may be explained by greater ecological stress found the former two systems. The lower plant species richness within agro-forests and mixed crop fields coupled with less canopy coverage is hypothesized to result in increased predation to tea plants with fewer types of host plants in the system and increased oxidative stress with heightened solar radiation. Thus, tea plants have a greater "need" to be "on the defense." Tea plants growing in relatively stressed agro-ecosystems may respond by utilizing their limited metabolic energy to produce fewer types of secondary metabolites compared to those in forest systems, but produce those compounds in greater quantities. Alternatively, the fewer secondary metabolites found in terrace gardens may be due to the use of pesticides and herbicides. The application of such agrochemicals likely decreases stress from predation and competition, and thus tea plants in terrace gardens loose the ecological cue to produce these compounds and conserve their metabolic energy.

Creation of Genetic Diversity with Selection and Exchange

Genetic diversity, measured by genetic distance of tea samples assessed through AFLP, was found in the order mixed crop field > agro-forest > forest > terrace gardens. These findings, coupled with farmer interviews, suggest natural dispersion and the role of smallholders in enhancing germplasm diversity through selection and cultural exchange and. The greater genetic diversity in mixed crop fields than the other tea management systems is likely a result of farmer selection practices for desired properties, experimentation, and germplasm exchange between different communities. This genetic diversity serves to buffer disease and is an important seed bank for commercial tea products. In contrast, terrace gardens typically utilize cloning for uniformity of product.

Increased Complexity of Pu-erh Tea Commodity Chains

The expansion of pu-erh tea commercialization has resulted in a more complex market chain coupled with heightened efforts to increase public awareness through marketing campaigns and greater consumer interest in pu-erh. In some aspects the pu-erh commodity chain has increased in length as new actors have entered. In other aspects, the commodity chain has shortened as increasing number of traders and vendors from major cities in China are buying pu-erh directly from tea mountains. The increased presence of market actors in the tea production mountains is likely to further influence production practices and presents interesting questions for future research. Some tea producers and vendors perceive that the increased numbers of new market actors threaten the sustainability of the pu-erh market because of their lack of management skills, short-term focus, and poor production practices. The increased complexity is also thought to result in greater variety of perspectives and less consensus on how pu-erh should be grown, processed, marketed, labeled, prepared, and consumed. Other producers and vendors suggested that the market chain should be still more complex with greater quality control and standardization to enable the pu-erh market to be sustainable.

Branding Terroir and Culture Commodification of Tea Mountains

Pu-erh is branded for diverse characteristics that highlight its habitat, associated cultural practices, age, health properties, and social and historical values. The most prevalent themes documented to market pu-erh are linked to its sourcing and *terroir*, or the environment and location in which tea is produced. This includes terms such as “ecological tea,” “ancient teagardens,” “wild tea,” and “famous tea mountain.” While the branding of pu-erh emphasizes sourcing from “ecological” systems and *terroir*, there is little consistency in the way these terms are understood. Further, these labels are often falsified. Interviews and observation suggest that there is more tea on the market labeled from old tea plants then such plants exist. This creates brand identity issues for managers of tea mountains that work to create particular production environments. Outsiders compromise their label by selling poor quality tea falsely labeled. Results showed the dynamic nature of marketing. During the peak of the pu-erh boom in 2007, tea was branded as a luxury collectible or souvenir with themes that invoked sophistication, refinement, and fashionable trends. The emphasis of branding shifted to promoting tea as a necessary product for human health during the bust of the pu-erh cycle in 2008 – 2010.

Correlation between Type of Management System, Taste, and Total Catechin Content

Structured interviews coupled with HPLC quantification provide evidence of the link between type of management system, taste, and total catechin content of tea. Findings indicated that a majority of informants perceive that the taste and health-related claims of tea are associated with the type of management system from which it was sourced. In particular, bitter tasting compounds of tea are thought to be from tea plants grown in a forest or "healthy environment", such as agro-forests that lack the input of pesticides, herbicides, and fertilizer. Such tea is also thought to contain greater wellbeing properties. Interviews revealed that expert informants were able to distinguish between tea sourced from agro-forests versus terraces gardens based on the bitter taste profile of the former. In addition, HPLC quantification of Total Catechin Content (TCC) validated local perceptions of the link between the environmental source of tea and health-related claims. Samples identified with the most health-related claims were found to contain the greatest TCC. Results from ANOVA indicate that the increase in human manipulation from agro-forests to terrace gardens is significantly associated with a decrease in TCC.

Validation of Traditional Gong-fu Style Tea Preparation Based on Variation of Total Catechin Content (TCC)

This study supports that traditional gong-fu style tea preparation gradually extracts compounds from one infusion to the next in what expert informants termed a "balanced composition." Total Catechin Content (TCC), Total Methylxanthine Content (TMC), and anti-oxidant activity significantly varied between infusions of a single sample. This highlights the role of traditional gong-fu preparation in gradually extracting phytochemicals with health related claims through a process of repeatedly infusing tea leaves.

Decrease of Total Catechin Content with Increased Processing from Green ("Raw") to Black ("Cooked") Pu-erh and Increased Demand for Bitter Pu-erh

Rural upland communities in southern Yunnan have customarily consumed bitter "raw" *sancha* (green pu-erh). Alternatively, urban connoisseurs developed a palate for "cooked" *shucha* (black pu-erh) in the 1970s during China's drive towards technological modernization, away from the "backwardness" associated with indigenous mountain cultures. However, the global urban green-food movement and attention to functional food diets have revitalized a taste for bitter and "ecological" pu-erh, now a highly prized commodity among urban tea drinkers in Asia. The demand for agro-forest "raw" green pu-erh has further been driven by consumer concerns about the presence of toxic chemicals in monoculture tea. Total Catechin Content (TCC) values of raw versus cooked pu'er tea samples were found to be in the order green pu-erh > aged green pu-erh > black pu-erh. Additionally, greater TCC was found from samples from agro-forests versus terrace gardens. The increasing trend to select *kucha* (bitter tea), *shengtaicha* (ecological tea), and *dashucha* (big tree tea) from agro-forests during pu-erh tea tasting plays a potential role to link human wellbeing associated with consumption of tea catechins with environmental health. It further highlights the significance of a desire for diversity in consumption habits and the need for future studies to understand links between environmental and human health.

