#### Understanding coupled human nature system dynamics under payments for ecosystem services



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September 23, 2016

Presented to the CNH PES-Golden Monkey Project summit meeting, San Diego, USA

#### Human-environment science

- Traditional approach
  - Unidirectional
  - Disciplinary
  - Top-down approach
- Coupled human and natural systems (CHANS) approach (e.g., Liu et al. 2007)
  - Feedback
  - Time lags
  - Heterogeneity
  - Nonlinear relationships, etc.

#### Payments for Ecosystem Services (PES)

- Incentives paid to users of natural resources
  - Protect the environment: ecosystem structure, function, and services
  - Protect the people: economic incentives help maintain quality of life and well-being
- Lack of sustainability
  - Resource users return to pre-PES behavior
  - Effective for a short time (The curse of no "permanence")

### Grain-to-green program (GTGP) (PES in China)

- Pay individual households for planting trees on sloped land:
  - Grain, cash, and seedlings
  - Technical support
- GTGP detail varies in:
  - Payment amount
  - Payment span
  - Steepness standard

#### National Forest Conservation Program (NFCP)

A program that conserves natural forests through logging bans and afforestation with incentives to forest enterprises (Zhang et al. 2000; Liu et al. 2008)

Zhang et al. (2000). China's forest policy for the 21st century . Science 288: 2135-2136. Liu et al. (2008). Ecological and socioeconomic effects of China's policies for ecosystem services. PNAS 105: 9477-9482



#### **Fanjingshan National Nature Reserve**

- Guizhou Golden monkeys
  - The only and last habitat of ~800 animals
  - "Endangered" by IUCN
- Local communities
  - II,000 local residents (subsistence)
  - Over 70,000 tourists
  - PES in operation



#### **NSF Project Introduction**



CNH: Sustainability of Payments for Ecosystem Services in Coupled Natural and Human Systems (自然人类耦合系统中生态系统服务功能支付项 目的可持续性)

### SDSU-UNC研究团队

Name	Brief credentials related to this project	Major role	
Stuart Aitken	Leading human geographer with expertise in qualitative methods, social survey, and participatory mapping with 25 years' experience	Participatory mapping; stakeholder survey; qualitative analysis	
Li An	Leading systems modeler in agent-based modeling on human-nature systems	Project coordination, agent-based modeling, Quantitative analysis	
Richard E. Bilsborrow	Leading demographer in migration, survey methods, population processes, statistical modeling with experience over 40 years.	Population processes, stakeholder survey, statistical analysis	
Xiaodong Chen	Rich experience in GIS, spatial analysis and modeling, and Grain-to-Green Program	PES research design, GIS analysis	
Rebecca Lewison	Exceptional ecologist in vegetation sampling, & species occupancy modeling	Monkey habitat survey and analysis	
Douglas Stow	Accomplished remote sensing scientist with tremendous experience and publications	Forest & land cover characterization	
Minjuan Wang	Exceptional records in using technology in teaching and training: including the use of online and mobile learning in K-12 classrooms.	K-12 education (U.S. & China), summer workshops, & internal evaluation	

## Chinese experts (中方专家)

Name	Brief credentials related to this project	Major role
Prof.Weihua Xu (徐卫华研究 员/教授)	China's environmental policy, biodiversity conservation (Chinese Academy of Sciences)	Policy scenario design, logistic help
Prof. Yeqin Yang (杨业勤 研究员)	Expert in Golden monkey habitat use and behavior, local socioeconomics, and policy (FNNR)	Habitat & vegetation sampling design, stakeholder survey, logistic help
Director Weiyong Zhang (张维勇局长)	Expert in local socioeconomics, conservation management, and policy (FNNR)	Policy analysis, stakeholder survey, logistic help
Lei Shi (石磊 科长)	Expert in local socioeconomics, botany	Survey coordination, species identification, data transfer

### Postdoctoral researchers

- Dr. Hsiang Ling Chen: Conservation ecology, habitat modeling/analysis, behavioral ecology with integration of human socioeconomics
- Dr. Guangming He: computer programming, agent-based modeling, parallel computing

#### Graduate students

Name	Brief credentials related to this project	Major role	
Shuang Yang	Systems modeling, computer science, statistics	Data collection, analysis, and dissemination; fieldwork manager	
Cindy Tsai	GIS, remote sensing, LULCC	Data collection, analysis, and dissemination; fieldwork	
Jie Dai (2014)	GIS, remote sensing, policy analysis	Data collection, analysis, and dissemination; fieldwork manager	
Evan Casey	Geospatial and statistical analysis & modeling	Data analysis, system maintenance	
Past students			



## Research goals

- 1. What measurable environmental changes have taken place after implementing the PES programs?
- 2. What changes have arisen in human livelihoods, demography, and their interrelationships following PES implementation? And how are these changes feeding back on the PES program?
- 3. How does the coupled system evolve over space and time as humans and the environment interact with one another and with PES?

