Perception and Decisions in Modeling Coupled Human and Natural Systems: A Case Study from Fanjingshan National Nature Reserve, China

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Abstract

Examining environmental perception is vital for a more integrated understanding of complex coupled human and natural systems (CHANS). Modeling complex systems with human dominance or influence presents many challenges, including incorporating structure and agency and addressing uncertaintyin CHANS components and their relationships.Making assumptions is a way to deal with such uncertainty, particularlythat in relation to human decisions or behaviors.However, model assumptions may be biased or false without including perceptions behind such decisions or behaviors. Exploring perceptions not only gives us insight into decision-making (agency) but also reveals structural constraints influencing those decisions (including perceived constraints). This study focuses on the human-nature dynamics of Fanjingshan National Nature Reserve (FNNR) in China, a biodiversity hotspot and the only habitat for the Guizhou golden monkey (*Rhinopithecusbrelichi*). The monkey is endangered and increasingly threatened by growing human activity and development but also affected by changing habitat through reforestation programs. This research aims to understand how demographics, a recent reforestation program (Grain-to-Green), land use, livelihood, and conservation perception may affect local people's perception of human impact on the environment. This basic concept underlies manyland use decisions yet remainsincompletely shared among FNNR inhabitants. Using logistic regression, the data from a 263-household survey conducted in the spring of 2010 were analyzed. The results indicate Grain-to-GreenProgram participation is insignificantly related to environmental perception of human environmental impact. Rather, personal observation of the golden monkey is vital to locals reporting an enhanced appreciation for potential human environmental impacts. Other significant factors predicting sensitivity to human environmental impacts include having heard of climate change, interest in tourism entrepreneurship, current worries of food security, viewing FNNR regulations as restrictive, income source, and fuelwood consumption. Results suggest the importance of integrating human perceptions to better understand decision-making in coupled human and natural systems.

Keywords: Guizhou golden monkey; environmental perception; modeling decision-making in coupled human and natural systems;endangered species conservation; human-environment; protected areas management

Abbreviations

FNNR	*Fanjingshan National Nature Reserve*
CHANS	*Coupled human and natural systems*
LULCC	*Land use land cover change*
GLM	*Generalized linear model*
VIF	*Variance inflation factor*
GTGP	***Grain-to-Green Program***
NFCP	***Natural Forest Conservation Program***

1. Introduction

Modeling changing human-environment dynamics remains a pressing concern today in order to address challenges of sustainability in the face of major environmental issues. Research on coupledhuman and natural systems (CHANS) is emerging as a cutting edge in science. CHANS integrates a broad range of techniques and approaches to better understand, quantify, and project these dynamics. Complexities are rife in CHANS modeling when attempting to incorporate decision-making, structure and agency, nonlinear responses, thresholds, and emergence (Liu et al., 2007). One way to approach CHANS is through looking at land use and land cover change (LULCC). Considering the myriad of far-reaching land use consequences (Foley et al., 2005), understanding LULCC remains vitally important to CHANS research as well as to sustainability.

Modeling LULCC is an important research frontier (Lambin and Geist, 2006). In addressing the uncertainty present in modeling LULCC, researchers often employ assumptions to link different system components or decisions.Without exploring the knowledge and perceptions behind individual land use decisions, our understanding of LULCC may remain incomplete or based upon false assumptions. Incorporating perceptions can lend insight to the structure and agency behind many LULCC observations as well as previously unobserved underlying relationships. Such insight could account for some 'surprises'in system outcomes(Liu et al., 2007).

This project explores the complex interaction among policy, human socioeconomics, and environmental perception of human impacts in Fanjingshan National Nature Reserve (FNNR). As a subtropical area subject to rapidly changing land use and land cover (Defries et al., 2006) as well as growing activity and development in the future (Li and Han, 2001), FNNR is important not only to golden monkey survival but also to understanding many CHANS-related processes, especially local land use decision-making and its interplay with sensitive habitat. Without understanding how local inhabitants perceive their surrounding environment, the formulation of protected area policy may have unintended consequences or limited efficacy. This investigation thus holds implications both for modeling CHANS and for conservation policy and management.We begin by providing background on the study area, then move on to the theoretical framework. Lastly, we describe the methods and discuss the results. We conclude with implications for conservation and rural livelihoods in the FNNR and for future CHANS modeling.

1.1 Background: FNNR and Forest Change

Study Area: Fanjingshan National Nature Reserve (FNNR), approximately 160 square miles in area (Bleisch et al., 1993), is located in Guizhou province, southwestern China (see Appendix A: Figure A.1). FNNR is within one of the 25 global biodiversity hotspots identified by Myers et al. (2000), with over 3,000 animal, plant, and insect species (Yang et al., 2002). FNNR has a local population of 21,000 residents living within or near the boundary of the reserve, many of which live in villages over a hundred years old. It was established in 1978 as a protected area for the Guizhou golden monkey, although conservation within FNNR borders extends to other animal and plant species within the management zone. FNNR remains the sole habitat for the endangered monkey(Bleisch et al., 1993). Rumors about the existence of the Guizhou golden monkeys remained unjustified until they were "rediscovered in the early 1960s by Chinese researchers" (Bleisch et al., 1993).

Called ‘golden’ for their coloring or alternatively ‘snub-nosed’ for their appearance, the snub-nosed monkeys ranged much farther 400 years ago(Li et al., 2002). The snub-nosed monkeys are currently limited to 5 species in 3 countries: the Guizhou, Sichuan, and Yunnan snub-nosed monkeys in China, the Tonkin snub-nosed monkey in Vietnam, and the Burmese snub-nosed monkey in Myanmar (Geissmann et al., 2011). Focused research on the Sichuan snub-nosed monkey (*Rhinopithecusroxellana*) has brought much knowledge to the field (Tan et al., 2007). Still, the Guizhou golden monkey has yet to be subject to extensive research, which is especially an issue considering the major threat to the Guizhou golden monkey—direct and indirect effects from human activity (Xiang et al., 2009). Human activities (some regulated or forbidden) are widespread in FNNR, not limited to areas outside the reserve boundaries. With human activities (such as tourism) growing in China’s nature reserves (Li & Han, 2001; Liu, 2003) like FNNR, research on the monkey and impacts of activity is vital in order to better protect biodiversity in the reserve.

