From Vulnerability To Sustainability:

A study of sustainable development in the context of climatic and institutional changes in rural China

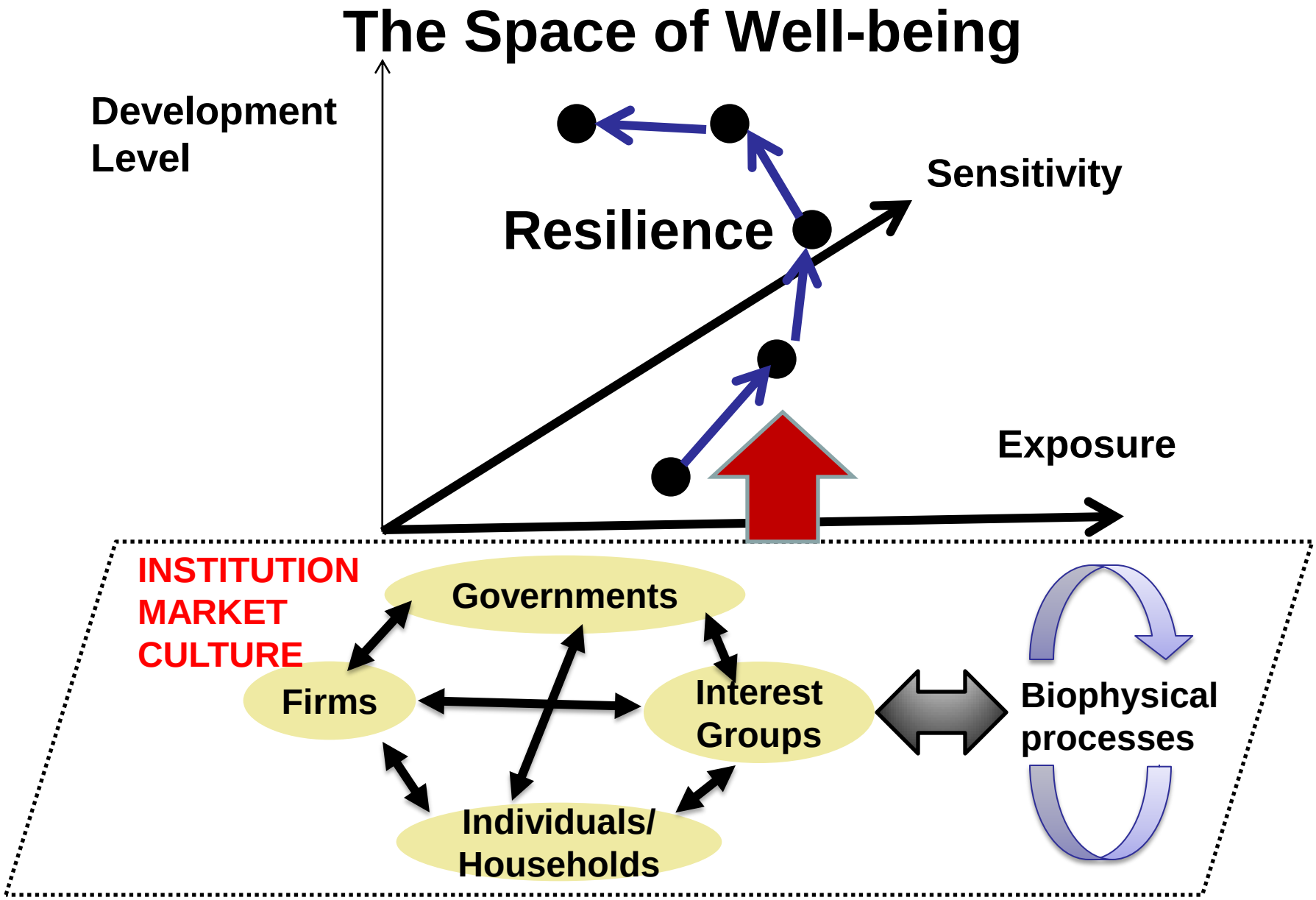
Qing Tian, PhD Candidate
Adviser: Dr. Dan Brown
School of Natural Resources and Environment
University of Michigan

General Goals

- to contribute to sustainability science by proposing a new conceptual and methodological framework for studying sustainability from the perspective of coupled human-environment systems (CHES);
- to provide useful information for government development policy making in the Poyang Lake region.

A Conceptual Framework of Sustainability of CHES

in the context of Climate Change/Variability



Toward Sustainability

Three Steps	Analyses	Implementations
1. Where is the system?	**Assessing well-being**	**Remote Sensing** + GIS + social-economic data
2. How do actions & interactions drive state change?	**Analyzing multi-source & multi-level causes** of well-being	quantitative + qualitative (surveys + interviews)
3. What if we do things differently?	**Exploring the dynamics** of sustainability	agent-based model + network analysis + mathematics

A Case Study in the Poyang Lake Region, China

The Poyang Lake Region (PLR)

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

Practical Goals:

- *Provide a scientific basis for government development policy making in the context of flood hazards;*
- *Generate insights into how the farmer households can better respond to the uncertainty of social-environmental changes.*

In the past — **Reforms** — **At the present** — **Into the future**

I. An regional assessment of well-being combining remote sensing, GIS & social-economic data

II. An in-depth analysis of well-being at finer scales and its causes based on surveys & interviews

III. Exploring the future & the dynamics of the system with ABM

Part I:

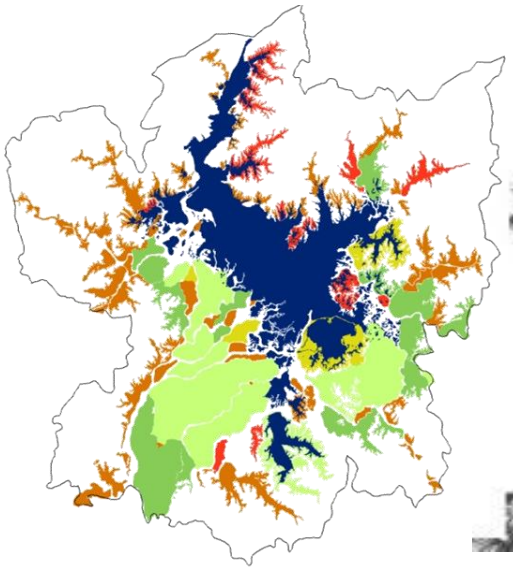
A Regional Assessment of Well-being
combining GIS, remote sensing and social-economical Data

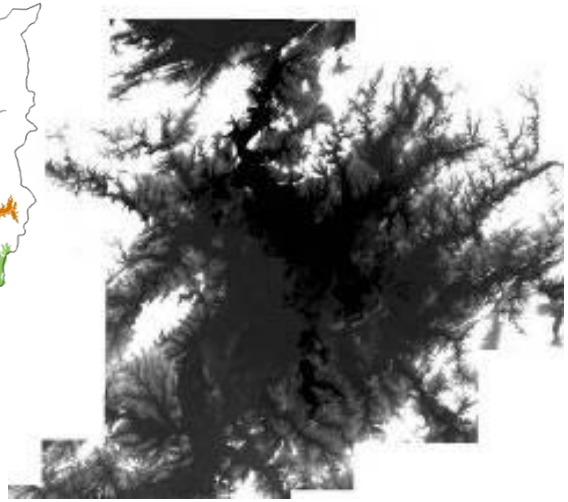
To provide scientific information for development policy making in the context of flood hazards in PLR.

