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Farm Types and Farmer Motivations to Adapt: Implications for Design of Sustainable Agricultural Interventions in the Rubber Plantations of South West China

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Abstract

Tropical land use is one of the leading causes of global environmental change. Sustainable agricultural development aims to reduce the negative environmental impacts of tropical land use whilst enhancing the well-being of the small holder farmers residing in those areas. Interventions with this goal are typically designed by scientists educated in the Western tradition, and often achieve lower than desired uptake by small holder farmers. We build on work done in farm type classification and studies of factors that influence adaptation, trialling a suite of household survey questions to elucidate the motivational factors that influence a farmer's willingness to adapt to external change. Based on a sample of 1,015 households in the rubber growing region of Xishuangbanna, South-west China, we found that farm types based on structural characteristics (e.g. crops, livelihoods) could not be used to accurately predict farmers' motivations to adapt. Amongst all six farm types identified, the full range of motivational typologies were found. We found six motivational types, from most to least likely to adapt, named: Aspirational Innovators, Conscientious, Copy Cats, Incentive-centric, Well Settled, and Change Resistant. These groups roughly corresponded with those identified in literature regarding diffusion of innovations, but such classifications are rarely used in development literature. We predict that only one third of the population would be potentially willing to trial a new intervention, and recommend that those sectors of the population should be identified and preferentially targeted by development programs. Such an approach requires validation that these motivational typologies accurately predict real behaviour – perhaps through a panel survey approach. Dedicated data gathering is required, beyond what is usually carried out for ex-ante farm typologies, but with some refinements of the methodology presented here the process need not be onerous. An improved suite of questions to appraise farmers’ motivations might include value orientations, life satisfaction, and responses to various scenarios, all phrased to be locally appropriate, with a scoring system that uses the full range of potential scores and a minimum of follow up and peripheral questions.

1. Introduction

Tropical land use for the past century has been dominated by conversion of forested lands to agricultural land, leading to loss of biodiversity (Barnes et al., 2014; Gibson et al., 2011), increased carbon emissions (Houghton et al., 2012; Le Quéré et al., 2014), changes in evapotranspiration patterns (Lawrence and Vandecar, 2015; Zhang et al., 2016), and the degradation of ecosystem services (Foley et al., 2005; Power, 2010). Proposed solutions tend to focus on the potential benefits that solutions could bring (e.g. Foley et al., 2011) or on evaluating the trade-offs in selecting one solution over another (Phalan et al., 2011). However, in most situations the decision to adapt one's behaviour is not taken by experts, but by small holder farmers. In a recent review, enhanced adoption of sustainable agricultural interventions was linked to three features of projects: a fine-scale understanding of local needs, appropriate market and service mechanisms, and engaging adopters through the research process (Coe et al., 2014). These are particularly salient in situations of decentralised decision making, as occurs where many small holder farmers are responsible for a mosaic landscape (Fox and Castella, 2013), which is the case across much of the tropics.

Rubber plantations in montane south east Asia have expanded leading to rapid replacement of diverse landscapes with monocultures, and giving rise to serious concerns about forest loss, ecosystem degradation, biodiversity loss and risky over-specialisation of livelihoods (Ahrends et al., 2015; Fox et al., 2014; Warren-Thomas et al., 2015; Ziegler et al., 2009). Scientific literature to date generally has focused on either potential management interventions (De Blécourt et al., 2014; Fu et al., 2010; Liu et al., 2015; Riedel et al., 2012; Thongyou, 2014; Viswanathan and Shivakoti, 2008), or potential policy interventions (Cotter et al., 2014; Smajgl et al., 2015b; Yi et al., 2014b). The efficacy of policy interventions is however determined by the interaction between policy mechanisms and the grass-roots responses (Smajgl et al., 2015a), therefore understanding the motivations of small holder farmers to adapt their practices is essential in designing appropriate interventions.

Farm typologies are one method for understanding how different segments of a farming population might react to proposed interventions. Farm typologies are typically based on observable structural characteristics such as farm size, household size, crops grown, livestock raised, and incomes. These farm typologies are useful in determining which interventions are appropriate to specific types of farm and form the basis for many ex-ante intervention and

prioritization analyses (Bongers et al., 2015; Herrero et al., 2014; Rufino et al., 2013; van Ittersum et al., 2008). The structural characteristics of a farm do not present the whole picture, however, and there is a temptation to use the structural characteristics to calculate the most efficient path to intensified production which disregards the system complexities that farmers deal with in their daily lives (van der Ploeg et al., 2009). Van der Ploeg *et al* (2009) found that consideration of the balance of livelihood activities and farmers' objectives can help to explain the plurality of farm styles, when considered in combination with the farm structural characteristics. Indeed, the diversity of farmers' characteristics can render interventions which try to address the 'average farmer' redundant (Marshall and Smajgl, 2013). Targeting interventions according to farmers' motivations may be a more fruitful approach: for example farmers with conservation oriented attitudes are correlated with a higher willingness to adapt practices in a way which enhances conservation goals, and that those farmers who are strongly economically oriented require financial incentives in order to adapt (Greiner et al., 2009). Meijer et al (2014) categorised factors influencing farmer motivations into 'extrinsic' and 'intrinsic' factors, where extrinsic are demographic, economic, geographical, and intrinsic are related to knowledge, perceptions, attitudes; and found that intrinsic factors in particular are often overlooked (Meijer et al., 2014). The goal of the present study was, therefore, to improve understanding of the relationship between the 'structurally' oriented farm types, and the different groups of factors which motivate farmers to adapt their behaviour. We posit that farmers' willingness to adapt is key to adopting new practices, and that understanding the farmers' motivations to adapt is therefore key to increasing adoption rates. From household survey data, we constructed one typology based on farm structural characteristics and livelihoods, and constructed a separate typology based on farmer motivations to adapt. We then assessed the linkages between the two groupings, and drew out the implications for design of agricultural interventions with a higher adoption potential.

2. Methods

Xishuangbanna is an autonomous prefecture of about 19,000 km^2 in Yunnan province, southwest China. Together with Hainan island, it is the only area of sub-tropical forest inside China's borders. The average temperature in Xishuangbanna is 20-22.5°C, with an average high temperature of 25-27°C occurring in May-June. Average precipitation is 1200-1800mm per year and the wet season lasts from May to October during which 90% of the rain falls. The terrain is densely undulating, land elevation ranges from 400 to 2,400 metres above sea level, and there are four bio-climatic zones: warm temperate and moderately moist (high elevations); hot and moderately

moist; extremely hot and moderately moist; and extremely hot and moist (low elevations) (Zomer et al., 2014). The primary crops are rubber, tea, and rice.

Xishuangbanna was originally heavily forested. In 1976 forests accounted for about 70% of land mass (Li et al., 2006). There has been a trend of deforestation since then. Accurate figures on deforestation are difficult to acquire from official governmental sources. However, two systematic studies of satellite imagery between 1976 and 2003 (Li et al., 2009, 2007) found that by 2003 forest cover in Xishuangbanna shrank from 69% to less than 50% of the landscape; that the important tropical seasonal rainforest shrank from 10.9% to 3.6%. There has been no systematic study of forest area since 2003; but we may infer that deforestation has increased, as the amount of land planted with rubber almost tripled between 2002 and 2010, from 153,000 ha to 424,000 ha (Xu et al., 2014).

Household survey data was gathered in a single campaign during 2010, in 50 villages, amongst two counties within the province of Xishuangbanna, South West China (Table 1). One thousand and fifteen households were interviewed. Villages were selected in discussion with government officials to cover the full altitude gradient of the rubber growing region, distributed across seven townships where rubber cultivation is prevalent. Three or four village committees were selected per township, and then two natural villages per village committee, making a total of 50 villages. Households were then selected at random from the government village register.

Altitude varied amongst the surveyed villages from 500m above sea level to 1600m. This altitude range strongly effects the viability of certain crops (rubber, coffee, tea); different ethnic groups tend to inhabit specific locations which can be defined by altitude; and altitude can also be seen as a rough proxy for development, where the communities at lower altitudes tend to have more developed educational, transport and market infrastructure.

** Insert Table 1 **

The survey consisted of a ten-page printed questionnaire which took approximately one and a half hours to complete and was implemented in Mandarin Chinese. The survey was written by Smajgl and Ward (co-authors to this manuscript), and has been described elsewhere (Hassenforder et al., 2015; Smajgl et al., 2016, 2015c, Smajgl and Ward, 2015, 2013). The main topics covered were household demographics, ownership of assets including land, livelihood activities and incomes, personal value orientations, attitudes, perceptions of the likelihood of future events, and stated intentions to adapt under four hypothetical scenarios.

Household demographics included questions on family size, education, location, and ethnicity. Assets included farm size and land uses, as well as vehicles, machinery, and domestic appliances. The livelihoods section included crop and livestock yields and incomes, off-farm incomes, and non-cash gifts. Together, the data on household demographics, assets, and livelihoods are referred to from here on as 'farm characteristics'.