Forest Change in FNNR: With a history of settlement and farming by Han and several ethnic minorities (i.e. Tujia, Miao), and rapidly changing economic and demographic patterns, there is a multitude of land change dynamics at play in FNNR. Transition in FNNR forest cover is distinguished by the general dynamics of deforestation and reforestation. Activities towards deforestation include fuelwood gathering, construction, timber harvesting, quarrying, development (i.e. for roads, parking, and tourism), forest fire, and small-scale forest disturbances with potentialcumulative effects (e.g.,illegal mining, mushroom and herb gathering, and poaching). Forest fires in FNNR can be started by people burning tributes to the dead at tombs or also by the practice of burning grass on the fields to clear and fertilize them, both of which can cause serious damage through fires. Local regulations in place include fire and mining prohibition, designated location and amount for wood and plant harvesting, and development (Guizhou FNNR Administration Bureau, 2004). All of these activities have the potential to affect golden monkey habitat, both of which are important to species viability.

The framework for reforestation includes the regulations mentioned above, migration effects, and national reforestation policy. Temporary migration plays a part in reforestation and revegetation through reducing local labor availability(Liu et al., 1999; An et al., 2006). In many families, young adults are absent from FNNR for much of the year either attending school or working. This labor force reduction sometimes results in temporary abandonment of less productive fields or entering land into reforestation and development programs. However the implications of temporary migration for local land use change could be complex because, along with other factors such as education, temporary migration may also change consumption habits and thus bring forward new land use patterns (Davis and Lopez-Carr, 2010).

Major land changes in FNNR include reforestation programs, such as the Natural Forest Conservation Program (NFCP) and the Grain-to-Green program (GTGP). Restricting logging to allow for forest growth (Liu et al., 2008), the NFCP is geared towards preserving forests, water, and soil for higher plantation productivity and forest use diversity (Li, 2004). The GTGP arranges planting of trees in place of farmland on steep slopes, and the farmers are compensated through cash, rice, or corn (Feng et al., 2005). Since FNNR is already a high priority conservation area, implementation of the programswithin the reserve takes precedence over outer areas, meriting more government support (Li, 2004). We chose the GTGP as a focus for the study due to the widespread participation of locals and the direct interaction locals have with the program while they enroll land and receive compensation.

Reminiscent of the U.S. Conservation Reserve Program, the GTGP was intended to address erosion but has broader effects than its original focus (Liu et al., 2008; Ribaudo et al., 2001). Also of note, the GTGP is not designed to return forests to heterogeneous, native states but rather to provide participants with construction timber or economic cash crops after a certain amount of growth (interviews in the spring of 2010). Hence it involves monocropping as well as pine and fir plantations. One unintended effect of conservation and reforestation within FNNR may be an increased boar population (Wang et al., 2006), which poses challenges for local farmers because of the crop damage in boars' acquisition of food.

Regarding conservation policies such as GTGP in the context of our investigation, it is reasonable to hypothesize that GTGP program participation would increase environmental awareness and knowledge of human impacts on the environment. This is based on the understanding that the GTGP, as a payment for environmental services (PES) program, places an economic value on reforestation, compensating participants for their land and for their caretaking of the new reforestation areas. As PES was created to offer a monetary meaning for conservation value, participation in a PES program may increase understanding of the value of conservation. Furthermore, positive attitudes towards the program could translate to behavior in other areas of environmental conservation (Horsley, 1977).

1.2 Theory: Perception in modeling

In this investigation, our methodology approaches modeling through exploring the link between environmental perception and land use decisionswithin CHANS. Incorporating perception in addressing complexity in CHANS can contribute to a structure-agency approach (Chowdhury and Turner II, 2006). Specifically we will examine how local agents perceive their environment and livelihood options through the structures of policy and management. This not only provides added depth to understanding decision-making, essential in modeling, but also may lend insight into underlying processes and previously unobserved relationships that could manifest themselves within the system in nonlinear responses or emergence. If agents are making decisions under motivations and perceptions other than those supposed, modeling and analysis could be based upon false assumptions. Incorporation of livelihood, through understanding local capacities, economic opportunities and perceptions, could thereof provide more complete understanding towards the system of interest.

LULCC, decision-making, and perception: The importance of decision-making in understanding land use dynamics is intrinsic but not often explicitly acknowledged (Defries et al., 2006). Incorporating this dimension holds potential for formulating effective conservationstrategies(Salafsky and Wollenberg, 2000), better understanding complex human-nature systems, and developing useful techniques to address CHANS-related complexities. Land change science incorporates complexity theory and structural function of systems in analyzing land use and land cover change (Turner II and Robbins, 2008). A major application of complexity theory has challenged the equilibrium paradigm (Manson, 2001), which considers systems as developing towards stability (O'Sullivan, 2004). This application has led to the rejection of many assumptions within the field and brought about an approach that considers instead 'coupled human and natural systems'. These systems "vary across space, time, and organizational units. They also exhibit nonlinear dynamics with thresholds, reciprocal feedback loops, time lags, resilience, heterogeneity, and surprises" (Liu et al., 2007). Studies of these systems often share commonalities such as interdisciplinary study teams, integrative methods, and longitudinal, context-specific analyses (Liu et al., 2007). This new conceptualization is a

major change in many disciplines and has been increasingly adopted by the scientific community, raising support for innovative study design.