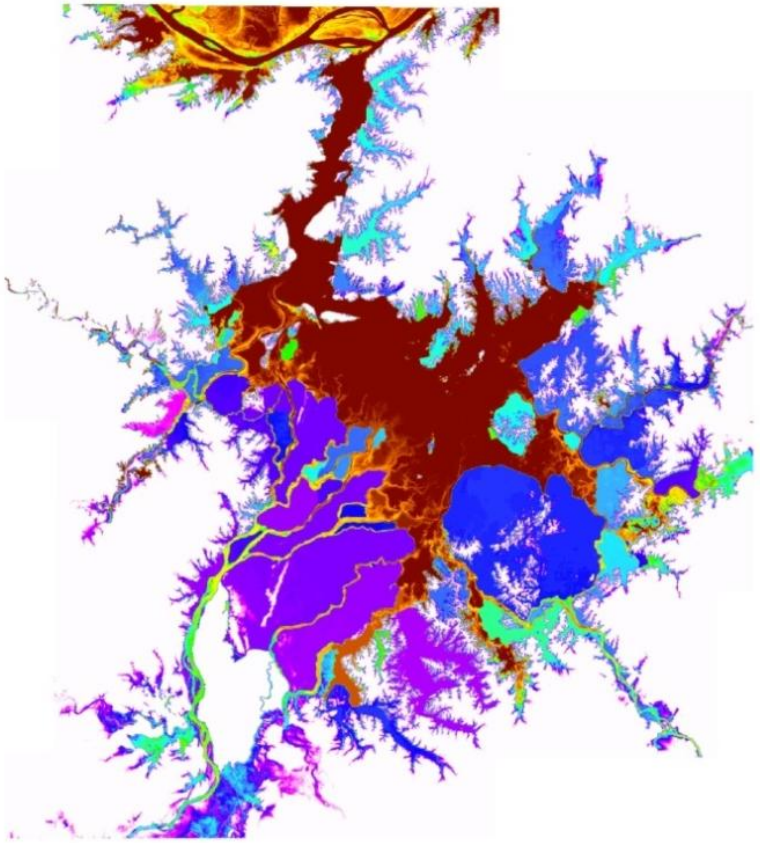
Representing Well-being of Towns

Well-being	Variables
Exposure	**Land -** Percentage of land in high flood risk zone
Sensitivity	**Human Life -** Percentage of people living in high flood risk zone
	Land Use - Percentage of farmland in high flood risk zone
Development Level	**Income** - Percentage of households spending 50,000yuan (or more) in housing
	Education - Percentage of people with a high school (or above) diploma
	Health - Infant mortality rate

Mapping Flood Risk



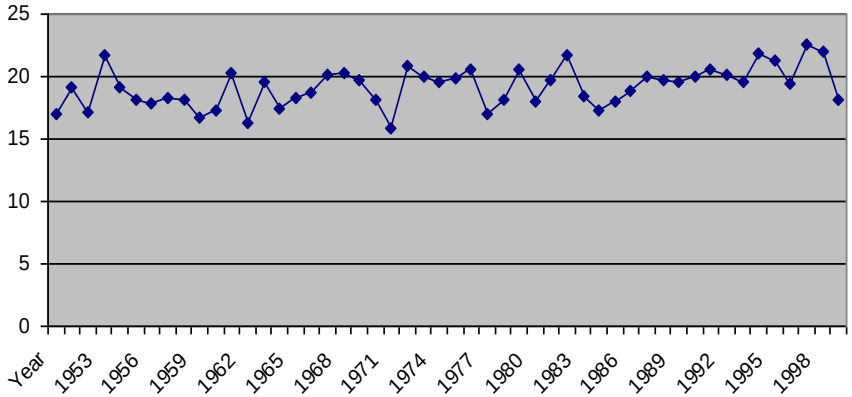




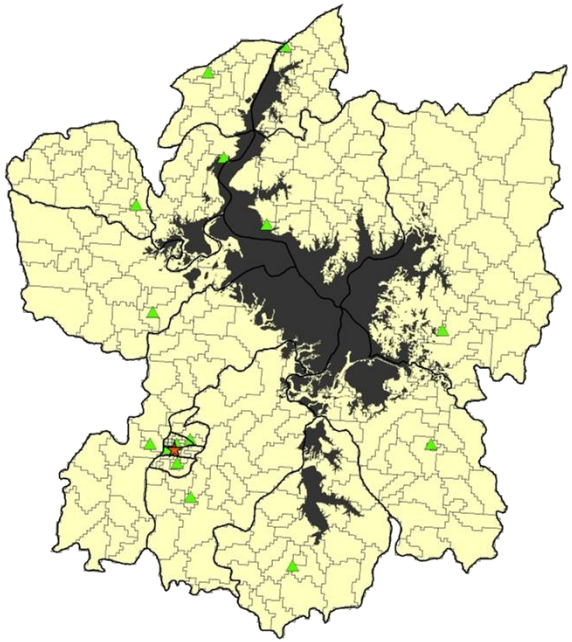
Levees

DEM

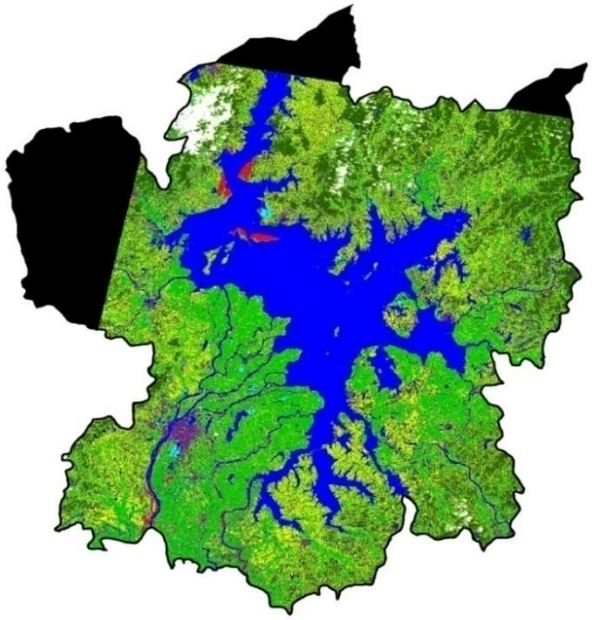
Historical lake levels



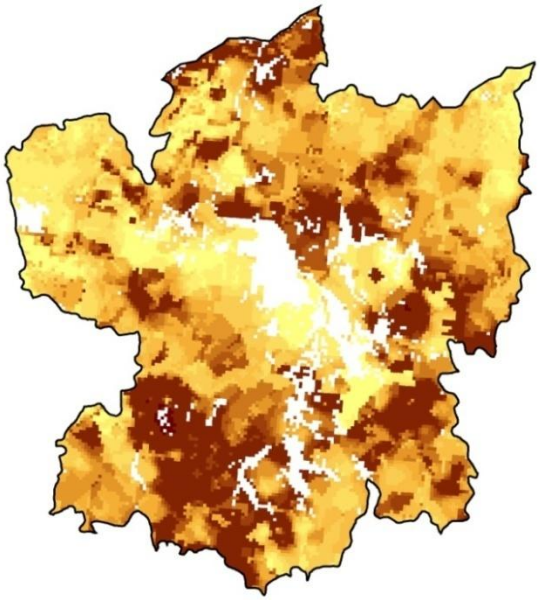
Deriving Variables for the Assessment



Township boundary



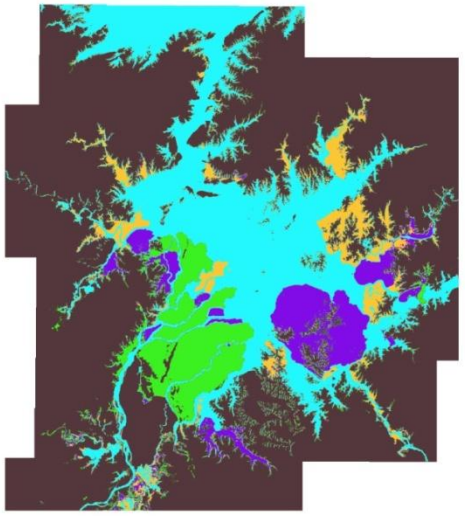
Land use



Population density

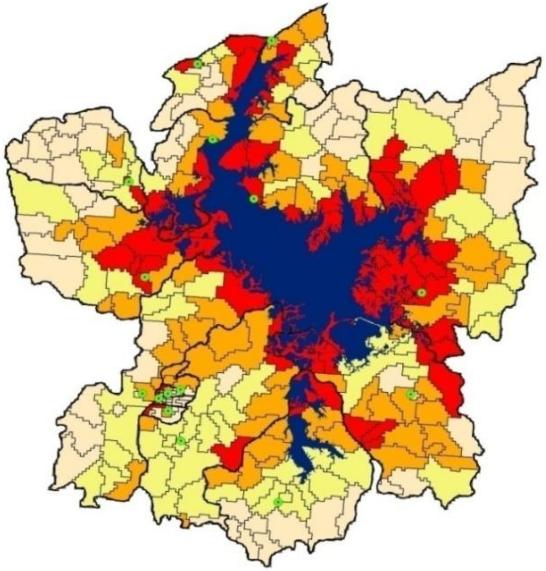
For each town in PLR:

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

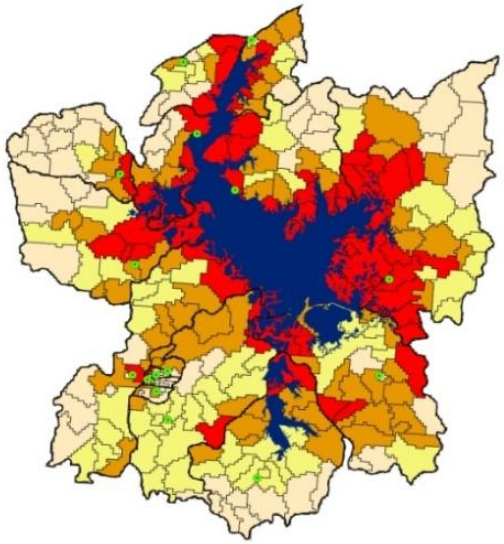


Flood risk zone

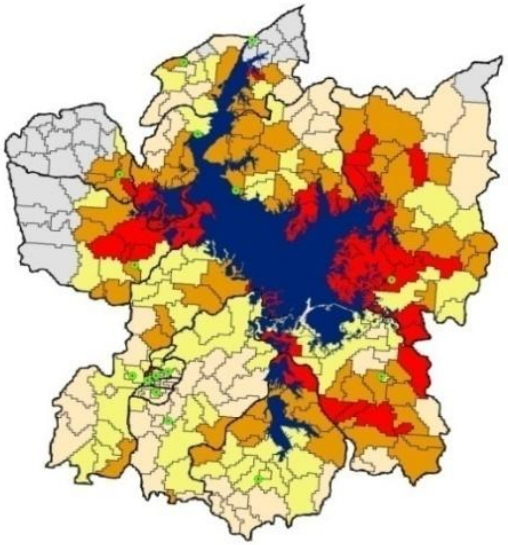
Assessment Results



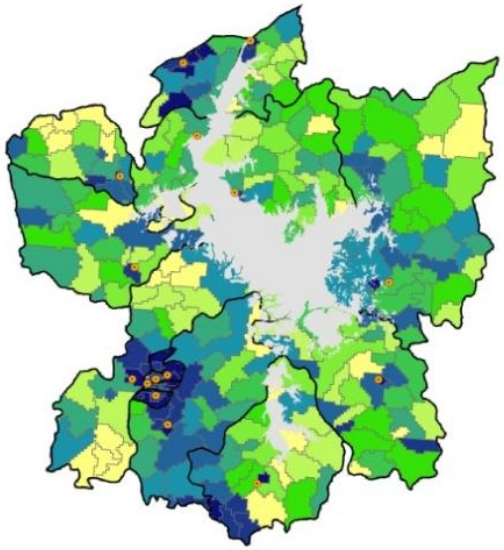
Exposure



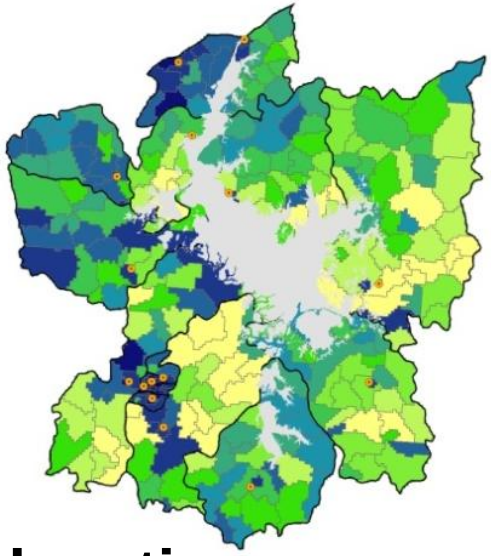
Sensitivity - Population



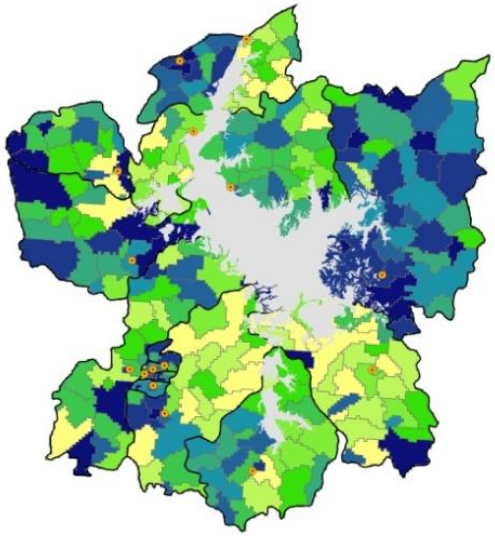
Sensitivity - Farmland



Income - Pct spending 50,000yuan+ in Housing

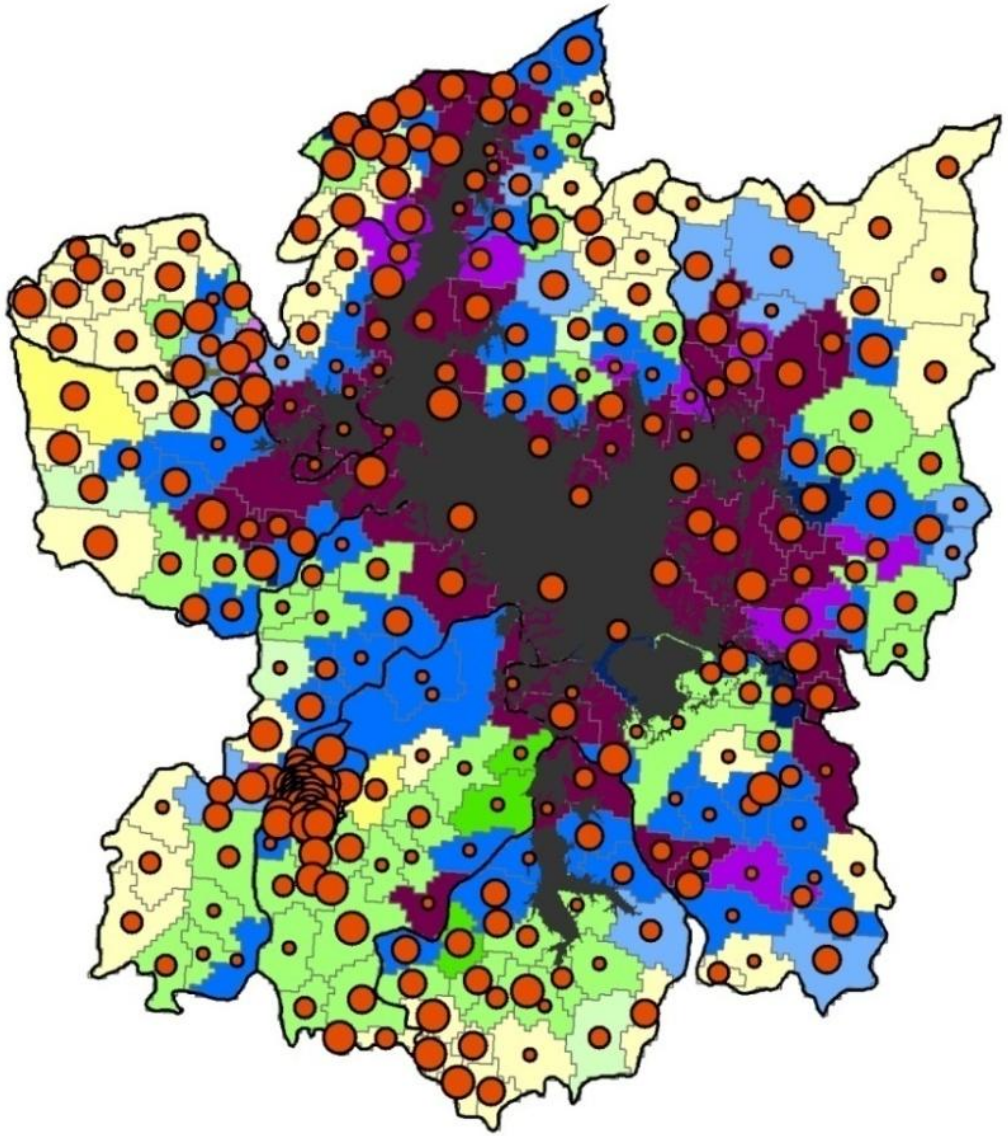


Education - Pct with High School



Health - Infant Mortality Rate

Overall Well-being



Legend

Exposure, Sensitivity

- 1, 1
- 1, 2
- 1, 3
- 2, 1
- 2, 2
- 2, 3
- 2, 4
- 3, 2
- 3, 3
- 3, 4
- 4, 3
- 4, 4

Development Level

- Ist Quartile (4 - 11)
- 2nd Quartile (12 - 15)
- 3rd Quartile (16 - 21)
- 4th Quartile (22 - 30)

Exposure	Sensitivity		Development Level	Implication
	Human Life	Land Use		
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 Well-being at Finer Scales and its Causes

based on social surveys and interviews

Question: **WHAT** factors (including household characteristics, the large social-economic-political setting & physical environment) & **HOW** these factors interacting with each other **affect the well-being of a household** *through its land-use & livelihood decision-making process*?