The data on value orientations, attitudes, likelihood of future events and stated intentions to adapt are used to inform about farmers' motivations to adapt their behaviour, and are referred to from here on as the 'motivations' data. The conceptual basis is that personal values influence value orientations, which influence attitudes and norms, which influence stated intentions, all of which influence actual behaviours. Through measurement of some of these variables it may therefore be possible to predict actual behaviour. A recent review explains this in more detail (Jones et al., 2016), and links between these variables have been well established (de Groot and Steg, 2007). Nevertheless, the degree to which a typology based on these variables can predict actual behaviour in a context of rural development has not been proven. Such a proof would require an initial survey to establish a baseline and a motivation typology, predictions to be made, and then a follow up survey to establish if the predictions were accurately matched actual behaviour. This work is only able to complete the initial steps of establishing a baseline and motivation typology, and making some predictions about farmer behaviour. A follow up survey would be required to establish the accuracy of the predictions. Acknowledging this limitation, we divide the population into sub-groups according to their differing motivational traits, where the assumption is that these sub-groups would behave differently. We then relate the motivational sub-groups to the more traditional typology based on observed 'farm characteristics'.

Value orientations are based on the theory that there are underlying values which are common world wide, and which can be elucidated using a standardised set of questions (Schwartz, 1992; Schwartz and Bilsky, 1987). The standardised questions have been streamlined for easier use (Stern et al., 1999, 1998) and tested in subsequent work (de Groot et al., 2008; de Groot and Steg, 2007). The five value orientations are: altruistic, egoistic, biospheric, openness to change, and traditionalism. Altruistic, also referred to in the literature as self-transcendence, means having interests in the well being of others. Egoistic, also referred to as self-enhancement, means improving one's own situation in life. Biospheric means having an interest in the well being of non-human life. Openness to change and traditionalism (also referred to as conservatism) represent opposite poles in terms of likelihood of trying out new ideas or practices. A more complete explanation of these terms and their empirical testing is provided in a recent review (Dietz, 2015). Three questions were used to appraise each of the five value

orientations (Smajgl and Ward, 2015), and the mean was used to determine the score for each value orientation. The interviewees' attitudes towards up to eight variables related to economy, environment and community were gathered using numerical scales between 0-10 to assess their perception of the 'importance of' each variable and their 'satisfaction with' each variable. Interviewees were asked select up to eight variables from a longer list of 38 and then scored the selected variables. They were also asked to rate their overall life satisfaction on a scale of one to ten.

The subjects' predictions for near future changes regarding natural resource decline (e.g. water, soil), farming practices (e.g. mechanisation, market orientation) and wider socio-economic changes (e.g. urban employment, increased tourism) were gauged using a modified seven-point Likert scale for both perceived likelihood and perceived impact upon the household. Eight questions were asked for each futures theme (Ward and Poutsma, 2013), which were then used to determine a mean score for each theme.

Finally, four hypothetical scenarios were outlined with multiple choice answers offered to the respondent. The four scenarios were: a 50% drop in the value of their main crop, lucrative urban employment opportunities, unpredictable climate change (hotter and dryer), and a government subsidy program for native trees replacing rubber trees, matching present income. The four scenarios were chosen through a multi-level participatory process (Smajgl et al., 2015a; Smajgl and Ward, 2015), where the first three were selected as feasible future scenarios and the fourth as a potential government intervention (Smajgl et al., 2015b)

The options available to respondents were: to ignore the scenario and carry on as usual, modify their current behaviour in some way, completely replace their current behaviour, or leave and go to a new place. Follow up questions were then asked probing the reasons for their decision, and if they decided to modify their behaviour, what would they modify and to what degree, and if they chose to migrate where would they go, for how long, and what would they do. The full questionnaire has been archived on Dataverse.

Once gathered, the data was compiled into a Microsoft Excel spreadsheet. Four observations were dropped due to missing data points or inexplicably high outlier values. Data analysis was conducted using R (R Core Team, 2012) and R Studio software (RStudio Team, 2016), and using the following packages: vegan (Oksanen et al., 2016), multcomp (Hothorn et al., 2008), ggplot2 (Wickham, 2009a), and plyr (Wickham, 2009b).

The two datasets ('farm characteristics' and 'motivations') were analysed separately, although both datasets went through a similar analytical process. The objective was to generate a meaningful typology based on each dataset, and then explore to what degree a typology based on farm characteristics can predict farmers’ motivations to

adapt. Typologies were generated using a hierarchical cluster analysis (Kaufman and Rousseeuw, 2009) of the most informative variables in each dataset . The most informative variables were selected using principle component analysis (PCA) (Jolliffe, 2002). Once derived, all variables were mapped onto the clusters and the clusters were interpreted as typologies. Significance of difference between clusters (‘farm types’) for individual variables was tested using a post hoc Tukey test of honest significant difference (Jaccard et al., 1984). Up to this point the methodology followed the approach commonly outlined in manuals for multivariate statistical analyses (Coghlan, 2013; James et al., 2013). The independence of the 'farm characteristics' typology and the 'motivations' typology was tested using a Pearson’s Chi squared test, and redundancy analysis (RDA) (Legendre and Legendre, 2012; Ter Braak, 1986) was used to determine the degree to which certain farm characteristics variables could be used to predict farmers’ motivations.

Prior to the PCA logically incompatible variables were excluded and remaining variables checked for normality of distribution. Where necessary and possible transformations were applied to bring distributions close to normal. Variables were dropped from further analysis if they were strongly correlated with another variable on all principle components, or if they showed little correlation with any principle component. Prior to cluster analysis variables were re-scaled to similar ranges. Cluster analysis was performed using a Gower dissimilarity matrix (Gower, 1971), which permits mixed data types including of numeric, ordinal and categorical data. Some data that were not appropriate for principal component analysis (e.g. multiple choice scenario responses) could therefore be included in the cluster analysis, along with the variables identified as most important through the PCA. The Ward minimum variance clusters method (Ward, 1963) was used to perform the hierarchical cluster analysis on the dissimilarity matrix. The final number of clusters was selected according to the point at which the explanatory power of further cluster subdivisions plateaued (see Supplementary Material Figures S1 and S2).

3. Results

3.1 Farm Characteristics: Site Overview

Households had a mean size of 4.3 members, median farm size of 2.9 ha, and median gross income of 7,500 USD per year. All incomes are referred to in gross terms. Both the farm size and the total income were highly variable,

with standard deviation approximately as large as the mean. The median amount of land per person was 0.75 ha and the median income per person was 5.1 dollars per day. Median agricultural incomes accounted for 5900 USD per household per year (or 2900 USD per hectare), and off-farm incomes 450 USD per household per year. In terms of income the study population is wealthier than most farmers in developing countries, which is due to the prosperity brought by the rubber boom and also to the rapid and sustained growth in China's economy.

The major crop for most households was rubber. Sixty-seven percent of households rated rubber as their most important and most reliable crop. Tea was rated as most important and most reliable by 24% of households and 4% of household rated maize as their most important and reliable crop. The most commonly practised agricultural activities were as follows; rubber (82%), rice (60%), maize (55%), livestock (54%), tea (37%), horticulture (15%), fruit trees (6%). Median annual incomes from those crops were as follows: rubber ($5900), rice ($0), maize ($0), livestock ($250), tea ($1200), horticulture ($200), fruit trees ($450). Rice and maize were widely grown crops but were generally used for household consumption and feeding of livestock – hence median income values of $0 from those crops. Note that the median value of crops is calculated only from households who reported growing that crop. Other minor activities mentioned were fishing and aquaculture, forestry, forest products and mushroom cultivation. Households on average practised three agricultural activities.

Almost all households (97%) had some form of off-farm income, but usually from passive sources, such as state subsidies (which 72% of household received), income from rental of land (42% of households), pensions (18% of households), and governmental compensation for land lost to industrial developments (5%). Active employment is much less common. The main activities and the proportion of households who undertook active off-farm activities were as follows; family business (e.g. shop, restaurant) (9%), government employment (8%), agricultural labouring (5%), tourism (3%), construction (3%), services (2%), and remittances (1%). The passive activities are typically lower income. Median annual incomes from off-farm activities were as follows; subsidies and pensions ($100), land rental ($950), land compensation ($650), family business ($2500), government employment ($200), agricultural labour ($650), tourism ($1500), construction ($1300), services ($450), remittances ($500). Again the median values are calculated only from households who report receiving some income from that activity.

Six ethnic groups were reported. Listed in decreasing order of frequency, they were Dai, Akha, Yi, Bulan, Han,

and 'other'. Household heads were typically reported to be male (96%) with an average age of 46 years. Fifty percent of household heads had received primary education and 19% reported basic secondary education. Twenty-five percent were illiterate. Youth education (youth defined as children of household head) was higher, with over fifty percent reporting basic secondary and approximately twenty percent reporting advanced secondary. Only 2% were illiterate. About half of the surveyed households were at lower elevations (500-700m), about one quarter at mid elevations (700-900m) and the remainder at high elevations (900-1600m).

