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Working With Locals to Restore Biodiversity to a Rubber Dominated Landscape

Francis Commercon
SIT Graduate Institute - Study Abroad

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Commercon, Francis
Academic Director: Lu Yuan
Advisor: Harrison, Rhett
Colorado State University
Biological Sciences and Fish, Wildlife, and Conservation Biology
云南省，猛腊县，勐仑镇，曼俄村

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Abstract: Xishuangbanna, in Yunnan,China, contains the country's highest concentration of biodiversity. Since the 1980s,rubber plantations havereplaced a significant portion of the prefecture's lowland Seasonal Tropical Rainforest, leading to wildlife habitat loss and other environmental issues.Monoculture farming practices also leave farmers economically vulnerable to market fluctuations. To learn the best solutions for increasing ecosystem services and income stability in rubber-dominated areas, the World Agroforestry Center (ICRAF) project Green Rubber engages smallholders directly in establishing and maintaining scientifically rigorous intercropping experiments in their villages.

Using Man'e village and the Green Rubber project as a case study, I asked to what degree and through what means can local knowledge improve environmentally-friendly rubber initiatives. I employed formal surveys of residents (sample of 52), guided interviews with several key informants, tours to the local nature reserve, and visits to rubber farms to discover what local knowledge exists of use in designing intercropping projects. To learn how scientists may use such knowledge, I employed participant observation during the scientists' process of establishing initial communication with the village.

My results indicate that there is significant knowledge present in the village that can be of use for restoration ecologists in designing green rubber that is adapted to the local economy and local resource consumption patterns. This knowledge lies scattered in disparate aspects of the community; finding it requires lookingcarefully and learning holistically about the community. Furthermore, before they can establish a practical platform from which to engage locals in their project, researchers must develop closecommunication with the villagers.

These results can inform initial planning at future study sites within the Green Rubber project and other initiatives to encourage rural communities to adopt sustainable rubber growing practices.

Key Words: Agriculture, Natural Resources and Conservation, Ethnobotany

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INTRODUCTION:

Over the past few decades, population growth and economic development have caused significant land use change in the world's tropics, especially conversion of natural forest to agricultural land (Li et al 2007). Deforestation in tropical areas reduces and fragments wildlife habitat, reducing populations and causing local extinctions (Kai et al 2014). Lowland tropical rain forests contain the highest concentrations of species diversity in the world, and much of this diversity has yet to be described to science. Current levels of land use change in these areas thus pose a severe threat to tropical biodiversity and global climate, which is increasingly of concern to the international community.Land conversion to monoculture cash crops such as rubber, oil palm, tea, and bananas, is one of the leading causes of rainforest loss in SE Asia(Xu et al 2014).

Background on Xishuangbanna:

XishuangbannaDai Nationality Autonomous Prefecture, in southern Yunnan, China, represents the most thoroughly studied and perhaps most dramatic example of this phenomenon (Xu et al 2014, Hauser 2015). With a biological and cultural landscape more similar to Southeast Asia than most places in the People's Republic of China, Xishuangbanna prefecture (XSBN) is easily the most biodiverse part of China. While only accounting for 0.2% of China's entire land area, it contains 16% of China's plant diversity, 36.2% of the nation's birds (427 species), 27.7% of the nation's mammals and 14.6% of its amphibians (Zhang and Cao 1995). XSBN is part of the Indo-Burma biodiversity hotspot (Myers 2000), and more than 7500 plant species have been recorded here (Chen 1999). Globalization, integration into the market economy, and government policies have put severe pressure on the region's ecological balance and local biodiversity in the past few decades. Much of the ecological threats come from conversion of natural forest to cash

crop monocultures with low biodiversity and high inputs of herbicides, pesticides, and other agricultural chemicals (Xu et al 2014). Rubber,*Heveabrasiliensis,* stands as perhaps the most ecologically infamous of these cash crops.

History of Rubber in the Area:

Originally from South America, rubber arrived in XSBN in 1940 and did not become widely planted until the 50s when the national government established a series of large state-owned rubber farms (Xu et al 2014). Uneasy relations with neighboring countries and international embargoes on trade encouraged the new central government to produce as much of its own industrial raw materials as possible. As it steered the country into a rapid period of industrial development, the government identified natural rubber as a key industrial material. Along with Hainan Prefecture, XSBN supports a massive national demand for latex. This national demand has only increased in recent decades with the booming automobile industry and the use of latex in car tires (Xu et al, 2014, Hauser et al 2015).

For the first three decades of its history in XSBN, rubber was primarily confined to the state plantations. By 1976 rubber comprised only 1.1% of the prefecture (Li et al 2007). Following the Household Responsibility Program and the abolishment of communes in the early 80s, however, farmers could choose for themselves what to plant on their land and they could keep their profits. Producing natural rubber offered smallholders significantly higher income (Qiu 2009), and farmers cleared forest to plant rubber trees all across the province, mostly in the lowlands (below 900m) where rubber grows best. Seasonal Tropical Rainforest, the principle forest type in XSBN lowlands (600-800m) and the most species rich of XSBN's forest types (Zhang and Cao 1995), decreased by 67% between 1976 and 2003. By the turn of the millennium, rubber covered 11.3% of the prefecture, and seasonal tropical rainforest had decreased to only

3.6% of the land area (from 10.9% in 1976; Li et al 2007). As latex prices tripled in the first decade of the 21st century, rubber plantations expanded another 271,000ha between 2002 and 2010 and now cover one fifth of all XSBN's land area (Xu et al 2014, Qiu 2009, Davis 2015). The spread of rubber agriculture in the lowlands forced other agricultural activities such as slash and burn agriculture, into higher elevations causing deforestation there as well. The nationwide Natural Forest Protection Plan (NFPP), introduced in 1998,and the Sloping Lands Conversion Program (SLCP) further encouraged the spread of rubber farms by defining rubber farms as forest cover (Li et al 2007, Liu et al 2006, Xu 2011). Mengluncounty, the site of the present study, has experienced a 328% increase in land covered by rubber plantation (Liu et al 2006) mostly at the expense of natural forest. Between 1988 and 2006, rubber plantations increased from 12% to 46% and natural forest has decreased from 49% to 28% (Hu et al 2008).

Environmental Impacts of Rubber:

These massive landscape scale changes have resulted in broad patterns environmental change across XSBN. Rubber farms consist of single-aged trees arranged in neat rows without any understory vegetation or emergent trees. Farmers apply herbicide as often as necessary to kill herbaceous plants and tree saplings. The elimination of structural complexity and plant diversity makes these rubber farms effectively biological deserts in comparison to the lush rainforests they replaced. A walk through a rubber forest is silent and eerie. The natural forest has been fragmented and reduced to mere islands in a sea of rubber farms and other land uses. Outside of the nature reserves, virtually no natural forest remains in XSBN (Xu et al 2014). Fragmentation in combination with habitat loss has reduced some wildlife populations and altered plant species composition within the remaining forest fragments (Zhu et al 2004).

Furthermore, the lack of an understory in rubber forests leads to erosion and low soil water retention(Hauser et al 2015). Conversion of forests to rubber plantations reduces streamflow, affecting local people's water security. By producing a thick fog during the winter, evapotranspiration from rainforest vegetation maintains the moisture necessary for rainforest vegetation to exist at this high latitude. But conversion of natural rainforest to rubber plantations has been linked to a reduction in the number of foggy days and an increase in annual temperatures in rubber-producing areas over the past half century, threatening the region's remaining tropical vegetation. Nutrient cycling and soil carbon are reduced in rubber plantations. Conversion of forest to plantations also contributes to climate change through both the forest clearing process and by reduced long-term carbon sequestration. (Xu et al 2014, Hu et al 2008, Hauser 2015).In Mengluntownship specifically, conversion of land to rubber plantations has resulted in a net loss of ecosystem services value of $11.43 million (27.7%), with the greatest reductions in nutrient cycling, erosion control, and climate regulation (Hu et al 2008).

Income Instability:

Whileintensive rubber cultivation has significantly improved local people's incomes (Liu et al 2006), it leaves farmers vulnerable to market fluctuations. Rubber trees take about seven years to reach maturity, before they can be tapped (Qiu 2009). Switching one's land to rubber production is a major investment, and it is not easy to convert a plantation to another use quickly if the price of rubber drops suddenly. Because standard rubber farms have no other cultivated species, farmers have few other sources of income. In the event of a price drop, they must find work in cities or cut their forests and replant with another crop. In the past two years, the wholesale price of rubber has dropped from more than 30RMB per kg to only 8RMB per kg due to a global oversupply to the rubber market that is expected to continue into the future (Hauser et

al 2015). At the same time that their incomes have risen on average, smallholders cannot feel secure in their future if a price drop requires them to completely shift their livelihoods (Liu et al, 2006, Hauser et al 2015)

Solutions for preserving XSBN's ecological balance:

The Dai religion protects the forest from conversion to agriculture by establishing sacred mountains, sacred forests, and through cultivating a diversity of plant species in temples (Wang Jianhua, personal communication, November 8, 2015). Each basin, or Meng (勐) protects a sacred hilltop, and at one point XSBN had 1000 holy hills (Lily Zeng, personal communication, November 14th, 2015). The Dai believe spirits reside in the holy forests and they go occasionally to pray, but many are fearful to enter. Each village, or Man (曼)has its own sacred forest, occupied by spirits and ghosts and the ashes of the deceased. Although religious beliefs and values can change in the future, these sacred patches of forest may have played a role in preserving some plant diversity.