Reconfiguring Land Use and Reallocating Labor in Response to Expanded Markets for "Ecological" Tea in the Akha Uplands

Increased market integration and value of "ecological" tea has heightened the role of tea agro-forests in livelihoods at the study site in the Akha uplands of Yunnan. This has led to a process of decision-making where Akha smallholders are reconfiguring labor and land use. Tea production has transitioned from being an occasional women's activity to a key livelihood occupation that men increasingly take leadership in. Local Akha have restructured their livelihood activities to dedicate five to six days per week from the start of the spring harvest in March through the end of the fall harvest in October. Land use has simplified since the early phase of the Yunnan tea boom as smallholders direct labor and land use to tea production. Since 2005, Akha at the study site have stopped managing upland dry rice fields and upland wet rice terraces, documented as the most significant land-use categories in previous research conducted in 2005. This land-use decision is in response to state discouragement of shifting cultivation and to opportunities presented by tea markets. Increased value of tea agro-forests has contributed to reconfiguration of land use and spatial rearrangement of landscape-level biodiversity. Smallholders have intensified management in existing tea agro-forests through selective girdling of associated woody plant species. At the same time, locals are transforming some swidden fields previously managed for upland rice into areas that are being regenerated as tea agro-forests. Thus, while plant biomass decreases in forests and agro-forests, it is being enhanced in swidden areas that are being transformed to tea agro-forests.

Heightened Tea Varietal Knowledge with Increased Market Integration

Findings indicate a relationship between the perceived value of a commodity and a rise in varietal knowledge and market-driven institutions associated with it. These results are in contrast to most studies in the literature. Observations demonstrate that Akha smallholders at the study site have been enterprising in tapping into customary resources and developing social networks with tea traders to capitalize on commercial opportunities presented by expanded markets for pu-erh. These customary resources include local institutions of natural resource management and associated ecological knowledge, experience with self-organization, and experimentation with plants and land use. Locals have further initiated a community group to unite individual household management, processing, and marketing of tea towards creating brand recognition for the community. Social networks within the community, with other communities, and with tea industry agents provide locals a platform for debate on diverse perspectives, sharing and negotiation of information, and articulation of agreed knowledge of tea resources. Social exchange also serves to integrate individual knowledge of tea resources and foster the accumulation of group knowledge. The community's open-mindedness norms, cognitive diversity, and recognition of local experts further assist in the development of group knowledge.

Ecological Knowledge Scores (EKS) of tea landraces at the study site indicate that knowledge of tea resources is increasing with expanded market integration and is shifting from women to men. Middle-aged men are tapping into traditional ecological knowledge, increasing interaction with tea resources, and enhancing linguistic discernment of tea types. This has been facilitated through social networks within the community, nearby communities, and with tea industry agents. Tapping into customary ecological knowledge and social institutions while developing new knowledge and social networks has proven to be an effective strategy for hedging market uncertainty. The interplay of these customary and market factors has allowed the community to enjoy a level of affluence previously unknown and enabled it to endure the recent pu-erh bust cycle. While the regional pu-erh market has experienced a bust period (starting in 2008), connoisseurs remain willing to pay premiums for high-quality product from old agro-forests at the study site. Social exchange and cooperation with tea industry agents—combined with customary strategies of experimentation with plant resources, risk management of livelihood activities, and the transmission and development of knowledge—has provided a competitive market advantage.

Variation of Land Use Valuation between Age Classes of Smallholders

As annual income from tea sales has increased over 2,000 times over the past decade at the agro-forest study site, Akha smallholders continue to rely on farming, foraging, and home gardening for daily subsistence. This decision is driven by local food preferences, cultural history, and seasonal inaccessibility to markets. Interviews onvalues attributed to various land-use types suggests local Akha have a multidimensional value system that varies among the community as indicated by Principle-Components Analysis (PCA) of land-use valuation. These data suggests a gradual shift towards a cash economy among the younger generations. As Baljalpuxeevq becomes more accessible with infrastructure development, local value systems and institutions are predicted to continue shifting towards a market orientation.

State-Driven Expanse of the Monoculture Model and Promotion of Migrant Workers in the Uplands

Research findings indicate that the greatest land-use change at the agro-forest study site is a result of private enterprises leasing communal and private land from the community. Through contracts, the provincial government has encouraged and facilitated commercial tea enterprises to sublease over 2,500 ha of swidden land from communities in the Bulang Mountains for the creation of tea monocultures between 2006 – 2010. These enterprises hire lowland migrant workers and create laborer settlements in land previously managed by upland smallholders. The state-facilitated subleasing of village lands to commercial tea enterprises to establish expansive monocultures is expected to further influence local values and may have adverse implications to upland ecosystems. Run-off from fertilizers, pesticides, and insecticides used by commercial tea enterprises may pose an environmental health risk to surrounding land and food systems, particularly to the village paddy rice fields in the valleys immediately below the new monocultures and to aquatic fauna in the stream below the village. The tea clones introduced to the uplands by these enterprises poses the risk of genetic pollution to the reservoir of tea diversity managed by local Akha for decades. The influx of hundreds of lowland migrant laborers poses additional environmental risks. These laborers are generally not familiar with local ecology and developed their conceptions of nature elsewhere. They also most likely bring with them increased industrial products and associated disposal issues. The environmental interaction of lowland migrant laborers working in the new upland tea enterprises may ultimately damage the "ecological" branding of local tea.

