The Relationship between Ecosystem-based Adaptation with Poverty Alleviation: A case study from Southwest forest communities in China.

Beilu Duan
August, 2017

Master Thesis Committee:
Professor Maria Carmen Lemos,
Assistant Professor Robyn C. Meeks,

School for Environment and Sustainability (SEAS),
University of Michigan, Ann Arbor

Table of contents:

Chapter 1: Introduction:

Poverty is a long-lasting societal problem; by 2004 one fifth of the people living in developing countries still struggle with absolute poverty and over 76 percent of the poor live in rural areas (World Bank 1990, Ravallition et al. 2007). In this context, climate change impact is expected to disproportionally worsen poverty conditions, especially in rural areas that have natural resources-based economies likely to be negatively affected by flooding and drought that further exacerbate their poverty (Olson et al. 2014). According to the International Panel on Climate Change (IPCC), climate change adversely influences poor livelihoods and assets by mainly negatively affecting agriculture production and food price, and through climate disasters (Olsson, et al. 2014, Hertel, Thomas W. & Rosch, D. S. 2010). Rural households' livelihoods, such as planting crops, extracting forest products and raising livestock, largely depend on natural resources, making them generally more exposed and sensitive to climate variations and climate disasters.

However, there is growing evidence that anti-poverty interventions can and do work as in, for example, the Millennium Development Goals program, through which absolute poverty dropped by nearly half (United Nations 2015). Hence understanding the factors that drive their success is paramount (Banerjee and Duflo 2011; Lemos et al. 2016).). This understanding is particularly important in the case of triple win interventions that combine anti-poverty, climate resilience and sustainable development actions (Denton et al. 2014) such as ecosystem-based adaptation (EbA). Through restoration, conservation and management of biodiversity and ecosystem services, scholars and policy-makers, increasingly believe that many of the problems at the intersection of climate change and poverty can be addressed (Secretary of Convention on Biological Diversity, 2009).

Ecosystem-based adaptation (EbA) uses biodiversity and ecosystem services to help people to adapt to the adverse impacts of climate change (Secretary of Convention on Biological Diversity, 2009) and often overlaps with other social-economical goals such as sustainable development and poverty alleviation (Muang et al. 2014). In China, poverty highly overlaps with ecological vulnerable areas that are sensitive to climate change (Oxfam 2009). China's southwest mountainous area, although high in biodiversity, is one of most ecological vulnerable area in the country.

This study focuses on an ecosystem-based adaptation project under China's policy "Grain for Green" implemented by the government in southwest China's forest communities. It aims at exploring the links between ecosystem-based adaptation (EbA) and poverty alleviation and adopts a basic-needs approach (BNA) to measure poverty (Hicks & Streeten 1978). Moreover, it examines the effect of government-funded EbA initiatives on rural households' life quality and subjective well-being (SWB) (Sen 1991). In BNA, the fulfillment of needs may be measured by the concept of subjective self-determination that is similar to subjective well-being (Guardiola & Garcia-Munoz 2011). Both subjective fulfillment of needs (hereafter SFBN) and subjective well-being (hereafter SWB) are measured with self-evaluation, which, in turn, is affected by social-economic contexts as well as personal perceptions. SFBN is a self-comparison approach that is relatively more absolute in terms of standards and consensus and may be a better indicator for poverty. In our study, we use both SFBN and SWB as outcome variables to regress how they may be affected by social economic factors, demographic characteristics and EbA intervention projects.

Specifically, this thesis has two main goals. First it seeks to better understand the intersection between poverty and climate impact and how it affects rural livelihoods in China. Second it aims at exploring how EbA can play a role in mitigating their negative impact in these livelihoods. This study addresses three main research questions:

1. Is EbA correlated with the subjective fulfillment of basic needs?
2. If yes, how does EbA correlate with the subjective fulfillment of basic needs?
3. How can EbA help poor households improve their fulfillment of basic needs?

This study is divided in four parts. In Chapter 2, we review the literature relevant to poverty and climate change impacts on the poor, including research on forest community and poverty, ecosystem-based adaptation and China's anti-poverty policy. Chapter 3 describes the case sites in detail and the methodology employed in this study to address the research questions. Chapter 4 presents the statistical model and the results of the analysis. Chapter 5 discusses the meaning these results and suggests future research to further address the research questions. Finally, we conclude with a discussion of our third research question and suggest some policy recommendations.

Chapter 2: Literature Review:

❖ Poverty

Poverty is a multidimensional phenomenon. The poor are those who lack food security, basic needs, income and assets, investment assets and freedom of choice (UN 1995, MFA 2002, Reardon and Stephen 1995). The narrowest definition of poverty emphasizes absolute economic income, while others include aspects like social inequity and hunger. Poverty is a phenomenon that occurs more in developing countries compared with developed countries (Chen and Ravalltion 2008). In 1990, nearly half of the people in developing countries lived below the poverty line of $1.25/day but this number dropped by 44% by 2015 under the Millennium Development Goals (United Nations 2015). Compared with urban poverty, rural poverty is still dominant around the world, particularly, in developing countries (Jazairy et al., 1992). According to the World Bank, while only 58 percent of the total population live in rural areas, over 76 percent of the poor are rural population (Ravallition et al. 2007).

There are many circumstances leading to the rural poverty. Dalal-Clayton et al., for example suggest that rural poverty may be caused by the following processes: policy-induced processes; dualism; population growth; natural resources and management; natural cycles and processes; the marginalization of women; culture and ethics; exploitative intermediation; internal political fragmentation and civil strife; and international processes such as globalization (Dalal-Clayton et al. 2003).

To better understand poverty and its solutions, the Basic Needs Approach (BNA) emerged in the 1970s and has been viewed as an alternative method to measure development and the reduction of poverty, especially for absolute poverty (Jolly 1976, Hicks and Streeten 1978). Unlike income approaches which focus on monetary growth, the multidimensional basic needs approach recognizes the essential role of meeting or improving human basic needs including food, shelter, education and health in achieving development (Gultung 1980, Streeten 1981, Streeten et al. 1981). Some scholars criticize this approach, claiming that the concept of basic needs is much too vague. They also claim that BNA aims at reaching consumption outcomes rather than focusing on building the capability that people need to eradicate poverty (Ghai 1978, Streeten 1984). However, while other approaches such as the cost of obtaining basic needs (Ravallion 1998) along with Sen's capacity approach (Sen 2001, Alkire 2005) have been developed to complement the BNA, the basic needs approach remains one of the most important ways measure poverty and development such as those achieved in the Millennium Development Goals (Ki et al. 2005, Tsui 2002, Watson 2014, Sumner 2003).

Fulfillment of basic needs can be measured through objective and quantitative approachs such as absolute poverty line or basic needs indices (BNI) (Ravallion 1998, Ki et al. 2005). It can also be captured by self-determination approaches that overlap with the concept of Subjective Well-Beings (SWB) (Tay & Diener 2000, Diener et al. 2002, Guardiola & Garcia-Munoz 2011).

Both SFBN and SWB are affected by culture and social contexts. Subjective fulfillments of basic needs, based on self-evaluation, focuses on basic standards of living, which include basic food supply, shelter, health, and education (Streeten et al. 1981).

Subjective Well-Being (SWB) is defined as a person's cognitive and affective evaluation of his or her life (Tay & Diener 2000, Diener et al. 2002, Guardiola & Garcia-Munoz 2011). Studies show that subjective well-being also correlates with factors that affect personal perceptions; it can be more susceptible than SFBN to factors such as personalities, age, gender, wealth, education status and specific situational factors (Diener et al. 1999, Diener & Suh 2000, DeNeve et al. 1998). In particular, subjective well-being incorporates comparisons of one to one's neighbors and one's cognitive goals that may shift across age or generations. In some contexts, people have been found to adapt to adverse living conditions and showed higher subjective well-being than expected (Clark 2009). In terms of the links between poverty and subjective well-being, some studies have found that in contexts where most of the income is used to meet people's basic needs, there is a positive relationship between subjective well-being and absolute income as opposite to relative income (Diener and Biswas-Diener 2002, Rojas 2015, Asadullah and Chaudhury 2012).

- **Forest communities and poverty**

As one of the most important natural resources human depends on, forest supports the living of rural communities that live near it. According to the World Bank "More than 1.6 billion people depend to varying degrees on forests for their livelihoods. In developing countries about 1.2 billion people rely on agroforestry farming systems that help to sustain agricultural productivity and generate income" (World Bank 2002). The Center for International Forestry Research (CIFOR) divides forest communities into four categories based on their relationships with forests: 1) Forest dwelling populations, who reside in forested environments and are highly depend on forests; 2) Agriculture populations living near forests, who use forest as a way to diversify their livelihoods; 3) Agriculture populations with agroforestry resources, who plant trees in their farm land; and 4) Forest product producers, who trade forest products and employees of forest-product enterprises (Arnold 2001). This study focuses on agroforestry and agricultural communities living near forests in southwest China.

To the poor who depend on forest ecosystems, forests link with poverty in a complex way. On the one hand, forests provide them with food, timber products and non-timber products, ecosystem services, and employment opportunities that could help them reduce their poverty (Angelsen and Wunder 2003, Arnold 2001, Sunderlin et. al., 2003,). One the other hand, living in rural forest areas means heavily depending on natural-resources that are increasingly unstable due to environmental changes like land degradation and climate change (Scherr 2000, Maraseni 2012), which in turn may lead to further poverty. Moreover, poverty in forests may also be caused by 1) economic reasons like the fluctuation of markets, 2) physical reasons like remoteness, and 3) other social-political reasons such as the marginalization of certain groups (i.e. ethnicity, gender), inequality, lack of land rights, low capacity of local institutions and management systems, and unequal forest policies (Levang et al. 2005, Scherr 2000, Arnold 2002, Angelsen and Wunder 2003).

❖ **Climate change and poverty**

In recent decades, climate change has become an emerging factor linked with poverty especially in rural communities because of people's dependence on climate-sensitive incomes (Scones 1998; Olson et al. 2014; Lemos et al. 2016). According to Intergovernmental Panel on Climate Change (IPCC) report, climate change such climate-related hazards and changing climate trends affect the poor by affecting their livelihoods and assets, e.g. decrease of crop yields, losses of structures such as houses, tools, irrigation and roads, and increasing food price (Olsson et al. 2014, Hertel and Rosch 2010). Moreover, it is estimated that climate change will continue disproportionately influencing the poor mainly through agricultural production and uncertain food price even though influences differ spatially and timely.

Relative to forest-dependent livelihoods, climate change may affect forest ecosystems by changing of forest production, water provision, pest regulation and other ecosystem services (Dasgupta et al. 2014). Under climate stress, impacts are likely to increase mortality of temperate trees (especially big trees) (Allen et al. 2010) and change patterns of wildfires and of outbreak of insects (Adams et al. 2012, Edburg et al. 2012). There is also high certainty that that climate change will affect biomass change in tropical forests (Dasgupta et al. 2014). All these impacts are likely to further expose and increase the sensitivity of forest dependent livelihoods.

Climate change impacts in China

In China, climate change brings tremendous impacts on agriculture, humans, and the economy. Since the 1990s, climate extremes-related disasters have cost two thousand lives annually and average of US$20 billion annually in economic losses (China Climate Change Plans, 2013). While on the one hand, research on the agricultural sector have speculated that increasing levels of CO_2 may increase crop productivity and improve food security in China (Ye, Liming et al. 2013, Xiong 2009), on the other, China has experienced impacts of heavy rainfall, heatwaves and drought in the past few decades (Piao et al. 2010). In the south, severe droughts and floods caused by heterogeneous rainfall disturbed the cultivation of staple food such as rice and led to food insecurity (Oxfam 2009). In China's southwest mountainous area, it is projected that mudslides caused by heavy rainfall may destroy farmland as well block roads. Also, heavy snows affect economically important forests such Chinses fur, and constant rainfall could severely reduce the productivity of maize. It is projected that in the next few decades, southwest China will experience a decrease of annual rainfall days and an increase in annual precipitation due to the increase of oscillation in rainfall patterns (Zhai et al. 2005). These trends of increasing impacts from extreme events are more significant to smallholder subsistence farmers not only because of their dependency on climate sensitive resources, but also because of their lack of resources to outweigh the adverse impacts as large commercial farmers do. Piao et al. suggested adaptation options that may be used to reduce the negative impacts, including increased use of fertilizers (Huang et al. 2007), expanded irrigation (Wang et al. 2009); and diversification of crops through genetic engineering etc. (Liu et al. 2009, Zhou et al. 2007).

Climate change adaptation and poverty alleviation in forest communities

Climate change adaptation may help to reduce poverty caused by climate stressors. For example, proactive adaptation may alleviate poverty for the poor in tropical Africa who suffer from low production of food due to increasing climate variation (Sanchez 2000). Moreover, climate change adaptation may also reduce chronic poverty by building generic adaptive capacities that are beneficial to both adaptation and development to alleviate poverty (Eakin et al. 2014, Tanner & Mitchell 2008). By reducing the potential losses and damages in the future that will be caused by increasing climate change, adaptation may also be a cost-beneficial approach to reduce the investments on development and poverty alleviation (Stern 2007). Finally, although climate change and poverty alleviation overlap because have the same goal of improving people's well-being (Eriksen et al. 2007), they should not substitute each other as they still have different focuses. Indeed, poverty alleviation and climate change adaptation may trade-offs or conflict, which needs further research to illustrate (Cannon and Muller-Mahn 2010).