Land change researchers are increasingly using a diversity of modeling approaches such as multi-level modeling and agent-based modeling (ABM) in a growing number of applications in land use studies(Verburg et al., 2004; An et al., 2005, 2006; Rindfuss et al., 2008; An and Liu, 2010). Both approaches have potential for applications in understanding complex CHANS questions such as land use decisions and livelihood strategies. Multi-level modeling is appropriate for incorporating hierarchy, which is especially important in areas like FNNR with strong influences from community and governmental structure. Complementary to multi-level modeling, ABM can spatially capture the cumulative effects of small-scale agent decisions (e.g., on resource use) and the interactions of system components. However, danger lies in certain usage that "may lead to the impression that bottom-up models include so many parameters that they can be fitted to data whether or not their structure and processes are valid" (Grimm et al., 2005). The inclusion of perception in modeling decision-making can contribute to more robustness in modeling CHANS dynamics because it provides added depth to addressing the issue of model uncertainty(Grimm et al., 2005; for more on modeling human decision-making see An, this issue).

Examining perception (of the environment, of policy, or of livelihood) offers a way to better understand many CHANS-related complexities, such as feedback and nonlinearity. Previous such research has bordered on the topic of CHANS but has not addressed CHANS explicitly. Similarly, work to incorporate perception in modeling and decision-making has been pursued in several fields, including behavioral economics (e.g., maximization of different benefits; Simon, 1959).In addition,efforts have been devoted to addresslimitations on decision-making, such as bounded rationality, which allows for imperfectinformation acquisition and processing during the decision-making process (Simon, 1972). Research within economics has focused on perception as a way to understandeconomic behaviors such as water consumption (Nieswiadomy and Molina, 1991) and technology adoption (Kuan and Chau, 2001). Agricultural research also examines adoption (an economic decision), with applications related to CHANS not only through exploration of human and natural interaction but also through incorporating feedbacks between perception and adoption (Negatu and Parikh, 1999).

Previous work has also endeavored to understand perception in decision-making through investigating conceptualization of risk(Johnson and Tversky, 1983; Slovic, 1987; Sjöberg, 2000; Wester-Herber, 2004), social psychology (e.g. reasoned action and planned behavior; Fishbein and Ajzen, 1975; Ajzen, 1991), andconservation policies and programsin the context of livelihoods (e.g. in Nepal;Müller-Böker and Kollmair, 2000). Risk perception, psychology, and conservation have all given attention to learning and the construction of knowledge, including but not limited to experiential learning (Epstein, 1985; Finger, 1994; d'Agincourt-Canning, 2005; Fazey et al., 2006),and depletion crisis and ecological understanding models(Berkes and Turner, 2006; Turner and Berkes, 2006). Drawing on this prior work in perception from economics, risk analysis and management,social psychology, and livelihood literature could be instrumental in increasing the capacity of CHANS research to explore the agency dimensions of perception in land use decisions and take into account the mediation of political and social structures. Such incorporation would allow us to integrate agency and structure more comprehensively in modelingsystems and to delve into deeper understanding towards decision-making processes in complex CHANS.

Structure and agency:The relationship between population and agriculture has been described through different approaches by Malthus (reprint 1996) and Boserup (1965). Recent work has added to this literature by incorporating multiphasic demographic change (Davis, 1963)in linking Malthusian and Boserupian approaches (Bilsborrow, 1992) to address issues of land use and cover change (Ghimire and Hoelter, 2007; Carr et al., 2009; Massey et al., 2010; Davis and Lopez-Carr, 2010). Application of multiphasic response theory adds to understanding human-environmental interaction through describing the avenues of population reactions and strategies in the face of growth (Davis, 1963). The resource-population discussion approaches human-environment relationships. A related approach is structure and agency.

Structuralist and humanistic debates on human action focus on structure versus agency. Proponents of structural explanations such as Durkheim and Harvey (Johnston et al., 2000) conceive of action through the underlying bindings (i.e. policies, regulations) that control activity. On the other hand, agency proponents such as Febvre (Johnston et al., 2000) maintain the importance of humans acting as autonomous agents that deserves more attention. Efforts to reconcile the two lines include structuration theory from Giddens (Livingstone, 1993), which is also subject to criticisms including its relative exclusion of culture and subjectivity. In proposing actor-network theory in 1995, Serres and Latour took this debate further by including the possibility of non-human agents (Aitken and Valentine, 2006). Another way of understanding this dichotomy is through the push and pull between the focus on agency in cultural ecology and that on structure in political ecology (Chowdhury and Turner II, 2006). In understanding CHANS and building upon the legacy leading to land change science, it is important to find ways to balance the effects of both structure and agency (Chowdhury and Turner II, 2006).

Integrative approaches are increasingly utilized in the pursuit of understanding human-nature systems (Parker et al., 2003), and researchers and policymakers are gaining appreciation for the contribution that land change science can make in understanding patterns of drivers and consequences of environmental change. Manson discusses the applications of emergence in addressing agency and structure and the lack of research on the "effect of macro-structure on the micro-scale" (Manson, 2001). Incorporating perception in decision-making can add useful insight to human-environmental interaction, especially related to LULCC drivers, but also deepen analysis by calling for the inclusion of actual and perceived structural constraints within systems. This investigation contributes to research on complexity and land use by addressing perception in deepening our understanding of agency, structure and ecological knowledge in understanding complex human-environment interactions.