Importance of Cultural Identity in Classification and Selection of Tea Varietals

Cultural identity is the primary character used in selecting tea types at the agro-forest study site, which locals differentiate as "Akha people's tea" versus "Han terrace tea". "Akha people's tea" and "Han terrace tea" have the greatest agreement between informants' classification schemes. Local landraces have the greatest frequency in the community's tea agro-forests and are preferred by all informants while state-introduced cultivars occur in lowest frequency and are least preferred. The maintenance of local tea types emphasizes the role of cultural preferences in preserving landraces and contributes to Akha cultural identity. More recently, monetary values accompanying increased market demand for "ecological" tea that has complex taste profiles contributes to landrace maintenance and is beneficial for cultural continuity and prevention against genetic erosion.

Persistence of Butter-Tea Consumption in a Transitioning Diet

Diets at the Tibetan study sites centered on salted butter-tea systems that extends into virtually every component of life. The web of butter tea serves to connect land use, food procurement, medical practice, ritual, family structure, and social networks. The higher reported Dietary Diversity Score for historic diets are from previously greater consumption of supplementary foods to the main meal of butter tea, including wild vegetables, mushrooms, and nuts. Wild vegetables are now harvested infrequently because of the shift to cultivated vegetables from market integration and the introduction of home gardens. In addition, labor has been re-directed at market harvesting activities, specifically collection of cordyceps and masutake. Food intake at dinner reflects the influence of a Chinese Han diet with rice as the staple grain and greater quantities of meat, condiments, store-purchased oil, and cultivated vegetables than previously consumed. Households are increasingly sourcing food items for dinner from the market, particularly in the two communities nearest a commercial center. Rice replaced barley flour as the staple grain for dinner since the state collectivism period. Households attribute the increased consumption of meat to opportunities from the commercialization of natural resources. The diets of children and the younger generation most notably reflect a dietary transition from traditional diets towards processed food items.

Perceived Increase of Health Conditions with Shifts Away from the Traditional Butter-Tea Diet

Butter tea ranked prominently on all survey responses in Tibetan communities regarding the most valued foods, most important foods in the diet, foods that can treat illness, and foods that can prevent illness. Tea is valued in combination with butter and salt to maintain health and as a source of energy in order to carry out strenuous herding and agricultural activities at high altitudes. Butter tea is valued to provide the body with *dangs-ma* (essential nutrients) that nourish the vital and physical energies, that in turn create the body's structure and maintain wellbeing. Surveys indicate that butter tea is further valued in diets for preventing joint pain, high blood pressure, and blood circulation diseases. These conditions are associated with excess "cold" in the body from exposure to strong cold winds and wet ground of the extreme high altitude environment. Joint pain and blood circulation diseases are additionally associated with strenuous herding and agricultural work that require excessive effort because of the low productivity of the land.

Change of diets and increased consumption of food purchased from the market was reported as the most prevalent cause of health condition in surveys. Elder informants said that many new health imbalances arrived to the community after the state collective period. These new illnesses are particularly common among the younger generations who have the greatest change of diet. Households link foods from the market with health conditions because the use hormones, pesticides, herbicides, and chemical fertilizers. These foods are perceived not to provide the *dangs-ma* (essential nutrients) that nourish the body's vital and physical energies that are responsible for creating the body's structure and maintain wellbeing.

Decline of Tea Quality in Traditional Tea Consumption Communities in Response to Increased Markets for Pu-erh

Interviews indicate a decline in tea quality consumed by Tibetan households at the study sites. Findings further support that tea quality dropped in 1949 when the Chinese government nationalized resources. China's Collective period directly resulted in the collapse of commodity connections and social networks between northwest and southwest Yunnan. The quality of tea available at the study sites further dropped during Yunnan pu-erh boom and bust cycle as tea was re-directed to new markets and to consumers able to pay price premiums.

Elders at the study sites associate the decline with the loss of social connections with centers of tea production an to a shift towards harmful cultivation and processing practices that use pesticides, herbicides, and fertilizers. Elders particularly believe that the function of butter tea to strengthen the body is compromised with the drop in quality of tea. Quantification of total catechin content of tea samples consumed by Tibetan households at the study sites suggests they are no longer receiving the same potential health benefits from tea as before. This is likely due to the decline in tea quality and the associated degradation of polyphenolic compounds associated with terrace tea systems that rely on agro-chemicals and the use of old leaves in tea processing.

HYPOTHESES RE-VISITED AND IMPLICATIONS

The following section re-visits this study's hypotheses and evaluates if data support or refute the hypotheses.

Hypothesis 1: Yunnan's increased market integration, agricultural expansion, and development policy have influenced tea management systems through a decline of: (i) plant species richness and evenness, (ii) complexity of vegetative structure, (iii) morphological, phytochemical, and genetic diversity and, (iv) ecological knowledge of tea varieties.

The data support this hypothesis in the overall simplification of biodiversity associated with the monoculture mode of production that has been promoted in Yunnan by development policy. In contrast to terrace gardens, the traditional tea management systems of Yunnan, including forests, agro-forests and mixed crop fields, have greater plant species richness and evenness, complexity of vegetative structure, morphological, phytochemical, and genetic diversity and, ecological knowledge of tea varieties. However, this study rejects notions that this trend is linear with increased human manipulation. Findings demonstrate that local diversity is maintained at the genetic, species, and ecosystem levels in agro-forests and mixed crop fields. Variation of plant species richness and genetic diversity among the different types of tea management systems provide evidence of domestication as a continuous process. The interactions between farmers and tea management systems also provide valuable information for the study of domesticated plants and the process of domestication and selection.