In the early 1980s, the central government established five national level nature reserves in XSBN. Taken together, these reserves covered 240,000ha or 12% of the land area (Xu et al 2014). Their value in protecting biodiversity and ecological function cannot be understated. However, boththe reserves and the holy forests suffer from severe human influences in the form of clearing land, encroachment of agriculture, and illegal hunting (personal observation,Xu et al 2014). Currently, the number of holy hills in XSBN has been reduced to about 200, many only about a hectare in size (Lily Zeng, personal communication, November 14th, 2015). Even if nature reserves and holy forests were perfectly protected, they still only represent isolated, fragmented patches of the original forest. One initiative by the Asian Development Bank aims to improve habitat connectivity by providing financial incentives for villages to protect or restore

their forests (Qiu 2009). Still, most of the world's biodiversity exists in a human-modified agricultural landscape. The best solution for conservation must involve improving wildlife habitat and ecosystem services in the agricultural areas between protected within the rubber plantations between the reserves (Chazdon et al 2009).

When it was first introduced to Indonesia in the early twentieth century, locals used rubber as a fallow crop in the cycle of shifting cultivation. Farmers planted hundreds of low-value seeds in a field just after it was abandoned and allowed them to grow up during the fallow period amidst the other natural vegetation. This system allowed farmers to derive economic benefit from their land even when it was not being farmed. Rubber trees worked well for this, as they are naturally characteristic of an early stage in forest succession. A rubber forest with significant understory and emerging canopy trees mimicked the diversity and ecological functions of a young regenerating forest (Gouyon 1993).

Although this style of rubber production fell out of favor due to increased population densities and the introduction of high-value cloned rubber seedlings (which farmers could not afford to lose from interspecific competition), it does provide inspiration for conservation biologists, restoration ecologists, and government officials hoping to solve the problems associated with rubber plantations in their areas. In 2009, the head of the Xishuangbanna Tropical Botanical Gardens (XTBG) proposed a plan to the Prefecture government to create "Environmentally Friendly Rubber Plantations" (huanjingyouhaoxingjiaoyuan; Schillo 2012). XTBG established a research group dedicated to finding a solution to reduce rubber's environmental impacts. Most research has focused on intercropping solution, in which other crop species are inter-planted underneath rubber (Davis, 2015, Yi Zhuangfang, personal communication, November 15th, 2015). Biodiversity has been shown to increase with habitat heterogeneity in agricultural landscapes (Benton et al 2003), and as a general principle,

intercropping should improve biodiversity and ecosystem function by increasing system complexity (Bhagwat et al 2008, Rhett Harrison, personal communication, December 2nd, 2015). Within a short time, several groups of researchers initiated experimentstesting yields and environmental benefits of various economic plants intercropped under rubber.

Within the grounds of XTBG, scientists have experimented with intercropping, planting rows of tea, coffee, cacao, and a medicinal plant,大叶千斤扳. XTBG also maintains a small area of "Jungle Rubber," where rubber trees form the canopy, a medicinal tree and fruit tree form the mid story, and a rare medicinal shrub forms the understory. Lianas have been introduced to increase structural complexity, and the area, called the "Artificial Rainforest," is designed to mimic a natural secondary rain forest (Tang Jianwei personal communication, November 16th, 2015).

Dr. Yang Xiaodong, at XTBG, established an intercropping experiment three years ago in a private rubber company near Menglun. Dr. Yang has established four experimental treatments within the company's holdings: a control rubber area with no intercropping but not agrochemical application, rubber intercropped with tea, with cacao, with 大叶千斤扳 and a small "jungle rubber" area where he has introduced the topsoil (including humus and seed bank) from a natural forest. Dr. Yang will measure latex production in the different treatments. He will also analyze soil nematode diversity, insects, and birds across the different treatments. The goal is to provide the government with a model for intercropping so it can design programs to help farmers implement these practices across large areas. (Yang Xiaodong, personal communication, November 11th, 2015)

Beginning three years ago, Dr. Tang Jianwei, also at XTBG,began collaborating with Nabanhe nature reserve and the Yunnan Nature Reserve Bureau to establish an intercropping

experiment within the Nabanhe nature reserve. No herbicides or pesticides are used in the experimental area. The local smallholdersmanage the rubber trees and the intercropped plants. The intercropped species should provide locals with benefits in addition to rubber. For example, 萝芙木 produces a medicine that decreases blood pressure, 肉桂 is used as a culinary spice and an herbal medicine, and 降香黄檀 is a valuable timber species. 大叶千斤扳 fertilizes the soil by fixing nitrogen, produces expensive medicine in its roots, and has edible shoots and leaves that are good for livestock forage. Dr. Tang has planted roughly 400 hectares of land in this way, and he hopes to study how this form of intercropping affects smallholder income and various environmental variables (Dr. Tang Jianwei, Personal communication, November 16th, 2015).

Beginning in 2013, the XSBN prefecture government instituted a program to convert 10000 亩 of smallholder rubber farms, about 666ha, to environmentally friendly practices each year until 2020. This program targets rubber farms along roads and in valleys. The government encourages rubber farmers to stop putting herbicides and to inter-plant cash crops informed by the research coming out of XTBG. Dr. Tang is one of the scientists providing technical support to farmers in this project (Davis, 2015;Yi Zhuangfang, personal communication, November 15th, 2015).

Despite these efforts, there remains much progress to be made. The government programespecially encourages intercropping of 大叶千斤扳, for which there is no market and no medicine processing facility. The current intercropping experiments mentioned above are too new to provide conclusive results. Neither Dr. Tang's or Dr. Yang's experimental crops have matured enough to be harvested, and neither researcher has collected enough data to determine how intercropping has affected ecosystem services yet. The oldest research on intercropping, that within the Botanical Gardens, falls short of providing conclusive results, because nobody

harvests the intercropped species to determine their yield; in the Artificial Rainforest, collection of the intercropped species is forbidden. Furthermore, none of the principal researchers on this subject know who taps the rubber in XTBG or if anybody keeps track of latex production.Perhaps the greatest barrier to determining the best methods to both improve environmental variables and the incomes of smallholders is a lack of experimental replication. Dr. Yang's experiment has two replicates in addition to data he intends to collect from the Garden plots, and Dr. Tang's study is a single site (Yang Xiaodong, personal communication, November 11th, 2015, Dr. Tang Jianwei, personal communication, November 16th, 2015).

The Experiment in Man'e:

The World Agroforestry Center in Kunming (ICRAF) is currently designing a scientifically rigorous experiment to thoroughly examine the environmental and economic benefits of various levels of intercropping schemes. The project, called Green Rubber, has received funding to investigate intercropping options in China (XSBN), Laos, and Thailand. In each rubber-growing region included in the study, researchers will conduct initial socioeconomic studies across broad areas before initiating intercropping experiments on smallholder farms in selected villages in the area. The primary investigator, Dr. Rhett Harrison, was involved in the first years of environmentally friendly rubber research at XTBG, and he is now collaborating with the Yunnan Tropical Crops Research Institute (YITC) and the Bio-industrial Crops Office of the Prefecture government in Jinghong to establish an initial study site in the village of Man'e (曼俄), just outside the Botanical Gardens.

曼俄 will be the first of many study villages, in each of which the same intercropping experiment will be replicated. Replication will also occur within each village, with three to five 1ha study plots, each containing four 0.25ha intercropping treatments. The four treatments would

range from least to most structurally complex and are as follows 1) control (no understory, as current conditions), 2) intercropping with a single species of short term economic value, 3) intercropping with many species, including some with delayed economic value like timber and 4) intercropping with many species and allowance for natural vegetation regrowth. Across each experimental treatment, researchers will monitor variables concerning the success of each intercropped species (growth rate, harvest, etc). They will also monitor ecological and environmental variables in each intercropping situation. Although each individual treatment area is small, measuring microhabitat structural complexity and diversity could even serve as indices for biodiversity if the treatment was applied over an extensive area. Through its unique nested design and multi-level replication, Dr. Harrison's experiments could provide the scientifically conclusive assessment of the best general intercropping solution for both locals and the environment, and, because of its scope, it could provide valuable site-specific information to inform future intercropping activities in each study region (Rhett Harrison, personal communication, Nov. 6th-Dec. 2nd, 2015).

This study is especially unique in that the organizers intend a high degree of smallholder participation throughout the process of the experiment. Villagers will participate voluntarily in the study. They will be asked for input beginning with the initial decisions regarding specific intercropping species for each experimental treatment and where study plots will be planted. This project involves the locals early in the detailed decision making process for two reasons: 1) researchers want the participants to take ownership of the project. The smallholders will be the ones to plant the intercrops, and they will have to take responsibility for maintaining them and harvesting them. It is thus very important for the success of this experiment that the farmers feel that they are listened to and that this is their own choice. 2) While the botanists and restoration ecologists know a wealth of general knowledge regarding intercropping theory and potential

plants, the local villagers may have local knowledge regarding potential intercropping species that are particularly suitable to the specific location. Locals may have knowledge that the scientists lack about what species can and cannot be sold in local markets. Furthermore, it is important to gather all sources of information relevant to a project before beginning to avoid making avoidable mistakes. Local knowledge is another source of potentially valuable information.