Approach: Quantitative + Qualitative

- Focus on the *livelihoods of people**;***
- Synthesize perspectives from *vulnerability analysis, sustainable livelihoods analysis & development economics*;
- Examine and explain variations of well-being at three levels: *community, group & household*;
- Look into *flood impacts on the current land-use practices and land-use drivers*;
- Examine the *land-use & livelihood decision-making process* of households to understand how these factors interact with each other affect the well-being of the households.

Conclusions

- **The livelihoods** of farmer households **are not greatly sensitive** to flood impacts, **but the current land-use system is.**
- The differences between villages are not significant, and each village has its unique characteristics suggesting different sustainable development pathways.
- Different groups of households exist, but **the levels of well-being of households are essentially determined by their livelihood profiles**.
- Four major types of livelihood profiles are identified, and each can lead to high levels of well-being.
- **What type of livelihood profile a household has and to what degree it is successful** in executing the profile **are mostly determined by its characteristics** (social connections, education, labor, risk taking and hard working)
- The livelihoods of a household are also **influenced by some factors at the community level** (location, and more importantly the social capital of the village)
- Overall , the livelihoods of rural households are **greatly affected by policies and macro-level processes** (reforms at the national level, land polices & urbanization process)

Other Important Insights from Household Analyses

- **The Key Issue of Sustainability** in PLR & Rural China is **BAD Resilience;**
- Farmer households are economic agents, most have few feasible options, constrained by
  - *- limited farmland resources*
  - *- their own characteristics*
  - *- the social-economic-political setting*
- Current small farmland holding of households is a significant barrier to agricultural productivity and rural development;
- Rural development is tightly linked to the growth of industrial sector and the urbanization process.

Major Policy Recommendation

- Implement appropriate migration policies to absorb some migrant workers formally to the urban system;
- Promote local urbanization by developing featured local industries to further absorb the surplus of rural labor;
- Further reform land policies to increase land-use efficiency and rural income through large scale farming.

Part III:

Exploring the Dynamics of Sustainability

with agent-based modeling

Questions:

(i) Can these recommended policies break the bad resilience of the system?

(ii) Under what conditions?

The Future of the System		Conditions								
		Wage Increase Rate			Agricultural Product Price Increase Rate			Off-farm Work Opportunity		
		5%	10%	…	5%	10%	…	100%	90%	…
Policy Scenarios	**Status Quo** (private negotiation of leases)									
	Formal Land Rental Market only									
	Land Rental Market & Migration Policy									

Outcome Measures:

- **Total Wealth & Wealth Distribution**
- **Total Agriculture Production**

Acknowledgements

Advisers:

Dan Brown (Chair) & Maria Lemos (SNRE)

Stephen Salant (Economics)

Rick Riolo (Center for the Study of Complex Systems – CSCS)

A special thanks to:

Prof. John Holland (Computer Science & Psychology & CSCS)

Aaron Bramson (A PhD student in Political Science & CSCS)

Dr. Shuming Bao (China Data Center)

Prof. Lin Zheng, Shuhua Qi, Ying Liu (Jiang Xi Normal University)

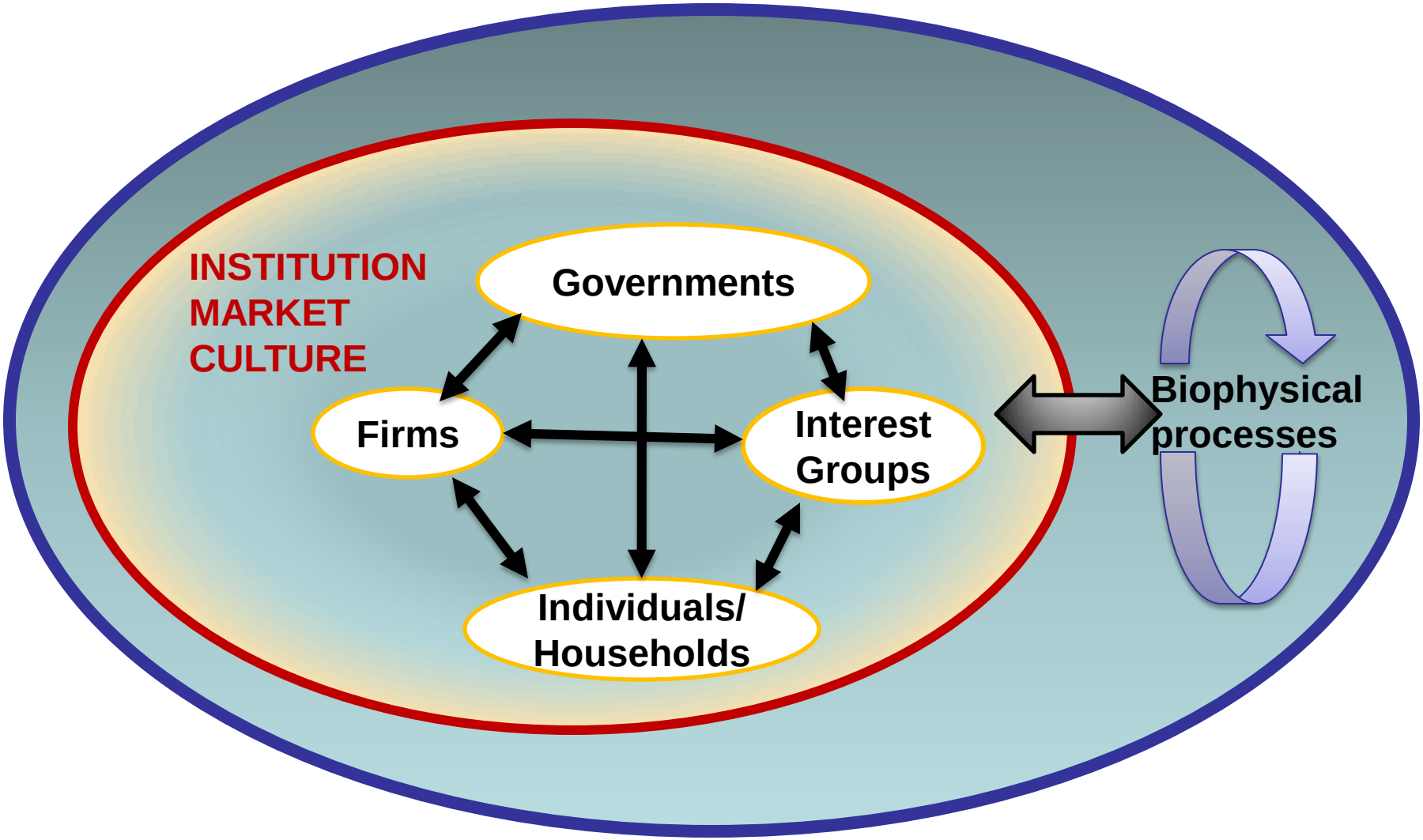
Farmers around Poyang Lake

This dissertation builds upon a NASA-funded project on land use and vulnerability, led by Dr. Dan Brown.

Thank you!