3.2 Farm Characteristics Typology: Cluster Analysis

The following variables were used in cluster analysis: annual household income from rubber, fruit trees, tea, other agricultural sources combined, and off-farm incomes, number of agricultural and non-agricultural activities per household, farm size, age of household head, education level of household head and altitude above sea level. Selection of six clusters was identified as most appropriate, in order to keep the number of clusters manageable whilst showing the most meaningful diversity in farm characteristics (see figure S1 for justification). Verbal descriptions of the clusters are presented in Table 2 and numerical data (with significant differences marked) are presented in Table 3.

** insert tables 2 and 3 **

The six clusters (Tables 2 and 3) were named Young Rubber, Traditional Rubber, Rubber and Business, Mixed Cash Croppers, Tea Farmers, and Upland Mixed, and from here on will be referred to as ‘farm types’. In the first four farm types the main source of income was rubber, total income was relatively higher and farms were located at lower elevations. The latter two farm types were poorer, resided at higher elevations and derived the bulk of their income from sources other than rubber farming.

Household heads in the Young Rubber farm type were younger and better educated than others, and engaged in more off farm activities than Traditional Rubber farmers, although their off farm incomes were not significantly higher. Traditional Rubber farmers focused primarily on rubber for income, maintained medium level of diversity of subsistence crops, relied more upon remittances than other farm types, and were also the worst educated of all farm types. The Rubber and Business farm type showed the highest frequency of (and incomes from) off-farm activities of all farm types, in addition to their rubber farming activities. Although the Mixed Cash Croppers

derived their main income from rubber, they also derived a substantial income from other agricultural activities, including livestock, horticulture, and most notably fruit trees and perennials, by far the most profitable of which was banana. The Tea Farmers reside at high elevations and relied on tea for the majority of their income, supplemented by some staple crops. Upland Mixed farmers were the poorest of all farm types, relying on a variety of staple crops, rubber and tea for income, as well as a moderate amount of off-farm work.

Livelihood activities per farm type are presented in Figure 1. Rubber was the major income source for the Young Rubber, Traditional Rubber, Rubber and Business, and Mixed Cash Crop farmers, generating a mean of around 9000 USD per year per household (with standard deviation about the same as the mean, see Table 3 for means per farm type). Perennial fruits, such as banana, had the potential to generate large income of up to 10,000 USD per year, although only the Mixed Cash Croppers generated such a high income so far, and even that was relatively few farmers (<10% of the cluster). Tea generated a substantial income for the Upland Mixed farm type, of 2000 – 3500 USD per year per household. Although other farming activities were widely practised (rice, maize, livestock, horticulture) the products were mainly for self consumption and sales of those products generated between 5 and 20% of the household income. Most farm types derived a small proportion of their income from government subsidies and land rents (200 - 1000 USD per year). Far fewer households in all farm types engaged in the more profitable off-farm activities incomes. The average incomes per activity were highest from private businesses (including restaurants, shops, and trading agricultural produce) for most clusters at 3000 - 6000 USD per year. Farmers in the Upland Mixed and Rubber and Business farm types earned around 5000 USD per year in industrial work, and the Young Rubber cluster derived significant income from farm labouring work, although frequency of participation was lower than for private businesses.

** Insert Figure 1, on livelihood activities per farm type. **

3.3 Farmer Motivations: Site Overview

Households rated their overall life satisfaction at a mean score of 7.6. Satisfaction with economic factors was rated at 7.3, family factors at 8.7, and natural environment 8.0. Importance of the economy was rated at 9.5, importance of family at 9.7, and importance of natural environment at 9.4. The distributions of all 'importance' and 'satisfaction' responses were highly skewed towards the upper end of the scale. There was a particularly low

variance associated with measures of 'importance'.

Value orientations were calculated for five themes; egoistic, altruistic, biospheric, conservative, and innovation. Mean scores on a scale of 0 to 10 were as follows: egoistic 7.0, altruistic 7.8, biospheric 7.6, conservative 8.2, innovative 6.2. Conservative, altruistic, and biospheric value scores were skewed towards the upper end of the scale, while the egoistic and innovative values were approximately normally distributed.

Perceived likelihood of future events and estimated impact upon the household were calculated for three broad themes. Mean scores for likelihood, normalised to a scale of 0 to 10, were as follows; farming optimism 6.9, environmental pessimism 6.2, and sweeping socio-economic changes 3.9. Mean scores for impact were; farming optimism 6.1, environmental pessimism 6.7, and sweeping socio-economic changes 6.0. Distributions were approximately normal.

The four scenarios outlined to the farmers were: a) a 50% drop in value of main crop; b) lucrative urban employment opportunities; c) unpredictable climate change, and d) a government subsidy program for native trees to match present income. For a projected halving in the value of main crop, 41% of the population said they would ignore it and continue as normal, 57% said they would adjust their activities accordingly, 1% said they would totally replace their activities with something new, and 0.2% said they would leave and go somewhere else. Regarding the urban employment scenario, 73% said they would ignore the new opportunities, 23% said they would adjust their activities, 3% said they would completely change their activities, and 0.3% said they would leave and go somewhere else. Regarding the climate change scenario, 43% said they would ignore it, 50% said they would adjust their activities, 6% said they would completely replace their activities, and 1.4% said they would leave and go somewhere else. Regarding the native tree subsidies scenario, 30% said they would ignore it, 68% said they would adjust their activities, 0.5% said they would completely replace their activities, and 0% said they would leave.

When households were asked why they would not leave and go to a new place, the most frequent response for each scenario was “this is the village of our ancestors” (47-53% of responses chose this answer under each scenario). Other answers given were “we would not be affected”, “we're fine as we are”, “we like what we are

doing", and "we don't have the skills". The other answers ("no money", "need government support", "too risky", "no land in other place") however were not consistently chosen between scenarios and were typically selected by around 10% of the population. When asked why households would not adjust their activities to respond to a scenario, the most common answers across all scenarios were "we like what we are doing" (20-40% selected this response). Other answers given were "we would not be affected", "we're fine as we are", "it would be too risky" and "we don't have the skills".

3.4 Farmer Motivations Typology: Cluster Analysis

The following variables were retained and used in the cluster analysis: overall life satisfaction score, altruistic, egoistic, biospheric, and openness to change value scores, future environmental pessimism, future farming optimism, and frequency that the respondent reacted to the outlined scenarios. Six clusters were identified (see figure S2 for justification). Verbal descriptions of the farm types are presented in Table 4 and numerical data with significant differences between clusters are presented in Table 5.

** insert tables 4 and 5 on motivation type clusters **

The six clusters were named Aspirational Innovators, Copy Cats, Conscientious, Incentive-centric, Well Settled and Change Resistant, and from here on will be referred to as 'motivation types'. The Aspirational Innovators scored the highest on innovation related indices – openness to change and stated willingness to adapt to scenarios – and also expressed discontent with their economic, family and environmental circumstances, although they maintained a positive outlook for the future, and hence were interpreted as aspiring to improve their situation. The Conscientious cluster also scored highly on innovation indices, altruistic values, and showed the highest levels of concern regarding environmental and social issues, and very high satisfaction scores. The Copy Cat motivation type expressed high willingness to adapt their activities, but scored low on personal values relating to openness to change and egoistic behaviour, implying that they are not so strongly driven to experiment as some other motivation types. Therefore although they would be willing to adapt their activities, they might prefer to copy someone else rather than be the first to experiment. The Incentive-centric motivation type were primarily motivated by financial incomes and scored moderately on innovation indices. The Well Settled motivation type

were generally satisfied with all aspects of their lives and did not feel much imperative to modify their activities. The Change Resistant cluster showed middling levels of satisfaction, no specific guiding values, and very little interest in altering their activities for any reason. The most numerous motivation types were Aspirational Innovators, Incentive-centric and Change Resistant, and the least numerous were the Copy Cats (see Tables 4 and 5).

Figure 2 shows the reasons given by respondents as to why they would choose not to respond to the scenarios which were outlined to them, broken down by motivation type. The Change Resistant motivation type presented the most reasons in total why they would choose not to respond to external stimuli, and they presented the most diverse reasons, followed by the Incentive-Centric type, and then the Well Settled type. Aspirational Innovators, Copy Cats and Conscientious motivation types showed similar profiles to one another in terms of total number of barriers reported and diversity of reasons. The most commonly cited barriers to adaptation did not differ between motivation types, and indeed were the most commonly reported for the whole study sample: “we like what we are doing” and that the change would “not affect us”. Lack of money and the perceived risk of making changes also feature highly for all motivation types. Lack of skills, knowledge, infrastructural support and land were cited as barriers to adaptation only by the most change adverse motivation types (Change Resistant and the Incentive-Centric).