In the forest communities, climate change adaptation and poverty alleviation may be linked through natural resources and their management (Innes and Hickey 2006). Agroforestry has been found to help in climate issues as well as development (Garrity 2004, Torlakson and Neueld 2012). Also, co-management of forest resources is likely to empower people and foster solutions to solve the problem of land rights and inequity that lead to poverty (e.g. Richards 2003, Glaser and de Silva Oliveira 2004).

- **Ecosystem-based Adaptation**

Ecosystem-based adaptation (EbA) is the use of biodiversity and ecosystem services as part of an overall adaptation strategy to help people adapt to the adverse effects of climate change (Secretary of Convention on Biological Diversity, 2009). Approaches include sustainable management, conservation and restoration of ecosystems for the purpose of providing services to help people adapt to climate change impacts. Specifically, for terrestrial forest communities, EbA may include interventions of conserving or restoring forest on the land slope to reduce landslides or losses of water (Pramova et al. 2012); or developing diversified agroforestry to deal with climate variabilities (Tengö and Belfrage 2004, Thorlakson, T. and Henry, N. 2012); and conservation of agrobiodiversity to provide specific gene pools for crops or livestock to adapt to climate change.

EbA as a natural solution to climate change has been acknowledged to also have many co-benefits beyond the adaptation (UNDP 2015). Studies have shown that EbA can be more cost-effective and accessible to rural communities than adaptation interventions that use hard infrastructures or engineering methods (Jones et al. 2012, Vignola et al. 2015). In rural areas, EbA usually overlaps with other social-economic goals such as sustainable development and poverty alleviation, especially for smallholder farmers (Munang et al. 2014, Campos et al. 2014, Howe et al. 2013, Munang et al. 2013). In terms of evaluating the outcome of EbA, 63% of peer-review papers and 31% grey literature show quantifiable evidence of success (Doswald 2014).

However, most of the evaluations only use physical and biological parameters (e.g. disaster reduction, crop yields) or absolute monetary improvements to measure influence of EbA (Wamsler et al. 2016, Fedele et al. 2015), which may downplay other outcomes. Some use community perceptions based on experience but still with a focus on biophysical changes. Furthermore, there are even less studies illustrating and measuring the co-benefits of EbA although there are numerous studies showing the contribution of forest ecosystem to poverty alleviation, and how adaptation helps with poverty (Martin et al. 2010, Tanner & Mitchell 2008). This study uses a case study in China to provide quantified social economic evidence for how Ecosystem-based Adaptation (EbA) overlaps poverty alleviation through the lenses of fulfilment of basic needs and subjective well-being.

❖ **Rural livelihoods, diversity and climate change adaptation**

In recent decades, the livelihoods approach has dominated the analysis of rural lives worldwide (Scoones 2009). Livelihood perspectives recognize the essential value of the intersection of multiple disciplines (i.e. ecology, political, social and economic aspects) in addressing complex rural development processes. In this tradition, in the 1990s, Scoones et al. advanced the notion of sustainable rural livelihoods, which place rural development in a long-term perspective while focusing on environmental changes and stressors (Chambers and Conway 1991, Scoones 1998). In this sustainable livelihood framework, access to a range of assets that are influenced by organizational structures and institutional processes could lead to different livelihood strategies. For example, human capital in terms of knowledge and skills are essential to expand and sustain new livelihoods (Ellis 2000). However, access to knowledge and technical assistant happen mostly via organizations and external support although farmers also acquire limited knowledge and information through market and social networks (Bebbington, 1999). Here, limited education will directly affect the sustainability of specific livelihoods, especially in rural areas where education access is constrained by remoteness of villages and households' social economic status. For example, Chen et al. found that in rural China low human capital is a result of both lack of access to education and group marginalization, which include divorced and widowed women (Chen 2012). Similarly, knowledge-intensive sustainable practices have been gradually replacing green revolution practices that highly rely on outside chemical inputs and technology transfer. This change, however, requires more active learning and empowerment beyond solely technology demonstration in pursuit of sustainable livelihoods (Rolling and Van De Fliert 1994, Anandajayasekeram 2007).

Many studies showed that increasing the livelihoods diversity can reduce the local's vulnerability to climate variabilities by providing a wide range of options of livelihoods that have different sensitivity under climate risks (IUCN 2013, Howden et al. 2007). In particular, when addressing climate change, the rural poor may take five types of actions, depending on their resources and assets, to cope with or adapt to climate change: mobility, storage, diversification, communal pooling and exchange (Agrawal and

Perrin 2009). Expanding livelihoods is also a strategy to generate more income source and thus alleviating poverty if diversification does not conflict with labor needs (Ellis 2000). Drivers of livelihoods diversification may vary from autonomous coping strategies under climate variabilities to proactive governmental policies and projects, and the support from other institutions (Osbahr 2008).

In facing the climate impacts or variation, well-off households often find it easier to diversify their livelihoods when compared with the poorer ones as the former have more capitals and assets to access multiple options at different scales (Ellis 2000, Maraseni 2012). The poor, however, generally may only rely on their own or limited support at the local level.

❖ **Climate change and Poverty in China, Grain for Green policy**

In China, rural poverty areas largely overlap with ecologically vulnerable places which include southwest mountainous areas and southern lowland. According to Oxfam (2009) people's lives largely depend on vulnerable natural resources in these areas. Thus, climate variation, which has greater impacts on ecological vulnerable areas, is one of the main stressors that lead to rural poverty. For example, in 2005, 42 % of the six-hundred poorest counties were affected by severe adverse impacts from climate disasters. Frequent severe drought threatens people's food security in Northwest China Yongjing county. Although the government provides people with cash subsides for natural disasters, whenever drought occurs they fall back in poverty due to shortages of food and income. Oxfam (2009) also indicates that as the impacts of climate change increases over next few decades, it will increasingly aggravate current rural poverty.

During the four-decade period since 1970, China has experienced fast economic growth but at the price of deforestation and land degradation (Liu and Diamond 2005). Huge losses in natural resources and corresponding ecosystem services led to catastrophic social-economic consequences as well as losses of people's lives through frequently severe climate disasters including floods, droughts and dust storms (Liu et al. 2008). In order to tackle the problem of over production of grains together with the restoration of nature resources and their services, in 1999 the Chinese government enacted the Grain for Green policy at the upstream watershed of Huanghe, Yangtze River and Zhuajiang (SFA 2003). This policy aims at returning the farmland located on steep slopes to forest land to conserve water and soil and thus mitigate climate disasters. The Chinese government also encouraged restoration of forests on unused lands. Restored forests constitute two types: ecological forests, which are mainly used for conservation purposes, and economic forests that may also provide timber or non-timber forest products. Depending on the area of replaced farmland, government compensates farmers with monthly cash subsidies and grains that last for five to eight years depending on forest types. Many studies have focused on the effects of Grain for Green policy to show that this policy successfully reduces climate disasters while barely affecting food security at the national level (Dan-Feng et al. 2006, Xu et al. 2006, Liu et al. 2008). However, the Grain for Green policy may have significant effect on food supply and livelihoods at local scale or household level (Feng et al. 2005). Xu et al. and Li et al. suggest that most households gain from the policy, but some may lose depending on factors like household's dependent ratios and livestock structures (Li and Liang 2010, Xu et al. 2006). Zhang et al. analyzed the long-term policy effects on household's livelihood sustainability and found that as cash subsidies accounts for 15% of the income, when government stop subsidizing forests, people may not be able to produce food or gain enough income to maintain the quality of their lives (Xie et al. 2010, Knight 2009). Contrary to what the government hoped, incomes from livestock livelihoods did not show significant increase. Additionally, people are seeking more off-farm jobs as a strategy facing the land use changes. However, due to the remote nature of rural areas, travel to cities and conduct off-farm livelihoods are also difficult for rural farmers.

Chapter 3: Methods & Case Study Site

Data Sources:

In this study, we use the data from the Poverty and Environment Network (http://www.cifor.org/pen/). In particular, we use data from a survey conducted by Dr. Nicholas John Hogarth in Tianlin county, China during 2006-2007 under the framework of Poverty and English Network questionnaire version 4. In addition, we also use data from field observations and narratives from Dr. Hogarth's account (with his permission).

Case Study Site

This study focuses on subtropical forest communities in Tianlin county (24- 25° N, 105- 106° E), which is located in Guangxi, in the Southwest China. The majority of the people in Tianlin county belong to the Zhuang ethnic group with others in Yao, Han groups. Tianlin county is characterized by low and middle altitude mountain ranges (200m-1900m) and many river valleys (Tianlin County Government 2007). Tianlin consists of two types of mountainous landscapes: one is Kast rocky mountain (5.2%) which is barren and lacks forest resources and water; the other is a loaming sand mountain (94.8%) which lies in low land and is surrounded by narrow rivers. With a typical subtropical climate, Tianlin has an annual average temperature of 17-20 ° and 1,300-1500 mm of precipitation. Most of the rainfall concentrates in the summer and is scarce during other seasons. This climate pattern makes the county, especially the southeast low land, subject to flooding during the rainy seasons and droughts in the high land in early spring and fall (Tianlin County Government 2007). Outbreaks of pests in crops also threatens people's livelihoods in spring and fall. There are other natural disasters like strong winds, hail, earthquakes but they are not as intense and severe as floods or droughts.

Tianlin is on Chinese national-wide list of the 592 "National Poorest Counties" (IFAD 2010). The remoteness of rural villages and its lack of natural resources are the main reasons of poverty in Tianlin county. For rural farmers, the main income is from forest products such as Badu bamboo shoots and Tung-oil seeds (Youtong) and farmland crops including rice and maize. Tianlin has a long history of cultivation of Badu bamboo (*Dendrocalamous latiflorus*) (Tianlin County Government 2004, Tianlin County Government 2007). Tianlin county has been entitled "Hometown of Badu Bamboo" in 2009.

Between 1996-2000, Tianlin County Government, together with a private company that process and market bamboo shoots, conducted "Liulong Farm Bamboo Migrant Project" (henceforth referred to as "the Bamboo Project") to relocate close to 4,000 nearby households who had poor natural resources bases and high levels of absolute poverty to Liulong Farm specifically to grow bamboo shoots as a cash crop (Tianlin Poverty Alleviation Office, 2004). This project has been seen as an ecological poverty alleviation project as it combines both concepts of "Grain for Green" policy which transfers the sloped farmlands to forests or restore under-used lands to forests in the upstream watershed as to conserve soil and water; and "8-7 poverty alleviation plan," which help people to develop new livelihoods as to alleviate their poverty (Guangxi county annals committee 2013). As part of the contract with the cooperated private bamboo company, migrant bamboo households were only allowed to grow bamboo on their allocated bamboo forest lands (1~2 ha depends on the household size) and exclusively sell their harvested bamboo shoots to the company (Tianlin Poverty Alleviation Office, 2004). However, most households were able to farm on other under-used lands for other crops such as maize and vegetables but not rice as it is generally restricted by the "Grain for Green" Policy (Hogarth 2014). Migrant households received grains and cash subsidies for five years until 2000, when the newly planted bamboo started to produce bamboo shoots and was able to be sold for basic income (Tianlin Poverty Alleviation Office, 2004).

In this case study, village and household sample were selected based on following procedures (Hogarth 2014):

"Three out of 14 of Tianlin's townships were purposefully selected for this study to provide the best presentation of county's forest cover, geographic and socioeconomic diversity. Two administrative villages were randomly selected from each of the three townships. Then, two natural villages were randomly selected from each of the six administrative villages. Finally, twenty households from each of the 12 natural villages were randomly selected using the local's government's household record (note that for practical purposes, natural villages with less than 20 households and those without year-round access were excluded from the sample), making a total sample of 240 households (80 households per township, 40 per administrative village, and 20 per natural village) (Table M1, Figure M1)." Among all the selected villages, village 2 Guopu and village 4 Pingzhaixin are the only two villages that are in the Bamboo Project.

Sample townships	Total No. of admin. villages in townships	Randomly selected admin. villages	Total No. of natural villages in admin. villages	Randomly selected natural villages	Total No. of hhs in natural villages	No. of hhs selected & sampling intensity (%)
Liulong Township	18	Mentun	6	1) Mentuntun	76	20 (26%)
				2) Guopu	63	20 (32%)
		Zhongtun	6	3) Zhongtuntun	52	20 (38%)
				4) Pingzhaixin	31	20 (65%)
Badu Ethnic Township	17	Fuda	6	5) Fudatun	88	20 (23%)
				6) Liutun	60	20 (33%)
		Bailiu	5	7) Zhaotun	37	20 (54%)
				8) Nadu	29	20 (69%)
Nabi Township	5	Nala	12	9) Dongta	24	20 (83%)
				10) Nalatun	58	20 (34%)
		Liuyin	7	11) Daping	30	20 (67%)
				12) Liuyintun	78	20 (26%)
Total	**40**	**6**	**42**	**12**	**626**	**240 (46%)**

hh = household

Table M1. Sampling intensity of study villages and households in Tianlin County (Table Made by N. Hogarth).