#### **Data collection**

- Human socioeconomic & demographic variables
  - Demography (HH location too)
  - Local off-farm business
  - Resource extraction
  - Agriculture
  - Migration & place attachment
  - Household living conditions
  - GTGP and NFCP information
- Hypothetical questions about participating in GTGP (enrollment) and NFCP (patrol)

### Human decision making

- Discrete choice modeling
  - Probability (PES decision) =
    - f (PES features, household/personal features, land/forest features)
  - A Probit multilevel model is built
  - Nurture an agent-based model

#### "By accident" we found...

# PES programs are weakening (occasionally strengthening) each other!!!

# Receiving NFCP pay would increase GTGP

### <u>enrollment</u>

 The odds of GTGP enrollment will increase by 31% if NFCP payment is received

## More NFCP land,

## **lower GTGP enrollment**

• The odds of GTGP enrollment will decrease by 3% with additional hectare of NFCP forestland

# More dryland enrolled in

### **GTGP, more NFCP**



• The odds of patrol effort will increase by 6% with each additional hectare of GTGP land

### **The closer GTGP**

## parcels, the more likely

## to do NFCP patrol

 The odds of supportiveness will decrease by 7% with an additional hour of travel

#### **Overall interactions**



### Systems integration (系统整合)



- Tasks (任务)
  - Agent-based modeling using RePast
    - Parallel computing
    - Modify and refine the ODD
    - Develop it under open-source convention
    - A simplified version in Netlogo
    - Web-based model
  - Education (participatory modeling and K-12)
- Data(数据)
  - All data in Table I
  - Heuristics
- Fieldwork (野外工作)
  - Based on other parts of the project 0

### Build an agent-based model

- Agents: households in four FNNR villages
  - Possibly person agents
  - Rules from the above regression results, household economy, time economy, governmental data, etc.
- Environment:
  - DEM for local topography
  - Satellite data for land cover and use
  - Camera trapping data for monkey habitat use

#### Why is ABM very useful in PES studies?

- **PES** are in **People-Environment Systems** 
  - People: agents at hierarchical structures
  - Environment: also agents (objects)
- <u>Interactions</u> occur at various levels
  - Between agents and the environment
  - Among agents
  - Among agents of various levels (HHs, villages, etc.)
- Dynamics is of <u>policy</u> relevance
  - Is the environment getting better? \$\$ worthwhile?
  - People may adjust their PES decisions
  - A platform to policy experiments/tests



- Agent-Based and Individual-Based Modeling: A Practical Introduction (S.F. Railsback, Volker Grimm)
- Dr. C Michael Barton' web <u>https://www.openabm.org/</u>
- My postings at <u>https://github.com/anlisdsu</u> and <u>http://complexities.org/Methodology/CHANS-</u> ABMs/CHANS-ABMs.htm
- Agent based modeling of complex human-environment systems (book in preparation; By L.An et al.)

### Acknowledgement

National Science Foundation



- Dynamics of Coupled Natural and Human Systems (CNH) Program
- Partnerships for International Research and Education (PIRE)
   Program
- Cyber-enabled Discovery and Innovation (CDI) Program
- NASA Land Use and Land Cover Change Program
- NIH Population and Environment Program
- Fanjingshan National Nature Reserve, China
- Chinese Academy of Sciences
- San Diego State University



### THANKYOU

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#### **Project web: http://complexities.edu/pes**

	Variables (data to gather)	Collection methods	Unit	Time scale
Environ ment	<ul><li>I. Canopy fractional cover (CFC)</li><li>2.Vegetation classification</li><li>3. Golden monkey habitat (quantity and quality)</li></ul>	I-2. Remote sensing 3. Camera trapping	Pixel	Prior, and post PES
Humans (Demography and livelihood)	<ul> <li>Ia. <u>Demography</u> (Individual level): Age, gender, education, ethnicity, etc. and related decisions</li> <li>Ib. <u>Demography</u> (Household level): Household size and composition, changes over time due to births, deaths, migration in and out;</li> <li>Ic. <u>Migration</u>: Who, when, where to migrate, whether sends money; etc.</li> <li>2a. <u>Local off-farm business/work</u>: what kind of business and location; time spent, people in household involved, earnings/income (or %)</li> <li>2b. <u>Local extraction (Part. mapping)</u>: what is collected, season and location, time spent/year, people involved (age, gender, education, etc.), where to extract</li> <li>2c. <u>Agriculture</u>: land in use, crop outputs, income, and their changes over time, # and location of parcels enrolled in PES, # of animals raised by type, market sales and own-consumption; technology, seeds, use of fertilizers, pesticides, etc.</li> <li>3. <u>Place attachment</u>: how farmers feel about their livelihoods and their place in the larger ecosystem; focus on their perceptions of food security and PES</li> <li>4. <u>Household living conditions</u>. Quality of dwelling; ownership of household durable assets; GPS location and distances to important sites (market, protected forest, school, health clinic, etc.); household income from all sources.</li> </ul>	<ul> <li>Ia-Ic:</li> <li>Stakeholder</li> <li>survey</li> <li>2a. Same</li> <li>2b.</li> <li>Participatory</li> <li>mapping</li> <li>2c.</li> <li>Stakeholder</li> <li>survey</li> <li>3-4.</li> <li>Stakeholder</li> <li>survey</li> </ul>	Ia. Person Ib. HH* 2a. HH 2b. HH 2b. HH 2c. HH, parcels 3-4. HH & Person	Prior and post PES
Payments for ecosystem services	<ol> <li><u>Compensation</u>: what, how much, duration of the payments.</li> <li><u>Obligation</u>: what parcel(s) returned to forest or refrained from felling, total area, land quality for agriculture (slope); penalty if not doing well;</li> <li><u>Influences</u>: loss of income from less land available, how did household respond, such as change in other activities</li> <li><u>Stated choice</u>: under hypothetical conditions about the above 1-3.</li> </ol>	I. Stakeholder survey 2. Same 3. Same	I. HH 2. HH & land parcels 3. HH	From PES