Data support that agro-forests may provide attractive strategies to achieve conservation of biodiversity and economic development. The practices and perceptions accompaning the management of agro-forests points to the strong cultural basis for the creation and maintenance of these anthropogenic landscapes. Tea agro-forests and the biodiversity associated with them can be maintained by integrating local cultural practices and beliefs in conservation. To overcome the many challenges for the effective integration of biological diversity and cultural practices in conservation actions, conservation programs should tap into local natural resource management institutions linked to traditional agriculture systems.

Hypothesis 2: Increased market demand of tea from "ancient tea gardens" (agro-forests and mixed crop fields) has resulted in their increased valuation in livelihoods and land use, and to expanded area dedicated to tea production.

Market expansion of tea from agro-forests has led to development in ecological knowledge and institutions associated with tea resources at the study site managing agro-forests. At the same time, the intense interest in tea production coupled with state discouragement of shifting cultivation in Yunnan has led to modifications in land use, most notably away from upland rice and terraced hillside paddy. The large influx of cash into the community has resulted in positive development of a shared community infrastructure, such as road improvements and a new community center. At the household level there has been an increase in consumer goods, many of which would have been considered luxury items a few years before.

FUTURE STUDIES AND RESEARCH DIRECTIONS

This study was limited in its examination of the diversity associated with tea management systems by focusing on floristic composition and cultural practices. Future studies should enhance our understanding of the diversity associated with tea management by exploring the range of other species and factors associated with tea management systems, including microorganisms, pollinators, and soil fertility, that contribute to the function and processes of these systems.

The present study demonstrated that agricultural and processing conditions have notable influence on tea phytochemicals. However, there remain knowledge gaps on how a range of production variables across tea growing areas worldwide influences tea phytochemicals, and numerous associated types of bioactivity. Further studies on the impact of agricultural and processing conditions on tea phytochemicals and a range of bioactivity could provide valuable data to help inform cultivation practices for enhancing the production of functional phytochemicals. Tea, with its recognized bioactivity and socio-economic significance in global consumption, is a well-qualified subject for such future biomedical studies.

This study provides useful baseline data to examine long-term change linked to expanded market integration. Despite dramatic change occurring throughout China due to rapid economic growth, this study presented one example of how such growth can have unintended and surprising consequences. For example, market expansion at the study site of Baljalpuxeevq has led to development in ecological knowledge and institutions associated with tea resources. At the same time, the intense interest in tea production coupled with state discouragement of shifting cultivation has led to changes in land use, most notably away from upland rice and terraced hillside paddy. The large influx of cash into the community has resulted in positive development of a shared community infrastructure, such as road improvements and a new community center. At the household level there has been an increase in consumer goods, many of which would have been considered luxury items a few years before. These dynamics point to the complex nature of social and environmental change and refute simplistic models of market integration and the loss of ecological knowledge.

This study further provides useful baseline data to examine an engagement of ecosystem ecology with anthropology (Abel and Stepp 2003). If the considerable changes occurring at the study sites in the last few years are indicative of broader dynamics, indigenous upland communities in southern Yunnan involved in tea production will likely see substantial social, cultural, economic and political transformations in the near future.

APPENDICES

APPENDIX ONE. Tea Production and Consumption Survey

Types of Tea and Uses

1. What are tealeaves used for? Why do people drink tea? What impacts does it have on the body? Mind? Health?
2. Are there different types of tea?
3. Do different types of tea have different uses?

Teagarden Ownership and Management

4. Do you have a teagarden?
5. What are the governments' laws and rules of using land in your community and surroundings?
6. How did you acquire your teagarden (inherited? purchased?)
7. Approximately how long has this teagarden been in your family?
8. How large is your teagarden?
9. Approximately how many tea trees are in your teagarden?
10. Approximately how old are tea trees in you teagarden?
11. What are all the activities that occur in the teagardens?
12. What is the local calendar? What activities related to teagardens and tea resources occur during different seasons?
13. How long have you been managing tea resources?
14. How did you learn about how to take care of your teagarden?
15. Do you have any management practices that are special to you, your family and your community?
16. Do you plant tea trees? How do you plant tea trees? Do you use seeds or seedlings? When do you plant tea trees? How much tea do you plant? Where do you plant it?
17. Where do you get seeds / seedlings of tea plants to grow in your garden? Do you get seeds / seedlings from forest populations? How do you decide which tea trees to get seedlings from?
18. How do you plan how much tea to grow?
19. Do you exchange tea seeds or seedlings within the community? Between communities?
20. How do you think the productivity of the tea grown in your teagarden compares to modern teagardens? What management practices and other factors do you think are responsible for this?

Harvesting

21. Who harvests tealeaves in your community?
22. Do you harvest tealeaves?
23. How are tealeaves harvested? Are there different ways of harvesting tealeaves?
24. When are tealeaves harvested (time of day and season)?
25. How much tea do you harvest daily? Seasonally? Annually? How do you decide how much tea to harvest?
26. How do you decide how much tea to harvest?
27. What do you do to the tealeaves after they are harvested?

Processing and Preparation

28. How is tea processed?
29. Who harvests tea in your community?
30. How is tea prepared?

Tea in Forests

31. Are their tea trees in the forest near your community? Do you harvest from these tea trees?
32. How is tea from wild tea trees different than tea from teagardens?

Tea Habitat

33. What are the ideal habitat conditions for growing tea?
34. What environment conditions are bad for growing tea?
35. Other than tea, what plants grow in your teagarden? How do these plants impact the growth and yield of tealeaves?
36. What distinguishes tea that grows here from tea that grows in different habitats?
37. How are your surroundings changing? How have they changed over the course of your lifetime?

