Sustainability as an Emergent Property of Human-Environment Systems (CHES)

A Framework for Studying Sustainability of CHES

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General Goals:

➢**Advance sustainability science** *from the perspective of* ***CHES***

- Concretize the concept of sustainability
- Provide analyses for achieving sustainability

➢**Integrate climate change into development**

- Integrate useful ideas from climate change research with a larger framework of sustainability
- Facilitate mainstreaming climate change into development

Theoretical Background: The Science of Complexity

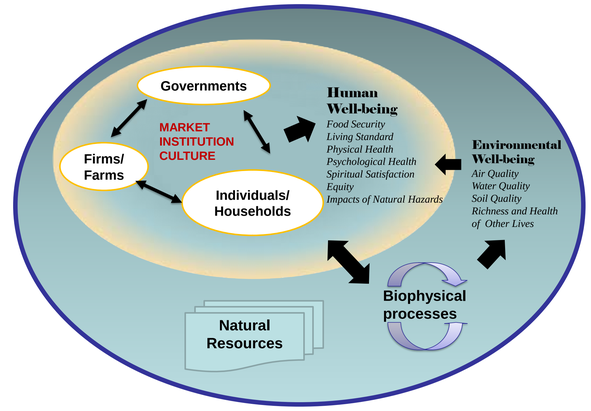
Coupled Human-Environment Systems (CHES)

Systems Dynamics:

- **Use multiple system-level variables to represent the state**
- Explain the dynamics by interconnected changes of these variables
- Differential equations & **mathematics**

Complex Adaptive Systems (CAS)

- **Explain global patterns by the actions and interactions of the agents at the micro level**
- **Agent-based & network modeling**



What is Sustainability?

SUSTAINABILITY

IS

a Global Property of a CHES

EMERGENT from

❖the actions and interactions of multiple human players under the social-economical-political setting

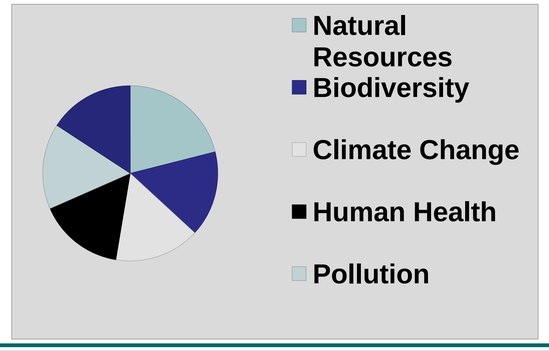
❖ the biophysical processes of the environment

❖the interactions between humans and the environment

ESSENTIALLY about

the **WELL-BEING** of a CHES in a **LONG** time horizon

Multiple Dimensions of Sustainability



A Conceptual Framework for Studying Sustainability

in the Dimension of Climate Change/Variability

Two key concepts for characterizing sustainability of a CHES:
WELL-BEING and RESILIENCE

Well-being describes the state of a system at one point in time.
Resilience describes the state of a system in the dynamic term.

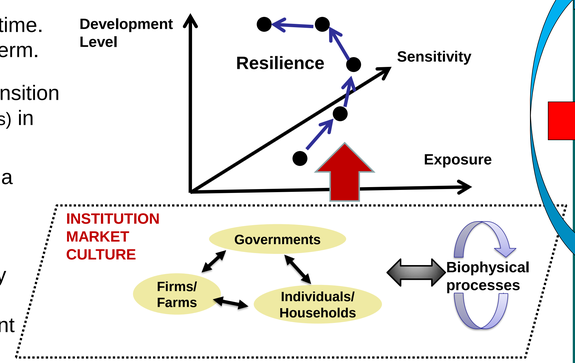
A system is **RESILIENT** if it does not experience sudden transition between CRITICAL states (specified by thresholds of variables) in the face of social or environmental shocks.

A system is **SUSTAINABLE** if its development has reached a certain level, **and** it is resilient.

Notes:

Exposure of the human system to climate change/variability is determined by the environment;
Development level includes various aspects of development in economic achievement, education and health;
Sensitivity reflects how human development is affected by climate change/variability.

The Space of Well-being



Some Simplified States and Implications

Development	Exposure	Sensitivity	Possible Implication
High	Low	Low	No problem
H	L	H	Stupid – needs to locate the sensitive part of the development and improve
H	H	L	Smart
H	H	H	Serious problem – need to seek for both engineering and "soft" measures to reduce sensitivity
L	L	L	Key issue is development, but make sure not to do stupid things
L	L	H	Key issue is development, also need to reduce sensitivity
L	H	L	Further develop, may need engineering work to keep sensitivity low
L	H	H	Worst case – migration away?