** Insert Figure 2: Reasons given by motivation types for why they would not respond to scenario changes. **

3.5 Linking the Farm Types and Motivation Types

The farm typology based on farming practices, livelihoods and household demographics showed almost no significant differences between the farm types in terms of motivations variables (few enough to be discarded as false positives). Likewise the motivation typology groups showed few significant differences in terms of livelihoods, farm practices or demographics. The only exceptions were that Aspirational Innovators, Copy Cats and Conscientious clusters tended to have more off-farm income activities than the other motivations clusters. This implies that farmers’ motivations to adapt cannot be inferred from standard farm typologies.

** Figure 3 on cluster distribution amongst clusters ***

However, the frequency distribution of households in farm types and motivation types was significantly non-random (Pearson's Chi Squared, $p<0.01$), meaning that some motivation types are more common in some farm types. Figure 3 shows the proportions of different motivation types in each farm type. Each of the six farm types contains households in all six of the motivation types. Hence, there is no obvious, or invariant, link between farm characteristics and farmer motivations. Observations can be made by comparison of the observed frequencies of motivation types within each farm type, compared to the expected frequencies should motivations and farm types be independent, with the caveat that statistical significance cannot be attributed to individual observations. Figure 3 illustrates this point: the Traditional Rubber, Tea Farmer, and Upland Mixed farm types show a higher proportion of households in the Change Resistant motivation type than would be expected (given independent distributions), where as the Young Rubber, Rubber and Business, and Mixed Cash Croppers show a lower proportion of household in the Change Resistant motivation type than would be expected. The Traditional Rubber farm type showed about one third fewer of the Aspirational Innovator motivation type than would be expected, and also Traditional Rubber and Tea Farmer types showed a higher proportion of the Well Settled motivation type. The Rubber and Business farm type showed notably higher proportions of motivation types more likely to adapt – Aspirational Innovators and Conscientious – and lower proportions of the motivation types less likely to adapt. Overall, we found significant evidence that farm type was linked to motivational type, and trends could be observed that three of the farm types (Traditional Rubber, Tea Farmers and Upland Mixed) were generally less likely to adapt, and one farm type (Rubber and Business) was more likely to adapt.

Redundancy analysis confirmed that farm characteristics variables explained a significant but low proportion of the variance within the farmer motivations variables (5% of the variance, $p<0.001$). Livelihood strategy (income generating activities) explained 2.5% of the total variance in motivations variables, altitude explained 1.4 %, household demographic information explained 1.2%, the number of agricultural activities and off-farm activities explained 1% and farm size explained 0.2%.

4. Discussion

While we found a statistically significant link between farm types and farmers' motivations to adapt their behaviours, the predictive power was low. A farmer's motivations could not, in this case, be reliably inferred from his livelihood and farm characteristics without having gathered separate, specific information regarding motivations. Such data is not usually collected, and socio-demographic proxies are usually used instead (Pattanayak et al., 2003). In this study, the usual proxies (age, ethnicity, education) showed no significant predictive power of farmers' motivation type. Our results here show that predicting how likely a farmer is to adapt his behaviour based on the usual farm typology data of farm structural characteristics, livelihoods or demographics (van der Ploeg et al., 2009) is not a very reliable strategy, and that consideration of 'intrinsic motivations' (Meijer et al., 2014) should be done separately. However, we acknowledge that further work is required to test the degree to which these motivation types accurately predict actual behaviour. A panel survey approach would be very valuable in this regard, particularly where farmers' responses to an intervention or set of interventions could be monitored.

When considering the farmers' motivations types and the farm types in combination, the most striking observation was that the full range of motivations type was found in every farm type, albeit with some differences in relative proportions (see Figure 3). This has significance for the number of households who would be interested to adapt their behaviour, and potentially become adopters of a new practice, any program could realistically expect to engage: across the whole population only about 25-35% of households are motivated to and willing to try out new innovations (Aspirational Innovators and Conscientious motivation types), and potentially about 40% of households could be expected to take up innovations once proven successful by other users and assuming that appropriate support mechanisms were in place (Copy Cats, Incentive-centric and Well Settled motivation types), and the remaining 25% of households were very resistant to uptake of new innovations (Change Resistant) (Tables 4 and 5). In the 'diffusion of innovations' literature potential adopters are classified into five groups, ranked in decreasing order of eagerness to adopt new products or practices; innovators, early adopters, early majority, late majority and laggards (Rogers, 2010). These classifications could well apply in the present study, whereby the Aspirational Innovator type equates with the innovator group, Conscientious type the early adopters, Copy Cats early majority, Incentive-Centric and Well Settled types sitting somewhere between the early majority and the late

majority, and finally the Change Resistant type as the laggards (although it should be stressed that the present study assessed willingness to adapt behaviour in a variety of ways, rather than willingness to adopt a specific practice). The relative proportions of the population who fall into these categories and their structural characteristics has long been studied in marketing literature (Uhl et al., 1970) but not so much in the development literature, so it is difficult to know if the proportions we have identified are replicated in other locations. There are also strategic implications as to which groups should be targeted by programs promoting new innovations – initial focus on the more innovative types is likely to bring about a higher adoption rate due to the higher willingness of those groups to adapt their behaviours, but the most innovative may not be the most in need of assistance.

The motivations data can also be used to inform the design of mechanisms that encourage farmers to adapt their behaviours. Typically such mechanisms are grouped into awareness raising/education, regulatory instruments, and economic incentives. Probably the most widely used mechanism is subsidy, although many others exist. We found that about half of the population appeared to be strongly motivated by economic factors – the Aspirational Innovators and Incentive-centric motivational types – but that only the Aspirational Innovators were generally willing to adapt and try out new practices (see Tables 4 and 5). The Incentive-centric cluster scored highly on innovation values, but showed a relatively low willingness to adapt their behaviour and cited more obstacles to behaviour change than most other clusters (see Figure 2), therefore subsidies alone are unlikely to motivate them to trial new practices. In line with other research in Xishuangbanna, we therefore suggest that subsidies are not the most appropriate mechanism to encourage a change in behaviour (Smajgl et al., 2015b; Wigboldus et al., 2016; Yi et al., 2014b), but should form part of a wider strategy of removing obstacles to adaptation. It is interesting to note that out of the four scenarios outlined to participants in this study, the one which elicited the most positive response from participants was the government subsidy program for native trees replacing rubber trees to match present income – but also that a small number of households also rejected this scenario with the reason that they did not believe it was feasible. With mean rubber incomes at around 9000 USD per year for a rubber growing household at the time of the study (Table 3), it is indeed almost impossible that such a high subsidy scheme could be offered.

Awareness raising and educational mechanisms to encourage adoption appear to be the most necessary. The number one cited reason that households did not wish to adapt was that they did not see the relevance of external

changes to themselves (Figure 2). In order to increase the perceived imperative to adapt, making interventions relevant to issues which the potential users consider important seems sensible. All groups reported strong identification with their sense of place (almost all respondents would not consider leaving) and reported high importance of family. Financial variables were considered very important for about half the households, and few groups reported much concern about environmental variables. Environmental benefit is a key driver for science and policy efforts to curb unsustainable land use (Ahrends et al. 2015), and although there is widespread agreement amongst respondents that ecosystem services related to water, soil and biodiversity are declining (Table 4), only about 11% of the surveyed population appeared motivated by such messages (the Conscientious motivation type). Messages which appeal to sense of place and long term benefit to family might therefore be more successful than messages relating to environmental impacts. These findings are in line with recent work based on integrative qualitative assessment in Xishuangbanna (Wigboldus et al., 2016).

More material barriers to adaptation such as lack of money, lack of skills or lack of land are cited considerably less frequently (Figure 2). Although this has also been reported elsewhere (Kiptot et al., 2007), it is often overlooked in the design of projects which aim to promote new agricultural practices. We found that general resistance to change was a greater impediment to adaptation than the more material or specific issues which government/development programs often seek to address. This trend is particularly marked for the clusters which are more likely to be early adapters – the Aspirational Innovators, Conscientious and the Copy Cats. These data suggest that in order to achieve higher adoption rates, interventions should be accompanied by educational and participatory components which respond to the needs identified as important to the farmers: an explanation of the problem the intervention addresses, a realistic exploration of the risk profile, and a sensitive, pragmatic consideration of how the intervention would interact with the farmers' existing work schedules. Such nuanced trappings require re-organization of traditional research modes into a more dynamic configuration (Schut et al., 2014), and need strong relationships with community members which preclude the falsely efficient 'one size fits all' development packages which can be deployed in multiple locations.

The overall picture from the survey data however is of a society which is fairly well satisfied, wealthier than most developing world farming communities, and quite mixed in terms of adaptation and trying new ideas. People are generally optimistic about their future, and believe that they will continue farming and their standard of living will

continue to improve. This optimism may be founded upon the rapid upwards trajectory of development in Xishuangbanna and in China as a whole over the past few decades. We cannot say if the findings of the motivations typology and the weakness of the link between farm type and motivation type would be the same in poorer and more desperate locations. It would certainly be worth testing.