Organoleptic Properties and Quality

38. How do you ensure to grow good quality tea?
39. Please describe characteristics of excellent tea.
40. What factors involved in growing tea make it excellent?
41. What factors involved in processing tea make it excellent?
42. What factors involved in preparing tea make it excellent?
43. Please describe characteristics of bad tea or poor quality tea.
44. What factors involved in growing tea make it bad?
45. What factors involved in processing tea make it bad?
46. What factors involved in preparing tea make it bad?
47. Is there a particular season for getting the best tea?
48. Is there a particular season where tea is of lower quality?
49. Overall, how consistent is the quality of tea from one batch to the next? From one year to the next?
50. Do different tea trees yield tea of different taste, smell and quality? Do different trees in your garden yield tea of different taste, fragrance and quality?
51. Are there different types of tealeaves that yield tea with different characteristics? If so, what are these?
52. Are there characteristics in taste, smell and quality that distinguish teas that grow in different geographic regions? If so, what are these?

Sales and Consumption of Tea

53. Who buys tea from you?
54. What type of tea is in demand this year? How does this preference compare with the type of tea demanded last year? Five years ago? Ten years ago?
55. How knowledgeable do you think your customers are about tea? Has this knowledge changed in the past five years? If so, what do you think is responsible?

56. How are tea market trends established?
57. What recent developments and changes have you observed in the tea trade?
58. What do you feel about the current relationship between supply and demand of the tea trade? Do you think the tea sources in Yunnan can meet demand? Do you think there is an oversupply of tea?
59. How do you think the tea trade will develop in the next year? Next three years? Next five years? Next ten years?
60. How much tea do you sell?
61. What are the prices of the different teas you sell?
62. For how long have you been selling tea?
63. How did you get involved in selling tea?

Education

64. Who taught you about tea?
65. Where can I learn more about tea?
66. Do you think the knowledge about tea is increasing, decreasing or staying the same?
67. Do you think your community can teach other teagarden communities about tea? If so, what can you tea?
68. Is there any information you would like to know about growing tea, the properties of tea, the tea trade or anything else related to tea?

Costs and Benefits

69. What are all the material costs related to growing tea?
70. How much income do you make from selling tea?

APPENDIX TWO. DNA Extraction Protocol

1. Set incubator to 65˚C.
2. Place leaf in 15ml Falcon tube on dry ice.
3. Store at -70˚C.
4. Pour liquid nitrogen into tube. Crush tissue with a glass rod by hand, then vortex with the rod in the tube. Maintain liquid nitrogen in the tube until pouring DNA extraction buffer.
5. Add 700 uL DNA extraction buffer and 10 ul B-mercaptoethanol into the Falcon tube with pulverized tissue and then transfer into a microcentifuge tube. Vortex until all pulverized tissue is suspended in the liquid and keep at room temperature for 10 minutes.
6. Incubate samples in microcentifuge tubes at 65˚C for 30 minutes.
7. Add 700 ul phenol-chloroform-isoamyl alcohol (25:24:1). Use the lower phase in the bottle of phenol-chloroform-isoamyl alcohol, vortex, r.t, 10 min.
8. Spin in centrifuge for 10 minutes at 14,000 rpm.
9. Transfer supernatant to a new tube containing 1/10 vol. of 3M sodium acetate (ca. 50 ul) and 500-700 ul isopropanol. Vortex.
10. Spin 10 minutes and discard supernatant.
11. Wash pellet with 150 uL 70% EtOH.
12. Spin 5 minutes and discard supernatant.
13. Air dry the pellet. Dissolve 100 uL TE solution.
14. Quantify DNA.

DNA Extraction Buffer Recipe:

- 200 mL gDNA ext. buffer.
- 40 mL 1M Tris. HCl ph 7.5
- 10 mL 5M NaCl
- 10mL EDTA
- 5 mL 20% SDS
- 135 mL H_20

APPENDIX THREE. AFLP Protocol

The AFLP protocol employed was adapted from Vos et al. (1995) and Mueller et al. (1999).

RESTRICTION LIGATION

A. Anneal adaptor pairs

1. Anneal adaptor pairs (Mse1 and EcoR1 adaptors) at 95˚C for 5 minutes.
2. Cool at room temperature for 10 minutes and spin for 10 minutes at 14,000 RPM.

B. Prepare restriction-ligation master mix

- 10 x T4 DNA ligase buffer with ATP: 0.66 uL / sample
- 0.5 M NaCl: 0.38 uL / sample
- 10 mg/mL BSA: 0.063 uL / sample
- MSE I (10,000 U/mL): 0.6 uL / sample
- EcoR1 (20,000 U/mL): 0.6 uL / sample
- T4 DNA ligase (4000 U/uL): 1 uL / sample
- Water: 0.8055 uL / sample

C. Run the following profile:

1. 37˚C for 2 hours
2. Hold at 4°C

D. Dilute 3.3 uL DNA product with 100 uL water

PRE-SELECTIVE AMPLIFICATION

A. Prepare pre-selective master mix

1. ExTaq: 6 uL / sample
2. dH_20: 2 uL / sample
3. Pre-selective primer pairs (525, 526, and 527 with 1174): 0.3 uL / sample each

B. Combine 5.4 uL DNA product with 6.6 uL master mix

C. Run the following PCR profile:

1. 94°C 2 min
2. 26 cycles:
    i. 94°C 1 min
    ii. 56°C 1 min
    iii. 72°C 1 min
3. 72°C 5 min
4. Hold at 4°C

SELECTIVE AMPLIFICATION

A. Prepare selective master mix
   1. Taq polymerase: 6 uL / sample
   2. Dye primer: 0.5 uL
   3. Selective primer (AGT and GTG): 0.6 uL
   4. H_20: 2.8 uL / sample
   5. Selective primer: 0.6 uL / sample each

B. Combine 4.2 uL pre-selective product with 7.2 uL master mix

D. Run the following PCR profile:
   1. 94°C 2 min
   2. Twelve cycles:
      i. 94°C 30s
      ii. 65°C 30s
      iii. 72°C 1 min
   3. Twenty three cycles:
      i. 94°C 30s
      ii. 56°C 30s
      iii. 72°C 1 min
   4. 72°C 2 min
   5. 4°C soak

C. Dilute restriction-ligation with 100 uL H_20

PREPARE SELECTIVE PRODUCT FOR SEQUENCER

A. Prepare plate for sequencer:
   1. Add 35 uL formamide / sample to sequencing plate.
   2. Add 1 uL size standard / sample to sequencing plate.