RESEARCH QUESTION:

Given the intention of Green Rubber to include local participation in the process of designing the specific details of each village-level experiment, I have asked the following research question: **To what degree and through what means can local knowledge inform methods of growing environmentally friendly rubber?**

This question contains two inseparable parts. In asking, **"To what degree,"** I first seek to establish how much local knowledge is really present in the village. Is villager participation important for the sake of learning relevant information, or do we involve the locals simply because we need to win their support for practical reasons? Knowing how much knowledge we can expect to gain from involving locals will help to establish how important their participation is at various stages during the project. Furthermore, how easy is it to access this information? What amount of information can scientists expect to uncover given a limited amount of time to interact with villagers? In asking "**Through what means,"** I seek to learn how scientists can access local knowledge if it is present. How should foreign researchers initiate contact with communities throughout the process of this experiment? Before we can learn from locals, what should foreign researchers consider when trying to harness local participation in the first place? These answers will not only inform future research under Green Rubber, but they should inform

efforts by government agencies and NGOs to introduce environmentally friendly rubber to smallholders at a larger scale.

METHODS

Study Area

The village of Man'e is located only about 2 kilometers west of Menglun, in Menglun township of Mengla County, Xishuangbanna Prefecture. The population of Man'e has risen from around 40 households in the 60s to 170 households and between 800-900 residents today. The village officials consist of a village head and a village treasurer, and five sub-leaders of village sub-districts, although there are many informal leadership roles throughout the community. Nearly all the residents of this village are of the Dai ethnicity, although many Han have immigrated here in the past decades and have integrated into the community. The principle language spoken is Dai, although most younger people can speak Mandarin. The religion is a mix of Theravada Buddhism and an animist religion that preceded Buddhism. The elder generation preserves the community's religious values. In the style of every Dai village in the area, there is a central shrine, a temple by the road where monks live, a sacred burial forest, and various sacred fig trees around the village. The village has two Bozhang, or spiritual leaders. They attained high positions as monks before assuming the responsibilities of guiding religious activities in the village.

In the 1950s and 1960s, villagers relied entirely on what they personally grew and harvests from wild plants such as bamboo shoots, which could be dried and last a family for a year. The staple crop was glutinous rice. Most households owned pigs or water buffalos, and much meat came from the forest. The good hunters went to the forest once a week for meat to eat and share. Up until the 1970s there were no markets for people to sell things for income.

After the Household Responsibility Program in the early 1980s, villagers were permitted to choose how they used their land, and many cleared forests for rubber. By the mid 2000s nearly every household grew rubber (village head). The relatively small Menglun Nature reserve, established in the early 80s, preserves most of the remaining natural forest. Without the nature reserve, villagers would likely continue to convert forest to rubber plantations; some villagers blame the nature reserve for a scarcity of land on which to grow rubber. A tourist attraction within the reserve a few kilometers to the west of Man'e provides locals with some employment, and the locals are permitted to collect "reasonable quantities" of non-timber forest products (NTFP) from the reserve's core area. The village sources all of its water from within the reserve. Hunting and felling trees is prohibited within the reserve, though enforcement of the law is very weak (Wang Guanghai, reserve patrol officer, personal communication, November 20th, 2015).

Currently, villagers purchase rice and most produce at the markets in Menglun. Most meat also comes from the markets in Menglun, although one household in the village still raises pigs to be killed during holidays and celebrations. Many young people in the village still hunt illegally in the nature reserve, but the laws against hunting, the scarcity of natural forest, and the scarcity of wildlife relegate wild meat to the status of a sport.

Most residents own land both in the hills to the north, east and west of the village and also some land in the flat rice paddy fields to the south of the village in the plain between the mountains and a tributary of the Luosuo river (罗梭江). Villagers use the hills around the village for rubber forests and in nearly any direction one walks out of the village, one will encounter extensive and continuous rubber farms. Villagers have mostly converted their rice paddy land to other agricultural activities, and a large vegetable company from Hainan rented much of this land from the villagers four years ago, bringing in low cost migrant laborers from Laos and Myanmar

to pick vegetables such as peppers, eggplants, and cucumbers. Similarly to many areas around Menglun, some villagers grow horticultural plant seedlings for sale with knowledge they derived from working at XTBG. The horticultural nurseries are located along the north edge of the paddy fields.Villagers derive income from a wide variety of sources, but rubber income is the primary income source for the vast majority.

The old highway between Jinghong and Menglun runs through the village, providing villagers easy access to Menglun and the Xishuangbanna Tropical Botanical Gardens, where a sizeable portion finds employment for a supplemental income. Children go to school in nearby Menglun. The average educational level in the village is junior high school, however this village produced XSBN's first Dai PhD.

Dates of the Study

I conducted my study between 11/6/15 and 12/6/15. I used 11/6/15 through 11/9/15 to gather general background information and interview experts in Kunming, and I used 11/10/15 through 11/12/15 and 11/16/15 to gather locally specific background information and interview experts at XTBG. 11/13/15 through 12/6/15 was devoted to an ethnographic community study of Man'e, where I lived as a guest in the home of Bo Zhuangfang and MiehZhuangfang, parents of Yi Zhuangfang, a local who obtained her PhD at XTBG and currently works at the World Agroforestry Center. Yi Zhuangfang, who I met through an exchange of emails, put me in contact with her family.In total I estimate that I spent 376 hours in the field (16 hours awake every day over 23.5 full days in the study village)

To What Degree—Botanical Knowledge

Using input from villagers, the researchers at ICRAF must first decide on what species will be intercropped in the various experimental treatments. The ideal species must both be

native to the area, able to grow well in the shade, and have current economic value for villagers.I identified the major potential sources of local botanical information that could provide insights regarding intercrops suitable for local growing conditions and local markets: 1) currently grown crop species, because these already have markets and villagers know how to grow them, 2) NTFPs from the nature reserve, because these plants have value and they most likely can grow in the shady conditions underneath rubber trees, 3) plants people put around their houses for personal consumption.

1. Currently marketable plants and general household information:I interviewed villagers about their past and current agricultural practices and their knowledge about what crops of economic value would be able to grow in the shade, specifically in the shade of rubber plantations. In this questionnaire I also included questions about villagers' rubber farming methods such as the rationale behind herbicide application. To obtain better background information about the village as a whole, I asked questions regarding rubber farm size, household size, and this year's income. I also asked about villagers' relationship with the local nature reserve and NTFP collection activities to determine the prevalence of NTFP related knowledge in the community. These interviews acted as a way to canvas the community in search of ideas for intercropping from many people. I conducted these interviews at three of the village's four breakfast noodle restaurants. With the exception of the very elderly, every resident, male or female, young or old, eats breakfast at one of these noodle restaurants. I waited until a customer had sat with his or her noodles, and then I sat with him/her and asked if I could ask a few questions for my school project. If they consented, I asked questions following my predesigned survey and added or subtracted questions as seemed appropriate given the conversation. The questions included in the survey changed over the course of my stay in Man'e, as I learned which

questions gave productive, new information and which wasted the participant's time. With practice, interviews could be completed within the time the informant consumed his/her noodles.

In addition to the noodle restaurants, I took advantage of any appropriate opportunity to direct a conversation according to my survey questions. I tried to limit my interviews to village residents and interview only one member from each household so as to prevent repetition of household data. This involved keeping track of people's relationships and clarifying if I felt somebody might be related to a previous informant. In total, I contacted 55 people, or slightly less than 15% of the village population. 6 people were unwilling to talk, leaving me with information regarding 49 households, or about 29% of the village total.Because I did not ask some survey questions to some people and answers were not always clear, the sample size for any given piece of data is smaller than 29%. I will present sample size along with any statistics in the results section. I included data from my host family in statistics from this survey.

To learn about horticultural plants sold as seedlings, I also arranged an interview with a man from the village who owned a nursery in nearby 五乡. I noted potentially shade tolerant horticultural seedlings villagers grew during personal excursions in the area.

2. Wild edible and Medicinal Plants: To investigate knowledge specifically from NTFP collection, I entered the nature reserve on two occasions with locals to learn from them about edible and medicinal plants. The first occasion was with a man called Bo Yinghamla on 11/15/15, and the second was with Ai Yingham, AiJianham, Ai Xiang, Ai Jianand Ai Pom on 11/20/15. On these occasions I asked my guides to point out any edible or medicinal plants they knew of. I followed closely and took notes and photos of each plant. I also took advantage of every opportunity I had to inquire about uses and collection of wild edible and medicinal plants. If people talked about their collection of wild plants during my interviews, I included those in my list. Information about each plant came from many sources, as often even my guides knew only

the Dai name of a plant, and other villagers often offered different opinion on the uses and value of plants. To ensure data was contained within the study system, I only included plants about which villagers in my study village provided knowledge. I relied on help from 岩香甩 and Lily Zeng to identify many species, and I used the website 百度百科 to learn scientific names.