Whilst scientists are seriously concerned about the risks posed by declining levels of biodiversity, soil health and economic vulnerability due to rubber cropping (Ahrends et al., 2015; Warren-Thomas et al., 2015), concerns about economic well being predominate amongst the local population (Wigboldus et al., 2016) and rubber farming has been the route out of poverty for most households surveyed. This is not a society which would be easy to influence unless some sort of crisis were to destabilise the social equilibrium. Such an opportunity may be provided by the crash in rubber price from over $6 per kg in 2011 to approximately $1.5 per kg in 2013. The time may well be ripe for a combination of financial incentives and educational messaging which promotes alternative land use practices, with government and private sector efforts to develop associated infrastructure and markets for alternative crops. Motivations typologies might be useful in design and targeting of such a strategy.

If motivations data can be used to understand how many households might be expected to adapt, at what point in time (e.g. early adopters, late adopters), and to help design promotional mechanisms for interventions, farm structural characteristics data is useful to inform what those adaptations could be. Interventions proposed for making rubber more sustainable can be divided into four broad categories: improved farming practices and technology, improved knowledge and awareness, market and value chain measures, and policy measures. Market and value chain measures could be a promising avenue, as some households report running their own small businesses, and the entrepreneurial Rubber and Business farm type accounts for about 20% of the total population (Tables 2 and 3). Likewise, amongst the more impoverished upland farmers, private businesses are a major source of income and may indicate the entrepreneurial basis required for value chain developments. Farm practice interventions can be further subdivided into two types: modifying rubber management (e.g. less pesticides, planting density, alternative hybrids) and alternative crops (e.g. intercropping, land use zoning). Alternative crops obviously require a route to market in order to be a viable option, which is why the value chain measures are so important. Changes to rubber management may be easier therefore to achieve in the short term, but are affected by the concerns outlined regarding adoption rates and connecting to farmers' motivations. The Traditional Rubber

farm type – the largest of all the farm types – would be the most difficult to influence regarding changes to farm management. The household heads tend to be older, less educated, they tend to have lower cropping diversity (Table 3), and the Tradition Rubber farm type contains more Change Resistant and Well Settled motivation types than any other farm type (Figure 3). Interventions regarding changes to farming practice may therefore be better targeted towards younger household heads (Young Rubber), or households which are already engaged in a greater diversity of cash crops (Mixed Cash Croppers) (see Tables 2 and 3). The Upland Mixed farming cluster are also worthy of further discussion: they were the poorest cluster, and had the lowest profit rubber plantations, which were established at elevations 700-900 metres, around the maximum elevation where rubber trees can be profitably grown (Yi et al., 2014a). These farmers may be especially hard hit by the rubber price crash, as their plantations are now unlikely to be viable. Subsidy schemes and participatory training methods to encourage alternative cropping linked with value chain developments and ecological management of high elevation water courses might be especially appropriate for the upland farmers.

The implications for improving adaptation rates through enhanced understanding of farmers' motivations have significance for tropical farming systems broadly, indeed in any site where the development interventions are proposed by actors who have a different world view and different priorities to the intended users. This appreciation of the users' needs and motivations has often been overlooked (Meijer et al., 2014; Pattanayak et al., 2003) and can help to achieve the appropriate service delivery mechanisms and co-learning methods identified as key to achieving up-scaling in agricultural development (Coe et al., 2014; Schut et al., 2014). The approach we trialled appears to yield useful information and we propose that it should be further developed and tested. Particularly useful were the questions on guiding values developed from the field of social psychology (de Groot et al., 2008). These questions were extensively tested in the European context (de Groot and Steg, 2007), and that they delivered useful findings in an Asian context is promising for the global applicability of this method. The value orientation questions could however be modified to better suit the local context, and the scoring system could be improved encouraging respondents to use the full range of the scale. The scenario questions were also very useful in determining stated willingness to adapt behaviour (contingent upon hypothetical events), and the perceived obstacles to adaptation, although most of the detail gathered in follow up questions was not useful in this analysis. In future it may be better to ask about more scenarios but with less follow up questions. The questions asked about attitudes, satisfaction and future perceptions were less useful in differentiating households

in this study. With these further refinements it might be possible to develop a more streamlined suite of questions which would allow rapid exploration of farmer motivations, without resorting to inaccurate assumptions based on socio-demographics or livelihood proxies.

5. Conclusions

Six farm types were identified, four of which relied primarily on rubber crops and could be considered wealthy by regional standards. Six motivation types were also identified, ranging from farmers who were most likely to innovate, farmers motivated primarily by income or by community and environmental benefit, to farmers reluctant to innovate under any circumstance. The full range of motivations types were found in all six farm types, albeit with a small but significant variation in proportions between farm types. This has two implications: (i) when designing interventions for a group of farmers defined by their farming practice, the full diversity of motivational orientations should be considered, and only a sub-group of those farmers should be expected to engage actively with new interventions; and (ii) in order to understand farmer motivations additional data is required beyond the usual farm characteristics and livelihood information. We found that an assessment of value orientations (Smajgl and Ward, 2015; Stern et al., 1998), along with stated response to some hypothetical external influences and a simple rating of overall life satisfaction data types were the most useful in defining farmers' motivations to adapt their behaviour.

Rubber farmers in the study population are wealthy by developing world standards, and any proposed changes to their farming practice would need to compete economically with mean incomes of around 9000 USD per year per household. However, due to the recent rubber price crash, households may now consider alternative activities with lower incomes. Maintaining adequate income is only one factor which motivates households, with about half the population strongly motivated by income, but messages which appeal to a sense of place and family well being have wider appeal. Without widespread awareness raising and education, arguments using environmental degradation as a motivating message for farmers to adapt their behaviour are unlikely to achieve much success. The obstacles to adaptation which were identified most frequently were conceptual rather than material: households felt that changing their behaviour would be unnecessary and irrelevant rather than feeling that they

lacked the skills or capital in order to make changes. Amongst the study population, only about one third could be classed as keen to innovate and try out new practices, which, if found to be true elsewhere, explains in part the challenge of promoting new agricultural interventions more generally.

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Reference List

Ahrends, A., Hollingsworth, P.M., Ziegler, A.D., Fox, J.M., Chen, H., Su, Y., Xu, J., 2015. Current trends of rubber plantation expansion may threaten biodiversity and livelihoods. Glob. Environ. Chang. 34, 48–58. doi:http://dx.doi.org/10.1016/j.gloenvcha.2015.06.002

Barnes, A.D., Jochum, M., Mumme, S., Haneda, N.F., Farajallah, A., Widarto, T.H., Brose, U., 2014. Consequences of tropical land use for multitrophic biodiversity and ecosystem functioning. Nat Commun 5.

Bongers, G., Fleskens, L., Van De Ven, G., Mukasa, D., Giller, K., Van Asten, P., 2015. Diversity in Smallholder Farms Growing Coffee and Their Use of Recommended Coffee Management Practices in Uganda. Exp. Agric. 1–21. doi:10.1017/S0014479714000490

Coe, R., Sinclair, F., Barrios, E., 2014. Scaling up agroforestry requires research “in” rather than “for” development. Curr. Opin. Environ. Sustain. 6, 73–77. doi:10.1016/j.cosust.2013.10.013

Coghlan, A., 2013. A Little Book of R For Multivariate Analysis.

Cotter, M., Berkhoff, K., Gibreel, T., Ghorbani, A., Golbon, R., Nuppenau, E.A., Sauerborn, J., 2014. Designing a sustainable land use scenario based on a combination of ecological assessments and economic optimization. Ecol. Indic. 36, 779–787. doi:10.1016/j.ecolind.2013.01.017

De Blécourt, M., Hänsel, V.M., Brumme, R., Corre, M.D., Veldkamp, E., 2014. Soil redistribution by terracing alleviates soil organic carbon losses caused by forest conversion to rubber plantation. For. Ecol. Manage. 313, 26–33. doi:10.1016/j.foreco.2013.10.043

de Groot, J.I., Steg, L., de Groot, J, Steg, L., 2008. Value Orientations to Explain Beliefs Related to Environmental Significant Behavior. Environ. Behav. 40, 330–354.

de Groot, J.I.M., Steg, L., 2007. Value Orientations and Environmental Beliefs in Five Countries: Validity of an Instrument to Measure Egoistic, Altruistic and Biospheric Value Orientations. J. Cross. Cult. Psychol. 38, 318–332. doi:10.1177/0022022107300278

Dietz, T., 2015. Environmental value, in: Brosch, T., Sander, D. (Eds.), Handbook of Value: Perspectives from Economics, Neuroscience, Philosophy, Psychology and Sociology. Oxford University Press, Oxford, pp. 329–349.