B. Dilute selective product with 50 uL formamide / sample.
C. Add 3 uL diluted selective product to sequencing plate.
D. Add 1 drop mineral oil to each well in the sequencing plate.
E. Prepare buffer plate for sequencer.

APPENDIX FOUR. Tea Market Survey

Tea Market Survey

1. Location of market (city, province and country)
2. Name of market
3. Name of store, stall or other type of vendor
4. Type of vendor (tea store, tea counter in larger store, permanent stall, temporary stall or other)
5. Date of establishment of vendor (When did this store open?)
6. Date of visit
7. Researcher(s)

Types of Tea Traded and their Production

8. What are all the different types of tea you sell?
9. What is the most popular type of tea you sell?
10. What is the most valuable type of tea you sell?

For the most popular tea and for the most valuable tea, please address the following:

11. Where did you buy this tea? Who sold it?
12. Where is it grown?
13. What type of habitat does it grow in? What surrounds the area this tea grows?
14. How old are the tea plants that yield this tea?
15. Who harvests it (nationality, gender, age group)?
16. When was it harvested?
17. Where is it processed?
18. Who processes it (community member, commercial entity)?
19. How is it processed?
20. How do you prepare this tea?
21. What distinguishes this tea from other teas?

Market Terms

22. What is the history of Pu-erh tea?
23. What does the term "ecological tea" mean to you?
24. What does the term "organic tea" mean to you?
25. What does the term "ancient tea tree" mean to you?

Organoleptic Properties and Quality

26. Please describe the characteristics of the tea we are tasting.
27. Please describe characteristics of excellent tea.
28. What factors involved in <u>growing</u> tea make it excellent?
29. What factors involved in <u>processing</u> tea make it excellent?
30. What factors involved in <u>preparing</u> tea make it excellent?
31. Please describe characteristics of bad tea or poor quality tea.
32. What factors involved in <u>growing</u> tea make it bad?
33. What factors involved in <u>processing</u> tea make it bad?
34. What factors involved in <u>preparing</u> tea make it bad?
35. Is there a particular season for getting the best tea?

36. Is there a particular season where tea is of lower quality?
37. Are there different types of tealeaves that yield tea with different characteristics? If so, what are these?
38. Are there characteristics in taste, smell and quality that distinguish teas that grow in different geographic regions? If so, what are these?
39. Overall, how consistent is the quality of tea from a supplier from one batch to the next? From one year to the next?

Consumption of Tea

40. Why do people drink tea? What impacts does it have on the body? Mind? Health?
41. Who buys tea from you? What are all the different types of customers you have (socio-economic class, gender, nationality, age, and other characteristics)?
42. What types of tea do your different types of customers prefer?
43. What type of tea is in demand this year? How does this preference compare with the type of tea demanded last year? Five years ago? Ten years ago?
44. How knowledgeable do you think your customers are about tea? Has this knowledge changed in the past five years? If so, what do you think is responsible?
45. How are tea market trends established?
46. What recent developments and changes have you observed in the tea trade?
47. What do you feel about the current relationship between supply and demand of the tea trade? Do you think the tea sources in Yunnan can meet demand? Do you think there is an oversupply of tea?
48. How do you think the tea trade will develop in the next year? Next three years? Next five years? Next ten years?

Quantity, Availability, Value of Tea Traded

49. How much tea do you sell?
50. What tea is most rare to find?
51. What are the prices of the different teas you sell?
52. What price range does the average customer buy tea from?
53. How much do you think the average customer spends on tea in a year?

Background of Tea Vendors / Traders

54. Gender
55. Approximate age
56. What is your nationality?
57. Where is your hometown?
58. What city/town/village do you currently reside in and for how long?
59. For how long have you been selling tea?
60. How did you get involved in selling tea?
61. Who taught you about tea?

Tea Education

62. Where can I learn more about tea?

APPENDIX FIVE. Oral History of the Akha of Baljalpuxveeq Village

Migration was historically a norm for socio-linguistic groups of southern Yunnan. The Akha in the upland village of Baljalpuxeevq in the Bulang Mountains, Menghai County, Xishuangbanna Dai Autonomous Prefecture, Yunnan have a history of moving and settling 11 times within the Bulang Mountains in the past 200 years. Their ancestors arrived to the Bulang Mountains from Yoanjiang in Simao Prefecture, Yunnan. They found extensive tracts of land managed for swidden agriculture as well as tea cultivated in mixed crop plots cultivated by the Bulang. The Bulang had been living in the area for hundreds of years and thus the Akha knew they the area was inhabitable for humans. Records have been found on leaves and papers in Dai Buddhist temples in Xishuangbanna that suggest the Bulang arrived to the Bulang Mountains approximately 1,370 years ago led by a headman, Fashutuo, who ruled both Bulang and Dai in the Menghai area. Fashotou stayed in Menghun town while some of his men explored settlements deeper in the mountains. There were no other inhabitants when the Bulang arrived. However, an old tomb of the Wa was found in the area that is estimated to be 2,000 years old. The Wa are considered the older siblings of the Bulang from whom the Bulang descended. The Wa also had the cultural practice of tea cultivation from whom the Bulang probably learned this practice. Thus, the history of tea cultivation in the Bulang mountains maybe as old as 2,000 years, but this is uncertain. Locals are certain that tea cultivation in the area is as old as the earlier Bulang settlements. However, the oldest tea trees are much younger than the practice of tea cultivation in the area because of the life span of the tea plant. Most tea trees in the old tea gardens are considered to be around 200 years old.