1.3 Objectives:

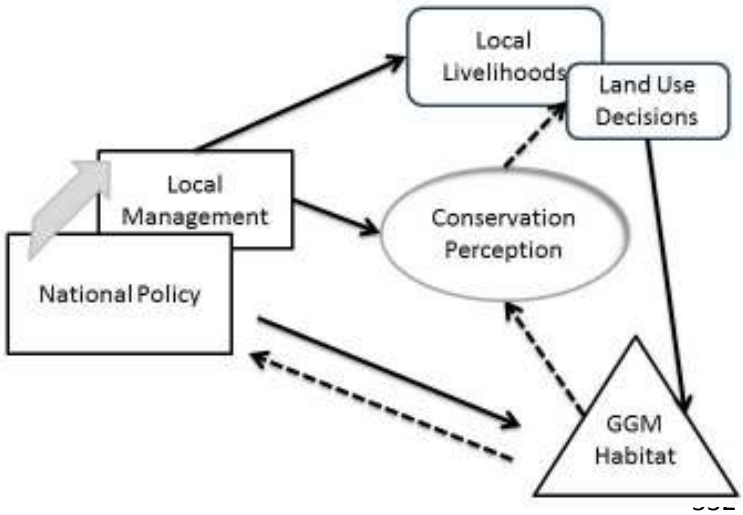
The overarching goal for this project is to contribute to improved understanding of human-nature interactions by incorporating perceptions into modeling approaches. Underlying this main goal, several related aims follow. First, we will analyze current FNNR conservation policy and offer potential areas of policy improvement, within the overall bounds of national and provincial policy, in order to enhance golden monkey conservation. Furthermore, modeling of coupled human-nature systems requires integrated approaches (Liu et al., 2007), which has been evidenced by modeling approaches moving towards uniting top-down tools with a focus on structure and bottom-up toolswith a focus on agency. The challenge of integrating the structural constraints (i.e. policy) on decision-making with the cumulative effects of decision-making processes (i.e. changing land or resource use) is a major one in modeling human-environment interactions in systems like CHANS. Thus we secondly seek to improve our understanding of

CHANS through including perception to approach combining aspects of structure and agency in our CHANS modeling efforts. This integration can lend insight to relationships that would otherwise remain uncaptured(Chowdhury and Turner II, 2006). Last, our investigation will analyze trade-offs among land use choices (Defries et al., 2006) in the context of local and individual ecological and structural perceptions in FNNR.

Without understanding the trade-offs people consider in their decisions, CHANS modelers often capture their choices and the ensuing land use changes in a snapshot manner. Using such snapshot data alone mayoverlook decision-making in the context of the full process and de-emphasize the impacts of historical perceptions and cultural values. In viewing decisions in the context of perception, it is not just the action of agency that CHANS modelers should consider, but the motivation to that action as well. In the modeling arena, we strive to acknowledge the local context and influencing factors in the process we are modeling. To fully capture these processes, we urge caution inchoosing the variables to which we attribute observations or data collection. Further investigation of underlying relationships (such as those behind perceptions leading to actions) could potentially explain some of what is perceived as nonlinearity and emergence, elucidating complex linkages between decision-making factors. Through this investigation, including our analysis and modeling through generalized linear models (GLMs), we explore what factors may affect local people's environmental perceptionsrelated to impacts of human activity. Shedding light upon the influencing factors and their interplays in FNNR, our research may facilitate improved modeling of CHANS and better policy formation and implementation.

1.4 Conceptual Model& Hypotheses:

The conceptual model (Figure A.2) presents the framework:



ADD EXPLANATION &HYPOTHESIS: (program participation would increase environmental awareness)

2. Material and methods

2.1 Survey:

In the spring of 2010, the first author developed a two-tiered or multi-stage probability sample in FNNR, and surveyed 268 households within 8 villages in 2 counties. At the top tier, we randomly selected villages from those within the reserve, as those were the only ones able to participate in the GTGP. We then selected households randomly from lists of reforestation participants within the chosen villages. We based sampling and survey design on earlier CHANS work in Guatemala(Carr, D.L. et al., 2008), Nepal (Yabiku, 2006; Ghimire and Hoelter, 2007), and China(An et al., 2002, 2005, 2006). The interviewees included GTGP (see Section 1.1) participants and non-participants. For villages partially within and outside FNNR, we adopted a 'trimmed village' approach, involving only those groups within FNNR, since those outside did not have the option to participate. We chose non-participants within the 'trimmed villages' based upon strategic sampling of every 4th

house within the groups, as the sampling proportion averaged at 23% for the 'trimmed villages' sampled. Questions probed quantitative and qualitative data, focusing on demographics, livelihood status and concerns, reforestation participation, crop damage from pest species, land and resource use, and perception of conservation and regulation. Complementing the mixed methods survey, we also selected 16 village leaders and reserve personnel to participate in individual qualitative interviews, the results of which supplemented the household survey in providing the status of broader community livelihood factors.

2.2 Logit regression:

Model fitting and comparison: The investigation employed the generalized linear model (GLM) technique in analyzing the survey data, using the logit link function in a binomial GLM. Falling under the term logit regression (Guisan and Zimmermann, 2000), we chose this technique for its flexibility and applications in predicting probabilities. First we coded survey data and reviewed itfor data completeness and accuracy, resulting in a final sample of 257 household responses. Due to incomplete answers, we removed eleven. Any further missing values, we excluded from each single predictor logistic regression and omitted in the multiple logit regression models. We complete the analysis using the R statistical program. We performed binomial logit regressions separately with each of the independent variables as a single predictor, which may signal the relevance and importance of each independent variable in explaining local people's environmental perceptions.

The next step was to conduct stepwise multiple logit regression with and without control variables (age, gender, ethnicity, education). The multiple logit regression stage of modeling provided a more complete characterization of influential and related factors in local perceptions of human impact. Multicollinearity diagnostics included the variance inflation factor (VIF) within the regressions (VIF value not exceeding 2 suggests the associated variable is relatively exempt from the multicollinearity problem), Pearson's r, biserial and point biserial correlation testing, and Chi-squared testing for categorical data. We analyzed model fits based on indicators such as model deviance and Akaike Information Criterion (AIC).To estimate uncertainty within models, we completed simulation graphically within R usingthe code and technique (the arm package) developed by Gelman et al. (Gelman and Hill, 2006; Gelman, 2007). We also calculated confidence intervals in R using the MASS package(Venables and Ripley, 2002).