Foley, J.A., DeFries, R., Asner, G.P., Barford, C., Bonan, G., Carpenter, S.R., Chapin, F.S., Coe, M.T., Daily, G.C., Gibbs, H.K., Helkowski, J.H., Holloway, T., Howard, E.A., Kucharik, C.J., Monfreda, C., Patz, J.A., Prentice, I.C., Ramankutty, N., Snyder, P.K., 2005. Global Consequences of Land Use. Science (80-.). 309, 570–574.

Foley, J.A., Ramankutty, N., Brauman, K.A., Cassidy, E.S., Gerber, J.S., Johnston, M., Mueller, N.D., O/'Connell, C., Ray, D.K., West, P.C., Balzer, C., Bennett, E.M., Carpenter, S.R., Hill, J., Monfreda, C., Polasky, S., Rockstrom, J., Sheehan, J., Siebert, S., Tilman, D., Zaks, D.P.M.,. Solutions for a cultivated planet. Nature 478, 337–342.

Fox, J., Castella, J., 2013. The Journal of Peasant Studies Expansion of rubber (Hevea brasiliensis) in Mainland Southeast Asia : what are the prospects for smallholders ? 37–41. doi:10.1080/03066150.2012.750605

Fox, J.M., Castella, J.C., Ziegler, A.D., Westley, S.B., 2014. Rubber plantations expand in mountainous Southeast Asia: What are the consequences for the environment? Asia Pacific Issues.

Fu, Y., Chen, J., Guo, H., Hu, H., Chen, a., Cui, J., 2010. Agrobiodiversity loss and livelihood vulnerability as a consequence of converting from subsistence farming systems to commercial plantation-dominated systems in Xishuangbanna, Yunnan, China: A household level analysis. L. Degrad. Dev. 21, 274–284. doi:10.1002/ldr.974

Gibson, L., Lee, T.M., Koh, L.P., Brook, B.W., Gardner, T.A., Barlow, J., Peres, C.A., Bradshaw, C.J.A., Laurance, W.F., Lovejoy, T.E., Sodhi, N.S., 2011. Primary forests are irreplaceable for sustaining tropical biodiversity. Nature 478, 378–381.

Gower, J.C., 1971. A general coefficient of similarity and some of its properties. Biometrics 857–874.

Greiner, R., Patterson, L., Miller, O., 2009. Motivations, risk perceptions and adoption of conservation practices by farmers. Agric. Syst. 99, 86–104. doi:10.1016/j.agsy.2008.10.003

Hassenforder, E., Smajgl, A., Ward, J., 2015. Towards understanding participatory processes: Framework, application and results. J. Environ. Manage. 157, 84–95. doi:10.1016/j.jenvman.2015.04.012

Herrero, M., Thornton, P.K., Bernués, A., Baltenweck, I., Vervoort, J., van de Steeg, J., Makokha, S., van Wijk, M.T., Karanja, S., Rufino, M.C., Staal, S.J., 2014. Exploring future changes in smallholder farming systems by linking socio-economic scenarios with regional and household models. Glob. Environ. Chang. 24, 165–182. doi:10.1016/j.gloenvcha.2013.12.008

Hothorn, T., Bretz, F., Westfall, P., 2008. Simultaneous inference in general parametric models. Biometrical J. doi:10.1002/bimj.200810425

Houghton, R.A., House, J.I., Pongratz, J., van der Werf, G.R., DeFries, R.S., Hansen, M.C., Le Quéré, C., Ramankutty, N., 2012. Carbon emissions from land use and land-cover change. Biogeosciences 9, 5125–5142. doi:10.5194/bg-9-5125-2012

Jaccard, J., Becker, M.A., Wood, G., 1984. Pairwise multiple comparison procedures: A review. Psychol. Bull. 96, 589–596. doi:10.1037/0033-2909.96.3.589

James, G., Witten, D., Hastie, T., Tibshirani, R., 2013. An Introduction to Statistical Learning with Applications in R. Springer, New York, Heidelberg, Dordrecht, London. doi:10.1007/978-1-4614-7138-7

Jolliffe, I.T., 2002. Principal Component Analysis, Components, Springer Series in Statistics. Springer.

Jones, N.A., Shaw, S., Ross, H., Witt, K., Pinner, B., 2016. The study of human values in understanding and managing social-ecological systems. Ecol. Soc. 21. doi:10.5751/ES-07977-210115

Kaufman, L., Rousseeuw, P.J., 2009. Finding Groups in Data: An Introduction to Cluster Analysis, Wiley Series in Probability and Statistics. Wiley.

Kiptot, E., Hebinck, P., Franzel, S., Richards, P., 2007. Adopters, testers or pseudo-adopters? Dynamics of the use of improved tree fallows by farmers in western Kenya. Agric. Syst. 94, 509–519. doi:10.1016/j.agsy.2007.01.002

Lawrence, D., Vandecar, K., 2015. Effects of tropical deforestation on climate and agriculture. Nat. Clim. Chang. 5, 27–36.

Le Quéré, C., Peters, G.P., Andres, R.J., Andrew, R.M., Boden, T.A., Ciais, P., Friedlingstein, P., Houghton, R.A., Marland, G., Moriarty, R., Sitch, S., Tans, P., Arneth, A., Arvanitis, A., Bakker, D.C.E., Bopp, L., Canadell, J.G., Chini, L.P., Doney, S.C., Harper, A., Harris, I., House, J.I., Jain, A.K., Jones, S.D., Kato, E., Keeling, R.F., Klein Goldewijk, K., Körtzinger, A., Koven, C., Lefèvre, N., Maignan, F., Omar, A., Ono, T., Park, G.-H., Pfeil, B., Poulter, B., Raupach, M.R., Regnier, P., Rödenbeck, C., Saito, S., Schwinger, J., Segschneider, J., Stocker, B.D., Takahashi, T., Tilbrook, B., van Heuven, S., Viovy, N., Wanninkhof, R., Wiltshire, A., Zaehle, S., 2014. Global carbon budget 2013. Earth Syst. Sci. Data 6, 235–263. doi:10.5194/essd-6-235-2014

Legendre, P., Legendre, L., 2012. Numerical Ecology, 3rd Englis. ed. Elsevier.

Li, H., Aide, T.M., Ma, Y., Liu, W., Cao, M., Cao, Æ.M., Li, H., Aide, T.M., Ma, Y., Liu, W., Cao, M., 2006. Demand for rubber is causing the loss of high diversity rain forest in SW China. Biodivers. Conserv. 16, 1731–1745. doi:10.1007/s10531-006-9052-7

Li, H., MA, Y., GUO, Z., LIU, W., 2007. Land Use/Land Cover Dynamic Change in Xishuangbanna Based on RS and GIS Technology. J. Mt. Sci. 3, 3.

Li, H., Ma, Y., Liu, W.W., Liu, W.W., 2009. Clearance and fragmentation of tropical rain forest in Xishuangbanna, SW, China. Biodivers. Conserv. 18, 3421–3440. doi:10.1007/s10531-009-9651-1

Liu, W.W., Luo, Q., Li, J., Wang, P., Lu, H., Liu, W.W., Li, H., 2015. The effects of conversion of tropical rainforest to rubber plantation on splash erosion in Xishuangbanna, SW China. Hydrol. Res. 46, 168. doi:10.2166/nh.2013.109

Marshall, N. a., Smajgl, A., 2013. Understanding Variability in Adaptive Capacity on Rangelands. Rangel. Ecol. Manag. 66, 88–94. doi:10.2111/REM-D-11-00176.1

Meijer, S.S., Catacutan, D., Ajayi, O.C., Sileshi, G.W., Nieuwenhuis, M., 2014. The role of knowledge, attitudes and perceptions in the uptake of agricultural and agroforestry innovations among smallholder farmers in sub-Saharan Africa. Int. J. Agric. Sustain. 13, 1–15. doi:10.1080/14735903.2014.912493

Oksanen, J., Blanchet, F.G., Friendly, M., Kindt, R., Legendre, P., McGlinn, D., Minchin, P.R., O'Hara, R.B., Simpson, G.L., Solymos, P., Stevens, M.H.H., Szoecs, E., Wagner, H., 2016. vegan: Community Ecology Package.

Pattanayak, S.K., Mercer, D.E., Sills, E., Yang, J.C., 2003. Taking stock of agroforestry adoption studies. Agrofor. Syst. 57, 173–186. doi:10.1023/A:1024809108210

Phalan, B., Onial, M., Balmford, A., Green, R.E., 2011. Reconciling Food Production and Biodiversity Conservation: Land Sharing and Land Sparing Compared. Science (80-.). 333, 1289–1291.

Power, A.G., 2010. Ecosystem services and agriculture: tradeoffs and synergies. Philos. Trans. R. Soc. London B Biol. Sci. 365, 2959–2971. doi:10.1098/rstb.2010.0143

R Core Team, 2012. R: A Language and Environment for Statistical Computing [WWW Document]. R Found. Stat. Comput. Vienna Austria. doi:ISBN 3-900051-07-0,

Riedel, S., Schiborra, A., Huelsebusch, C., Huanming, M., Schlecht, E., 2012. Opportunities and challenges for smallholder pig production systems in a mountainous region of Xishuangbanna, Yunnan Province, China. Trop. Anim. Health Prod. 44, 1971–1980. doi:10.1007/s11250-012-0166-5

Rogers, E.M., 2010. Diffusion of Innovations, 4th Edition. Free Press.