The first Akha settlement in the Bulang Mountains was namsed *Aimaiya puchu*, previously Bulang settlement. The Bulang prefer the eco-niche of lower altitudes and moved to the lower montane elevations, thus allowing the Akha to take over management of forests and fields. This was not without controversy. The two groups settled their territories through fighting and through taxes. The Bulang allowed the Akha to settle in the area for the payment of grain. The Akha soon moved from their first settlement in the area and created a settlement named *Ligua buchu* and later moved and created *Maya butree* (both settlements no longer exist). This was followed to migration to *Arpieahzie butree* and then to the location of the current settlement, then known as *Zhenie butree*. They moved from this open area a few years later deeper into the forest to *Nuhungbutree* and then to *Minabutree*. A fire in *Minabutree* led to relocating in *Laiba butree*, then on to *Goxie butree* and eventually to the area where there present sister village of Lao Banzhang is currently located. They soon moved deeper in the forest and eventually in 1968 settled in the current location.

There were many natural, economic, and political causes for the Akha to move around the Bulang Mountains. The community often sought out areas considered more suitable for specific circumstances, including either more open areas or more forested areas. They often moved to escape snake and tiger attacks that took the lives of villagers, particularly children. Fires and other natural disasters occasionally destroyed villages and prompted migration. The Akha often moved to clear new lands for upland farming when their fields were in the fallow stage of regeneration. During the Guamintong period, villagers fled to more isolated areas to avoid being caught in the cross fire between the Communists and Guamintong who would occasionally battle fight in the mountains. They also tried to hide from these groups who sometimes threatened to shoot them if they didn't give up their silver adornments.

When the Akha migrated, the most vital things to bring to start a new village were their leaders, tools, and rice seeds. The heightened role of agricultural tools for livelihood strategies of the Akha of Buljalpuxeevq can be understood through the customary hierarchy of roles that enable the survival of a community. The hierarchy constitutes not only of village leaders but also farming and food processing tools as well as natural elements that enable food production. A village elder in Bajalpuzveeq shares, "Once a community has these eight things, it can survive". The *Zhoema* (village head) is at the top of the community hierarchy and is responsible for transmitting local oral history, ecological knowledge, and social norms though stories and songs. The knowledge and experiences embedded in oral stories and songs shape Akha identity, guide livelihood practices and advance collective action. Other customary leadership roles in the village included the *Bajee* (black smith of tools), *Buseh* (headman for external affairs, *Pbima* (keeper of oral history and intermediary to the ancestral realm) and *Nipa* (shaman).

The *Bajee* (black smith of tools) follows the *Zhoema* at the top of the hierarchy. Following the *Bajee* at the top of the village hierarchy are tools created by the *Bajee*, *meeche* and *dungha*. The *meeche* and *dungha* are used for cutting trees to construct homes and for clearing land for agriculture. *Meeche* and *dungha* are followed in the village hierarchy by the element of fire that is valued for burning upland fields for rice cultivation. The village hierarchy continues with *che mah* (tool for planting seeds), *yeh hou* (tool for harvesting crops), *shadhe langhou* (tool to beat and separate grain) and *bohseh* (tool to fan rice to remove its sheath). This hierarchy makes apparent the local importance of farming, particularly rice farming, and the ability to sustain off the land. Historically, agricultural activities in Bujalpuxeevq were based on rotational swidden cultivation between forests, fallow, and fields. Forests were cleared into fields for one to two year periods of crop cultivation and were then allowed to regenerate back into forests as a strategy for managing soil fertility.

If the Akha found their new settlement to be suitable for tea production or other crops, they would often return to their previous community to bring seeds to cultivate. They also often searched for environments that were suitable for tea production where either wild tea populations existed or where tea as cultivated by previous settlers. The Bulang cultivated the old tea systems that the Akha presently manage. The Bulang are believed to have cultivated tea in the Bulang Mountains for approximately a millennium. However, these systems appeared markedly different. They were surrounding by large fallow fields that the Akha allowed to regenerate and maintain as forests. This management strategy was to protect the village and the tea plants from wind, an element feared in Akha cosmology.

Traditionally, the Akha considered themselves rice farmers, not tea farmers. Their tea systems appear as agro-forest because of their lack of intensive use and the focus on upland rice farming for daily subsistence. Through observation and experimentation, the Akha learned about the benefits of the agro-forestry mode of production. Households would occasionally visit tea systems when they needed tea and other natural resources for household use or trade. Tea was occasionally traded along with opium when locals needed salt from the lowlands. For a period, opium farming replaced rice farming as the main livelihood activity because its relative ease and yields. Opium was than traded for rice from the lowlands.

Historically, the Akha of Bajalpuxveeq were monetarily poor. Some households only owned one set of clothes that their children would have to share depending on whom was leaving the village. Households often acquired clothes only when someone had passed away. The village would often see a shortage of grain, and thus relied on wild food plants to supplement their diets. Tea began to gain economic importance after the Liberation period in China. Chapter Eight describes this rise to valuation of tea resources in Bajalpuxveeq.

APPENDIX SIX. Questionnaire on Land use, Livelihoods, Health, Ritual, and Tea in the Tibetan Plateau

A. INTERVIEW DETAILS
A1 Site
A2 Date of interview (DD/MM/YYYY)
A3 Name of household interviewed
A4 Numbers of members in the HH interviewed (people who usually live & eat together in this household)
A5 Language(s) in which questionnaire is administered
A6 What kind of roofing material does the main house have? (Observation by interviewer)
A7 What material is the floor of the main house made of? (Observation by interviewer)

B. LAND USE, FARM ASSETS, AND AGRICULTURAL PRODUCTION
B1 What are all the land types your household utilizes?

1	11	21
2	12	22
3	13	23
4	14	24
5	15	25
6	16	26
7	17	27
8	18	28
9	19	29
10	20	30

B2 How many types of grazing land are around your community?