Dependent variable:We explored the following models using the answer to the question related to whether the interviewee thinks human activity would affect the environment as the dependent variable. Thinking human activity may affect the environment may seem self-evident, however prior work in the area indicated that the local relationship between humans and the environment is complex. In 40 interviews (preliminary fieldwork, Spring 2009) during which we asked respondents whether they think some human activities in FNNR are harmful to golden monkeys, everyone said "No". Questions formulated for the Spring 2010 household survey further explored the perceived human-environment relationship in FNNR, focusing on human activity impact on the environment instead of only on golden monkeys. Since indirect effects from human activities are indeed a main threat to the species (Xiang et al., 2009), it is important to investigate local understanding of human-environmental interactions.

In the spring of 2010 household survey, 30% of the respondents answered questions of general human activity damage to the environment affirmatively, listing impacts such as garbage, pollution, cutting wood, development, pesticides, industry, and fire; 70% of respondents

answered no/do not know/do not understand. For the purposes of our analysis we grouped the negative responses together, as we were interested in what distinguishes the people responding in the affirmative from the rest that were surveyed. This perception addresses the basic question of whether humans can noticeably impact the environment in their area at all. This is a premise inherent in ecological implications of land use decisions, and as such remains an important basic question when examining human-environment dynamics. If humans do not perceive their actions as affecting the environment, the trade-off in their decisions may be more unconscious and incompletely informed. In addition, if we do not understand the trade-offs that are taking place in people's decision-making, how can we completely understand resultant land uses? There is a drastic distinction between unknowingly harming the environment and intentionally causing environmental degradation. If modelers approach decision-making under a pre-existing base that humans are considered to impact the environment, then we need to make sure that base exists and what it is.

Independent variables: We chose independent variables based onthe aforementioned theoretical background and empirical observations from preliminary field work. We chose temporary work variables to address the growing trend of temporary work and potential ensuing changes in income, consumption (Grumbine, 2007), and knowledge that could arise from movement to and from cities and living (even part time) in urban areas. Several variables addressed the multi-faceted aspect of temporary work, including years worked, number of people in the household doing temporary work, and receiving remittances from family in the city (Table A.1). We included county and village information as dummy variables. The 2 counties have different levels of local autonomy, which we considered as a possible structural factor influencing people's experiences with environmental regulations.

We included household factors in our survey and the subsequent models. Ethnicity could reflectdifferences in cultural values and history,while education level and number of children or adults in the household could indicate exposure of adults to newer ideas of environmentalism shared by children in school.We further incorporated interviewee variables (age, gender, education) since educationachievement and access are different for younger generations and gender has been shown to be a factor in previous work on perception of conservation (Müller-Böker and Kollmair, 2000). Several of the household and interviewee variables thus became control variables in the stepwise logistic regression modeling.

Two major conservation foci in FNNR are the GTGP, in which a high percentage of local inhabitants take part (77% of our household survey population), and the protection of the golden monkey. We included reforestation variables in the models, and seeing the monkey was considered a potential factor impacting local environmental perception because of the high visibility of the monkey conservation program in FNNR. Since almost everyone interviewed in Spring 2009 and 2010 (98%) supported protecting the golden monkey, having seen the golden monkey was chosen as an independent variable for its connection to golden monkey conservation.

Other perception variables included livelihood concerns, lottery use, opinion of neighbor and personal activities damaging the environment, and attitude towards FNNR regulation impacts (Table A.1), since these variables potentially connect with the weighing of land use trade-offs in making decisions. Current and future concerns included responses such as food or fields, jobs and money, health, infrastructure, and education (Table A.1). Lottery use centered on the question of how people would apply money if they won 30,000 yuan in a lottery, with responses such as starting a business, using for medicine, investing for the future, and building

roads. We included environmental damage in the single predictor regressions to determine relationships among the perception of human impact on the environment on a general, community, and personal level. Participants perceived regulation impacts on their lives in several ways: as being minimal, aspreventing people from harvesting wood, as protecting the environment, as protecting people from forest fire, and/oras preventing people from killing wild pigs (to stop the crop damage they cause).

We further added variables describing livelihood measures to the regressions, since they may play a part in approaching trade-offs in land use choices (Defries et al., 2006). Measures of livelihood were frequency of meals, meat, egg, alcohol, crop, and fuelwood consumption, income, cropland, and crop damage (from animals such as wild pigs, rabbits, and rats). The crop consumption variable identifies the amount of surplus crops sold (a potential income source). Since underreporting of income is a possible challenge, we used several income measures. The income source variable (a dummy variable) captures the amount of income that comes from agriculture (i.e. rice, bamboo, potato, raising pigs, or tea cultivation) versus other sources (i.e. temporary work, restaurant, store, or hotel). The income source of 'none' merits explanation, as this may seem misleading. That response may include people who had recently given up their cropland and had no explicit occupation but were living off of compensation from the government for entering their land into the reforestation, road, or tourism development programs. People may also have described themselves as having no income if they only engaged in subsistence farming (i.e., growing crops only for their own consumption), having no outside income. The income variables thus complemented food consumption variables in describing relative livelihood levels in FNNR.

3. Results

3.1 Descriptive Statistics of Households:

Several factors characterize the surveyed households (Appendix A: Table A.9), including education, age, size, ethnicity, employment, and land use. Interviewees were predominantly male, with approximately 24% of interviews conducted mainly with female household members. We interviewed females less often for several potential reasons, including male heads of household being on the lists of participants, shyness, variation in survey experience among field workers and households, and different perceptions of women's roles (Aitken et al., 2011). Maximum household education levels varied, however half the households contained members who had reached a maximum of middle school education level at the time of the survey. For the overall sample of households, average age within households was 35.4, and the average household size was 4.55 (often parents, a grandparent, and a child). The majority of households sampled were of Han ethnicity (62%) followed by Miao (19%) and Tujia (17%). As for work and land use, an average of 42% of adults within households have engaged in or currently do temporary work in the city. This can mean construction work in the closest city or also work in urban, coastal areas of China (far from the central mountains). The average amount of cropland per household was 0.27 ha, and reforestation level (as calculated by dividing the amount of land in the GTGP by overall land in crops and in reforestation) was about 47% in the surveyed households.