RStudio Team, 2016. RStudio: Integrated Development Environment for R.

Rufino, M.C., Thornton, P.K., Ng, S.K., Mutie, I., Jones, P.G., Wijk, M.T. Van, Herrero, M., 2013. Transitions in agro-pastoralist systems of East Africa : Impacts on food security and poverty. Agric. Ecosyst. Environ. 179, 215–230. doi:10.1016/j.agee.2013.08.019

Schut, M., Paassen, A. Van, Leeuwis, C., Klerkx, L., 2014. Towards dynamic research configurations : A framework for reflection on the contribution of research to policy and innovation processes 41, 207–218. doi:10.1093/scipol/sct048

Schwartz, S.H., 1992. Universals in the content and structure of values: theory and empirical tests in 20 countries., in: Zanna, M. (Ed.), Advances in Experimental Social Psychology. Academic Press, New York, USA, pp. 1–65.

Schwartz, S.H., Bilsky, W., 1987. Toward a psychological structure of human values. J. Pers. Soc. Psychol. 53, 550–562.

Smajgl, A., Ward, J., 2015. Evaluating participatory research: Framework, methods and implementation results. J. Environ. Manage. 157, 311–319. doi:10.1016/j.jenvman.2015.04.014

Smajgl, A., Ward, J., 2013. A framework to bridge science and policy in complex decision making arenas. Futures 52, 52–58. doi:10.1016/j.futures.2013.07.002

Smajgl, A., Ward, J., Pluschke, L., 2016. The water–food–energy Nexus – Realising a new paradigm. J. Hydrol. 533, 533–540. doi:http://dx.doi.org/10.1016/j.jhydrol.2015.12.033

Smajgl, A., Ward, J.R., Foran, T., Dore, J., Larson, S., 2015a. Visions, beliefs, and transformation: Exploring cross-sector and transboundary dynamics in the wider Mekong region. Ecol. Soc. 20. doi:10.5751/ES-

07421-200215

Smajgl, A., Xu, J., Egan, S., Yi, Z.-F., Ward, J., Su, Y., 2015b. Assessing the effectiveness of payments for ecosystem services for diversifying rubber in Yunnan, China. Environ. Model. Softw. 69, 187–195. doi:10.1016/j.envsoft.2015.03.014

Smajgl, A., Xu, J., Egan, S., Yi, Z., Ward, J., Su, Y., 2015c. Environmental Modelling & Software Assessing the effectiveness of payments for ecosystem services for diversifying rubber in Yunnan , China. Environ. Model. Softw. 69, 187–195. doi:10.1016/j.envsoft.2015.03.014

Stern, P.C., Dietz, T., Abel, T., Guagnano, G.A., Kalof, L., 1999. A value belief norm theory of support for social movements: the case of environmental concern. Hum. Ecol. Rev. 6, 81–97.

Stern, P.C., Dietz, T., Guagnano, G.A., 1998. A brief inventory of values. Educ. Psychol. Meas. 58, 984–990.

Ter Braak, C.J.F., 1986. Canonical Correspondence Analysis: a new eigenvector technique for multivariate direct gradient analysis. Ecology 67, 1167–1179. doi:10.2307/1938672

Thongyou, M., 2014. Rubber Cash Crop and Changes in Livelihoods Strategies in a Village in Northeastern Thailand. Asian Soc. Sci. 10, 239–251. doi:10.5539/ass.v10n13p239

Uhl, K., Andrus, R., Poulsen, L., 1970. How Are Laggards Different? An Empirical Inquiry. J. Mark. Res. 7, 51–54. doi:10.2307/3149506

van der Ploeg, J.D., Laurent, C., Blondeau, F., Bonnafous, P., 2009. Farm diversity, classification schemes and multifunctionality. J. Environ. Manage. 90, S124–S131. doi:10.1016/j.jenvman.2008.11.022

van Ittersum, M.K., Ewert, F., Heckelei, T., Wery, J., Alkan Olsson, J., Andersen, E., Bezlepkina, I., Brouwer, F., Donatelli, M., Flichman, G., Olsson, L., Rizzoli, A.E., van der Wal, T., Wien, J.E., Wolf, J., 2008. Integrated assessment of agricultural systems - A component-based framework for the European Union (SEAMLESS). Agric. Syst. 96, 150–165. doi:10.1016/j.agsy.2007.07.009

Viswanathan, P.K., Shivakoti, G.P., 2008. Adoption of rubber-integrated farm-livelihood systems: contrasting empirical evidence from the Indian context. J. For. Res. 13, 1–14. doi:10.1007/s10310-007-0047-3

Ward, J., Poutsma, H., 2013. The compilation and summary analysis of Tonle Sap Household livelihoods: exploring Tonle Sap Futures Project. Canberra, Australia.

Ward, J.H.J., 1963. Hierarchical Grouping to Optimize an Objective Function. J. Am. Stat. Assoc. 58, 236–244.

Warren-Thomas, E., Dolman, P.M., Edwards, D.P., 2015. Increasing Demand for Natural Rubber Necessitates a Robust Sustainability Initiative to Mitigate Impacts on Tropical Biodiversity. Conserv. Lett. 8, 230–241. doi:10.1111/conl.12170

Wickham, H., 2009a. ggplot2: elegant graphics for data analysis.

Wickham, H., 2009b. plyr.

Wigboldus, S., Hammond, J., Xu, J., Yi, Z.-F., He, J., Klerkx, L., Leeuwis, C., 2016. Scaling green rubber cultivation in Southwest China—An integrative analysis of stakeholder perspectives. Sci. Total Environ. doi:10.1016/j.scitotenv.2016.12.126

Xu, J., Grumbine, R.E., Beckschäfer, P., 2014. Landscape transformation through the use of ecological and socioeconomic indicators in Xishuangbanna, Southwest China, Mekong Region. Ecol. Indic. 36, 749–

756. doi:10.1016/j.ecolind.2012.08.023

Yi, Z.-F., Cannon, C.H., Chen, J., Ye, C.-X., Swetnam, R.D., 2014a. Developing indicators of economic value and biodiversity loss for rubber plantations in Xishuangbanna, southwest China: A case study from Menglun township. Ecol. Indic. 36, 788–797. doi:10.1016/j.ecolind.2013.03.016

Yi, Z.-F., Wong, G., Cannon, C.H., Xu, J., Beckschäfer, P., Swetnam, R.D., 2014b. Can carbon-trading schemes help to protect China's most diverse forest ecosystems? A case study from Xishuangbanna, Yunnan. Land use policy 38, 646–656. doi:10.1016/j.landusepol.2013.12.013

Zhang, Y., Peña-Arancibia, J.L., McVicar, T.R., Chiew, F.H.S., Vaze, J., Liu, C., Lu, X., Zheng, H., Wang, Y., Liu, Y.Y., Miralles, D.G., Pan, M., 2016. Multi-decadal trends in global terrestrial evapotranspiration and its components. Sci. Rep. 6, 19124.

Ziegler, A.D., Fox, J.M., Xu, J., 2009. The Rubber Juggernaut. Science 324, 1024–5. doi:10.1126/science.1173833

Zomer, R.J., Trabucco, A., Wang, M., Lang, R., Chen, H., Metzger, M.J., Smajgl, A., Beckschäfer, P., Xu, J., 2014. Environmental stratification to model climate change impacts on biodiversity and rubber production in Xishuangbanna, Yunnan, China. Biol. Conserv. 170, 264–273. doi:10.1016/j.biocon.2013.11.028

Tables

Table 1. Sampling structure of the households surveyed within Xishuangbanna. Jurisdictional levels within the province of Xishuangbanna are county, township, village committee (a group of villages represented by a common government committee), and finally natural villages (normal villages – a group of houses located close to one another).

Table 2: Verbal descriptions and comparisons of the farm types based on structural characteristics and livelihoods. Differences mentioned are significant at 95%, tested with Tukey's HSD, and individual pairwise comparisons are shown in Table 3.

Table 3. Numerical descriptions of the farm types based on structural characteristics and livelihoods. Mean values are shown, with all incomes in USD and gross values. Letters after the numbers indicate significant differences between clusters, at $p<0.05$, using the Tukey HSD test. Abbreviations: ‘Agric.’ means agricultural, ‘excl.’ means excluding, ‘HH’ means household. Educational level was converted from ordinal to numerical data, where 0 means illiterate, 1 literate, 2 primary, 3 secondary and 4 post-secondary.

Table 4: Verbal descriptions and comparisons of farmer motivations clusters. Differences mentioned are significant at 95%, tested with Tukey's HSD, and individual pairwise comparisons are shown in Table 5.