Figure M1. Study sites; Tianlin County, Guangxi Zhuang Autonomous Region, P.R. China (Map made by Ron Ninnis and N. Hogarth)

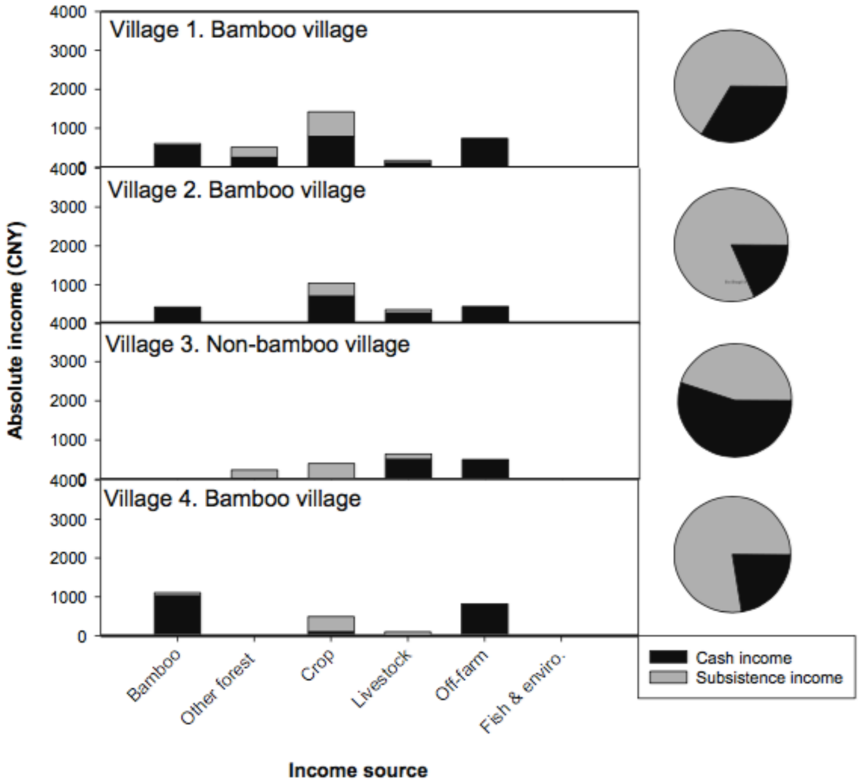
Nicolas Hogarth summarized the basic geographic, demographic and climate characteristics of six administrative villages (Table M2, Hogarth 2014) and the livelihood incomes of 12 natural villages (Figure M2-a, b, c.). Additionally, bamboo project households differ in initial economic status and forest resources, which are summarized in Figure M3-a, b.

Township	Liulong		Badu		Nabi	
Admin. village	**Mentun**	**Zhongtun**	**Fuda**	**Bailiu**	**Nala**	**Liuyin**
Geographic coordinates	N24°09'13.1" E106°09'10.1"	N24°09'43.5" E106°10'58.2"	N24°09'44.7" E106°10'10.8"	N24°19'38.0" E105°49'58.5"	N24°05'52.3" E105°39'22.3"	N24°06'21.5" E105°52'06.6"
Annual rainfall (mm)	1,200	1,200	1,300	1,350	1,450	1,300
Elevation (m)	361	396	345	345	413	863
Dist. to town market (km)	15	7	0	4	27	8
Dist. to county market (km)	35	~30	~60	~60	~100	~100
No. of households	199	202	368	211	345	255
No. of people	804	841	1,638	902	1,715	1,303
No. per household	4.04	4.16	4.45	4.27	4.97	5.11
Ethnicity	Zhuang 42% Yao 33% Han 25%	Zhuang 84.5% Yao 15% Han 0.5%	Zhuang 80% Han 14% Yao 6%	Zhuang 100%	Zhuang 96% Han 4%	Han 69% Zhuang 31%
Recent calamities	Minor drought, fire, pests & social unrest	Minor drought & flood, serious pest problems	None	Minor flooding	Minor drought, flood & pest problems	Minor drought, serious pest problems

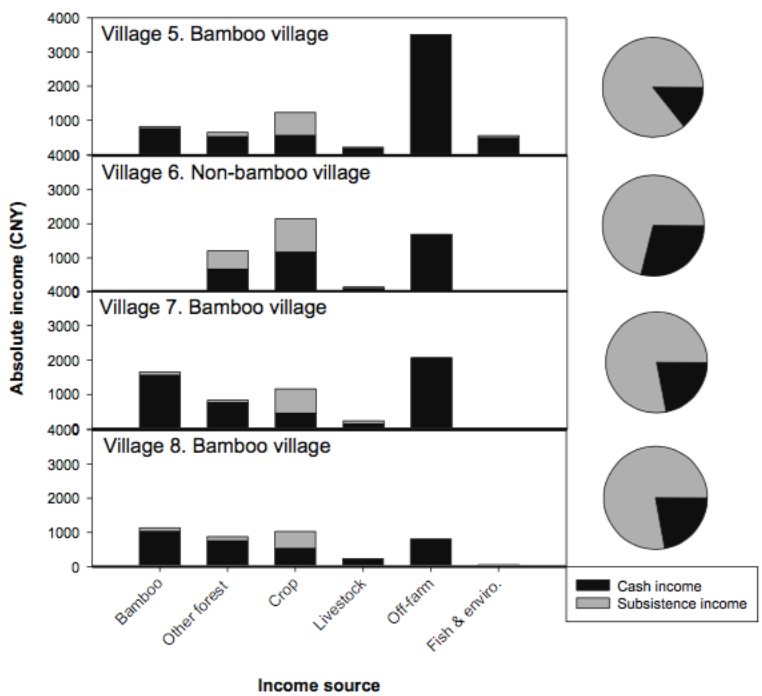
(Tianlin County Government, 2007; Tianlin County Population Statistics, 2007)

Table M2. Geographic, climate and demographic information for the six administrative villages in the sample. (Table Made by N. Hogarth).

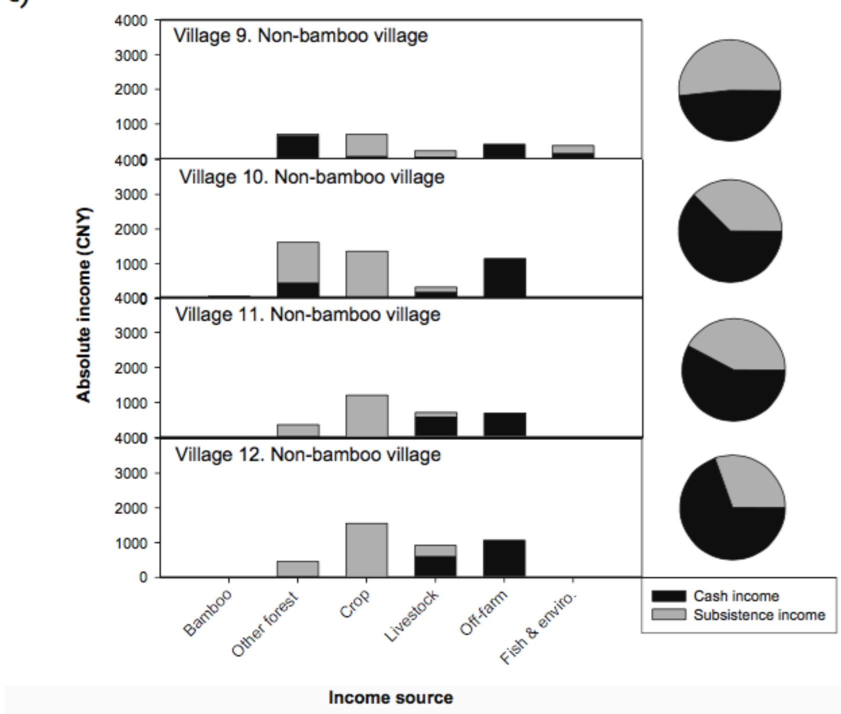
a)


Village 1. Bamboo village
Village 2. Bamboo village
Village 3. Non-bamboo village
Village 4. Bamboo village
Absolute income (CNY)
4000
3000
2000
1000
0
Bamboo
Other forest
Crop
Livestock
Off-farm
Fish & enviro.
Income source
Cash income
Subsistence income

b)


Village 5. Bamboo village
Village 6. Non-bamboo village
Village 7. Bamboo village
Village 8. Bamboo village
Absolute income (CNY)
4000
3000
2000
1000
0
Bamboo
Other forest
Crop
Livestock
Off-farm
Fish & enviro.
Income source
Cash income
Subsistence income

c)



*"Bamboo villages" indicate the average bamboo income accounts for 10% or more of the total income.

Figure M2- a, b, c. Livelihood spectrum and differences in the composition of cash and subsistence income. CNY equals to RMB which has a currency rate of 7.7 to dollars in survey year. (Figures made by Hogarth.)

Figure M3-a, b. a) it shows the difference in initial economic status at the beginning of the survey among the bamboo project households; b) project households have slightly difference in the sizes of bamboo forests, which was allocated depending on the household sizes.

Due to missing data or the presence of outliers, the valid sample size is 220. In order to explore the relationship between poverty alleviation and EbA, we selected and aggregated two outcome variables and twelve socio-economic and demographic variables to conduct our main ordinal logistical regression (Table M3). We are particularly interested in the variable "Bamboo Income", "Bamboo Project" and the interaction of these two. The main model is shown as below:

$$\begin{aligned}\boldsymbol{Sujective\ Fulfilment\ of\ Basic\ Needs\ (Subjective\ Well\ Being)} &\sim \boldsymbol{bamboo\ income} \\ &+ \boldsymbol{bamboo\ project} + \boldsymbol{bamboo\ income} * \boldsymbol{bamboo\ project} \\ &+ \boldsymbol{non\ bamboo\ climate\ income} + \boldsymbol{non\ climate\ income} \\ &+ \boldsymbol{income\ diversity} + \boldsymbol{agroforestry\ area} + \boldsymbol{farmland} + \boldsymbol{flood} \\ &+ \boldsymbol{drought}\ \&\ \boldsymbol{pest} + \boldsymbol{dependents\ ratio} \\ &+ (\boldsymbol{random\ variable\ villages})\end{aligned}$$

Variables	Details	Ranges	Units
Subjective Fulfillment of Basic Needs (SFBN):	Sufficiency of food and income in meeting basic needs. 1=not sufficient (n=11), 2: just sufficient (n=87), and 3=sufficient (n=130). In the regression, the odds ratio of higher level(s) of SFBN versus lower level(s) has been used for outcome variable.	1, 2, 3	Level
Subjective Well-Being (SWB)	Life satisfaction level. We aggregate the original five levels into three. 1= very unsatisfied or unsatisfied, 2= neither unsatisfied or satisfied, 3= satisfied or very satisfied. In the regression, the odds ratio of higher level(s) of SWB versus lower level(s) has been used for outcome variable.	1, 2, 3	Level
Bamboo Income	Annual total net income from bamboo harvests (Raw bamboo shoots and processed ones).	0 ~22	1,000 RMB
Bamboo Project*	A binary variable indicates whether people participate in the bamboo project. 0=In the project, 1=not in the project.	0, 1	NA
Bamboo Project*Bamboo income	An interaction term of bamboo project and bamboo income as to explore the moderation effect of bamboo income in affecting the correlation of bamboo project with SFBN.	NA	NA
Non-bamboo climate income	Annual total net non-bamboo agricultural income which are sensitive to climate change. It includes other forestry income (i.e. Yongtong seeds), crops, vegetables, and livestock.	-4.5~38	1,000 RMB
Non-climate income	Annual total income from non-climate-sensitive livelihoods. It includes incomes from small business, wages and subsidies.	0~44	1,000 RMB
Income Diversity	Total number of income sources. (e.g. bamboo raw shoots, meat sells)	3~22	NA
Farmland Area	Total area of farmlands that cultivate crops and vegetables.	0~3.4	Hectare
Agroforestry land	Total area of forest plantation lands for timber and other cash forest products. It is opposed to protected natural forests.	0~12	Hectare

Flood*	A categorical variable indicates the occurrence and severity of flood. 0= no flood, 1= minor flood, 2= severe flood. It is measured at village level.	0, 1	Level
Drought and Pests*	A categorical variable indicates the occurrence and severity of drought and its related pest disease. As pest disease is highly linked with drought, we combine drought and pest disease into one variable. 0= no drought or pests, 1= minor drought and pests, 2= minor drought and severe pests.	0, 1, 2	Level
Dependents Ratio	The household ratio of children under 12 and adults older than 60.	0~1	NA
Villages	The village number that households are in. Using as a random variable in the regression, it aims to take the geophysical characters into account when predicting the SFBN or SWB.	1,2,3,…, 11,12	NA

*measured at village level, otherwise at household level.

Table M3. Details of eleven variables in the ordinal logistic regression.

In our main ordinal logistic models, we used software R, package “ordinal”, command “clmm” to regress predictor variables on SFBN and SWB (Rune Haubo Bojesen Christensen 2015). In addition, in order to assess the marginal effect of bamboo project condition on bamboo income, we conducted simple slope test by follow tutors given by J. F. Dawson (Dawson 2014).