Policy Scenario	Agricultural Production	Total Wealth	Growth of Wealth	Future Outlook
Status Quo (Baseline)	**Low**	**Low**	**Slow**	Every household does some migrant work & some agriculture
Formal Land Market	**Higher**	**Higher**	**Faster**	**No specialization** will happen
Formal Land Market + **Migration Policy**	**Highest**	**Highest** *(several times higher)*	**Fastest** *(a **jump** in total wealth at some point & in some conditions)*	1. Some **specialize** in agriculture; 2. Some move out of the country; 3. Few still do both *(at some point & in some conditions)*

Coupled Human-Environment Systems (CHES)



SUSTAINABILITY

IS

a Global Property of a CHES

EMERGENT from

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

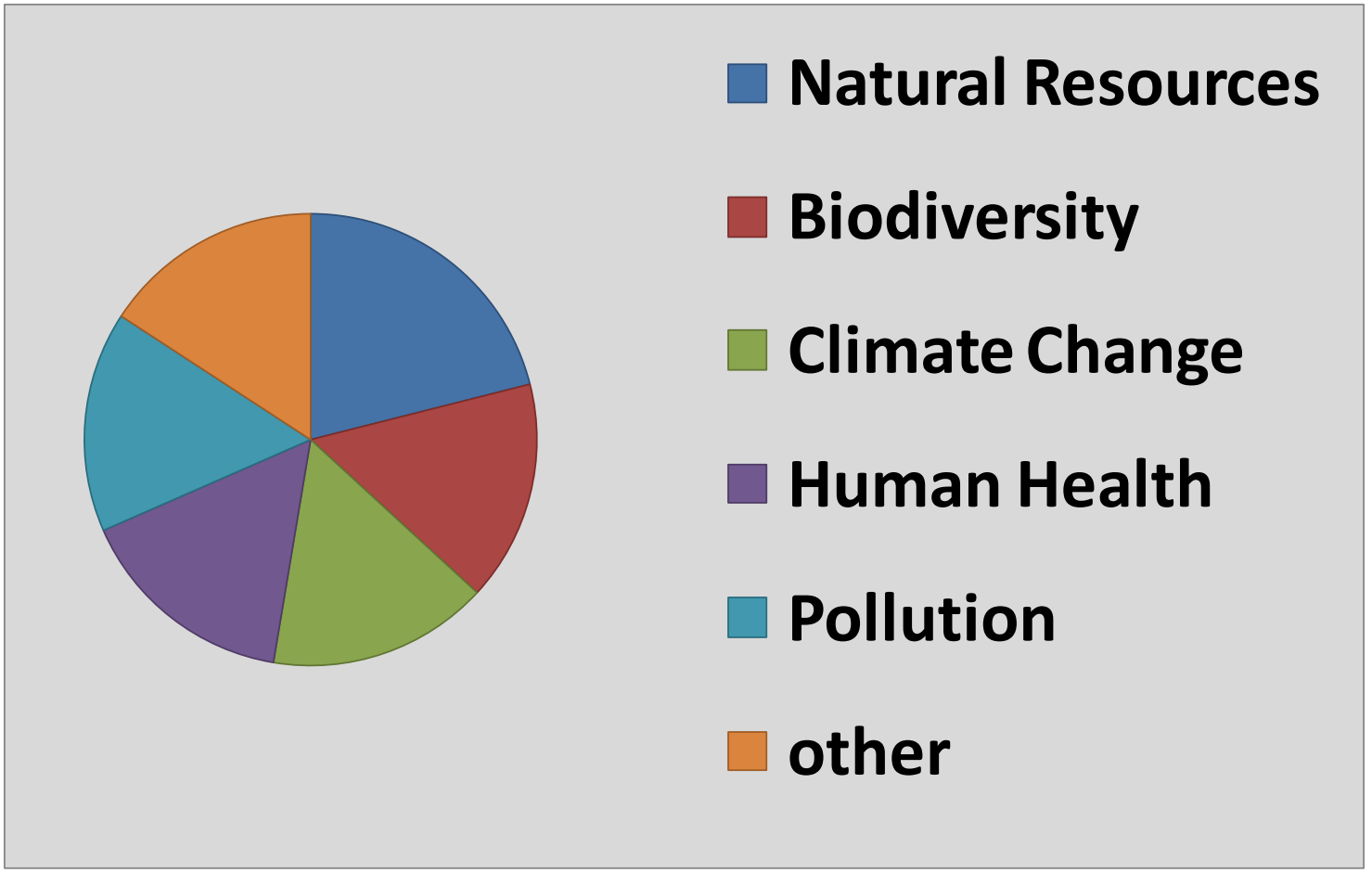
❖ the biophysical processes of the environment

❖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 of Sustainability of CHES

in the Dimension of Climate Change/Variability

WELL-BEING describes the state of a system at one point in time.

Three dimensions of well-being:

(1) Biophysical exposure *(of the human system to CC/V)*

(2) Development level *(in economic achievement, education and health)*

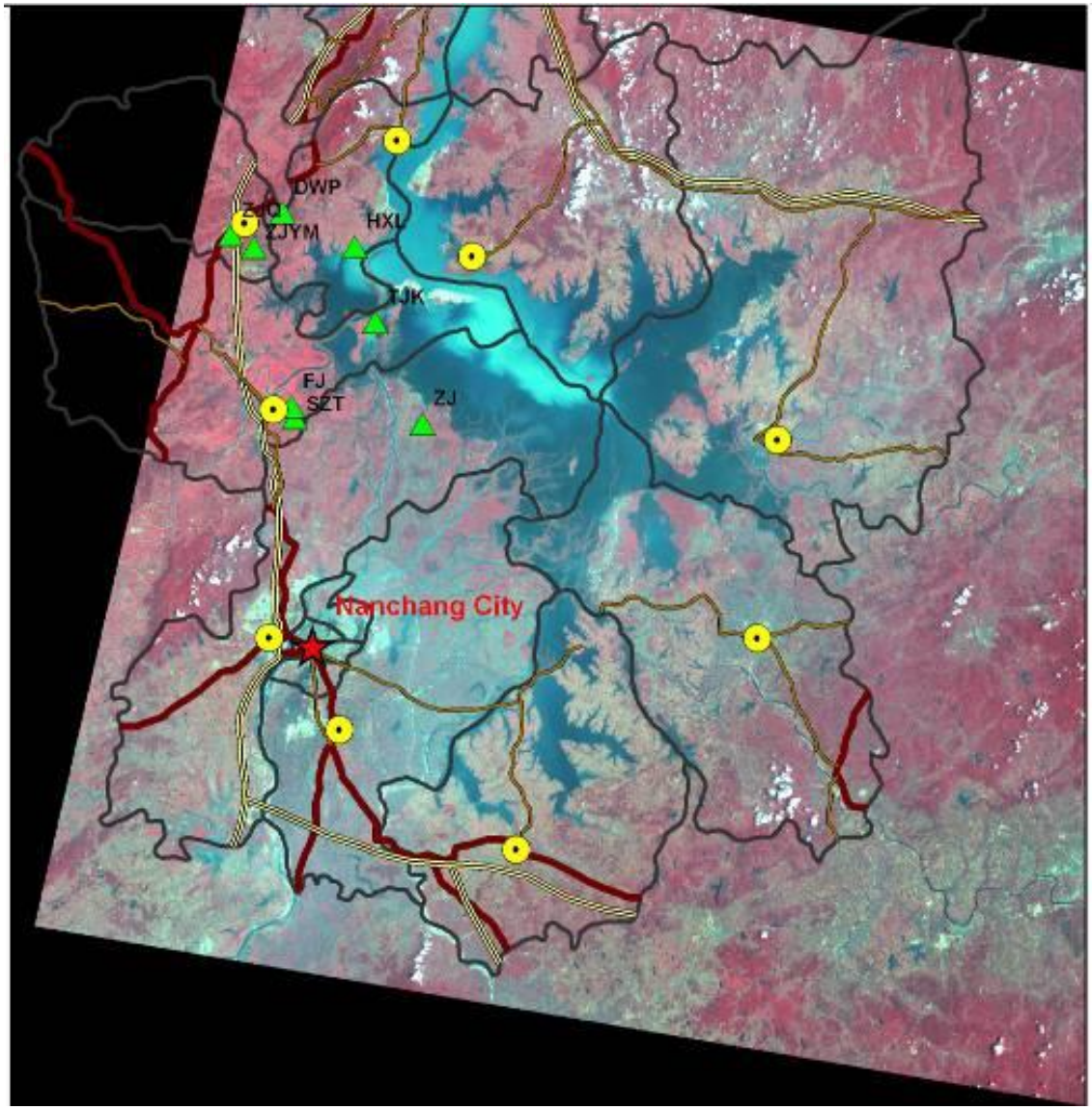
(3) Sensitivity *(of human development to CC/V)*

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

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

Surveys and Interviews

(villages selected based on **flood risk & distance to cities**)