3. Plants grown around the village: I participated in several social events centered on food, including a three day wedding celebration that included copious community cooking, and a one day infant-naming celebration (Man yue).I asked about the origins of different spices, fruits, and vegetables. In an effort to learn past knowledge regarding Dai homegardens, I also interviewed a handful of village elders. During regular walks around the village, I asked villagers opportunistically about the fruit trees and vegetables in their yards.

4. Two other sources of local botanical knowledge relevant to intercropping: I also had the opportunity to observe active intercropping within the village on four adjacent farmer's lands. I arranged guided tours of these farmers' rubber forests, during with I gathered information specific to the farmers' personal agricultural practices and the uses of the plants grown under rubber. A final source of local knowledge came from individuals who provided ideas and suggestions outside of my interviews and guided conversations.

To learn about whether the local botanical knowledge I collected matched up with the scientists' botanical experience, I consulted with 岩香甩 (Ai Xiangshuai), a locally-raised Dai botanist at YITC, the organization responsible for informing intercrop varieties to be suggested for inclusion in the Man'e intercropping experiment. In this way, I hoped to gauge to what degree the knowledge of locally useful plants I had gathered differed from ideas the scientists already had coming into the village. If plants were very different, it could either indicate that the plants names I had gathered were not useful or it could indicate that local experience could

provide new ideas to the scientists. Due to incomplete data and inadequate time, I only asked Ai Xiangshuai to evaluate a handful of the most promising species.

Limitations of study:

Because my research period and botanical knowledge were limited, the following lists do not include all of the potentially hundreds of useful plants that make up the collective lexicon of village knowledge. Of all the village residents with knowledge on this subject, I only learned from a small fraction. Furthermore, my identification of plants relies on local names in Dai and common names in Chinese. As I did not personally identify any of the plants in my study, I cannot guarantee all names are correct. Proper botanical identification using Latin names will be necessary for such plant lists to be practical for informing intercropping projects.

Through What Means—Observation of the Initial Interactions with Villagers

Dr. Harrison, representatives from YTCI, and the Bio-industrial Crops office organized an initial workshop to introduce the Green Rubber experiment to villagers on December 2nd, 2015. The meeting plan explicitly called for an atmosphere in which farmers could air their opinions confidently, where they could participate meaningfully in the discussion. Although Dr. Harrison and others had visited with the village officials the previous year to discuss the idea of the Green Rubber experiment, this was the first significant exposure the village had to the proposed study.

I took advantage of my position within the village to help the researchers at ICRAF and the other involved stakeholders communicate with the village leader to organize the workshop. Through this process, I observed from an insider's perspective scientists entering a community with the intention of establishing an intercropping experiment. I also observed the workshop itself, considering both the audience response and the on-the-spot experience of the scientists

conducting the meeting. I learned some of villagers' perspectives and ideas during the meeting and after the meeting.

RESULTS:

To What Degree—Botanical Knowledge

1. Currently Cultivated Crops: Of these 49 informants, 42 (86%) planted rubber. Of the seven households that did not grow rubber, the primary response was that they did not own land. A number of people in the village have immigrated from elsewhere in recent years.My surveys revealed that in addition to growing rubber, villagers grow 16 species of crops for sale. Out of 39 people I asked, 12 (31%) responded that they grew other crops besides rubber. These range from cereal grains like rice and corn to vegetables like eggplant and bokchoy. Villagers also grow trees for fruit, such as Pomelos and bananas, and one household grew red bean trees for use in making necklaces to sell.

Some of the tree species villagers grow for income could be useful for intercropping. However the vast majority of botanical knowledge regarding crops species concerns vegetables that are typically only grown in full sun.

Table 1: Currently Marketed Plants:

Chinese name	English name or Latin Name	Use or value
红豆树	Adenoniapavonia	Red beans made into necklaces that are sold for 5RMB ea. (wholesale). In market necklaces sell for 20ea, and one villager has an internet business.
菠萝蜜	Jackfruit	Sold as seedlings for 3RMB each, but grafted varieties sell for 25 RMB each. Some people raise the trees to sell the fruits.
荠菜	Fiddleheads	Cultivated in small plots, one bunch sells for 1-2RMB
柚子	Pomelo	Sell fruit for 5-6 RMB per fruit. 8 亩 can produce 10000RMB/yr
菠萝	Pineapple	Sell fruit; this is principle intercrop under young rubber
小黄姜		Principle variety of ginger used in cooking, sells for 2RMB/kg. One 亩 of this can produce 8000RMB
欧洲坚果		Sold as seedlings mostly; occasionally nuts are sold
茶叶	Tea	Both for sale and personal consumption; that for sale sells as a

		lower price than monoculture tea
凤凰树		Horticultural plant sold as seedlings
火焰木		Horticultural plant sold as seedlings
黄花梨		Timber or horticultural species sold as seedlings
木瓜	Papaya	Fruit sold,
四季豆		Vegetable sold.
谷子	rice	Grain sold and eaten
辣椒	Peppers	Sold on a large scale
菠菜	Spinach	Vegetable sold
白菜	Bokchoy	Vegetable sold
青菜	Various leafy vegetable	Vegetable Sold
香菜	Cilantro or other spices	Spices sold
茄子	Eggplant	Vegetable sold
芭蕉	Wild banana	Fruit and flowers sold, leaves used for wrapping meat for barbecues and for preparing glutinous rice cakes
包谷	Corn	Grain sold
沉香树		Seedlings sold
九翅砂仁	Amomumvillosa	Roots sold for a medicinal tea, seeds sold to be processed into a TCM medicine or to be used as flavoring in cooking. Seeds can sell for 30-40 RMB/kg
白花羊蹄甲	Bauhinia variegata	Sold as horticultural seedlings. When grown to maturity, the bark can be used to make rope.
彩霞变叶木	Codiaetumvariegatum	Beautiful red leaved horticultural bush.

2. Useful Wild Plants: A few older individuals collect wild medicinal plants for personal use. One old man harvested the roots of 玉竹 to make a kind of medicinal wine. A western style hospital opened in Menglun in the 40s or 50s, and use of traditional herbal treatments has long since declined. Some villagers know about medicinal plants that have high market value. 花叶开唇兰 can reputedly sell for 450RMB/kg, but there doesn't seem to be a market for it and my informant only learned of its value from a television program. My guides were particularly fascinated with a tree whose wood contains an expensive medicinal fungus but which they cannot feasibly harvest and process at the present. Locals know about many medicinal gingers, such as 黄姜，九翅砂仁，guoha4 and 草果, all of which they occasionally collect and which have economic value. One man actively cultivates 九翅砂仁 in the nature reserve for sale. Knowledge of medicinal plants is still present, though it is not associated with knowledge of folk remedies but rather oriented almost exclusively towards plants' monetary income.

My survey showed that some edible wild plants are used much more than others. The most commonly collected item is red mushrooms (大红菌; mentioned by 8 people). Bamboo shoots is the second most commonly collected item (mentioned by 7 people). Villagers collect large quantities of bamboo shoots for personal consumption and rarely for sale. The Red Mushrooms are mostly for sale. Many other mushrooms have economic value, such as 黄菌 and 奶香菌. I did not include fungi in table 2 because fungi cannot be planted. However after years of successful implementation of the complex intercropping option, valuable fungi might begin to grow naturally. Most villagers are familiar with 子梨果, which they call "Xiao zi li wu." It is a kind of tiny chestnut that looks like a hazelnut and does not come in a spiky fruit. The local variety is too small to be of major economic value at market, so locals simply value this nut as a common snack.

Other wild plants are extensively used as materials in making things. Rattan (省藤) and bamboo become beautiful tables and chairs that villagers sell for profit (100RMB/table). Bamboo collected from the reserve goes into making a diversity of baskets for sale (30RMB each) and for personal use, like for catching fish (although most people use electroshocking now).

Table 2. Wild Plants:

Chinese name	Latin name	Dai name	Uses
团花树	Neolamarckiacadamba		Good quality timber for construction
大红春			This valuable red-colored wood is currently used in signs and wood sculptures for sale
省藤		He wai	Collected from the reserve once a year to be made into tables and baskets for sale
单穗大节竹		Mae hohm2	Used in making tables and stools and baskets and fish traps. Also used in making structures for praying and in making supports in vegetable gardens. Used in making bridges across gullies. Bamboo shoots are extensively harvested from the reserve and anywhere around the village where they grow. Shoots are eaten in many Dai dishes.
苦笋			Edible variety of bamboo shoot