3.2 Single predictor results:

Logistic regression results (Appendix A: Table A.3) of the independent variables as single predictors (of the probability of thinking human activity impacts the environment) indicate the importance of several expected variables but also display the lack of significance to

reforestation variables, contrary to hypothesized connections. We do not include all dummy variables and their significance measures (p values) in the table. Instead, we chose categories of the dummy variables for display based on significance.

Significant of interest: The independent variables exhibited varying levels of explanatory power that characterize the population in FNNR. Fuelwood consumption was negatively related to thinking humans impact the environment. The correlation between fuelwood and education is positive (Kendall rank coefficient: 0.03) but not significant. Education itself we controlled for in the multiple logistic regression models (Section 3.3). Other significant variables include source of income, current and future livelihood concerns, being within certain villages (dummy), and regulation impact. Income source includes the dummy variables of no income, >50% income from agriculture, 50/50 agriculture/non-agriculture, and >50% income from non-agriculture. Both 'no income' (+) and '>50% agriculture' (-) were significant, although in opposing directions. Two village dummy variables were significant as well, in opposing directions. Main current and future concerns included the worry about jobs and money (-), with another important current worry being that of food or fields (+). Having hypothetically won a lottery of 30,000 yuan, a significant positive relationship exists between their environmental perception (or acknowledging human impact) and their aspiration to begin a business (often for tourism). The impact of regulations is significant for none (-) and for seeing regulations as limiting options in dealing with crop damage from wild pigs (+).

Not significant of interest: A noteworthy collection of variables are not significantly related to the general perception (human activity damage to the environment). Reforestation participation level and amount of land devoted to the GTGP was not significant, in opposition to our hypothesis that program participation would increase environmental awareness. Other variables of interest that are insignificant include those variables incorporated in the multiple regression models as control variables: ethnicity (which could have differed based on cultural values and history), age of interviewee, education levels, and gender. Further insignificant variables of interest are number of children or adults in the household (which could have indicated exposure of adults to newer ideas of environmentalism shared by children in school), average household age, household size, household income, the level of autonomy (i.e. semi-autonomous or not) for the county where the household lives, temporary work (including interviewee or overall household members engaged in temporary work and the years they have worked), and reception of remittances. Of particular interest is that crop damage is not significant although viewing regulations as restricting one's ability to kill wild pigs to prevent crop damage is significant.

3.3 Multiple Logistic Regression Models

Model 1(stepwise with control variables as final step): We included several variables in the multivariate logistic model based upon better model fit without incorporating the control variables from the beginning (Appendix A: TableA.4). These variables exert significant influences on the perception of human activity impact through: physically having seen the golden monkey (+), having heard of climate change (+), being interested in starting a business if winning 30,000 Yuan in a lottery (+), and currently being concerned about food security (+). All the variables are significant at the 0.05 (most ~ 0.03) significance level. Adding control variables (interviewee age, gender, age, and ethnicity) changes the significance (but not the sign) of 3 variables—seeing the monkey, hearing of climate change, and lottery winning business investment.

Seeing the monkey is significant with control variables when the climate change variable is not present, so we explored the correlation of climate change and lottery winning business investment variables with the control variables through Chi-squared testing, point biserial correlation, and biserial correlation testing. Neither climate change knowledge nor lottery winnings application significantly correlates with ethnicity or gender. Both are significantly correlated with interviewee age (point biserial correlation coefficient with climate change: -0.1297, $p = 0.0189$; biserial correlation coefficient with business investment: -0.265, $p = 0.000009$).Hearing of climate change is further correlated with interviewee education level (Fisher's exact test of Table A.5, $p = 4.945e-07$).From the test results, we determined that the proportion of respondents hearing of climate change is not the same for all education levels. Looking at Table A.5, we can see that the proportion of those who have not heard of climate change decreases with higher education levels.

Model 2 (stepwise with control variables from beginning):Controlling for age, education, gender, and ethnicity from the beginning, a somewhat different model emerges (Appendix A: Table A.4) in characterizing associated factors in environmental perception. Seeing the monkey is still significant, and indeed one of the basic components of both models. In addition, the impacts of regulation play a part (+), as well as income source (+) and fuelwood (-). All variables in the model are significant ($p<0.05$), with regulation and no income variables highly significant ($p<0.01$). Seeing regulations as being restrictive overall (+) was significant, but this was explored and attributed to the importance of restrictions on boar killing rather than on wood gathering or on both combined. The income variables are dummy variables for no income source and for even 50/50 agricultural/nonagricultural income source (>50% agricultural being insignificant when combined with monkey sighting and restrictions). Having no income source and fuelwood consumption are positively correlated (biserial correlation coefficient: 0.174, 0.003 significance), however fuelwood consumption is only significant when the 'no income source' dummy is included in the model.

Confidence and uncertainty: Considering the inclusion of the 'having seen the golden monkey' variable in both models, we undertook confidence interval calculation and uncertainty simulation to investigate the coefficient estimate variation. Using seeing the golden monkey as a single predictor of the probability of thinking human activities affect the environment, the simulation of uncertainty is shown graphically (Appendix A: Figure A.3) using techniques by Gelman et al. (2006). The concentrations of points in the four corners of the figure illustrate the distribution of seeing the monkey (0 or 1) versus thinking human activity affects the environment (0 or 1). The black line is the logistic regression curve, with the grey curves illustrating variation within the 1000 simulations. There is a range of estimated coefficients and predicted probabilities. The 95% confidence interval calculated in R for the coefficient estimate of seeing the golden monkey is 0.296 to 1.397.