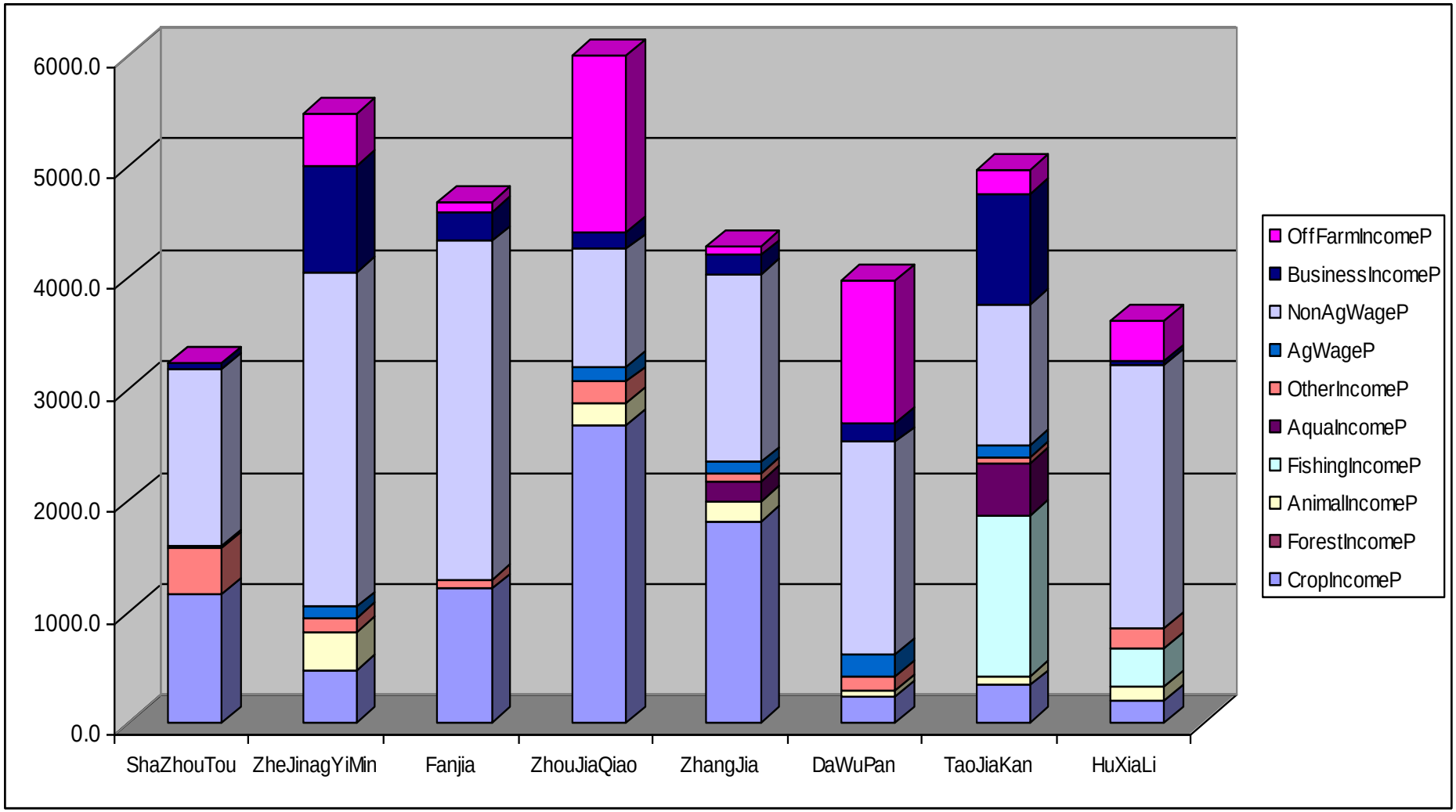


Number of surveyed villages	**8**
Number of Households Surveyed	**193**
Number of Households Interviewed (with open-ended questions)	**40+**
Number of local government officials & scientists interviewed	**10+**

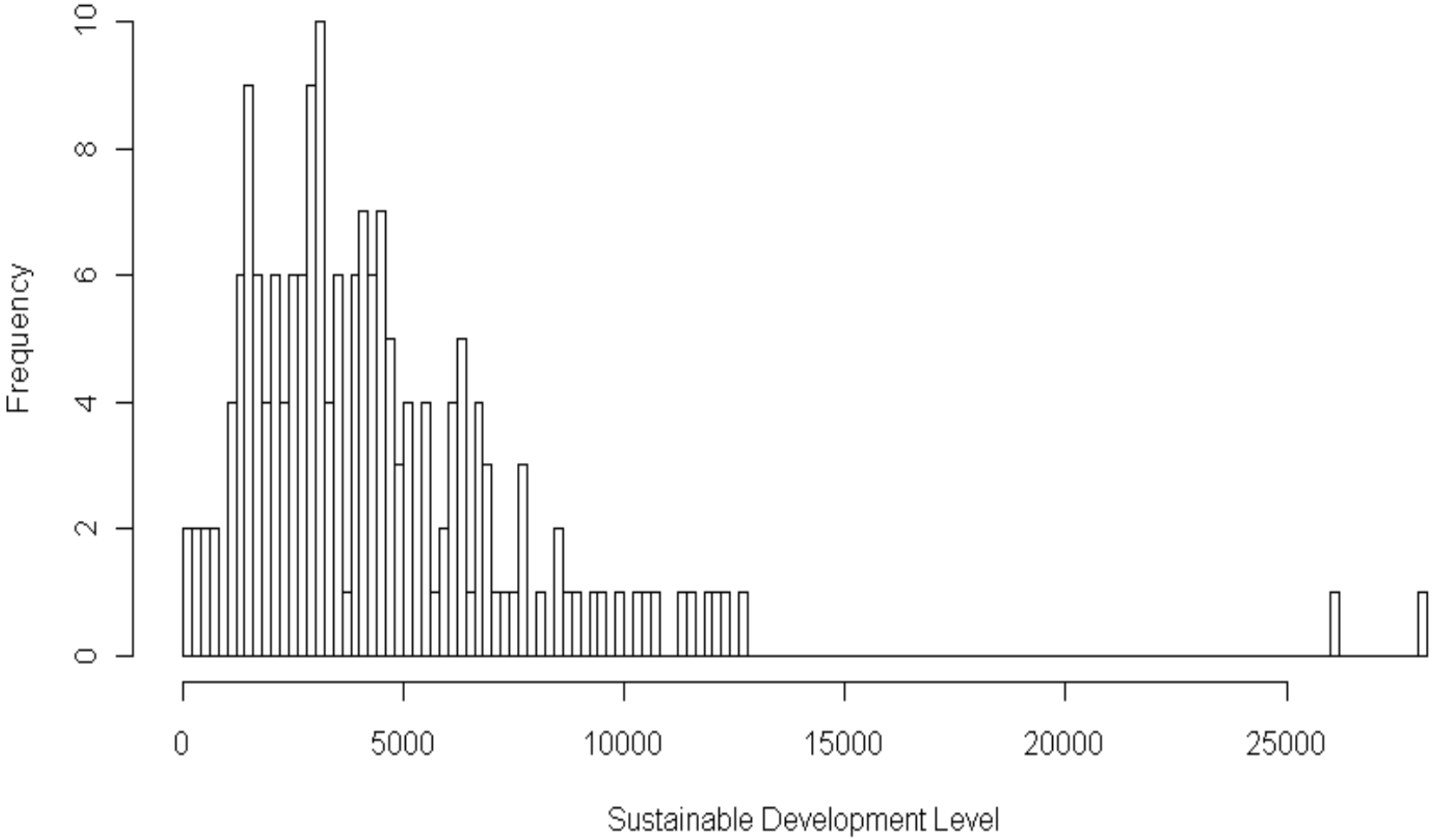
Representing Well-being
at the household level

Well-being	Variables	Measurement Scheme of Sustainable Development Level	
Exposure	**Flood Risk Zone**	Used to discount farming-related income. The discount rates for different degrees of exposure are: 1: 99%; 2: 95%; 3: 90%; 4: 75%; 5: 60%	Income Type 1 + Income Type 2
Sensitivity	**Income Composition**	Reflected in different discount rates for different income sources	
Development Level (All income used here is income per capita)	**Farming Income**	Income Type 1= (Farming Income + Agricultural Wage) * Discount Rate	
	Agricultural Wage		
	Non-agricultural Wage	Income Type 2= (Non-agricultural Wage + Business Income + Salary-based Income)	
	Business Income		
	Salary-based Income		