甜笋			Edible variety of bamboo shoot
泡竹孙			Edible variety of bamboo shoot
云南石梓 (酸树)	Gmelinaarborea	guodocshuo	Used to be used for making the barrels for preparing glutinous rice. The wood is extremely fragrant. It is used in making coffins. It is a good timber species and its flowers can be dried and used to make 糯米粑粑。
五加科	Araliaceae	Guo/bai Dang3	Flowers and new leaves are edible
槟榔青	Spondiaspinnata	Goh goick2	Sour fruits are used extensively in Dai cuisine, especially in meat and fish preparation.
三桠果	Baccaurearamiflora	Yi fei4 of yi fa1 (two varieties)	Sweet grape-sized edible fruit high in vitamin C
五桠果	Dillenia sp.		A softball sized sour fruit used to cook soup
(水茄)苦果	Solanumtorvum	Mae viang	a yellow-green pea-like soup fruit that can be stewed with meat. Very popular in this area. Fruits also used in a medicine.
子梨果			Tiny black chestnuts that look like hazelnuts. Very abundant and everybody goes to collect them. They are fried up in oil and eaten as a snack. Not frequently sold, but people do sell them once a year for about 5RMB per kilogram
		Bda	Sour, baseball-sized yellow fruits that can be collected and eaten or cooked but not often sold. Especially good for wildlife.
臭菜	Acaciepennata	Pac la	the finely compound leaves are sautéed and eaten in a soup or in eggs.
荠菜			Gathered, eaten or sold for food. One bunch sells for 1-2RMB
树麻根?		Xigan1	Woody; stems and edible and eaten boiled
九翅砂仁	Amomumvillosa	Man liang	There are two kinds, one has roots that can be made into tea and the other doesn't. The seeds can be sold as a medicine. This medicine sells for 30-40RMB/kg.
		guoHa4	Medicinal roots and seeds. Seeds can be used as culinary spice, and young shoots are edible. A kind of ginger
玉竹	Polygonatumodoratum	Ya hao5mai3	Medicinal root used in making glutinous rice or as a medicine to be steeped in wine.
黄姜		Waan3	A kind of ginger that produces large yellow roots used as a traditional chinese medicine for constipation. Can be harvested once every year and produces a decent yield. 5-7RMB/kg
沉香树	Aquilariasinensis		A kind of wood that has a really expensive cancer-curing fungus inside it
		Xia doehy2	A vine with internal toxins that act as an antiseptic when spread on cuts and scrapes. In the past used to be chewed with beetlenut
花叶开唇兰	Anoectochilusroxburghii	Yabeilai	It is an expensive medicine (1kg could be 450RMB)
		Guozook	Large palm with edible inner core wood.

3. Plants people grow around their houses: Vegetation around the village appears sparsely mixed among the densely spaced houses, but upon close inspection, one finds that most families

have a diversity of useful trees, herbs, vegetables, and vines growing around their homes and that nearly every plant allowed to grow in the village itself is consumed in some fashion. Some families grow larger quantities of vegetables than they can personally consume, which they sell or share with others in the village. Food grown around the village is more significant in people's diets than that collected from the comparatively distant and inaccessible nature reserve.

Table 3. Plants Cultivated Around People's Homes

Chinese Name	Dai name	English Name:	Use
水茄	Ma he4	Water eggplant	Edible vegetable, very common
杨桃		Starfruit	Edible fruits often used to make juice.
菠萝蜜		Jackfruit	Edible fruits
酸叶胶藤			Used in cooking as flavoring
鱼星菜	Pa ha doh		Edible leaves eaten in soup, roots used as a cough medecine
地瓜			Vine with edible tuber
红枣	Median4	Red dates	Edible fruit
油菜花		Rapeseed flower	Edible leafy greens, not used to make oil.
南瓜			Edible fruit
香茅草		Lemongrass	Common spice in Dai cuisine
红豆树		Red Bean Tree	Used to make necklaces for sale.
芒果		Mango	Common edible fruit
鸡蛋果			Common edible fruit
苦藤			Edible leaves and stems
酸角树			Sour fruit used in cooking.
牛角果	Mo Yi		Ground-growing chestnut-like fruit eaten as snack
		Unidentified Ginger	Roots used as medicine for mosquito bites
水香菜			Small-leaved leafy vegetable eaten in soups.
刺五加		Acanthopanaxsenticosus	Leafy green vegetable with properties to reduce blood pressure
番石榴			Edible fruits
冬瓜			Edible vegetable
葱		Onion	Used for flavoring in cooking
葫芦瓜		Bottle Gourd	Edible vegetable
芭蕉	Banana		Personal consumption and use of leaves in cooking
薄荷	mint		Personalconsumption
草莓	strawberry		Personal consumption
美登木		*Maytenus* SPP	Can be used as a medicine
乐梨果			Pine-cone like fruit can be eaten cooked, or made into medicinal wine or tea. It has properties that can cure cancer, improve lifespan, and promote manliness

4. Timber Species: Interestingly, villagers purchase most of their timber for building houses.桂花木 is a high value timber used in house construction and in making wooden parts of furniture. It still grows wild in the nature reserve and here and there among the rubber plantations. Villagers grow 黑心树 specificallyforfirewood, but rubber is equally important for this purpose. 团花树 is a timber tree that grows naturally in the collective forest and in various locations between rubber plantations. Villagers occasionally use wood from this tree to construct long canoes for sale. People know about timber species that are useful and that could grow in the area, such as 硅化木, which is the most commonly purchased timber species, and 大红春, whose dead stump wood (gathered from the reserve) some villagers use in artful wood carvings for sale.

5. Plants villagers directly suggested growing under Rubber: Some villagers did offer insightful suggestions for plants that could be intercropped. After the Dec. 2nd workshop, one man showed me 黄姜, a new kind of ginger nobody else had suggested. Called waan3 in Dai, its roots can make a valuable medicine, it produces large quantities yearly, and it is easily planted. He specifically noted it would suit the intercropping experiment. Another villager suggested that 大叶千斤扳 (Moghania macrophylla; he called it 三金片), could be intercropped under rubber successfully. He had heard this from scientists that came into the village to promote environmentally friendly rubber a couple years previously. Both of these people's knowledge proved anomalous. Other villagers told me that neither 黄姜 or 大叶千斤扳 would work because there weren't nearby markets to sell these products. A third man taught me about the plant he called 乐梨果, This plant can be made into a medicinal wine or tea or eaten cooked, it fights cancer, extends lifespan, and improves manliness, and he said that it would grow very well in the shade of rubber. He grew it on his roof terrace.

6. Current Local Experience with Intercropping:Intercropping is already a common practice under young rubber before it is tapped. Seedlings are planted 3 meters apart from each other in rows of about 7 meters apart, and when they are small, the trees barely shade the ground, allowing for nearly anything to grow on that land. Most commonly villagers grow dense monocultures of pineapple under their young rubber. In one plot, villagers interplant *Adenoniapavonia*, Pomelo, Tea, and Banana with their young rubber. Most villagers are familiar with this form of intercropping. Monoculture pineapple fields are commonly planted under very young rubber. Directly after cutting old rubber, smallholders contract out their land for a few years to "land managers" who plant and manage new rubber seedlings in exchange for the right to grow pineapple under the seedlings.

Of particular interest for intercropping designed to improve the environment over the long term are the plants that grow within the currently tapped rubber forests. On land that has not been sprayed with herbicide for several months, my host family collects useful plants for cooking such as wild onion, garlic, ginger, and a variety of herbs used as flavoring. Very old *Sennasiamea* trees grow between rows of rubber in some places, and villagers customarily leave exceptionally large trees growing amidst their rubber trees. One villager has started leaving saplings of young trees between his rows of rubber trees to prevent erosion. These trees are wild, however, and do not have economic value.

One household interplants 7-8 亩 of rubber trees with pomelo. They planted the pomelo trees at the same time as the rubber, a little over ten years ago, and the fruit trees began producing fruit many years before the rubber trees could be tapped. In a year of good harvest, this household can make over 10,000 RMB from selling their fruits. Unlike most villagers' land, this land is located in the flat bottom of a small valley, and they have left more space between

their rows of rubber trees than the typical 7 meters. On their more sloped land, this household has intercropped tea with rubber for more than thirty years. This family has experimented with intermixing other trees in small accidental clearings within the rubber forest, including a kind of chestnut tree (poor results led them to cut down the chestnut trees). They are currently experimenting with bananas (芭蕉) in both shady and sunny areas under their older rubber trees.

A neighboring farmer maintains several species of intercrops underneath three or four rows of 10 year old rubber. He plants large expanses of passionfruit under the rubber, intermixed with starfruit. In several separate plots he has planted pomelo seedlings, *Acacia pennata, Amomum sp.* and a shade-tolerant red-leafed horticultural bush whose exact name he did not know. This particular man can likely input more labor into his land than the average villager, as, because of his severe physical disabilities, he lives on his land and is probably taken care of by relatives. His extensive plantings are likely an economically profitable hobby.

The household of Ai Wendan and Bo La has over 30 亩 of trees that have been tapped for about twenty years. Two stream gullies border his land and converge at the base of his plot. The understory is very shady. Large stands of bamboo grow along both streams and are harvested for building material and for the edible bamboo shoots.Although the family applies herbicide on portions of their land, their plot of rubber has a much higher plant diversity than neighboring farms. Wendan is very familiar with the plants growing under or near his rubber trees.

He has planted five Baccaurearamiflora (三桠果) or two local varieties in shady locations along the stream gullies at the edge of his rubber, but they only produce limited fruit once every few years. He has planted several mango trees underneath his rubber and along the edges of his plot. These trees produce very few mangos very infrequently. Un-grafted Pomeloshe planted decades ago produce a good yield of fruit, though their bitter taste reduces their market value. A large jackfruit tree, an *Adenoniapavonia,* and a wild pomegranate tree(番石榴 or

Psidiumguajava), all grow successfully under or near his rows of rubber. A wild 酸角树 (Tamarindusindica) also grows by the rubber trees, but it has never produced fruits.