4. Discussion

4.1 Single Predictors:

The single predictor logistic regression revealed several important relationships. The negative relationships between fuelwood consumption and thinking humans impact the environment was contrary to our expectation. This expectation followed our reasoning that higher consumption of fuelwood would get closer to fuelwood harvest limitations within FNNR borders. One may expect interaction with these limitations to increase awareness of FNNR conservation principles and human impacts on the environment. This negative relationship

between fuelwood consumption and environmental perception may be mediated through lifestyle and education as follows.Higher consumption of fuelwood could possibly relate to more traditional subsistence-oriented livelihoods, in which more family members with lower educationare more likely to stay in the area instead of going to the city for temporary work. Alternatively, households with lower fuelwood consumption may be purposefully more frugal in their fuelwood collection because they are aware of and follow harvesting limits in FNNR.

Income source significance may also relate to FNNR regulations, as those with no income could have given their land to reforestation or development and found their subsequent economic options limited by FNNR regulations. A possible explanation for those significant village dummy variables is that Village 4 (+) was located in a tourist area, while Village 5 (-) was not. We expected thepositive relationship between tourism and perception of human impact on the environment because tourists or tourism campaigns/programs may bring in higher environmental awareness. However, factors beyond tourism may be important, thus explaining the lack of a significant relationship for other villages in tourist areas. For regulation impact, views of regulation impacts as being minimal or connected with wild pig rules are significant. This again indicates a trend of interaction with regulations as raising probability of acknowledging human impact.

Not significant of interest:The refutation of our hypothesis (program participation would increase environmental awareness) indicates that local farmers may be more concerned about the economic benefits of the program than its conservation purpose. Previous work on livelihoods and perception in conservation policy has indicated a similar disconnect between intended and perceived policy goals (Müller-Böker and Kollmair, 2000). Some locals have already converted reforestation land to other uses (i.e. from pine to tea), and if the program matures, locals may reconvert their reforested land to farmland given strong influences from social norms (Chen, this issue). In connection with farmland, the insignificance of crop damage may seem contradictory when viewing regulations as restricting one's ability to kill wild pigs to prevent crop damage is a significant variable. Since these are single predictor logistic regression results, correlation between independent variables is not a concern, so perhaps the measure of crop damage does not mirror the relationship between damage and perception. Alternatively, this may indicate the influence of group opinions, a history of crop damage even if there was not damage in the past year, or possibly the effect of having neighbors with crop damage.

4.2 Model without control variables (Model 1):

Approximately 39% of interviewees have experienced seeing the monkey either in the wild or at the rescue center, where sick or injured monkeys are rehabilitated and researched. Pictures of the monkey are visible around villages and the reserve, and the reserve broadcasts well that the monkey is a Class 1 Nationally Protected animal, potentially making identification of the monkey easier. In addition, the reserve has an education program in effect (we have seen the brochure at one of the management offices within FNNR). However, over half of the people in FNNR have not seen the monkey. Without personal observation, people may think of it as a distant creature that they do not affect.

Having heard of climate change and entrepreneurial lottery investment are both likely linked to tourism. Many people have heard about climate change from the TV or from interaction with tourists. It is possible that the tourism link also influences the perception of environmental impacts of human activity through spreading the concepts of ecotourism. Locals interested in starting a business for tourism may consider environmental quality and conservation linked to

economic gains. They may also view local ecotourism as an industry they should be able to profit from. Since 55 of 69 local residents interviewed did not think they benefited directly from ecotourism in FNNR between 2004 and 2009 (An et al., 2010), perhaps the younger generation is interested in tapping into the economic gains from that sector. The final variable, that of a current main concern for food or fields,suggests food insecurity. This indicates that local people's concerns about food affect their environmental awareness. This could have a broad range of explanations, including a history of agricultural dependence and loss of cropland with accompanying loss of economic options within the FNNR protected area.

When incorporating control variables, collinearity causes dynamics within the model to change. Those who have not heard of climate change have lower levels of education, primarily at the elementary or middle school levels. In additions, interviewees who have heard of climate change are generally younger and have higher education levels. This is logical in that public education in FNNR over the past decade has been mandated and made more affordable, and environmental concepts have been increasingly incorporated in educational materials. Like climate change knowledge, entrepreneurial lottery investment connects to younger generations, although the reasons may differ slightly, having more to do with risk taking. Younger generations are more inclined to engage in risk taking activities (Pålsson, 1996), such as starting a new business. This puts capital at risk that could be saved for use in case of eventualities. In addition, history of the area must be considered. During the 1959-1961 famine, it is estimated that 30 million people died prematurely (Ashton et al., 1984). The older generation may remember that time and consider that in their planning for the future, making them less likely to take risks, while the younger generation did not experience it directly.

4.3 Model with control variables (Model 2):

Considering regulations as restrictive overall was significant, but we explored and attributed this to the importance of restrictions on wild pig killing (which people wanted the freedom to engage in to protect their crops from damage) rather than on wood gathering or on both. This suggests that perceptions of regulation restriction relate to crop damage by wild pigs and not to fuelwood limitations. As mentioned earlier, current household crop damage severity was not a significant predictor, so the significance of perceiving regulations as restricting prevention of crop damage may indicate a more complex connection between crop damage and environmental perception. The understanding of FNNR regulations (wild pig protection in particular) as restrictive and negatively affecting livelihoods through uncompensated and largely unpreventable crop damage suggests that the perception that humans affect the environment is tied to negative experiences with FNNR regulations and wildlife besides the golden monkey; this holds serious implications for policy sustainability and efficacy.

We expected the correlation between fuelwood consumption and no income source since people with no current earnings may not have the ability to pay for electricity or coal and must use wood as their main energy source. It is possible that having no income source could lead to more awareness of the FNNR restrictions on human activity when searching for livelihood alternatives. However, high fuelwood consumers may be less informed or disregard regulations on wood gathering, possibly considering it benign to the environment.Thus the positive relationship between lacking an income source and the dependent variable could be lowered by interaction with the fuelwood consumption variable. Through the multiplicity of economic connections utilized by income-diverse households, household members may interact more with

a variety of regulations and people. This interaction may lead to more exchange of ideas, including environmental concepts such as awareness of human activity impacts.