1. **Results from the Main Model:**

Table 1 shows the results of how all predictor variables correlated with Subjective Fulfillment of Basic Needs and with Subjective Well-Being (Table R1-a, b).

$$\boldsymbol{Sujective\ Fulfilment\ of\ Basic\ Needs\ (Subjective\ Well\ Being) \sim bamboo\ income} \\ \boldsymbol{+ bamboo\ project + bamboo\ income * bamboo\ project} \\ \boldsymbol{+ non\ bamboo\ climate\ income + non\ climate\ income} \\ \boldsymbol{+ income\ diversity + agroforestry\ area + farmland + flood} \\ \boldsymbol{+ drought\ \&\ pest + dependents\ ratio} \\ \boldsymbol{+ (random\ variable\ villages)}$$

		Subjective Fulfillment of Basic Needs (SFBN)	
		Coef.	Expo. Coef.
Bamboo project	Binary (0=BP)	2.0011	7.3968
Bamboo income	Per 1,000 RMB	0.5714 *	1.7707
*Bamboo project*Bamboo Income*		-0.5950 *	0.5516

Non-bamboo climate income	Per 1,000 RMB	0.0746 *	1.0775
Non-climate income	Per 1,000 RMB	-0.0446	0.9564
Income diversity	Continuous	0.1187	1.1260
Farmland area	Continuous	0.0254	1.0258
Agroforestry area	Continuous	0.3472 *	1.4151
Flood	Binary	0.5530	1.7384
Drought & pest	Continuous	-0.9950 *	0.3697
Dependents Ratio	Continuous	0.5476	1.7291
n=220	*Signif.codes: '***' 0.001 '**' 0.01 '*' 0.05 LogLik= -146.37, AIC=320.75*		

Table R1-a. Results of the ordinal logistic regression on SFBN.

As we can see from Table 1, the variable of "Bamboo Project*Bamboo Income" is significant, which means both are significantly correlated with SFBN (P<0.05). The variable "Bamboo Income" is also significantly correlated with SFBN (P<0.05), suggesting that the more bamboo income that bamboo project households have, the more likely they have higher level of fulfillment of basic needs.

In addition, for the subjective fulfillment of basic needs, variables "non-bamboo climate income" and "agroforestry land" are statistically significantly correlated, positively (P<0.05). This suggests that the larger the non-bamboo climate income and bamboo agroforestry land area, the more likely households have higher level of fulfillment of basic needs. Moreover, for each increase of 1,000 RMB of non-bamboo climate income, and bamboo income or an increase of one hectare of agroforestry land, the odds ratio of higher level of fulfillment of needs increases up to 1.08, 1.77 and 1.42, respectively.

Moreover, variables "drought and pest" is significantly negatively correlated with the subjective fulfillment of basic needs (P<0.05). It indicates that the occurrence of drought will decrease the odds of higher subjective fulfillment of basic needs versus lower ones by 0.37. Meanwhile, variables measuring "non-climate income", "income diversity", "farmland area", "dependents ratio" are not statistically significantly correlated with the subjective fulfillment of basic needs (P=0.06, 0.09, 0.95, 0.48).

		Subjective Well-Being (SWB)	
		Coef.	Expo. Coef.
Bamboo project	Binary (0=BP)	0.9400	2.5600
Bamboo income	Per 1,000 RMB	0.2100	1.2337
*Bamboo project*Bamboo Income*		-0.2568	0.7735

Non-bamboo climate income	Per 1,000 RMB	0.0395	1.0402
Non-climate income	Per 1,000 RMB	0.0371	1.0378
Income diversity	Continuous	-0.0621	0.9398
Farmland area	Continuous	0.0989	1.1040
Agroforestry area	Continuous	0.5150 **	1.6736
Flood	Binary	-1.0309 *	0.3567
Drought & pest	Continuous	-0.8660 *	0.4206
Dependents Ratio	Continuous	1.0550	1.9981
n=220	*Signif.codes: '***' 0.001 '**' 0.01 '*' 0.05* *LogLik= -172.87, AIC=373.75*		

Table R1-b. Results of the ordinal logistic regression on SWB.

For subjective well-being, only the land dedicated to the agroforestry is positively correlated significantly with it (P<0.05), while both climate crisis "flood" and "drought and pest" are negatively correlated. It suggests that the more climate dependent income, except for bamboo, and the more agroforestry land area, the more likely people will feel satisfied with their lives. Specifically, for each increase of 1,000 RMB of one hectare of agroforestry land area, the odds ratio of higher levels of fulfillments versus lower ones increase by 1.67, which is about 15% higher than its effects on SFBN. Also, both flood and drought decrease people's satisfaction with their lives. The adverse effects of drought and pest on SWB is about 15% higher than its effects on SFBN.

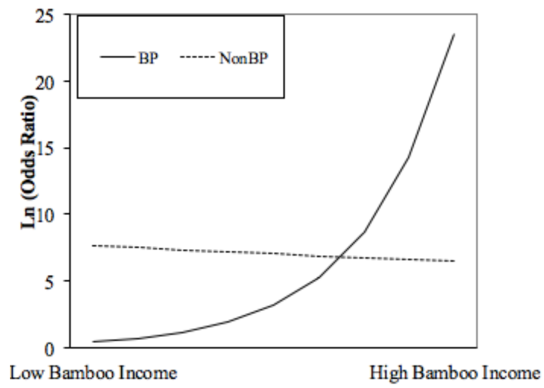
1. **The moderation effect:**

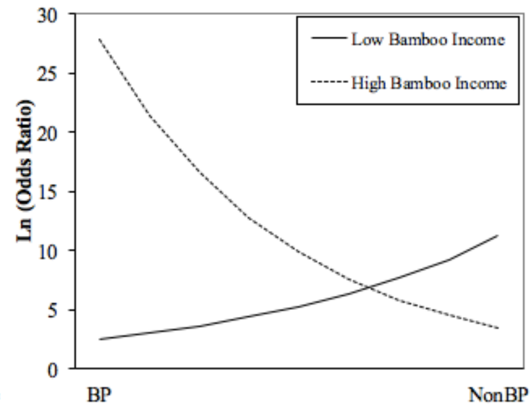
The moderation analysis involved all three variables that we are interested in: "Bamboo Project", "Bamboo Income" and the interaction "Bamboo Project*Bamboo Income". This analysis tells us how specifically, bamboo income and being in the bamboo project affect each other's correlation with SFBN.

We detected from the model and results in Table R1-a that bamboo project and bamboo income can serve as each other's moderator. In other words, they each affect the other's relationship with subjective fulfilments of basic needs. Also, by conducting the simple slope test, we find ranges of bamboo incomes that significantly correlated with SFBN or not.

On the one hand, bamboo project is a statistically significant moderator of the general linear relationship between bamboo income and SFBN (P<0.05). It means that the effects of bamboo income on SFBN is significantly different depending on whether a household is participating in the bamboo project. For example, if one non-project bamboo household starts growing bamboo shoots, earning 1,000 RMB from bamboo income cultivation does not significantly affect their quality of life. However, for the poorer households in bamboo project villages (Guopu or Pingzhaixin), an additional 1,000 RMB will significantly increase their quality of life.

Figure 1 shows how bamboo income affect the SFBN through the moderator bamboo project (Figure 1). Specifically, for households who participated in the bamboo project, the higher the bamboo income they have, the more likely they have a higher SFBN (P<0.05). For other households without the bamboo project, the result suggests that bamboo income has a slightly negative correlation with SFBN while this correlation is not significant.

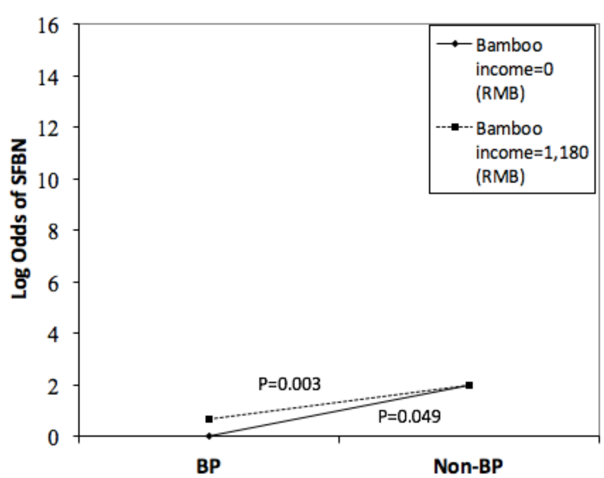




*The y axis "Log odds ratio" refers to the logistic result of the ratio of the probability of be in the higher levels of subjective fulfillment of basic needs versus the probability of lower ones.

Figure 1. Figure 2.

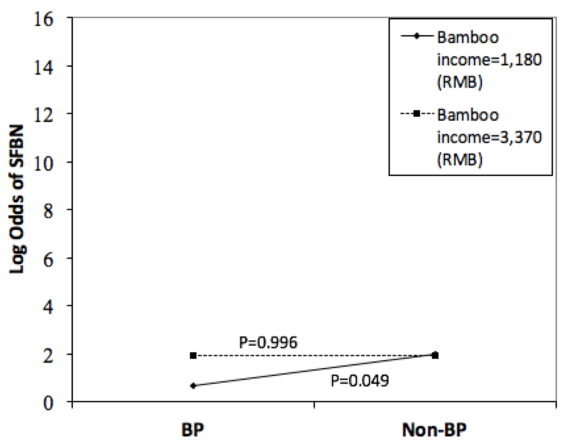
On the other hand, bamboo income is also a statistically significant moderator of the general linear relationship between bamboo project and SFBN (P<0.05, Figure 2). In other words, depending on bamboo income, bamboo project significantly affects SFBN and this effect varies significantly among different bamboo incomes (P<0.05). For example, the Bamboo Project does not significantly affect households in bamboo project villages with 5,000 RMB bamboo income while it brings higher quality of life for households with 10,000 RMB bamboo income compared to households in Zhaotun (non-bamboo project) with same bamboo income.

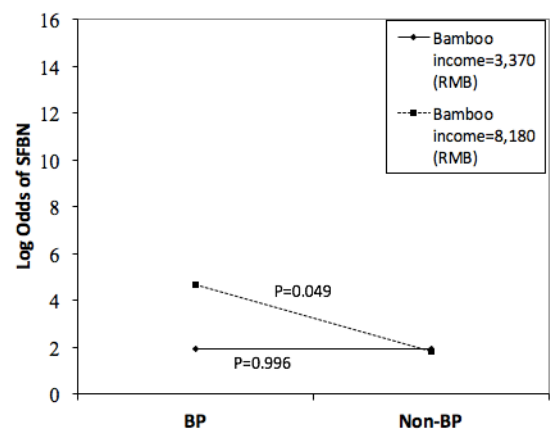


*The y axis “Log odds of SFBN” refers to the logistic result of the ratio of the probability of be in the higher levels of subjective fulfillment of basic needs versus the probability of lower ones.

Figure 3-a.

Figure 3-a plots the effect of bamboo project on the SFBN when bamboo income among the households ranges from 0 to 1180 RMB. As can be seen from the figure, households in the bamboo project have significantly less SFBN than non-bamboo project households although this difference declines as bamboo income increases (P<0.05). In addition, households in bamboo project villages with higher bamboo income show a significant higher probability of having better SFBN (P<0.05).

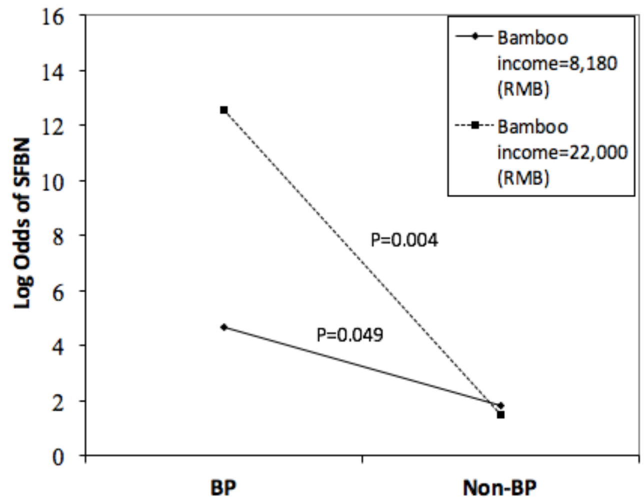




*The y axis “Log odds of SFBN” refers to the logistic result of the ratio of the probability of be in the higher levels of subjective fulfillment of basic needs versus the probability of lower ones.

Figure 3-b. Figure 3-c.

Figure 3-b and Figure 3-c separately plot the effect of bamboo project on the SFBN when household’s bamboo income ranges from 1180 to 3370 and from 3370 to 8170 RMB. In these range of bamboo income, the effect of bamboo project on SFBN are not statistically significant. However, the trend is within the range of bamboo income of 1,180 to 3370 RMB; households in the bamboo project are still more likely to have lower SFBN than non-bamboo project households. For the range of bamboo income of 3,370 to 8,170 RMB, bamboo project households may have similar or higher SFBN than non-bamboo project households. It is still a valid finding that households with higher bamboo income are significantly more likely to have higher SFBN than lower ones in the bamboo project villages (P<0.05).



*The y axis "Log odds ratio" refers to the logistic result of the ratio of the probability of be in the higher levels of subjective fulfillment of basic needs versus the probability of lower ones.

Figure 2-d

Figure 2-d shows the effect of the bamboo project on SFBN when household's bamboo income ranges from 8,187 RMB to higher. As illustrated in the figure, households in the bamboo project are significantly more likely to have a higher SFBN than non-bamboo project households and this difference is amplified by the increase in bamboo income. (P<0.05). In addition, households with higher bamboo income consistently show a significantly higher SFBN than lower ones in the bamboo project villages(P<0.05).