Three kinds of gingers grow in Ai Wendan's rubber forest. The first, called guoha4 in Dai, produces edible shoots, edible roots that taste like ginger, and seeds that can be used as a stomach medicine. He lets patches of these plants grow wild between his rows of rubber trees. Pointing to a patch of*Amomum sp.,* he explained that the yield of this kind of ginger is too low for him to bother harvesting it under his rubber trees, so he actively removes it. Instead, he actively plants a ginger called guogook4 (likely 草果, or *Amomumtsaoko*) that produces edible fruits around the base of the stalks. He sells these fruits at the local market.

The most common intercropped plant is tea, and some people, including the village treasurer, have planted tea extensively under their rubber trees. This crop mostly supports personal consumption and has an inferior taste, according to villagers. One man, Ai Wenxiang, grew 肉桂 (Cinnamon) amidst his intercropped tea. He also had 桂花木 on his rubber farm.

Expert Evaluation of Locally Useful Plants

Of the locally-useful plants I presented to Ai Xiangshuai, most did not correspond to those the experts had already considered in prior meetings. The expert declared a good number of these plants ecologically unsuitable for growing under rubber. However, he considered some plants that had not been on the list previously. These included 黑心树 (suitable for being grown on the edges of rubber farms, where it will not shade out rubber trees)， 云南石梓 (an emergent tree, suitable if planted interspersed so as not to shade the rubber, and 五桠果 (suitable along streams flowing through rubber plantations). Researchers had not considered bamboo, thinking it might grow too sporadically, but following my meeting with Ai Xiangshuai bamboo was added

to the list of suggested species. 臭菜 (*Acacia pennata)* and 水茄(*Solanumtorvum),* both important foods in local Dai cuisine,also had not been considered but was subsequently added to the list for the December 2nd workshop.

To What Degree—Accessibility of Knowledge

Loss of Direct Exposure with Other Crop Species

Over the past few years, villagers have planted fewer kinds of crops, often opting to rent their land. Of the 27 people (69%) who said they do not grow any other crops besides rubber, 16 (59%) cited that they once grew other crops and that they stopped. Of the 12 who still grow other crops, 2 (16%) said they now grow fewer varieties of crops than they did in the past. Overall, villagers considered income from these other crops negligible in comparison to income from rubber, even though the majority of villagers noted that their income from rubber this year was very low. Of the 12 respondents who noted they grew other crops, 50% noted their other crops were primarily for personal consumption, sharing with neighbors, or produced only a negligible amount of income. The most common reason cited for this decline (13 households or 36% of households asked about other crops) in agricultural diversity is that informants rented out their paddy fields, where they used to grow vegetables and cereal grains, to a foreign company from Hainan that now grows vegetables like chili peppers, green peppers, cucumbers, and eggplant.Direct exposure with diverse crop species seems to have decreased in this community.

Decrease in Exposure to Wild and Medicinal Plants

Knowledge about wild edible and medicinal plants could potentially inform species to intercrop underneath rubber. Through my formal interviews and asking about informants' family members, I gathered information about 66 individuals' habits concerning the nature reserve. The

majority of respondents (45 or 68%) rarely or never go to the reserve, and only two of these noted their age as the reason. Some respondents believed the government forbade locals to enter the reserve. 15 respondents (23%) said they go occasionally (or one to three times per year). Only 6 people (9%) go to the reserve frequently, and two of these people said they go mostly to hunt wild animals for sport. Of those who go rarely, occasionally, or frequently, 82% take resources from the forest, including wild or medicinal herbs, illegally killed wildlife, or firewood.

Preconceptions about Intercropping:

My questions related to rubber intercropping varied tremendously but all entailed a description of intercropping, the experiment, and the upcoming workshop and pressed for the informant's opinion. Of the 30 people to which I directly posed the intercropping question, I met only two people who say they intercrop underneath rubber. Four respondents refused the idea of intercropping without citing a reason, and seven refused saying that there was absolutely nothing that could be planted under rubber. Many did note that tea was an option, but they said tea grown under rubber was worthless and tasted bad anyway. Although six people did not provide clear answers, only 37% of people totally refused the idea of intercropping. In total, there were 13 people willing to try intercropping in the context of the experiment. Although not asked why, four people noted reasons that included benefits such as more practical or efficient use of land and increased income. None of the respondents mentioned the ecological benefits of intercropping. Of the 13 interested, 6 clearly expressed that they did not have any ideas for what could be intercropped, and a few directly expressed that they would be grateful for scientists to come give them good ideas.

Through What Means: Observing the Workshop:

Here I will provide a brief, objective summary of the process by which ICRAF, YITC, and the Bio-industrial Crops Office approached the village to introduce the Green Rubber experiment. In my Discussion Section, I will provide an analysis of lessons learned during this process.

Dr. Harrison and the other involved parties planned the initial workshop for November 19th, 2015. The meeting would involve only 9 interested villager participants (as this would provide the necessary amount of land for the experiment) and would include both morning and afternoon sessions of discussion and collaboration in a small-group atmosphere. However, when they called the village leader to ask about the workshop, he told them to call back once they had found another time more suitable for the village, citing rubber tapping and a wedding as reasons why villagers wouldn't have time to participate in a meeting.

Though the exchange of many emails, the researchers agreed on December 2nd, with an initial meeting in Jinghong on November 26th. I conveyed the information to the village head and treasurer, who agreed to allow us to use the village meeting space. The village leader, personally in favor of intercropping, found 8 people in the village willing to let their land be used in the experiment.

Upon meeting with these participants, I learned that their land added up to less than 20 亩 in total, much less than the 45-75 亩 of land required by the experiment. When I told him this, the village leader explained that he would simply make an announcement over the village speaker system and more than enough people would attend our meeting. Although the workshop organizers had planned for a small group of already interested farmers,I realized I would have to settle for the way the village typically handled its meetings: a vocal announcement on the loudspeakers the night before that would gather everybody in the village with time to come.

On the night of December 1st, the village leader called me to say that he didn't think the meeting should be an all day event. The village leader told me that the village usually only had either morning meetings or afternoon meetings and that nobody would take a whole day of their time to meet with us. Without any other option, Dr. Harrison rearranged the workshop to only an afternoon event, forcing him to leave out much of the essential information.

At 2PM on December 2nd, villagers congregated in the outdoor basketball court by the oldelementary school, where meetings are customarily held. Roughly seventy villagers attended in all, including men and women of ages around 30 to around 60. After a brief introduction, organizers asked participants to gather into groups and discuss the benefits and drawbacks to monoculture rubber cultivation. The meeting continued in this way, combining lectures describing the environmental problems of rubber, the necessity for the experiment, and the detailed experimental design with breakout discussion group sessions that gathered participant feedback.

The breakout sections attracted a higher level of interest and participation than the lectures. During these sessions, participants expressed concern that an individual farmer would not have enough land to undertake an experimental plot, and that it would be too complicated and labor intensive for an individual farmer to maintain all four treatments. They worried that even if 4 treatments were broken between four willing households' land, the land wouldn't be continuous. If one family got stuck with an experimental intercropping species that did not produce, they would have wasted time and effort.The villagers pointed out that the soil in rubber forests is no longer adequate for growing understory plants that need moisture. People suggested 三桠果 and bamboo shoots. They provided feedback that didn't exactly match the knowledge the

scientists had come in with. Importantly, participants suggested species that were not on the experts' list of suggested species, such as 磨芋，木瓜，草果， and 菠萝蜜。

Scientists gained useful negative feedback regarding some proposed species, such as rattan, as people immediately recognized that it would climb up the rubber trees. Villagers did not always agree on certain plants, such as 砂仁，which some said had great value but others said did not produce enough. Most suggestions from the meeting were general. Villagers stressed the need for fast-growing plants that produced benefits quickly after planting. They also said intercropped species needed to be short to avoid interfering with the rubber trees.

At the conclusion of the first meeting, we had gathered the names and contact information of 13 willing participants.However, as participants may not have suitable land or may drop out after a while, we felt the need to follow up and find anybody else in the village willing to participate who had left the meeting before we collected people's names. I contacted the village leader and asked him to make announcement to call all interested participants to come register their names. Although he promised he would do it, when the time came for me to pick up the list of names, he had made no announcement, explaining that it wasn't practical. Everybody would participate as long as we told them what to plant, he said, but nobody would register if they didn't know what they would have to plant. We would need to be content with the handful we had already gathered, hoping that nobody dropped out.

After the meeting, organizers planned to hold another meeting with potential participants in the experiment. They set the date for December 16th and 17th. Only after talking with many villagers did I learn that these dates could potentially conflict with Dai holiday called 关门节，or "Closed Door Day." The holiday, involvingcommunal praying and feasting, would make any meeting about rubber intercropping sparsely attended. However, none of the villagers agreed on the dates of the celebration. I called the village leader, but even he couldn't tell me the dates.

Finally I found the two villageBozhang. Because they disagreed on the dates, I asked for a lesson on the Dai religious calendar. In the process of that lesson they reached a consensus on the dates of 关门节 and I was finally able to confidently tell the scientists at ICRAF to shift the dates of their second meeting to the 17th and 18th. Only through this kind of deeper understanding of the local customs and religion were we able to avoid planning a workshop over a major holiday.