Three Steps toward Sustainability

1. Figure out where the system is;
2. Understand how the actions and interactions of the agents in the system determine the current state and drive state change *(treating climate as one of many factors in the system that affect well-being)*;
3. Explore the potential effects of alternative human behaviours /policies under various future scenarios *(including social and/or environmental changes)*.

Analyses and Implementations

1. Assessing well-being at large scales	**Remote Sensing** + GIS + social-economic data
2. Analyzing multi-source & multi-level causes of well-being	quantitative + qualitative analyses (surveys + interviews)
3. Shape the future & explore the dynamics of the system	agent-based model + network analysis + mathematics

Sustainability as an Emergent Property of Human-Environment Systems (CHES)

A Case Study in the Poyang Lake Region of China

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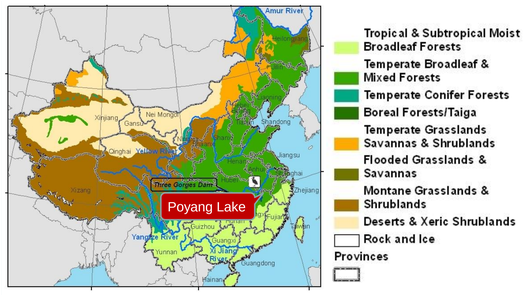
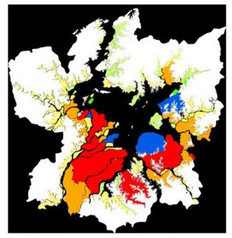
Acknowledgements

I'd like to thank many people who have supported this work, intellectually or practically:

Dr. Dan Brown (School of Natural Resources and Environment/University of Michigan)
Prof. John Holland (Computer Science, Psychology, and Center for the Study of Complex System/University of Michigan)
Dr. Shuming Bao (China Data Center/University of Michigan)
Several professors at Jiangxi Normal University
Prof. Stephen Salant (Economics/University of Michigan)
Dr. Maria Lemos (School of Natural Resources and Environment/University of Michigan)
Dr. Rick Riolo (Center for the Study of Complex Systems /University of Michigan)
Farmers around Poyang Lake …

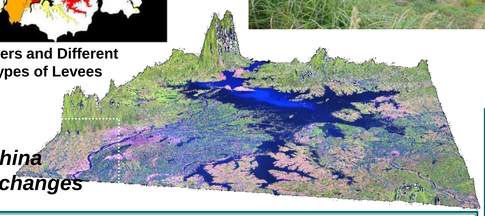
Financial supports were provided by NASA Earth and Space Science Fellowship and Graham Environmental Sustainability Institute Fellowship, University of Michigan.





Polders and Different Types of Levees

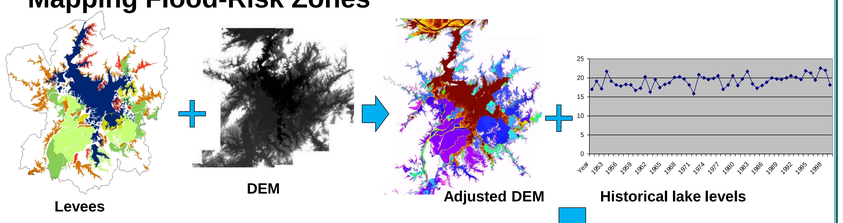
- A less developed rural area in Jiangxi province
- Subjected to flooding from the largest fresh water lake in China
- Experiencing rapid and dramatic social-economic-political changes



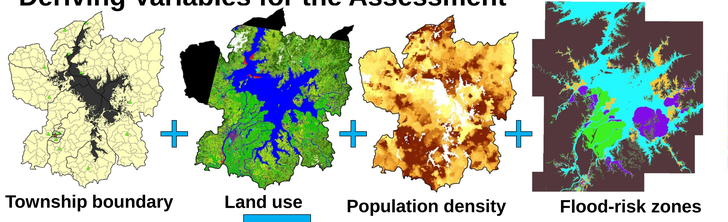
Part I — A Regional Assessment of Well-being Combining GIS, Remote Sensing and Social-Economical Data

Objective: To understand the state of development in PLR, especially variations between places in the region.