Livelihoods & Income Diversity in surveyed villages



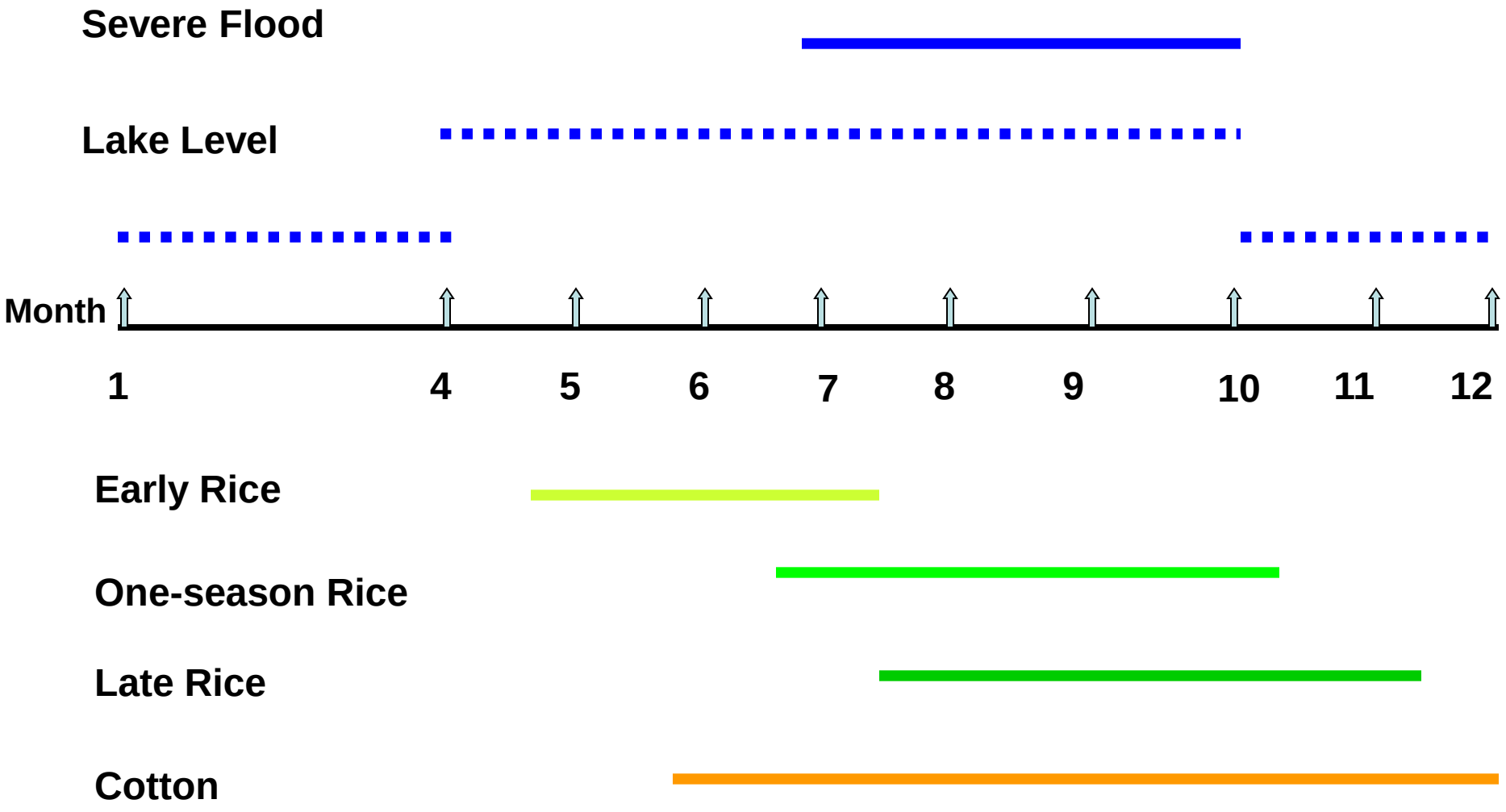
Distribution of sustainable development level among households



Livelihood Profiles and Household Characteristics

Livelihood Profile	Labor	Edu-cation	Risk Taking	Hard Working	Social Conn-ection	Others
Diversified near-home livelihood		*	*		***	Location nearby urban centers and government contacts
High-return livelihood		**	***		***	Requires investment capital and sometimes special skills.
Farming-based livelihood (production of high-cash-value crops or at larger scale)				***		market accessibility/ abundant land resources;
Combined income from farming and migrant work	***	***			**	