5. Conclusions

5.1 Policy implications:

Perception modeling results reflect concerns for current policy and directions for future improvement. Results indicate that environmental awareness is strongly linked to physically seeing the golden monkey, which is made more difficult by the characteristics of the species (e.g., shy and endangered) and long travel times from most areas to the rescue center. This link supports research in experiential knowledge and environmental behavior that illustrates the importance of direct environmental experiences in decisions (Finger, 1994; Fazey et al., 2006) while emphasizing the need for balanced approaches (Fazey et al., 2006). In FNNR, efforts could be made to increase visibility of the species, while still protecting it, perhaps through increasing access to viewing at the rescue center. Furthermore, conservation and educational efforts could be focused to emphasize the link between human actions and the golden monkey itself, showing how indirect effects from human activity can impact the monkey population. Otherwise, people who have not seen the monkey may think of it as a distant animal safely removed from human action. This lesson offers bitter irony for future policy prescriptions: monkey observation is negatively correlated with human impact so how do we promote sustainable land use policies in FNNR and environments with similarly charismatic fauna?

Awareness of impacts is further linked with viewing environmental regulations as restrictive in prohibiting locals from killing wild boars that damage their crops. The issue of wild pig damage to crops is neither limited to FNNR (People's Daily Online, 2010), nor is the perception of policy colored by animal damage to crops only in China (Müller-Böker and Kollmair, 2000). However, in FNNR wild pig crop damage is locally associated with awareness of human environmental impacts, though not directly through personal crop damage. This indicates not only an indirect relationship but also highlights a potential problem for management. Support for conservation may be limited orunsustainable if environmental and conservation programs are linked to negative experiences of regulations. For instance, local people may be aware of human impact on the environment but feel regulations (e.g., for forest conservation)are limiting their ability to stop a livelihood threat. In this case, the regulations may be unsustainable for local people.

For policy to successfully address negative attitudes towards regulation and the lack of golden monkey visibility, emphasis may usefully be on providing environmental and economic benefits to the local population. The use of critical environmental assessment education, with a focus on improved local understanding of and involvement inenvironmental principles and regulation, has potential applications for conservation and sustainable development in complex human and natural systems(Diduck, 1999). However, applications in FNNR towards increasing local participation in resource use management would face challenges in balancing administration and involvement in the local government structure. Improved understanding may reduce local people's negative feelings related to simply imposing many limits and restrictions on them to protect a 'distant' and shy, albeit beautiful, endangered species. It is important to illustrate the role of regulations as a solution (Kotchen and Young, 2007) and to make efforts towards highlighting win-win situations in conservation and land use programs (DeFries et al., 2004).

Ecotourism, when carefully planned and managed in consideration of several sensitive issues (e.g., economic equity among different groups as well as potential harms to local environment), holds potential to be a win-win option for FNNR. Ecotourism has been shown to have links to conservation attitudes through experiential learning (Tisdell and Wilson, 2005). In FNNR, itmayincrease monkey visibility. Furthermore, it may emphasize local conservation benefits and environmental impacts of human activity, leading towards a better understanding of trade-offs in land use decisions. The efficacy of these practices in FNNR remains to be seen but could improve the long-term sustainability of conservation programs and endangered species in other CHANS.

5.2 Implications for modeling and theory:

The above insights and implications not only have much to offer policy formation in protected areas, but also hold potential for modeling human decision-making in CHANS. Rather than taking many perception-decision relationships for granted, more efforts could be invested in understanding decisions contextually, identifying conscious and unconscious trade-offs behind land use decisions, and incorporating such relationships in models. Incorporation of perception in modeling can assist in better understanding system relationships and developing mechanistic and process-based models. Such models can lend insight that increases our understanding of CHANS (An, this issue). With these efforts, the effects of underlying or subtle relationships can be uncovered, leading to more robust results. In the context of this investigation, an underlying relationship is that between environmental awareness and negative perceptions of regulation impact.

Although a better understanding of the impacts of human activity is commonly considered to be a positive quality when advocating conservation, such understanding is linked to negative experiences with regulations in FNNR. If people perceive regulations as limiting their ability to protect their livelihoods against damage, they may act to secure more resources, most of which may be essential for protected species. This could lead to a feedback loop of increased environmentally-damaging activity that requires further conservation regulations, potentially leading to further perceptions of livelihood-damaging restrictions and so on. Alternatively, pressure from perceived restrictions could build up until unexpected environmentally-deleterious actions result as a threshold of tolerance is reached. Results from the investigation demonstrate that even basic environmental perceptions may not have solely positive linkages, despite commonly positive connotations. Without addressing perceptions in modeling human decisions-making, complex linkages may be ignored that could be part of underlying feedbacks or lead to unexpected nonlinear responses.

In this investigation, we have illustrated the strengths of our novel approach to modeling human decision-making in CHANS. Incorporation of perception in modeling CHANS has yet to be made explicit, although its usefulness has been illustrated in other contexts. Considering the interdisciplinary nature of CHANS research, it is important to draw on knowledge advanced in the fields of behavioral economics, social psychology,livelihood studies, and risk analysis in formulating a theoretical base for modeling human perceptions in CHANS. We have shown that modeling perception can contribute to this base through integrating structure and agency in understanding multiphasic land use decisions. This approach not only elucidates the complexities of agent actions and trade-offs in decision-making but also lends insight into perceived structural factors that affect system function. Agent perception of structures is critical to identifying

underlying relationships in modeling processes in CHANS. Further strengths of the approach include highlighting previously unobserved or counterintuitive relationships critical to reducing untenable assumptions in CHANS modeling.

The modeling approach not only allowed us to demonstrate the importance of close examination of driving forces (particularly perception) behind land use decisions but also to display its practical usefulness in assessing environmental programs (e.g., GTGP) and regulations. Future work will further investigate the relationships between income, livelihood variables, crop damage, and policies. The approach of incorporating perception can ultimately improve models of coupled human-nature systems by providing added insight into system complexity.

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