B3 What is the main source of drinking water for your household?

B4 How many ________ does your household own?
How many ________ were sold during the past 12 months?

	# Owned	# Sold
Yaks		
Cattle		
Hybrid Yak/Cattle		
Pigs		
Chickens		
Horses		
Mules		
Donkeys		
Sheep		

B5 How many __________ are owned by your household?

Motorcycles	Cars / Trucks	Tractors	Plows	Refridgerator

B6 Which crops did you plant and harvest this year? Are they used for HH food or fodder?
Area planted and quantity harvested?

B7 Has any new crop been introduced to your HH in the past five years? Ten years?

B8 Varieties: How many kinds of [name of crop] are there?

Barley	
Wheat	
Potatoes	

B9 Do you store seeds of [name of crop]?

Barley	
Wheat	
Potatoes	

B10 Is there seed exchange between the village or among villages?

B11 Has the government introduced any seeds to your village? If yes, what kind?

B12 Do you use fertilizer? Source?

B13 Do you use any pesticides or herbicides? Type? Source?

Which crops did you sell this year? Quantity?

1	6
2	7
3	8
4	9
5	10

B14 What livestock products do you prepare? Quantity?

B15 Did you consume any livestock you raised this year? Quantity?

B16 What are the most important animal products and crops for home consumption? Quantity consumed daily, monthly or annually?

B17 What is the primary type of grazing land your HH uses? Has this changed in the past five years? If so, how and why?

C. WILD FOOD RESOURCES

C1 Do you harverst any wild vegetables from the forest? Or collect other wild foods? Quantity?

C2 Do you have access to more, less, or the same amount of wild resources as you did in the past five years?

C3 If this amount has changed, what has caused the change?

D. INCOME SOURCES AND MARKET ACQUISITIONS

D1 What are all the sources of income for your HH? How much does your HH receive from each source?

1	6
2	7
3	8
4	9
5	10

D2 Do you think that your family is in better, the same, or worse economic conditions now compared to five years ago?

D3 During the past year, was any member of your HH active in the following activities?

a. Agricultural work on someone

b. Mechanics or construction

c. Transportation
d. Other wage or salaried

D4 Are you able to sell all of the products you bring to market?
D5 What goods do you purchase from market?

E. NUTRITION PERCEPTIONS & KNOWLEDGE
E1 What foods are important to eat?

1	6
2	7
3	8
4	9
5	10

E2 Why are these foods (listed above) important to eat? Do you know any health benefits of these foods?

E3 Can any of these foods be used to treat illness?

E4 If you don't eat any or enough [food name], does it cause any illness or other impact on the body?

E5 Do you know any food that you should not eat too much of? Why should you not eat too much of it?

E6 Where did you learn this information about food from?

E7 Some people say that drinking tea is a suitable substitute for eating vegetables and fruits.
How do you feel about this?
Agree
Disagree
Neither agree or disagree
Other comment:

E8 Some people say that eating ghee is a suitable substitute for eating meat. How do you feel about this?
Agree
Disagree
Neither agree of disagree
Other comment:

E9 Has there ever been a time when there has been a food shortage in your HH? If so, when?
How did you cope with this situation?

E10 Have you ever gotten information on the benefits of eating many different foods each day?
Where did you learn this information?

F. FOOD FREQUENCY
F1 Yesterday, how much of each of the following foods did each member of your HH consume at each meal?

	Meal 1	Meal 2	Meal 3	Meal 4
Ghee with Tea				
Naked Barley (spoons)				
Cheese (pieces)				
Wheat Powder Bread (pieces)				
Rice (bowls)				

F2 Is there a difference in diet when your family is in the high alpine grazing land versus in the village?

H. ILLNESS

H1 What are the most common illnesses in your community? What are the causes of these illnesses? How are they treated?

1	6
2	7
3	8
4	9
5	10

H2 What are the most common illnesses in your community? What are the causes of these illnesses? How are they treated?

1	6
2	7
3	8
4	9
5	10

H3 Where were the children in your HH delivered?

I. RITUAL

I1 Do you use any of the following items in ritual? If so, how are they used?
Tea
Ghee
Naked barley
Rice
Flowers
Wheat flour
Pinus sp.
Bamboo
Water
Quercus
Other:

I2 Do you offer seven bowls to Buddhist figures at the altar on a daily basis? Does each bowl signify
I3 something? If so, what is the significance?
I4 Do you offer a guiding light to your ancestors and Buddhist figures at the altar on a daily basis?
I5 Do you prey to the community's sacred mountain?
I6 Do members of your household visit the sacred mountain? If yes, who visits and how frequently?
I7 Do you have a Buddhist prayer altar in your home?
I8 Do you have a room reserved for visiting monks in your home?
I9 Do you have an incense stupa outside your home?
I10 Do you offer juniper incense on a daily basis at the incense stupa?
I11 Do you use any of the following items in ritual: tea, butter, barley, rice, marigold flowers, wheat, buckwheat, juniper, bamboo, corn, soy bean, quercus tree, red barley wine, brown sugar, shogah
How often do members of your HH visit the sacred mountain?

J. TEA

J1 Why do you drink ghee tea?

J2 How do you prepare tea? Do you use an electric blender or a traditional mixer?
Is there a difference in taste using an electric blender or traditional mixer?

J3 Why is tea prepared with ghee? Do you drink tea without ghee?
Is there a difference in the benefits it provides consumed with butter versus with water?

J4 Where do you get the tea your HH consumes? Where is it grown?

J5 How much does your HH consume per month (or annually)?

J6 How much do you spend each month (or each year) on buying tea?

J7 How stable is the price of tea? How has it changed in the past two years? Five years?

J8 Have you noticed a difference in quality in the tea your HH consumes? If so, when did you notice this?
What do you think is responsible for this?

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