2. Comparison of bamboo farmers in the project and out of the project.

In order to see how bamboo project affects households, a detailed summarizing table is shown below (Table 3). Table 3 demonstrates the comparison among households in the two bamboo project villages (village 2 and village 4) and other bamboo households that have the same range of bamboo income of the bamboo project households (village BBNP).

Subj. Fulf. of basic needs level	Level 1	Level 2			Level 3		
Villages	4	2	4	BBNP*	2	4	BBNP*
# Subj. Fulf. of basic needs (%)	25%	42%	40%	32%	58%	35%	68%
Bamboo income (CNY)	2658	2048	4358	4661	1702	6682	3894
Climate income no bb(CNY)	868	6070	2581	8748	6412	4388	10127

Non-climate income (CNY)	1580	2284	1816	9657	2029	6162	4458
Total climate income (CNY)	3526	8818	6938	13409	8119	11070	14021
Total income (CNY)	5106	10402	8754	23066	10148	17232	18478
Income per person (CNY)	1884	2324	2097	4823	2326	3525	3916
Income diversity	7	14	10	16	13	10	15
Income forest diversity	2	2	2	4	2	2	4
Income farmland diversity	2	3	2	4	3	3	4
Income livestock diversity	3	7	4	5	6	4	5
Income non-climate diversity	1	2	2	3	2	1	2
Agroforestry area (ha)	1.8	1.7	1.7	1.7	1.6	1.9	1.4
Farmland area (ha)	3.0	0.3	0.4	0.7	0.3	1.0	0.6
Flood	1	0	1	0.4	0	1	0.6
Drought & Pest	2	1	2	0.4	1	2	0.3
Dependents ratio	0.4	0.2	0.4	0.3	0.4	0.4	0.3
Education	4.6	5.6	4.2	5.8	5.9	5.2	4.8
	V4 (n=20)	V2 (n=19)		V_{BBNP} (n=57)			

* BBNP refers to the bamboo farmer households who are not in the project, but have bamboo income of the range that bamboo project households have (720 RMB <Bamboo income< 11234 RMB).

Table 3.

Table 3 suggests that for bamboo farmers that have similar amounts of bamboo income (V4_LV1 &V2_LV2; V4_LV2 & V_{BBNP}_LV3, the groups in the higher level of SFBN have more average climate income, non-bamboo climate income, and average income diversity with similar areas of agroforestry land. For the group in the same level of SFBN, no matter how bamboo income varies, bamboo farmers that are not in the bamboo project have a better average non-bamboo climate income and a higher average income diversity. For the bamboo farmers living in village 4, bamboo farmers in level 1 differ from other levels through distinct lower average income diversity (especially the livestock income diversity) and lower average non-bamboo climate income. When comparing within the same village, farmers in level 3 all have similar or usually more average non-bamboo climate income than farmers in level 2 although two groups have similar average income diversity.

In addition, although village 2 and village 4 are all in the bamboo project, households in village 2 show a higher average income diversity and a higher average non-bamboo climate income at all levels. This reflect the finding that households in the village 2 although have less bamboo forest income, compared to village 4, invested more time and labor in other non-bamboo livelihoods.

Chapter 5: Discussion

To answer our first research question whether Ecosystem-based Adaptation (EbA) is correlated with the subjective fulfillment of basic needs (SFBN) we ran an ordinal logistic regression model that regressed subjective fulfillment of basic needs (SFBN) against predictor variables, including socio-economic and demographic characteristics, climate risks as well as an indicator for participation in the EbA project. The results confirmed that EbA is correlated to subjective fulfillment of basic needs. Next, we used the regression model together with moderation analysis derived from the model to answer our second question regarding the ways EbA may be correlated to subjective fulfillment of basic needs (SFBN). Our results also support our second hypothesis in that EbA may affect our households' subjective fulfillments of basic needs depending on the project design and a household's social-economic status. Finally, for our third research question regarding how EbA may help to increase the subjective fulfillment of basic needs of our households, we speculate on a few possible ways and suggest a actions that can improve households' SFBN.

- Subjective Fulfillments of Basic Needs and Subjective Well-Being.

The results for Subjective Well-Being (SWB) are some different from ones of the Subjective Fulfillments of Basic Needs (SFBN). Here, we focus on discussing the results of SFBN.

Relationship to climate crisis

In our study, results demonstrate that extreme climate variation is one of the main stressors that decrease the subjective fulfilment of basic needs (SFBN) and thus aggravates poverty. Severe drought may undermine basic quality of life by directly reducing the drinking water supply, the survival of livestock, and the production of crops, including rice and maize. This is consistent with the finding that more than two thirds of the sampled households in the severely drought-affected village of Zhongtuntun reported serious crops failure due to drought and related pest outbreaks. Flooding, although usually believed to be one of the stressors that threatens people's lives, did not show direct correlation with SFBN. This finding may stem from the low severity of floods or the fact that the occurrence of floods may balance the adverse impacts of drought on pro-flood crops like rice (Jongdee et al. 2006). Climate crises may also indirectly influence the local price of water-sensitive agricultural products and thus decrease the probability of obtaining them (Weeler and Von Braun 2013). However, this study does not focus on this aspect.

Floods and drought, both of which are intensified by climate change, show a negative influence on subjective well-being (SWB). In other words, regardless of whether a climate crisis decreases the fulfillment of basic needs, people perceive the occurrence of flood and drought to impoverish their lives. Given that only drought affects the SFBN, this finding may reflect other influences of climate crises on livelihoods and living conditions or people's perception of how different climate crises affect different aspects of their lives. For example, flooding may influence people's daily lives by blocking roads or slowing down daily activities, thus negatively affecting quality of life even if not threatening their livelihoods directly such as drought. Also, long-term exposure to the climate crisis may cause people to feel less optimistic about their lives or future generations. This negative perception may result in low life satisfaction with or without the actual influence of increased variation by climate-change induced events.

Relationship to incomes

In contrast, we find that the Subjective Fulfillments of Basic Needs (SFBN) positively correlates with forest land resources and agricultural incomes. This illustrates that forest land resources and agricultural incomes such as money generated from forests, livestock and crops, are fundamental to maintaining the food supply and basic quality of life for subsistence farmers. Unlike SFBN, not all kinds of income are directly correlated with Subjective Well-Being (SWB). Two scenarios may contribute to this finding. First, no single income source leads to high SWB because of the trade-offs involved with different types of livelihoods. For subsistence farmers, income from bamboo and income from other agricultural products is essential for both meeting people's basic needs and maintaining their identity. However, compared to small business or wages, agricultural livelihoods are usually more climate-sensitive, more time-consuming and more labor-intensive, which in turn may reduce life satisfaction. Thus, it may be hard for a single type of livelihood to determine SWB. While this scenario may be at play, the importance of income in affecting SWB should not be underestimated. In fact, different types income may jointly affect SWB (Diener and Shigehiro 2000). This is especially true for the poor and middle-income bamboo farmers as material goods have greater impacts on their quality of lives. Second, the living environment may affect the SWB. SWB is the cognitive recognition of one's life. Many households with high income reside close to urban areas or big towns, and while the convenience to the market may boost their access to good and resources, it comes at the price of higher living expenses which could affect perceptions of satisfactory lives. On the other hand, the poor, especially in remote areas, may adapt to their living conditions and thus record higher SWB than expected (Lucas 2007). Therefore, households with same SFBN and incomes may show divergent SWB, suggesting income to be an limited or inadequate predictor of SWB.

Relationship to agroforest land resources

Forest land area is positively correlated with both SFBN and SWB. This aligns with findings of many studies that agroforestry may serve as a safety net by providing subsistence farmers with extra income, which is especially important when facing uncertainty through climate stressor (Verchot et al. 2007, Torlakason & Neufeldt 2012).

Forests may not only be able to regulate water variations, but also provide timber and non-timber products that are usually less sensitive to climate change than farmland livelihoods. Thus, increasing agroforestry land will improve SFBN and SWB. However, it is not clear what has the greater impact on the fulfillment of basic needs: overall agroforestry land area or the ratio of forest versus farmland. Moreover, in our study case, this correlation may stem from another situation: households owning large forestlands generally are more powerful. Within the same village, power also enables these households to access resources with higher priority. Abundant land resources bring wealth and may reinforce their power and social networks. For example, these households are more likely to have access to information through their large networks and to enjoy poverty alleviation policies that have limited beneficiaries. Therefore, households with more agroforest land have a higher probability of meeting their basic needs or achieving satisfactory lives. If the area of agroforestry land positively affects the SFBN through power, increasing agroforestry land alone may have less effect on improving the SFBN and SWB than expected. Further research needs to be done to understand how agroforestry land affects quality of life through the mediation of power.

Relationship to demographic characters and others

Both farmland area and dependency ratio are not directly correlated with SFBN. This suggests that these characteristics are relatively not important in influencing SFBN compared with income, climate risks, and agroforestry land. In addition, the homogeneity of households' farmland area may be an alternative explanation for its insignificant correlation.

- ❖ The effect of EbA project on Subjective Fulfilments of Basic Needs (SFBN).

EbA Project for Low Bamboo-Income Farmers

The Bamboo Project provides bamboo forests as an alternative livelihood to grain production (i.e. rice). With the intention of reducing the sensitivity of livelihoods to climate change and restoring the water regulation services, the Bamboo Project did help to achieve adaptation. However, when low-income households do not earn sufficient income from this livelihood, the results could be detrimental (Figure 3-a). Table 3 shows that households with low levels of SFBN had limited income diversity and limited agricultural incomes outside of raising bamboo. Therefore, the EbA project may actually cause lower quality of life for low-income farmers that participated in the project through the insufficient livelihood diversity and agricultural income.

This lack of diverse livelihoods and meager agricultural income may be a result of the inadequate design of the project and the initial level of vulnerability of the poor households targeted. First, the migration of bamboo project households to Liulong village may have limited their land use. Although survey data indicates that these migrants and the local population own similar amounts of farmland, reported conflicts over land rights suggest that the migrants may not have full access to the lands that they claim. Thus, these farmers may be unable to expand their farmland livelihoods (Ellis and Allison 2004).

Similarly, the Bamboo Project may constrain the choices of livelihoods not only by replacing rice growing but also depleting the resources needed for livelihoods that complement rice growing practices. For example, left-over plant matter and vegetables from rice-farming often provide forage for livestock. Thus, by choosing bamboo cultivation over rice farming, households may lose the opportunity of raising livestock. Also, more than half of the household's bamboo forests affiliated with the project are scattered and dispersed, making bamboo forest management more difficult and time-consuming (Hogarth 2014). Overall, quality of life for households participating in the Bamboo Project appear to depend largely on the income generated from bamboo. Households who do not receive sufficient bamboo income fall into the low level of SFBN. This is consistent with the finding in Table-1 that within the Bamboo Project villages, SFBN increases as income raised from bamboo harvests increases.

EbA Project for Middle Bamboo-Income Farmers

The effect of the EbA project on middle income bamboo farmers is not statistically significant. One explanation for this finding could be that among the middle bamboo-income farmers, the adverse impact of the Bamboo Project on households such as constraints of income diversity may be diluted by the positive influence of bamboo income that is generated by the project. Under this scenario, other factors including non-climate sensitive income, agroforestry land and the influence of climate change diminish the overall effect of the bamboo project in affecting SFBN. However, as farmers face increasingly severe impacts from climate change in the coming decades, the requirement of adaptation may surpass their adaptive capacity (Forsyth 2013). Therefore, actions to reduce the vulnerability of this group remain necessary.

EbA Project for High Bamboo-Income Farmers

Results suggest that for farmers with bamboo income higher than 8,180 RMB, households affiliated with the Bamboo Project are more likely to have higher SFBN compared with bamboo farmers unaffiliated with the project. Differences in locations and income diversity may contribute to this finding.

First, almost all the households with comparable incomes that did not participate in the project are distributed in three villages that are close to the center of town or have easy access to it through well-paved road (Hogarth 2014). However, the high-income bamboo farmers that participated in the project were mostly located much farther from town or did not have access to well-paved roads. The convenience of a near-town location to the market may provide farmers with more opportunities to trade for their agricultural products and to participate in off-farm livelihoods. However, this context may also bring high market competition, relatively higher living expenses and change the standard of basic needs and thus undermine their SFBN. The Bamboo Project provides households with a contract to a local company that purchases bamboo shoots from participating farmers on a regular basis. Therefore, these bamboo project households have a reliable market to sell their bamboo harvests and products to, without undertaking market competition and incurring higher living expenses by living closer to market.

Second, another factor at play is the dynamic perception of what constitutes a basic need. In rural China, children's education and health care are the two major expenses besides food. Households living near an off-farm labor market may consider a higher education is as important as food and health. This is because education enables children in the next generation to access higher-paying, off-farm livelihoods that require higher academic attainment or specialized knowledge and skills. With this in mind, although high bamboo-income farmers unaffiliated to the project have higher income than high bamboo-income farmers that live in the rural area, they have more requirements of basic needs and lower SFBN than the latter.

Furthermore, as shown in Table-3, households unaffiliated with the Bamboo Project have a higher average income diversity than households participating in the project. The high- income diversity usually indicates extra livelihood investment. For instance, farmers with extra savings can invest in livestock or small business such as running a grocery store. In this way, these households may undertake more risk due to extra investment and the delay of investment payback. Although these kinds of risks will not threaten high income households as much as poor subsistence farmers, the possible failure of investments and temporary shortage of cash may still hinder the fulfillment of their basic needs at times.