Flood Dynamics & Crop Growth Cycles



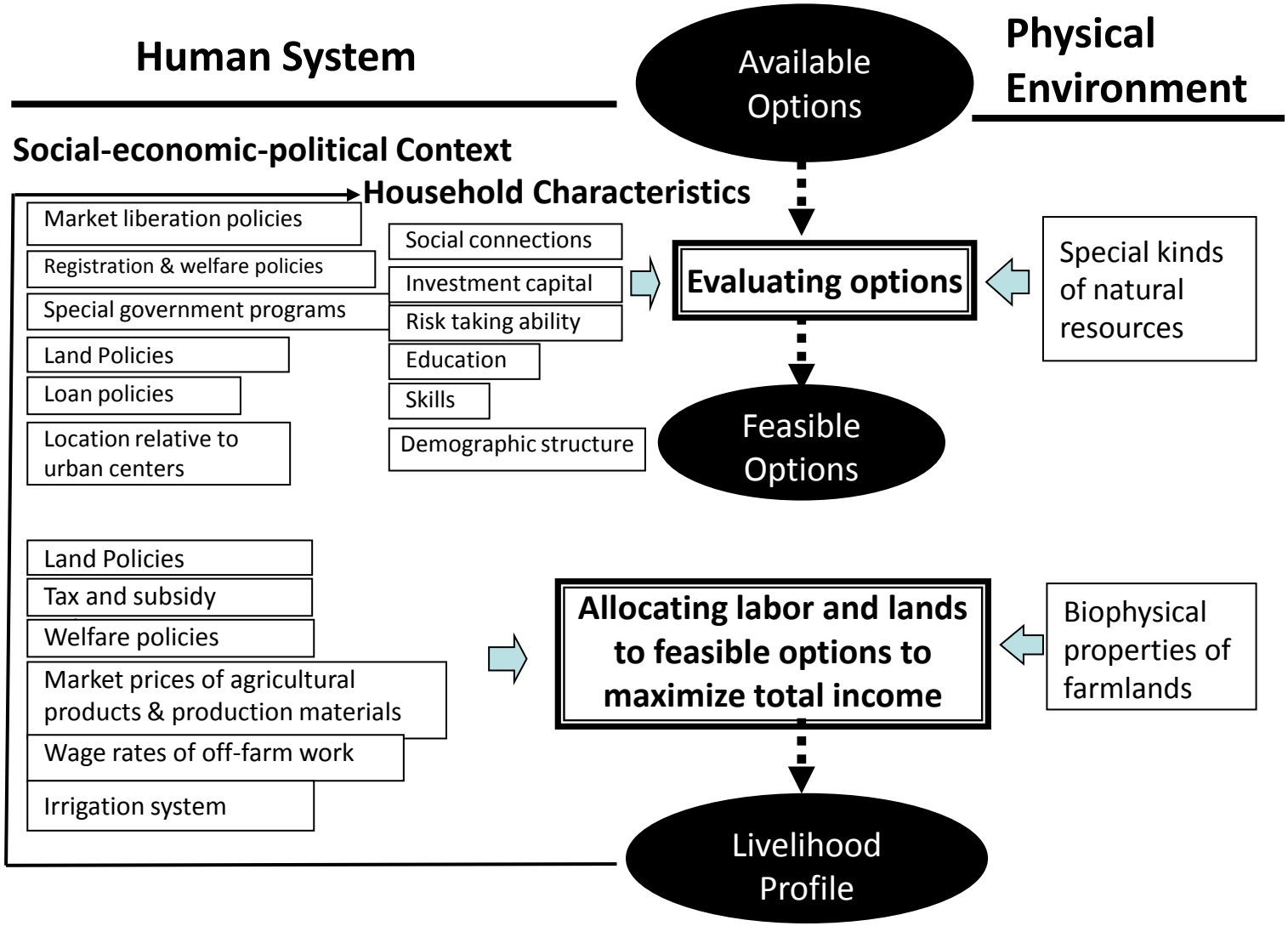
Three-level Models for One-season Rice

One-season Rice		Variables	With No Variables			M1	M2.1	M2.2	M2.3	M2	M3.1	M3.2
							Add Household Variables				Add Village Variables	
			Without Random Effects		With Random Effects	Add Plot Variables	Add Household Structure Variables	Add Land Resource Variables	Add Financial Variables	Add Social Connection &Education Variables	Add Irrigation Variable Only	Add Location Variable Only
Fixed Effects												
		Intercept	-0.342***		-0.652	-0.682	-0.522	-0.428	-0.501	-0.628	-0.965@	-1.894**
Plot Level		PlotSize				1.811***	1.806***	1.835***	1.828***	1.820***	1.819***	1.827***
		Fertility 2				0.663*	0.605*	0.588*	0.579*	0.603*	0.616*	0.603*
		Slope 2				-2.883***	-2.917***	-3.261***	-3.265***	-3.283***	-3.268***	-3.263***
		Distance				-0.015@	-0.015@	-0.014	-0.014	-0.013	-0.013	-0.014
House - hold Level	Household Structure	Household Type 2					-1.559*	-1.657*	-1.695*	-1.445*	-1.429*	-1.288@
		DependenceRatio					0.003	0.001	0.002	-0.0004	-0.0002	-0.0007
		PctFemaleLabor					-0.002	-0.004	-0.004	-0.007	-0.007	-0.009
		NumClgStudents					0.130	0.057	0.059	-0.032	-0.022	-0.092
	Land Resources	TotalArea						0.045	0.041	0.029	0.035	0.020
		PctFlat						-0.016*	-0.016*	-0.018*	-0.020*	-0.023**
		AvgPlotSize						-0.542	-0.521	-0.559	-0.619	-0.628
	Financial Variables	HaveLoans 1							0.165	0.253	0.203	0.171
		SqrtOff-farm Income							-0.0001	0.0005	0.0002	0.0002
	Social Connection &Education	WithGovContact 1								1.020**	1.019**	1.082**
		Education 1								-0.394	-0.381	-0.404
Village Level		Irrigation 1									1.016	
		CloseToCity 1										1.852*
Random Effects	Household Level				**0.5248**	**1.4989**	**1.3702**	**1.3565**	**1.3449**	**1.1359**	**1.1463**	**1.1267**
	Village Level				**0.9884**	**0.6587**	**0.5215**	**0.5476**	**0.6091**	**0.8910**	**0.6517**	**0.3621**
ROC			**0.5**		**0.7813**	**0.8838**	**0.8834**	**0.8839**	**0.8841**	**0.8810**	**0.8814**	**0.8810**

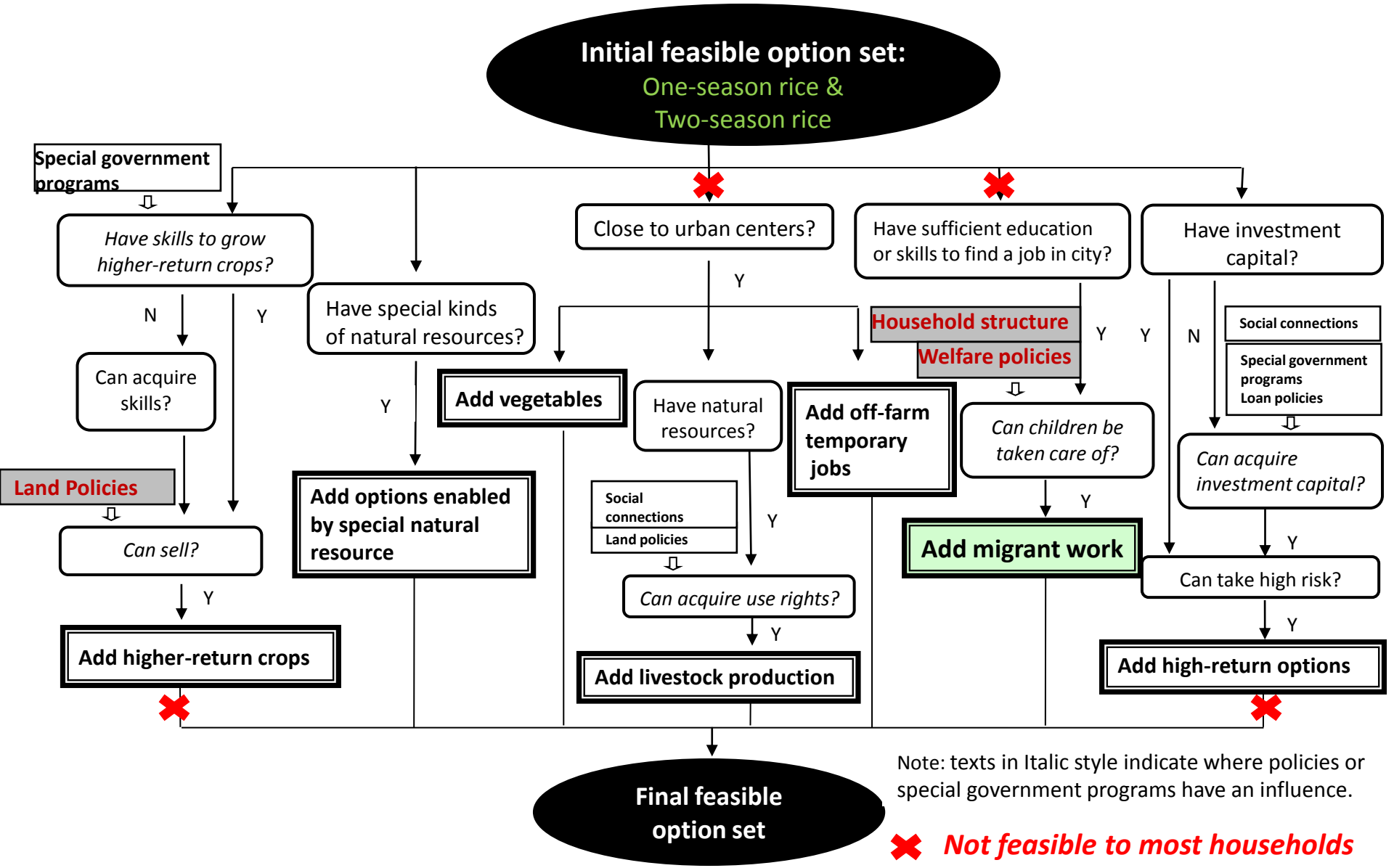
Three-level Models for Cotton

Cotton		Variables	With No Variables			M1	M2.1	M2.2	M2.3	M2	M3.1	M3.2
							Add Household Variables				Add Irrigation Only	Add Location Variable Only
			Without Random Effects		With Random Effects	Add Plot Variables	Add Household Structure Variables	Add Land Resource Variables	Add Financial Variables	Add Social Connection &Education Variables		
Fixed Effects												
		Intercept	-0.814***		-0.715@	-0.827@	-0.780	-0.744	-0.683	-0.642	-0.604	-0.038
Plot Level		PlotSize				-0.597***	-0.570***	-0.638***	-0.644***	-0.645***	-0.644***	-0.645***
		Fertility 2				-0.022	0.011	-0.002	0.001	-0.005	-0.004	0.004
		Slope 2				0.317	0.332	0.325	0.352	0.357	0.358	0.359
		Distance				0.014@	0.015*	0.017*	0.017*	0.017*	0.018*	0.017*
House-hold Level	Household Structure	Household Type 2					-0.380	-0.454	-0.472	-0.477	-0.486	-0.510
		Dependence Ratio					0.006	0.006	0.005	0.005	0.005	0.005
		PctFemale Labor					0.018***	0.018***	0.018***	0.018***	0.018***	0.019***
		NumClgStudents					-0.512	-0.429	-0.480	-0.443	-0.445	-0.430
	Land Resources	TotalArea						0.050@	0.058*	0.059*	0.060	0.061*
		PctFlat						-0.001	0.001	0.001	0.001	0.001
		AvgPlotSize						0.004	-0.106	-0.114	-0.110	-0.124
	Financial Variables	HaveLoans 1							-0.088	-0.094	-0.091	-0.096
		SqrtOfffarmIncome							-0.002@	-0.002@	-0.002@	-0.002@
	Social Connection &Education	WithGovContact 1								0.004	0.003	-0.009
		Education 1								-0.066	-0.066	-0.059
Village Level		Irrigation 1									-0.133	
		CloseToCity 1										-0.887
Random Effects	Household Level				**0.3095**	**0.2800**	**0.0913**	**0.0396**	**0.0272**	**0.0286**	**0.0261**	**0.0235**
	Village Level				**0.9959**	**1.0797**	**1.1188**	**1.1497**	**1.2456**	**1.2470**	**1.2396**	**1.1089**
ROC			**0.5**		**0.8008**	**0.8023**	**0.7840**	**0.7775**	**0.7779**	**0.7786**	**0.7783**	**0.7776**

Land-use & Livelihood Decision-making



Evaluating Options



Note: texts in Italic style indicate where policies or special government programs have an influence.

✖ ***Not feasible to most households***