DISCUSSION:

Local Knowledge is Present and Useful

My data suggests that there is a phenomenal potential for local knowledge to inform rubber intercropping projects. Through living with the locals and learning exclusively their knowledge for three and a half weeks, I learned about 26 species grown as crop plant, 28 species collected from the wild, and 28 species grown around people's homes. My rate of learning did not slow during my time there, and if I had stayed another month my records of local botanical knowledge could very well have doubled. According to my conversation with Ai Xiangshuai,there were a number of examples where local botanical knowledge could prove helpful.The list of locally-useful plants I provided Ai Xiangshuai was hardly complete, but there were some species important to the local villagers that researchers had not considered previously. This showed that gathering some knowledge of local plant use can provide useful new information to guide the design of rubber intercropping projects.

Furthermore, those species that were both already included in the scientists' plant lists and already grown or collected by local villagers could be especially promising for the intercropping project, given the convergence of both local and scientific knowledge about them. In this way, gathering local knowledge can help to narrow down the list of possible intercrops to the most suitable ones.

Local Knowledge is Very Difficult to Access

However, this knowledge is incredibly difficult to access for two reasons: first the majority of villagers know very little. As shown in my surveys, only a minority of rubber farmers cultivate other crops species besides rubber and even they consider those other crops as negligible compared to the income from rubber. This means that planting knowledge of use for intercropping could be on a decline as well. If people deal with fewer plant species on a daily basis, they may have less creative suggestions regarding intercropping options. Furthermore, botanical knowledge of wild plants is increasingly uncommon. Up until the 1970s, 50-60% of people's diets in this village came from wild plants, and an estimated 60% of men and women knew how to collect wild food (Bo Yingham, personal communication, December 4, 2015). But my survey found a strikingly small fraction of villagers go even occasionally to the reserve today. With increased incomes, access to convenient markets in Menglun, and a decrease in natural forest, nobody can rely on wild food as they did in the past. With the notable exceptions of highly valuable items such as the principle mushroom species, bamboo shoots, and perhaps *Amomumvillosa*, collection of wild plants has become a hobby or recreation. During my interviews, I found that people seldom provide specific names of wild plants (or even their own cultivated plants) during conversations in the village, and only when one accompanies a local into the fields or into the forest will the local remember the names and uses of plants. Because going to the nature reserve is now a recreational activity, one must look much harder to find a person who has time to act as his guide.

The second reason is that villagers with useful experience may see their knowledge in the context of rubber intercropping. Even my host family, who grew jackfruit seedlings underneath rubber, told me nothing could grow under rubber. When interviewing Yi Layue about

intercropping she said that tea could be intercropped but that not much else could. During our conversation, she failed to mention that her family actively intercropped pomelos under rubber at a large scale. Furthermore, she had actually missed the December 2nd workshop because she was busy planting intercrops under her rubber trees. Before visiting his rubber farm, Ai Wendan only told me he didn't like the idea of 三桠果, but he neglected to mention his mangos and ginger and all the other plants of value growing in the shade of his rubber trees. His name was not on the list of willing participants at the end of the workshop, and he did not offer his advice about 三桠果 when the scientists suggested in as a promising intercrop.

The majority of people I surveyed did not express interest in participating in the intercropping experiment because they didn't know what could be intercropped. Perhaps all of these respondents knew of a tree or bush of value that would do well under rubber. If you passed that plant with them they would tell you about its name and its functions. But they have never thought of it in a rubber-intercropping context. So if you asked about rubber intercropping they would still tell you little.

For locally-specific botanical knowledge to be of use to the intercropping project, researchers must gather it by bits and pieces here and there. They must learn about aspects of the community that initially seem irrelevant to rubber intercropping and combine them into a meaningful whole.Despite how I tried to organize the sources of the local knowledge I collected, I found pieces of knowledge everywhere, even in my friend's wood-carving studio (where I learned that villagers really would value 大红春). To go through such trouble is entirely justified, as not only will one learn the most appropriate plants to intercrop given local uses and experience with planting/harvesting, but one will also gain a deeper appreciation of the village that can only allow one to better tailor the intercropping design to locals' needs.

What Worked in Engaging the Villagers:

The workshop organizers designed the meeting in a way that reflected the unique focus of Green Rubber on harnessing local participation to gather useful local knowledge and establish a collaborative atmosphere. The first activity encouraged the villagers to think up both positive and negative aspects of monoculture rubber cultivation. In this way, the meeting could begin based on a background knowledge provided by the participants themselves, and scientists did not lecture villagers about their situation. Throughout the meeting, villager interest peaked during the several breakout discussion groups, indicating that, as expected, asking villagers for their input is the best way to engage them. Also, the organizers presented their list of specific intercropping options only after gathering ideas from villagers, which allowed participants to come up with their own ideas rather than simply respond to the ideas provided by the experts. This experience provides an example of how future such meetings can maintain a collaborative atmosphere and engage villagers to best gather their input.

Lessons From the Initial Contact with Villagers

The process of organizing both the first and the second workshops provide evidence that when scientists intend to have a meaningful dialogue with villagers about anything, especially something as complex as the ICRAF experiment, they need to dedicate an abundance of time to establishing a practical understanding of the community. Only then will they have a suitable platform on which to learn relevant local knowledge. Here are a few ideas to help improve the process in the future:

1. The first step would be to establishclose communication with the village leader. I foundthat the village head was not only essential to every aspect of organizing the workshop but

also a close ally in finding people to participate in the experiment. He was personally willing to intercrop on his land, and he looked for willing participants. He broadcasted the meeting details to the village and he let us use the village meeting area and microphone and speaker. We could not have achieved initial contact with the villagers if it was not for the village head.

Increased communication with the village leader would smooth the process and eliminate the spread of misunderstandings. If we had had clearer communication with him initially, he may have been more helpful in finding a small group of interested participants which whom we could have begun conversations with in the first meeting. If the village leader could have introduced the experiment to the villagers before we arrived and gathered participants, we would not have had to devote the entire first meeting to gathering participants ourselves.

2. Maintain contact with multiple locals during the weeks before entering the community. First, this would be infinitely useful in scheduling meetings with the villagers. Villagers are quite busy with both agricultural commitments as well as traditional holidays and celebrations. To convince villagers to care and participate in the project, scientists need to be careful to respect villagers' time. Having close contact with the village would let scientists understand what the best times are for villagers' to meet with them. For example, with contacts in the village, scientists could have anticipated that the rubber-tapping season ended only on 11/20 and that the massive wedding celebration might distract villagers from a rubber-intercropping meeting. This knowledge could have prevented the mistake of scheduling the initial workshop on the 19th.

3. Learn who in the village is critical to organizing village events.While both Chinese and foreign scientists may be accustomed to a system in which the government official will reliably provide information about important dates in a community, in Man'e one must talk to the village religious leader (bozhang) to learn reliable dates for village events. Because the specific dates can be calculated well in advance using the religious leader's special books, if organizers met

with the village religious leader and discussed the upcoming calendar in depth, they could learn the important dates to steer clear of well in advance.

Overall, all of these suggestions can be reduced to learning about the community better before introducing the experiment. Workshop organizers would find many benefits in an initial visit to the village for the sole purpose of familiarizing themselves with the community. At the minimum, such a visit, coupled with basic interviews of residents, could have revealed that villagers' land may not be as large or as continuous as planners had originally anticipated, knowledge essential for knowing how many participants to gather for the experiment. Also, an initial visit could have alerted planners to the benefits of using Dai rather than Mandarin in the workshop presentations, as most villagers only learn Mandarin as a second language. In a second workshop two weeks later, 岩香甩 presented in Dai and received a much greater degree of participation from villagers.

Understanding Locals' Psychology: Risk Averseness

After talking with many villagers following the meeting, I realized that a lack of specific details deterred people from participating. My host father explained to me that most people wanted to wait to see what intercropping designs worked best before they decided to intercrop on their land. Villagers didn't know what to plant underneath their rubber trees and so they wanted the researchers to tell them what to plant before they would commit to participate.

This directly contradicted the philosophy of the project, which relies on first having a core group of willing participants who would come prepared to contribute their ideas, then harnessing those ideas to make the specific decisions. People's reluctance to participate because of lack of knowledge begins a negative feedback loop that compounds the problem of lack of knowledge

This issue may have arisen because organizers underestimated how risk-averse villagers are. This year villagers are feeling economic pressures that, while in some ways make intercropping more appealing, in other ways make villagers nervous about wasting time on economically unproductive activities. We must appreciate that the economic benefits of intercropping must compete with the tried and true income from simply commuting to the nearby town for work.

A better appreciation of this risk-aversion could potentially help organizers design the meeting in a way that would capture a larger number of people to participate in the second meeting where specifics would be discussed. After first gathering ideas from villagers, organizers could spend more time presenting each plant in their list of suggested plants to show villagers' who feel they don't have ideas that the scientists can provide suggestions. Perhaps organizers could point out situations in which intercropping has succeeded. According to my own informal conversations with villagers and my morning surveys, locals' preconceptions of intercropping are on average too pessimistic.

At the same time, it is very important not to mislead farmers with a false sense of security. The nature of the results is simply that some treatment options will provide farmers more income than others. Raising people's expectations to attract participants for an experiment designed to address a lack of confidence in what will work—this could be unethical. Workshop organizers should learn about villagers' preconceptions before introducing the experiment and then aim to increase confidence in intercropping as a general concept, while avoiding "tricking" farmers by exaggerating benefits of any particular intercrop or treatment option.