Mapping Flood-Risk Zones



Deriving Variables for the Assessment



Township boundary | Land use | Population density | Flood-risk zones

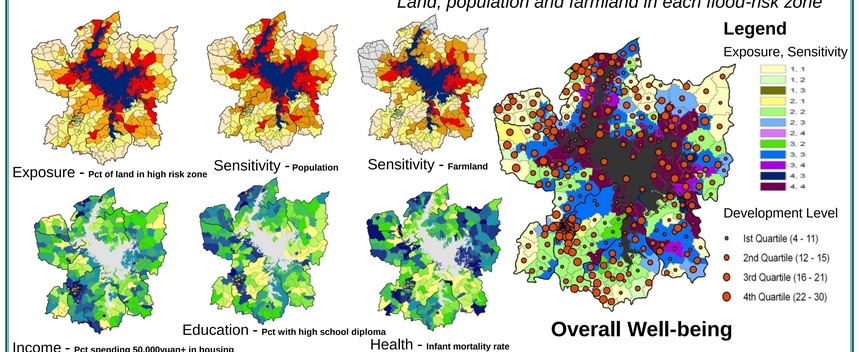
For each town (total of 298):

Percentage of land in high flood risk zone
Percentage of farmland in high flood risk zone
Percentage of population in high flood risk zone

Flood-Risk Zone	Area of Land	Population	Area of Farmland
Low risk	63.3%	68.2%	73.8%
Medium risk	7.4%	8.6%	15.5%
High risk	29.3%	23.2%	21.6%

Land, population and farmland in each flood-risk zone

Assessment Results:



Exposure	Sensitivity: Human Life	Sensitivity: Land Use	Development Level	Possible Implications for Different Types of Towns
High	High		Low	Candidates for wetland restoration or natural reserves
H	Extremely H			Induce or help people migrate away in the long run
H		H		Promote flood-damage-reduction agricultural practices
H	H		H	Examine development carefully & make adjustments accordingly
L			L	Look for reasons seriously in the human system

Part II — An In-depth Analysis of Causes underlying Household Well-being based on Surveys and Interviews

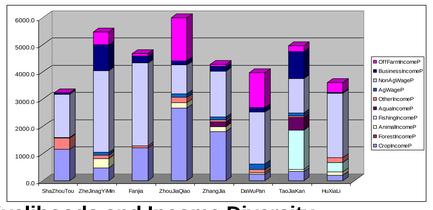
Question: How the complex interactions between individual household characteristics and their social and environment settings shape the well-being of households on average and variations between households?

Approach: Quantitative + Qualitative

(i) Focus on the livelihoods of people;
(ii) Draw insights from sustainable livelihoods analysis social vulnerability analysis, and development economics;
(iii) Examine and explain the variations between communities, groups, and households;
(iv) Examine household livelihood decision-making processes to understand how various social, economic, institutional, and environmental factors at multiple levels interact with each other to affect the well-being of rural households;
(v) Further look into flood impacts on the current land-use practices (the sensitive part of the livelihoods to flooding).

Number of surveyed villages	8
Number of Surveyed Households	193
Number of Households Interviewed (with open-ended questions)	40+
Number of local government officials & scientists interviewed	10+

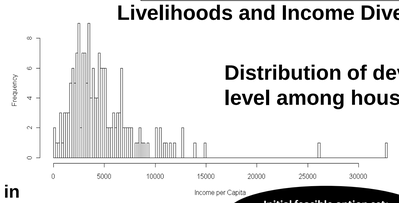
Some of the Analyses:



Livelihoods and Income Diversity

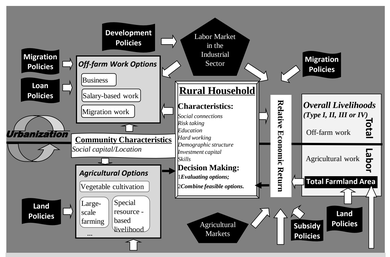
Representing well-being at the household level

Well-being	Variables
Exposure	Flood-Risk Zone
Sensitivity	Income Composition in:
	Farming Income
	Off-farm Income
Development Level	Income per capita