Differences among the households affect the EbA outcome

The direct outcome of EbA, in terms of bamboo income, can be affected by household differences. Reasons for why some households participating in the same Bamboo Project are poorer than others are complex and intertwined. First, as described above, EbA constrains the income diversity due to the its dispersed landscape design and innate characteristics as an alternative livelihood. Second, low bamboo income is highly linked with fewer bamboo forest land and generally overlaps with fewer initial savings and assets (Figure S2-a,b). The effect of EbA is limited by household generic capacity and resources. This echoes the findings in other studies of the intersection of poverty and climate impact in less developed areas that find that generic capacity and specific capacity to manage risk interact with each other to shape the overall vulnerability of households (Lemos et al, 2016). Lack of bamboo forests are detrimental given that people are constrained in their livelihood choices. Even with enough land, people who are poorer usually do not have enough assets, including money, to hire additional labor like big commercial farmers to achieve higher bamboo income. They must take on the intensive labor of bamboo management and may not have time to pursue additional and diversified livelihoods strategies. In turn, they may still be poorer than others with the same EbA project. Also, as bamboo forests were allocated depending on household sizes, this finding reflect how an ill-conceived policy may lead to inequality and thus aggravate poverty further. Finally, since bamboo project households are new migrants to the Liulong area, conventional bamboo growing is a relatively new livelihood to them. Developing new livelihoods through the restoration of natural resources, such as bamboo, can be challenging because it requires people to master new skills including management. Lacking the knowledge needed to thrive in this new livelihood affects success and the income generated from bamboo growing. Even though all the households attended training for basic bamboo management at the beginning of the project, studies indicate that there is still lack of knowledge of pest control and of how to maximize the production by changing the intensity of bamboo clumps (Hogarth 2014). Also, many participants stop following these directions after a few years. Further studies should explore the mechanisms behind this outcome. Moreover, EbA also has its limitations due to the limits of ecosystems itself. Periods of extreme drought or pest outbreaks, causing the ecosystems to reach its threshold, could cause poor households who solely rely on bamboo harvests to experience significant, adverse impacts (Figure S1, Tan et al. 2017). Multicultural instead of monoculture of economic forests may help to reduce this problem as the former will increase the resilience of ecosystem in facing the climate change (Kremen 2012).

Chapter 6: Conclusion

Using a case study of twelve southwest forest communities in Guangxi, where the government of China engaged in an ecological poverty alleviation project, we explored the relationship between Ecosystem-based Adaptation (EbA) and rural poverty alleviation. We found that: a) EbA is correlated with subjective fulfillment of basic needs; b) EbA affects households and can both help alleviate and aggravate poverty, depending on project design and how an EbA project may affect a household's overall livelihood and c) limited household generic capacity will constrain the beneficial effects of EbA on poorer households.

EbA Project, Livelihood and Poverty Alleviation

The outcome of EbA largely depends on the design and execution of EbA projects. Usually, EbA projects involve natural resources restoration and management, where the benefits of EbA projects are tied to the extent to which the project can successfully employ ecosystem services to benefit overall livelihoods. In our study, we find that by restoring bamboo forests to generate new livelihoods, EbA can reduce household dependency on grain farming, which is more sensitive to climate change (Bonan 2008), although the question of how ecosystem services will be affected by climate change need to be further studied. Yet rural poor farmers can better adapt to the stresses of a changing climate through the steady livelihood and income provided by growing and selling bamboo. Paring households with local sellers may reinforce the benefits of EbA on poverty alleviation by reducing individual household's investments on the access to markets and also by shifting market risks to companies.

In contrast, this study also suggested that EbA projects may limit the impact EbA has on poverty alleviation in two key ways—by failing to effectively transfer knowledge to local communities or by failing to account for problems that stem from migration and previous levels of vulnerability of households under the project. Education in develop and managing the new livelihood, although part of the EbA project has proven insufficient. One reason maybe because the quality of this education varies greatly and may limit the benefits of EbA programs (Crona and Bodin 2006). Other reason maybe that assimilation of new knowledge takes time and requires constant efforts as opposed to one-off training events. Households in our study although having basic skills in cultivating bamboo due to the educational workshop at the beginning of the workshop, were not familiar with knowledge of how to address bamboo pests and illness. Additionally, field observations suggested that many of the people that received proper instruction did not conduct the management as directed, illustrating that providing information alone does not guarantee compliance and proper management (McCaferry 2004).

Additionally, household migration is likely to encounter problems such as unideal distribution of natural resources in the new places or conflicts over land (Kates et al. 2012, Reuveney 2007). Our study finds that using dispersed lands to develop livelihoods increases the input of labor and time spending on management but may not proportionally increase households' incomes, making employment of such resources challenging and risky to smallholder farmers. This livelihood and its management may even reinforce a household's poverty as families adopt alternative livelihoods have meager returns, preventing them from accumulating enough money and assets to become more prosperous. Indeed, other studies have shown that biodiversity conservation may trap people in poverty through making them dependent on risky natural-resource-based livelihoods and inadequate systems of adaptive management (Barrett et al. 2011). Moreover, although restoring scattered resources may seem like a useful EbA management strategy, the scale to which this restoration can happen in an EbA program may limit the benefits of such an endeavor. For example, in the case of Southwest China, despite the well-intentioned efforts to help farmers to plant bamboo, disconnected pockets of bamboo groves are less likely to provide the full suite of beneficial services such as effective water and soil regulation (Mitchell et al. 2015). The improvement of landscape designs for restoration may help address this problem (Tscharntke 2005, Mitchell 2015).

EbA, Development and Poverty Alleviation

Goals of ecosystem-based adaptation may overlap with development in rural areas through the improvement of natural-resources-based livelihoods. In other words, by better harnessing the resources to climate variation and improve livelihoods, EbA has the potential to alleviate poverty for rural communities that are threatened by adverse climate change impacts. However, consistently with other research in the field, EbA affects different social-economic groups differently depending on how differentiated capacities (e.g. income, education, access to land) may limit the utilization of EbA to manage risk (Eakin et al. 2014). Poorer bamboo project households, besides being more likely to be affected by inadequate EbA design, are also limited by their low general capacity and assets. Our case study finds that EbA in the case of the bamboo project improves people's fulfillment of basic needs only for households that earn substantial income from alternative livelihoods that were brought by the project. Poorer project households who have insufficient bamboo forests and total savings and assets are negatively affected by the EbA project.

Ironically, EbA can inadvertently undermine the overall goals of poverty alleviation (Cannon and Muller-Mahn 2010, Schipper 2007). With focus on the single goal of climate adaptation, EbA may overlook the complexity of the whole livelihood system and in turn impede poverty alleviation. As shown in the case study, when alternative livelihoods provided by EbA projects are unable to bring in income comparable to traditional livelihoods, EbA can actually aggravate the condition of poor households that find themselves trapped by these inadequate alternative livelihoods. For example, in our study, the bamboo project underestimated the role that rice played in supporting the whole livelihood system (i.e. providing food for domestic animals), unintentionally decreasing other sources of income for participating families (i.e. money earned from raising livestock).

This finding has important implications for policy makers that are trying to mainstream climate change adaptation into overarching development plans. First, improving general capacity (e.g. farming equipment, land resources, access to farming knowledge and information) for sustainable development should be involved in designing EbA as to maximize its benefits. Second, for mainstreaming EbA to poverty alleviation policies, we suggest that the alternative livelihoods strategy should be adopted with caution. To maintain the health of whole livelihood system, the value of alternative livelihoods and those they would replace should be thoroughly examined and evaluated under the whole livelihood system before substitution. Moreover, the evaluation of these livelihoods should include their relative benefits across scales. Unlike conventional livelihood projects that primarily benefit the local community, the water and soil regulation services provided by restored forests through EbA projects can affect communities at the regional level. Calculating the benefits of alternative livelihoods at the landscape scale and offering additional compensation to upstream households in the watershed may allow for the maximization of regional benefits of such efforts as well as help the vulnerable poor to fully take advantage of EbA projects. Alternatively, newly developed livelihoods tied to EbA may be better implemented as additional livelihoods that complement instead of replace subsistence farming practices. Other studies focused on subsistent households suggest that livelihood diversification has the potential to maintain livelihood incomes under climate change (Ellis 1998, Paavola 2008). Still, livelihood diversification has its own risks, especially for the poor. This includes the consequences of failure when people have invested significant time and money in livelihood diversification or delayed returns on these investments (Eriksen et al. 2007). Much more needs to be understood about the relationship between livelihood diversity and poverty alleviation. Further studies are needed to explore this intersection, especially in the context of climate change adaptation.

Limitation and Further Studies

This study used the survey data that was conducted during 2006-2007 when the EbA project had been conducted for close to ten years. As the ultimate goal is to achieve sustainable development and adaptation, also given the time taking for restored bamboo forests to become productive economic forests, further collection and analysis data from subsequent years may further clarify how EbA linked with poverty alleviation.

And because our study does not have the initial/baseline social-economic data of the project households before migration, it may overplay the role of EbA can play. Thus, we use the savings and assets in the previous year of the survey as a proxy to capture the stratification of households, it may still fall short from a clearer picture.

In this study, we focused on the role of EbA in dealing with climate stressors through livelihoods and their related incomes in forest communities in Southwest China. To fully understand the relationship between EbA and poverty alleviation, however, we need to better understand how restoration and management efforts affect regulatory ecosystem services, including mitigating climate variations and corresponding losses and damages that impact household food supply and income. More linkages between EbA and the causes of poverty through social-political perspectives also needs to be explored. As EbA provides new livelihoods or improves resource management, it may also affect social networks and systems of inequity that are linked with poverty (Tomas & Twyman 2005). For instance, growing maize and rice requires intensive labor during the harvest season and farmers often depend on each other to help with the harvest. Such livelihoods provide opportunities for people to connect with each other as well as exchange knowledge and information at a low cost. Indirectly, these livelihoods help people build their social capital, an important resource for drawing on in times of hardship and uncertainty. Also, by promoting such livelihoods, farmers who do not get equal chance to access education and information due to the inequity of power and wealth may thus have low-cost opportunities to overcome it. In addition, since maintaining regulatory ecosystem services at the landscape scale requires collective action, EbA may also influence the social-political structures of common pool management which are deeply intertwined with inequality and poverty (Pretty 2003). Clearly, many questions remain on how EbA projects interact with rural development and poverty alleviation (Liu et al. 2007). Looking at the effects of EbA on the economy, although important, may only be a start to unfold and reveal the complex relationship between Ecosystem-based Adaptation and Poverty Alleviation.

Acknowledgement

I want to show my sincere appreciation to my advisors, colleagues, family and friends who have supported and helped me throughout the whole process of my master research and thesis. I could not finish this thesis without any of them! Thank you for being there for me all the time! First, I would like to thank my MSc committee, Maria Carmen Lemos and Robyn Meeks for their patience, encouragement, support, time and all the feedback about my research and writing. Maria gave me not only academic advice, but also life advice that means a lot to me during the research and writing! Furthermore, I would give many thanks to Nicholas Hogarth, who collected the data at the study sites based on a questionnaires developed by the Poverty and Environment Network (PEN). I appreciated his full support in providing the data and field observations that allowed me to develop my research and writing the thesis. Moreover, I give special thanks to my friend and colleagues Stefania Almazan Casali who supported me in developing the models and reviewing the results; and my friend Mary Jones who helped to review my thesis in terms of both English and developing ideas. I would also like to thank the support from the University of Michigan, especially CSCAR, the Sweetland Writing Center and English Learning Institute. Finally, I want to thank my family and friends, who gave all their support and time to help me complete this thesis. We did it together!

References:

Adams, H.D., C.H. Luce, D.D. Breshears, C.D. Allen, M. Weiler, V.C. Hale, A.M.S. Smith, and T.E. Huxman, 2012: Ecohydrological consequences of drought- and infestation-triggered tree die-off: insights and hypotheses. Ecohydrology, 5(2), 145-159.

Agrawal, Arun, and Nicolas Perrin. "Climate adaptation, local institutions and rural livelihoods." Adapting to climate change: thresholds, values, governance (2009): 350-367.

Alkire, Sabina. Valuing freedoms: Sen's capability approach and poverty reduction. Oxford University Press on Demand, 2005.

Allen, C.D., A.K. Macalady, H. Chenchouni, D. Bachelet, N. McDowell, M. Vennetier, T. Kitzberger, A. Rigling, D.D. Breshears, E.H. Hogg, P. Gonzalez, R. Fensham, Z. Zhang, J. Castro, N. Demidova, J.H. Lim, G. Allard, S.W. Running, A. Semerci, and N. Cobb, 2010: A global overview of drought and heat-induced tree mortality reveals emerging climate change risks for forests. Forest Ecology and Management, 259(4), 660-684.

Anandajayasekeram, Ponniah, Kristin E. Davis, and Sindu Workneh. "Farmer field schools: an alternative to existing extension systems? Experience from Eastern and Southern Africa." Journal of International Agricultural and Extension Education 14.1 (2007): 81-93.

Angelsen, Arild, and Sven Wunder. Exploring the forest–poverty link: key concepts, issues and research implications. No. CIFOR Occasional Paper no. 40. CIFOR, Bogor, Indonesia, 2003.

Arnold, JE Michael. Forestry, poverty and aid. No. CIFOR Occasional Paper no. 33 (E). CIFOR, Bogor, Indonesia, 2001.