<u>Make Friends with the Locals:</u>

I cannot stress enough the importance of establishing close friendships with the local villagers. While better communication with key village leaders and better practical knowledge of the communityare essential for establishing the platform from which to learn from locals (i.e. the meetings and workshops), the scientists must develop a friend relationship with participants in order to involve them productively in the intercropping experiment.

Perhaps the most substantial evidence of this comes from the day of the initial workshop. Wanting to treat the researchers and government officials to a decent meal within the village, I asked several of my local friends to arrange enough motorcycles to take the workshop organizers to the nature reserve, where they could explore the forest and have a Dai style barbecue picnic for lunch. On the morning of the second, a dozen local men buzzed up to the reserve and prepared a magnificent feast for the dozen or so foreign visitors. Ecologists, botanists, and local officials ate and drank and laughed in the forest with the local men until it was time for the meeting.

Over the three hours of the meeting, those in attendance dwindled to only about twenty people. I looked at the names of the thirteen people who had signed up and expressed their interest in our experiment. Perhaps these men truly felt more confident about intercropping. Perhaps they had understood the mandarin in the lectures more clearly. Perhaps they were naturally more apt to try new things. But most of them were my closest friends in the village, those who I had gotten to know best during my time there. And most significantly, they were almost exactly the same group of young men with whom we ate lunch in the forest that morning.

CONCLUSION:

With natural forests dwindling, biodiversity, water supplies, and local climate hanging in the balance, finding solutions for environmentally friendly rubber is an urgent priority. The

Green Rubber project of ICRAF in Man'e comes at a time when villagers are suffering from a severe drop in the latex price, an example of the income instability associated with monoculture rubber cultivation. The project will search for conclusive evidence of what is the best intercropping solution both for the people and the environment. The organizers of Green Rubber envision an experiment in which farmers take ownership of the experiments they've planted on their land, which requires including locals in the initial decision-making processes and uncovering relevant local knowledge. Such knowledge has potential to be useful in tailoring the design of the intercropping project to local needs and local experience, which would make such projects better welcomed and more successful. So how much local knowledge can the researchers expect to find and how hard should they search for it?

My results indicate there is significant botanical knowledge present in this case study village that can directly inform what species are intercropped in the experiment. Villagers cultivate an incredible variety of plants for income and for personal consumption. Some people have decent level of knowledge regarding the wild edible and medicinal plants. Through talking with locals, one could compile an immense amount of information about the economic value of local plants, both wild plants and cultivated ones. Despite this prevalence of knowledge, it is relatively inaccessible. This is because only a few villagers have the majority of the knowledge, and they often do not see their knowledge as relevant to rubber intercropping. There is a kind of psychological mental block preventing them from linking their local knowledge to our goals of intercropping. So researchers will have to engross themselves into the community and study all aspects of villager life to gather disparate pieces of local knowledge. Only the researchers can put the pieces into a meaningful whole.

Becoming more familiar with the community as a whole—not just the aspects most obviously related to the intercropping project, would also facilitate the process of engaging

villagers and gathering their interest and participation in the project. As many examples from the first contact with villagers in Man'e showed, maintaining closer communication with the village and learning more about it before entering would make the initial contact more effective and easier on a logistical level. Many practical problems could be avoided through an initial visit to learn about the community. Furthermore, developing an understanding of villagers' psychology regarding the project could help organizers anticipate and plan for farmers' preconceptions. Sending a person to establish a close contact with the village weeks before the first workshopcould both facilitate communication between researchers and the village and help develop the friend-level relationship necessary between villagers and scientists for optimal results.

Only when you develop knowledge about the community will the community's knowledge become available to you. This conclusion is applicable not only to all the future study villages in the Green Rubber project, but also for conservation initiatives targeting rural communities all over the world.

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Suggestions for Future Research

曼俄 is a good study site for questions 1 and 3, and nearby 城子 could be suitable for question 2. 勐仑 is good for question 4. XTBG is good for question 5.

1. The psychology of littering and improper waste disposal in rural China—what prevents people from properly throwing away their trash rather than simply throwing it on the ground? Through what means can community organizers encourage less littering?
2. Are Dai holy hills and sacred forests as important to communities as they used to be, and what implications has this had on conservation of biodiversity in Xishuangbanna?
3. How have people's relationships with the forest changed since it became a nature reserve? What is the psychology behind illegally hunting in the reserve, and is there potential within the community for a locally-based movement to stop illegal hunting?
4. Why do children drop out before high school? How does the Chinese education system handle minority students that speak Mandarin as a second language?
5. To what degree does the academic community at XTBG interact with local, neighboring Dai communities? Is there potential for XTBG to improve villagers' biological and

botanical education? Could the academics provide locals with pathways to success through involvement in XTBG research?

References

Bhagwat, S.A., Willis, K.J., Birks, H.J.B. & Whittaker, R.J. (2008). Agroforestry: a refuge for tropical biodiversity?*Trends Ecol. Evol.,* 23, 261-267.

Benton, T.G., Vickery, J.A. & Wilson, J.D. (2003). Farmlandbiodiversity: is habitat heterogeneity the key? *Trends Ecol. Evol.*,18, 182-188.

Chazdon, R.L., Harvey, C.A., Komar, O., (2009). Beyond Reserves: A Research Agenda for Conserving Biodiversity in Human-modified Tropical Landscapes. *Biotropica* 41(2); 142-153

Chen, J., Su, Y.C., Chen, G.Q., Wang, W.D. (1999).Ethnobotanical studies on wild edible fruits in southern Yunnan: Folk names; Nutritional value and uses. *Econ. Bot.*53(1):2-14.

Davis, B. (2015) China's High hopes for Growing all Those Rubber Trees. The New York Timeshttp://www.nytimes.com/2015/05/28/world/asia/chinas-high-hopes-for-growing-those-rubber-tree-plants.html?smid=fb-share&_r=1

Gouyon, A., Foresta, H., Levang, P., (1993). Does "jungle rubber" deserve its name?An analysis of rubber agroforestry systems in southeast Sumatra.*AgroforestrySystems* 22, 181-206.

Hauser, I., Martin, K., Germer, J., et al. (2015). Environmental and Socio-economic Impacts of Rubber in the Mekong Region: Challenges for Sustainable Land Use. 10 (27) 1-11

Hu, H.B., Liu, W.J., Cao, M., (2008). Impacts of Land Use and Land Cover Changes on Ecosystem Services in Menglun, Xishuangbanna, Southwest China. *Environmental Monitoring and Assessment* 146: 147-156

Kai, Z., Woan, T.S., Jie, L., Goodale, E., Kitajima, K. (2014). Shifting Baselines on a Tropical Forest Frontier: Extirpations Drive Declines in Local Ecological Knowledge. *PLoS ONE* 9(1): e86598.

Li, H., Aide, T.M., Ma, Y., Liu, W., Cao, M. (2007). Demand for rubber iscausing the loss of high diversity rain forest in SW China.*BiodiversConserv.* 16(6):1731–1745.

Liu, W.J., Hu, H.B, Ma, Y.X., Li, H.M., (2006). Environmental and Socioeconomic Impacts of Increasing Rubber Plantations inMenglun Township, Southwest China.*Mountain Research and Development*, 26(3):245-253.

Myers, N., Mittermeier, R.A., Mittermeier, C.G., Fonseca, G.A.B., Kent, d.J., (2000).Biodiversity hotspots for conservation priorities.*Nature* 403, 853–858.

Qiu, J., (2009). Where the rubber meets the garden. *Nature* 457, 246–247.

Robbins, P., Chatre, A. &Karanth, K. (2015).Political Ecology of Commodity Agroforests and Tropical Biodiversity.*Conservation Letters*, 8, 77-85.

Schillo, N. 2012. Prospective forests and farmers' perspectives: the politics of rubber trees and ecological restoration in southwest China. M.A. thesis, Simon Fraser University, Burnaby, British Columbia, Canada.

Sturgeon, J.C.,Menzies, N.K.,Schillo, N. (2014) Ecological Governance of Rubber in Xishuangbanna, China.*Conservation and Society* 12(4): 376-385

Xu, J., Grumbine, R.E., Beckschafer, P. (2014) Landscapetransformation through the use of ecological andsocioeconomic indicators in Xishuangbanna, SouthwestChina, Mekong region. *Ecological Indicators*;36:749–56

Xu, J., (2011). China's new forests aren't as green as they seem.*Nature* 477, 371.

Yi, Z.F., Cannon, C.H., Chen, J., Ye, C.X., Swetnam, R.D. (2014). Developing indicators of economic value and biodiversity loss for rubber plantations in Xishuangbanna, southwest China: A case study from Menglun township. *Ecol Indic*, 36:788-797.

Zhang, J.H., Cao, M. (1995) Tropical forest vegetation of Xishuangbanna, SW China and its secondary changes, with special reference to some problems in local nature conservation. *BiolConserv* 73:229–238

Zhu, H., Xu, Z.F., Wang, H., Li, B.G., (2004) Tropical Forest Fragmentation and its Ecological and Species Diversity Changes in Southern Yunnan. *Biodiversity and Conservation* 13: 1355-1372