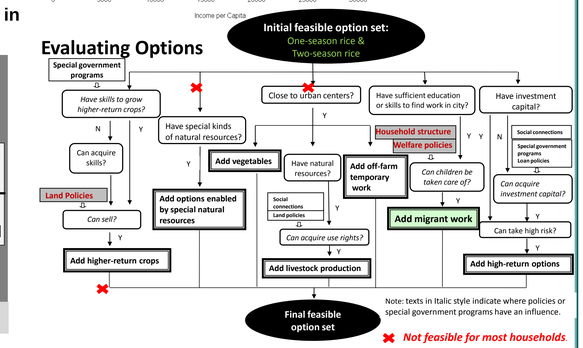


Distribution of development level among households

Rural household livelihood decision making in the process of urbanization



Evaluating Options



Major Findings:

- The majority of rural households are limited on feasible options. One important constraint on their livelihoods comes from the current small land holdings and land right insecurity inherent in the current short-term land-use-right exchange contracts.
- Some household characteristics (especially human and social capital) and local factors (location relative to urban centers, richness in natural resources, and social capital of a village) contributed to the variations of well-being between rural households.
- The livelihoods of most rural households in PLR are not greatly affected by flooding due to large proportions of off-farm income, but poor households are most affected by flooding because they commonly have a small-scale farming-dependent livelihood.
- Those households in farmland-poor villages have double development disadvantages because their farmland is usually protected by poor-quality levees that are constructed and maintained by local people.

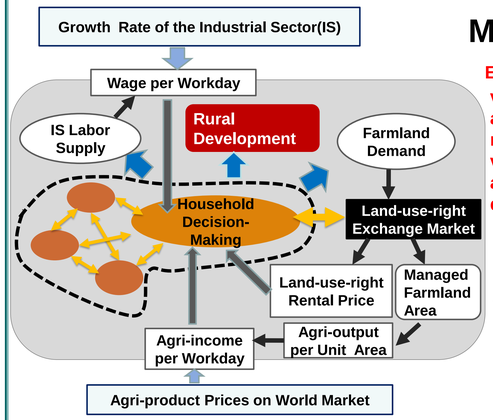
Part III — Shaping the Future: Exploring Potential Effects of an Alternative Policy with an Agent-Based Model

The household analysis suggests that the **Key Issue of Sustainability** in PLR & Rural China **is Negative Resilience**: rural income & agricultural production are low and difficult to grow.

Questions:

i. **H**ow effective is the current policy of subsidizing rice growers in increasing rural income and agricultural production?
ii. **W**hat if the government subsidizes long-term land-use-right renters ("**Rental Policy**") to facilitate larger scale of farming operations? How may policy effects vary across places that have different endowments on farmland resources?

The Modeled System: Boundary, Interactions & Feedbacks



Model Validation

Empirical data from three villages (with poor, average, and rich land resources respectively) were used to validate the model and answer the research questions.

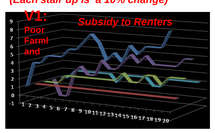
(i) Multiple macro-patterns as observed
(ii) Major land-use change as observed
(iii) Relations between land-use-right rental prices and other factors as expected

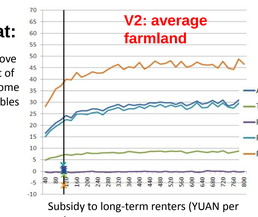
Some Experiments

Compare effectiveness of policies looking at:

(i) The End State of the System
(Changes by policies compared to an initial period with no policy)

(ii) The Trajectory of the System
(Each stair up is a 10% change)





Note: The vertical lines on the graphs represent the amount of subsidy to renters that makes the total subsidy to a village about equal to what it receives under the current policy. The symbols x indicate the change in the state of the system resulting from the current policy.

(iii) Cost, Benefit & Fairness

Major Insights:

- The current policy of subsidizing rice cultivation may have done little good for rural development; is not a fair policy in that farmland-rich places receive a lot more subsidy than other places; produces immediate and short-term effects.
- The rental policy appears to have apparent advantages in promoting rural development over the current policy. It is expected to move the agricultural system to a more desired state with less cost in most places. It is more socially fair by making every household in farmland-poor places better off. It is also expected to create the potential for continuous improvement in the agricultural system.
- The rental policy is unlikely to improve the agricultural system in places with rich farmland resources (much less costly than the current policy, though) where other types of policies or programs are needed.
- The rental policy's effect in increasing rural income is expected to be small across places. Rural development in China is tightly linked to and depends on the industrial sector's growth.
- While continuing to promote the development of the industrial sector, the government may use subsidy size for long-term renters as an instrument to effectively stimulate land rental markets and control the degree to which farmland is concentrated in rural areas to keep agricultural sector development synchronized with industrial sector growth.