Arnold, Michael. "Clarifying the links between forests and poverty reduction." The International Forestry Review 4.3 (2002): 231-233.

Asadullah, Mohammad Niaz, and Nazmul Chaudhury. "Subjective well-being and relative poverty in rural Bangladesh." Journal of Economic Psychology33.5 (2012): 940-950.

Barrett, Christopher B., Alexander J. Travis, and Partha Dasgupta. "On biodiversity conservation and poverty traps." Proceedings of the National Academy of Sciences 108.34 (2011): 13907-13912.

Bebbington, Anthony. "Capitals and capabilities: a framework for analyzing peasant viability, rural livelihoods and poverty." World development 27.12 (1999): 2021-2044.

Bonan, Gordon B. "Forests and climate change: forcings, feedbacks, and the climate benefits of forests." science 320.5882 (2008): 1444-1449.

Campos, Minerva, Alejandro Velázquez, and Michael McCall. "Adaptation strategies to climatic variability: A case study of small-scale farmers in rural Mexico." Land Use Policy 38 (2014): 533-540.

Cannon, Terry, and Detlef Müller-Mahn. "Vulnerability, resilience and development discourses in context of climate change." Natural hazards 55.3 (2010): 621-635.

Chambers, R., and G. Conway. "Sustainable livelihood-chambers and conway1991. pdf." (1991).
Chen, Haiyun, et al. "Livelihood sustainability and community based co-management of forest resources in China: changes and improvement." Environmental management 49.1 (2012): 219-228.
Chen, Shaohua, and Martin Ravallion. "The developing world is poorer than we thought, but no less successful in the fight against poverty." (2008).
China Climate Change Plans. (2013). Retrieved from: http://www.chinanengyuan.com/news/55223.html
Clark, David A. "Adaptation, poverty and well-being: some issues and observations with special reference to the capability approach and development studies." Journal of Human Development and Capabilities 10.1 (2009): 21-42.
Dalal-Clayton, D. B., Dent, D. (2003). Rural planning in developing countries: supporting natural resource management and sustainable livelihoods. London: Earthscan.
Dan-Feng, S. U. N., et al. "Characteristics of Steep Cultivated Land and the Impact of the Grain-for-Green Policy in China11Project supported by the Program for Changjiang Scholars and Innovative Research Teams in University (PCSIRT), China (No. IRT0412) and the Ministry of Land and Resources, China (No. 2003-2.2-2)." Pedosphere 16.2 (2006): 215-223.
Dasgupta, P., J.F. Morton, D. Dodman, B. Karapinar, F. Meza, M.G. Rivera-Ferre, A. Toure Sarr, and K.E. Vincent, 2014: Rural areas. In: Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Field, C.B., V.R. Barros, D.J. Dokken, K.J. Mach, M.D. Mastrandrea, T.E. Bilir, M. Chatterjee, K.L. Ebi, Y.O. Estrada, R.C. Genova, B. Girma, E.S. Kissel, A.N. Levy, S. MacCracken, P.R. Mastrandrea, and L.L.White (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, pp. 613-657.
Dawson, J. F. “Moderation in management research: What, why, when and how. Journal of Business and Psychology”, (2004) 29, 1-19.
DeNeve, Kristina M., and Harris Cooper. "The happy personality: a meta-analysis of 137 personality traits and subjective well-being." Psychological bulletin 124.2 (1998): 197.
Denton, Fatima, et al. "Climate-resilient pathways: adaptation, mitigation, and sustainable development." Climate change (2014): 1101-1131.
Diener, Ed, et al. "Subjective well-being: Three decades of progress." Psychological Bulletin 125.2 (1999): 276-302.
Diener, Ed, Richard E. Lucas, and Shigehiro Oishi. "Subjective well-being." Handbook of positive psychology 16.2 (2002): 63-73.
Diener, Edward, and Shigehiro Oishi. "Money and happiness: Income and subjective well-being across nations." Culture and subjective well-being (2000): 185-218.
Doswald, N., et al. "Effectiveness of ecosystem-based approaches for adaptation: review of the evidence-base." Climate and Development 6.2 (2014): 185-201.

Eakin, Hallie C., Maria C. Lemos, and Donald R. Nelson. "Differentiating capacities as a means to sustainable climate change adaptation." Global Environmental Change 27 (2014): 1-8.

Edburg, S.L., J.A. Hicke, P.D. Brooks, E.G. Pendall, B.E. Ewers, U. Norton, D. Gochis, E.D. Gutmann, and A.J.H. Meddens, 2012: Cascading impacts of bark beetle- caused tree mortality on coupled biogeophysical and biogeochemical processes. Frontiers in Ecology and the Environment, 10(8), 416-424.

Ellis, Frank. "Household strategies and rural livelihood diversification." The journal of development studies 35.1 (1998): 1-38.

Ellis, Frank. Rural livelihoods and diversity in developing countries. Oxford university press, 2000.

Ellis, Frank, and Edward Allison. "Livelihood diversification and natural resource access." Overseas Development Group, University of East Anglia (2004).

Eriksen, Siri H., and K. A. R. E. N. O'BRIEN. "Vulnerability, poverty and the need for sustainable adaptation measures." Climate policy 7.4 (2007): 337-352.

Fedele, Giacomo, Raffaele Vignola, and Marco Otarola. "8 Ecosystem-based adaptation."

Feng, Zhiming, et al. "Grain-for-green policy and its impacts on grain supply in West China." Land Use Policy 22.4 (2005): 301-312.

Forsyth, Tim. "Community-based adaptation: a review of past and future challenges." Wiley Interdisciplinary Reviews: Climate Change 4.5 (2013): 439-446.

Galtung, Johan. The basic needs approach. Univ, 1980.

Garrity, Dennis P. "Agroforestry and the achievement of the Millennium Development Goals." New Vistas in Agroforestry. Springer Netherlands, 2004. 5-17.

Ghai, Dharam. "Basic needs and its critics." IDS Bulletin 9.4 (1978): 16-18.

Glaser, Marion, and Rosete da Silva Oliveira. "Prospects for the co - management of mangrove ecosystems on the North Brazilian coast: Whose rights, whose duties and whose priorities?." Natural Resources Forum. Vol. 28. No. 3. Blackwell Publishing Ltd., 2004.

Guardiola, Jorge, and Teresa García-Muñoz. "Fulfilment of basic needs from a subjective point of view in rural Guatemala." International Journal of Social Welfare 20.4 (2011): 393-403.

Guangxi county annals committee. "Guangxi general records: poverty alleviation (1978-2000)" (2013). (In Chinese)

Hertel, Thomas W., and Stephanie D. Rosch. "Climate change, agriculture, and poverty." Applied Economic Perspectives and Policy 32.3 (2010): 355-385.

Hicks, Norman, and Paul Streeten. "Indicators of development: the search for a basic needs yardstick." World development 7.6 (1979): 567-580.

Hogarth, Nicholas J., et al. "The role of forest-related income in household economies and rural livelihoods in the border-region of Southern China." World Development 43 (2013): 111-123.

Howden, S. Mark, et al. "Adapting agriculture to climate change." Proceedings of the national academy of sciences 104.50 (2007): 19691-19696.

Howe, Caroline, et al. "Elucidating the pathways between climate change, ecosystem services and poverty alleviation." Current Opinion in Environmental Sustainability 5.1 (2013): 102-107.
Huang, Yao, et al. "Net primary production of Chinese croplands from 1950 to 1999." Ecological Applications 17.3 (2007): 692-701.
IFAD. "People's Republic of China West-Guangxi Poverty Alleviation Project: Completion Evaluation". Report 2200-CH. (2010). International Fund for Agricultral Development: Rome.
Innes, John L., and G. M. Hickey. "The importance of climate change when considering the role of forests in the alleviation of poverty." International Forestry Review 8.4 (2006): 406-416.
IUCN. “Food Security Policies: Making the Ecosystem Connections.” Gland, Switzerland: IUCN (2013).
Jolly, Richard. "The world employment conference: the enthronement of basic needs." Development Policy Review 9.2 (1976): 31-44.
Jones, Holly P., David G. Hole, and Erika S. Zavaleta. "Harnessing nature to help people adapt to climate change." Nature Climate Change 2.7 (2012): 504-509.
Jongdee, Boonrat, et al. "Improving drought tolerance in rainfed lowland rice: an example from Thailand." Agricultural Water Management 80.1 (2006): 225-240.
Kates, Robert W., William R. Travis, and Thomas J. Wilbanks. "Transformational adaptation when incremental adaptations to climate change are insufficient." Proceedings of the National Academy of Sciences 109.19 (2012): 7156-7161.
Ki, Jean-Bosco, Salimata Faye, and Bocar Faye. "Multidimensional poverty in Senegal: A non-monetary basic needs approach." n International Perspective (2005): 97.
Knight, John, S. O. N. G. Lina, and Ramani Gunatilaka. "Subjective well-being and its determinants in rural China." China economic review 20.4 (2009): 635-649.
Kremen, Claire, and Albie Miles. "Ecosystem services in biologically diversified versus conventional farming systems: benefits, externalities, and trade-offs." Ecology and Society 17.4 (2012).
Lemos, Maria Carmen, et al. "Linking development to climate adaptation: leveraging generic and specific capacities to reduce vulnerability to drought in NE Brazil." Global Environmental Change 39 (2016): 170-179.
Levang, Patrice, Edmond Dounias, and Soaduon Sitorus. "Out of the forest, out of poverty?." Forests, trees and livelihoods 15.2 (2005): 211-235.
Li, Shuzhuang, and Yicheng Liang. "Research on impacts of the policy Grain for Green on households' livelihoods: based on family structures under sustainable livelihood framework." Journal of Public Management (2010):1-10. (In Chinese)
Liu, Jianguo, and Jared Diamond. "China's environment in a globalizing world." Nature 435.7046 (2005): 1179-1186.
Liu, Jianguo, et al. "Complexity of coupled human and natural systems." science 317.5844 (2007): 1513-1516.
Liu, Jianguo, et al. "Ecological and socioeconomic effects of China's policies for ecosystem services." Proceedings of the National academy of Sciences 105.28 (2008): 9477-9482.

Liu, Y., Wang, E. L., Yang, X. G. & Wang, J. Contributions of climatic and crop varietal changes to crop production in the North China Plain, since the 1980s. Glob. Change Biol. doi: 10.1111/j.1365–2486.2009.02077.x (2009).

Lucas, Richard E. "Adaptation and the set-point model of subjective well-being: Does happiness change after major life events?." Current Directions in Psychological Science 16.2 (2007): 75-79.

Maraseni, Tek Narayan. "Climate change, poverty and livelihoods: adaptation practices by rural mountain communities in Nepal." Environmental science & policy 21 (2012): 24-34.

Maraseni, Tek Narayan. "Climate change, poverty and livelihoods: adaptation practices by rural mountain communities in Nepal." Environmental science & policy 21 (2012): 24-34.

Martin, Adrian, Andrew Blowers, and Jan Boersema. "Ecosystem services and poverty alleviation: assessing the constraints and opportunities." (2010): 99-104.

McCaffrey, Sarah. "Thinking of wildfire as a natural hazard." Society and Natural Resources 17.6 (2004): 509-516.

MFA. “Fighting Poverty.” The Norwegian Ministry of Foreign Affairs, Oslo (2002).

Mitchell, Matthew GE, et al. "Reframing landscape fragmentation's effects on ecosystem services." Trends in Ecology & Evolution 30.4 (2015): 190-198.

Munang, Richard, et al. "Harnessing ecosystem-based adaptation to address the social dimensions of climate change." Environment: Science and Policy for Sustainable Development 56.1 (2014): 18-24.

Munang, Richard, et al. "Using ecosystem-based adaptation actions to tackle food insecurity." Environment: Science and Policy for Sustainable Development 55.1 (2013): 29-35.

Olsson, L., M. Opondo, P. Tschakert, A. Agrawal, S.H. Eriksen, S. Ma, L.N. Perch, and S.A. Zakieldeen, 2014:Livelihoods and poverty. In: Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Field, C.B., V.R. Barros, D.J. Dokken, K.J. Mach, M.D. Mastrandrea, T.E. Bilir, M. Chatterjee, K.L. Ebi, Y.O. Estrada, R.C. Genova, B. Girma, E.S. Kissel, A.N. Levy, S. MacCracken, P.R. Mastrandrea, and L.L.White (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, pp. 793-832

Osbahr, Henny, et al. "Effective livelihood adaptation to climate change disturbance: scale dimensions of practice in Mozambique." Geoforum 39.6 (2008): 1951-1964.

Oxfam, “Climate change and poverty- A case study from China.” 2009, Derived from: http://www.greenpeace.org/china/Global/china/_planet-2/report/2009/6/poverty-report2009.pdf.

Paavola, Jouni. "Livelihoods, vulnerability and adaptation to climate change in Morogoro, Tanzania." Environmental Science & Policy 11.7 (2008): 642-654.

Piao, Shilong, et al. "The impacts of climate change on water resources and agriculture in China." Nature 467.7311 (2010): 43-51.