Table 5. Numerical descriptions of the Farmer Motivation types. Mean values are shown, and all variables are scored between 0 and 10, except for ‘Ignore Scenarios’. Ignore Scenarios is scored 0 to 4, where 0 means that the respondent chose to respond in some way to all four scenarios, and 4 means they chose to ignore (not respond) to all four scenarios. Letters after the numbers indicate significant differences between clusters, at $p<0.05$, using the Tukey HSD test.

Figures

Figure 1. Livelihood activities by farm type. The frequency that agricultural activities and off-farm activities are reported for household and the mean income for each activity is shown. Note that the total height of the bars for mean income of each activity does not equal the mean income of a household in that cluster, as not every household takes part in every activity. The mean household incomes per farm type are shown in Table 3. The total number of activities reported may be larger than the number of households in a cluster because some of the categories are made up of a more than one activity. Note that the total number of activities relating to Subsidies and Rent reported by the Rubber and Business farm type was 434, but the axis scale was limited to enhance overall readability.

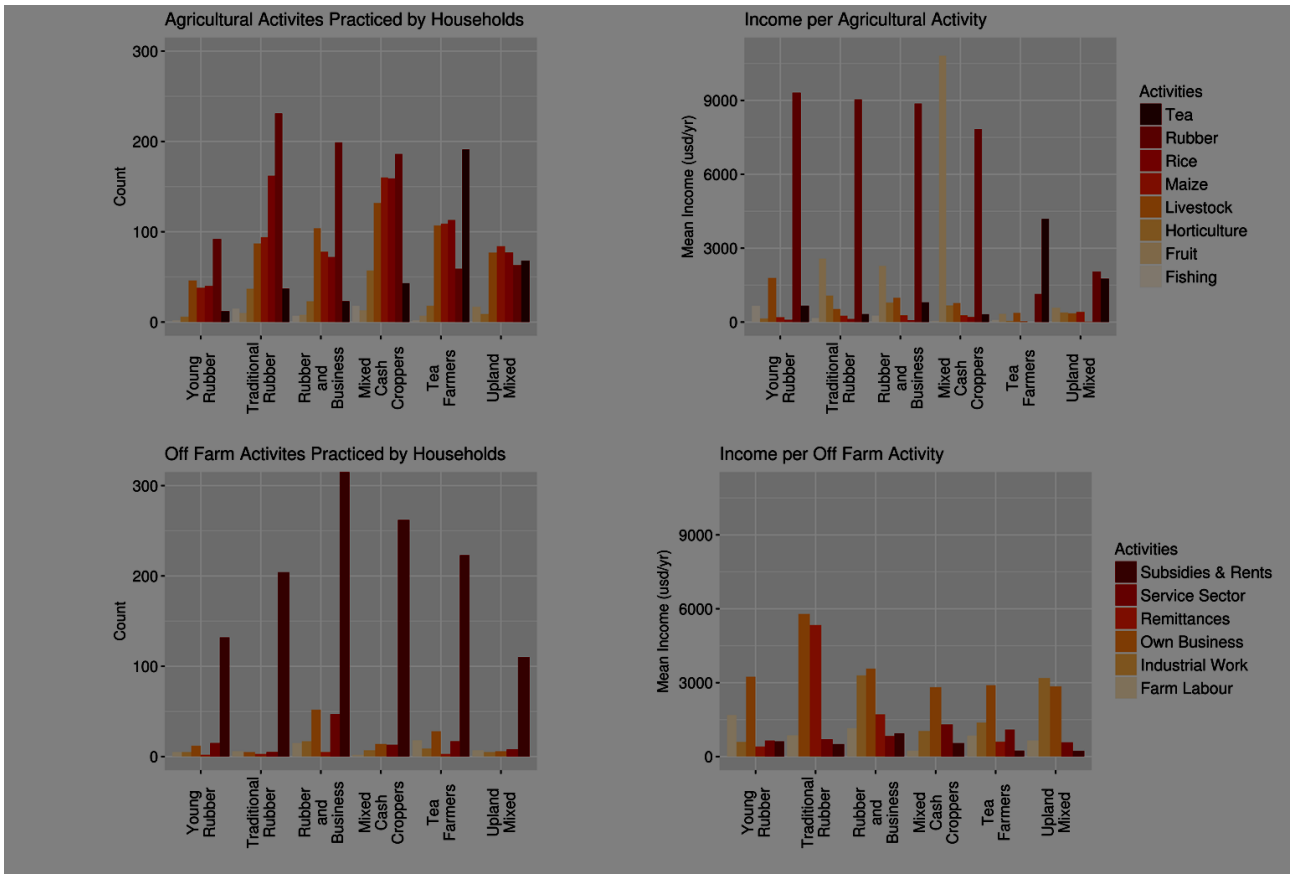

Figure 2: Reasons given by motivations clusters for why they would choose not respond to one or more of the four hypothetical scenarios outlined to them – i.e. why they would choose not to adapt their behaviour to an external stress. Some clusters chose not to respond to scenarios more frequently than others.

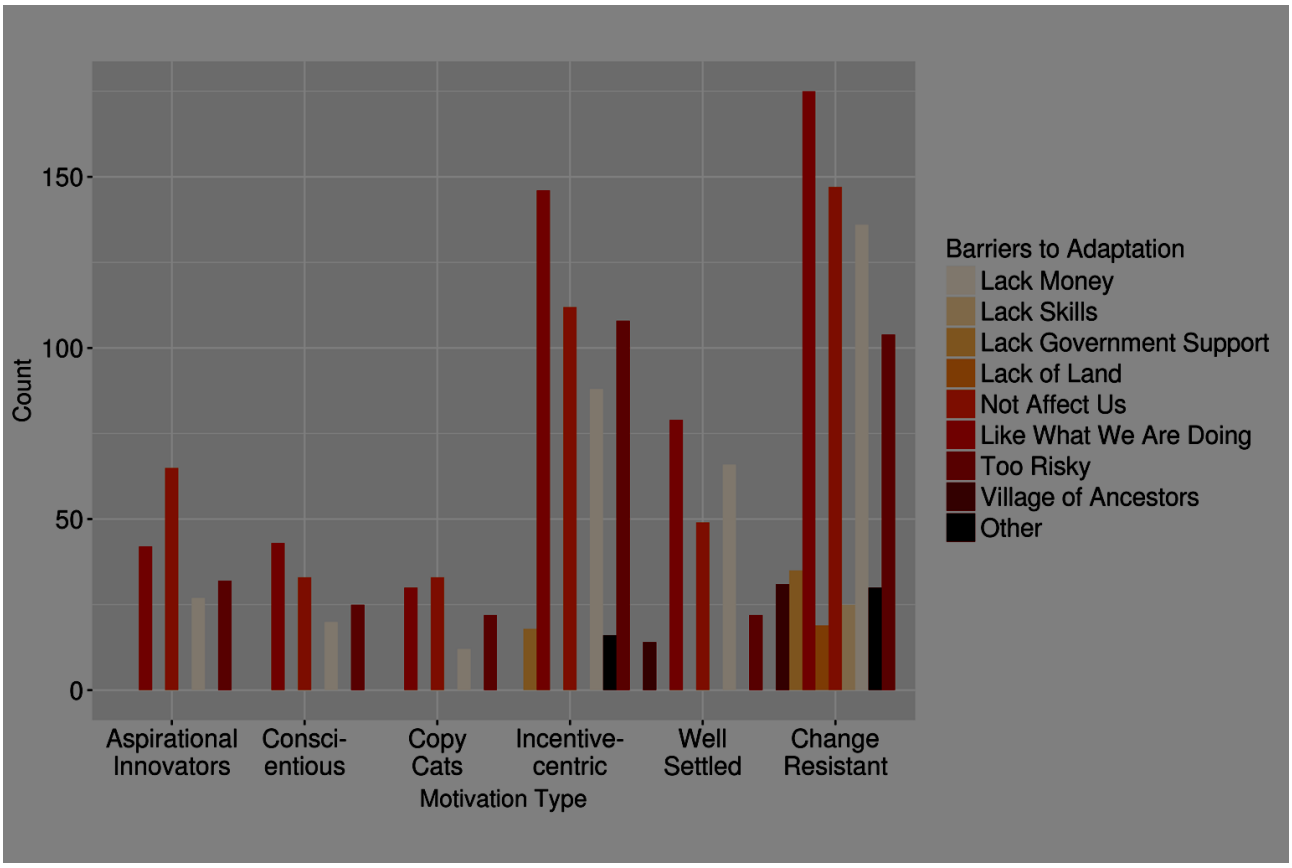

Figure 3: The proportions of motivation types found within each farm type. The distribution of motivation types amongst farm types is significantly non-random (Chi squared test, $p<0.01$), and it can be seen that some farm types contain visibly more of certain motivation types than others. Note that the motivation types are ordered from most likely to adapt ('Aspirational Innovators') to least likely to adapt ('Change Resistant').