Pretty, Jules. "Social capital and the collective management of resources." Science 302.5652 (2003): 1912-1914.
Ravallion, M., S. Chen, and P. Sangraula. 2007. “New Evidence on the Urbanization of Global Poverty.” World Bank Policy Research Paper 4199.
Ravallion, Martin. Poverty lines in theory and practice. Vol. 133. World Bank Publications, 1998.
Reardon, Thomas, and Stephen A. Vosti. "Links between rural poverty and the environment in developing countries: asset categories and investment poverty." World development 23.9 (1995): 1495-1506.
Reuveny, Rafael. "Climate change-induced migration and violent conflict." Political geography 26.6 (2007): 656-673.
Richards, Michael. "Poverty reduction, equity and climate change: global governance synergies or contradictions." London, Overseas Development Institute (2003).
Pramova, Emilia, et al. "Forests and trees for social adaptation to climate variability and change." Wiley Interdisciplinary Reviews: Climate Change 3.6 (2012): 581-596.
Rojas, Mariano. Well-being and the complexity of poverty: A subjective well-being approach. No. 2004/29. Research Paper, UNU-WIDER, United Nations University (UNU), 2004.
Röling, Niels, and Elske Van De Fliert. "Transforming extension for sustainable agriculture: the case of integrated pest management in rice in Indonesia." Agriculture and Human Values 11.2-3 (1994): 96-108.
Rune Haubo Bojesen Christensen. "Package ordinal". June 28, (2015). Retrieved from: https://cran.r-project.org/web/packages/ordinal/ordinal.pdf
Sanchez, Pedro A. "Linking climate change research with food security and poverty reduction in the tropics." Agriculture, Ecosystems & Environment 82.1 (2000): 371-383.
Scherr, Sara J. "A downward spiral? Research evidence on the relationship between poverty and natural resource degradation." Food policy 25.4 (2000): 479-498.
Schipper, E. Lisa F. "Climate change adaptation and development: exploring the linkages." Tyndall Centre for Climate Change Research Working Paper 107 (2007): 13.
Scoones, Ian. "Sustainable rural livelihoods: a framework for analysis." (1998).
Scoones, Ian. "Livelihoods perspectives and rural development." The Journal of Peasant Studies 36.1 (2009): 171-196.
Secretariat of the Convention on Biological Diversity. Review of the Literature on the Links between Biodiversity and Climate Change: Impacts, Adaptation, and Mitigation. No. 42. UNEP/Earthprint, 2009.
Sen, Amartya. "Welfare, preference and freedom." Journal of econometrics 50.1-2 (1991): 15-29.
Sen, Amartya. Development as freedom. Oxford Paperbacks, 2001.
SFA, "Sloping land conversion program plan (2001-2010)" State Forestry Administrative: Beijing (2003).
Stern, Nicholas Herbert. The economics of climate change: the Stern review. cambridge University press, 2007.

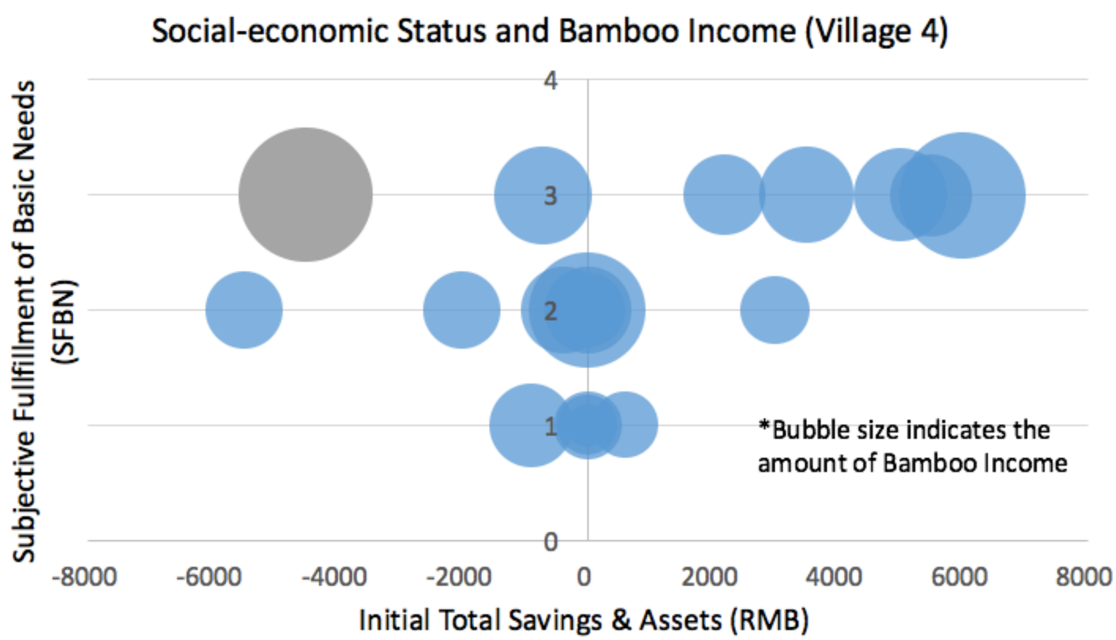
Streeten, Paul, et al. "First things first: meeting basic human needs in the developing countries." (1981).
Streeten, Paul. "Basic needs: some unsettled questions." World Development 12.9 (1984): 973-978.
Streeten, Paul. "The Distinctive Features of a Basic-Needs Approach to Development." Development Perspectives. Palgrave Macmillan UK, 1981. 334-365.
Sumner, Andrew. "Economic and non-economic well-being: a review of progress on the meaning and measurement of poverty." WIDER Conference: Inequality, Poverty and Human Well-Being. 2003.
Tanner, Thomas, and Tom Mitchell. "Entrenchment or enhancement: could climate change adaptation help to reduce chronic poverty?." IDS Bulletin 39.4 (2008): 6-15.
Tan, Zhenxiang, Dezhu Meng, and Qiang Li. "Baise Tianlin Badu bamboo reduce the productivity to half due to severe drought.". (In Chinese) Retrieved from: http://jx.cdianq.com/lbgqad/3159.html
Tay, Louis, and Ed Diener. "Needs and subjective well-being around the world." Journal of personality and social psychology 101.2 (2011): 354.
Tengö, Maria, and Kristina Belfrage. "Local management practices for dealing with change and uncertainty: a cross-scale comparison of cases in Sweden and Tanzania." Ecology and Society 9.3 (2004).
Thomas, David SG, and Chasca Twyman. "Equity and justice in climate change adaptation amongst natural-resource-dependent societies." Global environmental change 15.2 (2005): 115-124.
Thorlakson, Tannis, and Henry Neufeldt. "Reducing subsistence farmers’ vulnerability to climate change: evaluating the potential contributions of agroforestry in western Kenya." Agriculture & Food Security 1.1 (2012): 15.
Thorlakson, Tannis, and Henry Neufeldt. "Reducing subsistence farmers’ vulnerability to climate change: evaluating the potential contributions of agroforestry in western Kenya." Agriculture & Food Security 1.1 (2012): 15.
Tianlin County Government. "Bamboo industry development and immigration policy: Case study of successful experience from Tianlin County" Report, March 26, (2004). Tianlin Government: Guangxi Zhuang Autonomous Region, China. (In Chinese)
Tianlin County Government. "Tianlin County statistics 2007" (2007) Tianlin Government: Guangxi Zhuang Autonomous Region, China. (In Chinese)
Tianlin Poverty Alleviation Office. "Bamboo industry development and poverty alleviation" (2004) Tianlin Government: Guangxi Zhuang Autonomous Region, China. (In Chinese)
Tscharntke, Teja, et al. "Landscape perspectives on agricultural intensification and biodiversity–ecosystem service management." Ecology letters 8.8 (2005): 857-874.
Tsui, Kai-yuen. "Multidimensional poverty indices." Social choice and welfare 19.1 (2002): 69-93.

United Nations The Copenhagen Declaration and Programme of Action, World Summit for Social Development, 6-12 March 1995, New York, United Nations (1995)
United Nations, New York "The Millennium Development Goals Report 2015" (2015).
UNDP, United Nations Development Programme. "Generating multiple benefits from Ecosystem-based Adaptation in mountain ecosystems." (2015) Retrieved from: http://www.adaptation-undp.org/sites/default/files/downloads/undp_mt_eba_learning_brief_2_final_web_04.01.16.pdf
Vedeld, Paul, et al. "Forest environmental incomes and the rural poor." Forest Policy and Economics 9.7 (2007): 869-879.
Verchot, Louis V., et al. "Climate change: linking adaptation and mitigation through agroforestry." Mitigation and adaptation strategies for global change 12.5 (2007): 901-918.
Vignola, Raffaele, et al. "Ecosystem-based adaptation for smallholder farmers: Definitions, opportunities and constraints." Agriculture, Ecosystems & Environment 211 (2015): 126-132.
Wamsler, Christine, et al. "Operationalizing ecosystem-based adaptation: harnessing ecosystem services to buffer communities against climate change." Ecology and Society 21.1 (2016).
Wang, Fahong, et al. "Wheat cropping systems and technologies in China." Field crops research 111.3 (2009): 181-188.
Watson II, Derrill D. "Poverty and Basic Needs." Encyclopedia of Food and Agricultural Ethics. Springer Netherlands, 2014. 1529-1535.
Wheeler, Tim, and Joachim Von Braun. "Climate change impacts on global food security." Science 341.6145 (2013): 508-513.
World Bank Group. "A revised forest strategy for the World Bank Group." World Bank, Washington, DC, USA (2002).
World Bank, World Development Report: Poverty, New York: Oxford University Press (1990).
Xie, Xuxuan, S. Q. Zhang, and S. T. Zhu. "Impacts of sloping land conversion program on households' sustainable livelihood." Acta Scientiarum Naturalium Universitatis Pekinensis 46.3 (2010): 457-464.
Xiong W, Conway D, Lin E, Xu Y, Ju H, Jiang J, Holman I, Li Y. Future cereal production in China: the interaction of climate change, water availability and socio-economic scenarios. Glob Environ Change 2009, 19:34–44.
Xu, Zhigang, et al. "Grain for green versus grain: conflict between food security and conservation set-aside in China." World Development 34.1 (2006): 130-148.
Ye, Liming, et al. "Climate change impact on China food security in 2050." Agronomy for Sustainable Development 33.2 (2013): 363-374.
Zhai, P. M., Zhang, X. B., Wan, H. & Pan, X. H. Trends in total precipitation and frequency of daily precipitation extremes over China. J. Clim. 18, 1096–1108 (2005).
Zhou, Y. et al. Genetic improvement of grain yield and associated traits in the northern China winter wheat region from 1960 to 2000. Crop Sci. 47, 245–253 (2007).

Supplemental materials:

	BAMBOO PRODUCTION/HA	FARM INCOME/HA	BAMBOO INCOME/HA
+FLOOD	=	=	=
(MINOR DROUGHT) +FLOOD	/	=	/
+DROUGHT	=	=	=
(MINOR FLOOD) +DROUGHT	/	=	/
(MINOR FLOOD) +DROUGHT->++DROUGHT	/	Decrease, (p=2.806e-06, n=38, 35)	/
(MINOR FLOOD) 0->++DROUGHT	=	Decrease, (p=0.0002181, n=39, 35)	Decrease, (p=5.382e-06, n=39, 19)

Figure S1. Comparison of per-unit-land production and income of bamboo and farmland crops under climate variations.



*The grey bubble is the only household who has some savings but still in debt, indicating likely some investment

Figure S2-a. Scatter plot of initial social-economic status and bamboo incomes.

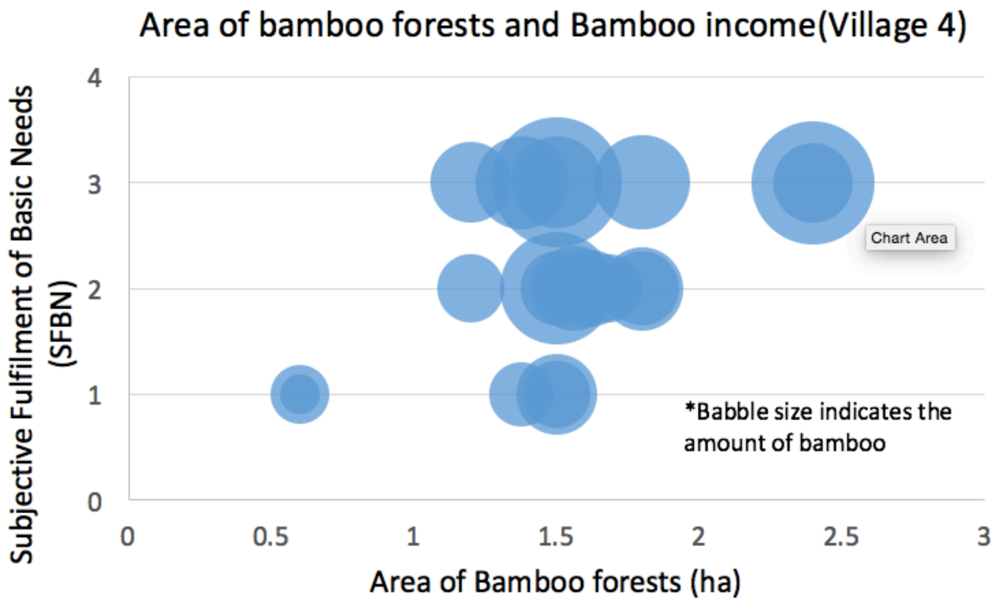


Figure S2-b. Scatter plot of area of bamboo forests and bamboo income.