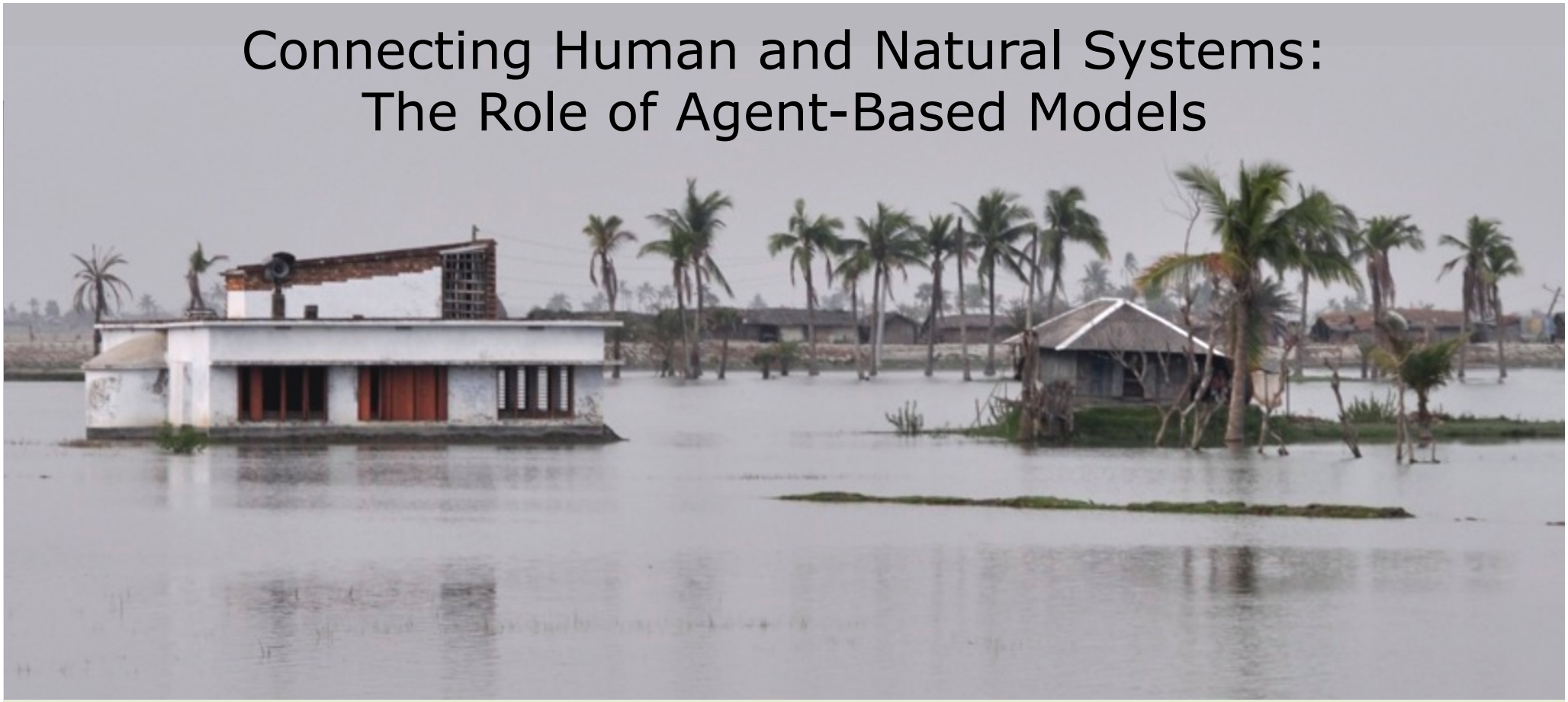
Connecting Human and Natural Systems: The Role of Agent-Based Models



Jonathan Gilligan
Vanderbilt University

Funding:
ONR MURI,
NSF WSC & Coastal SEES

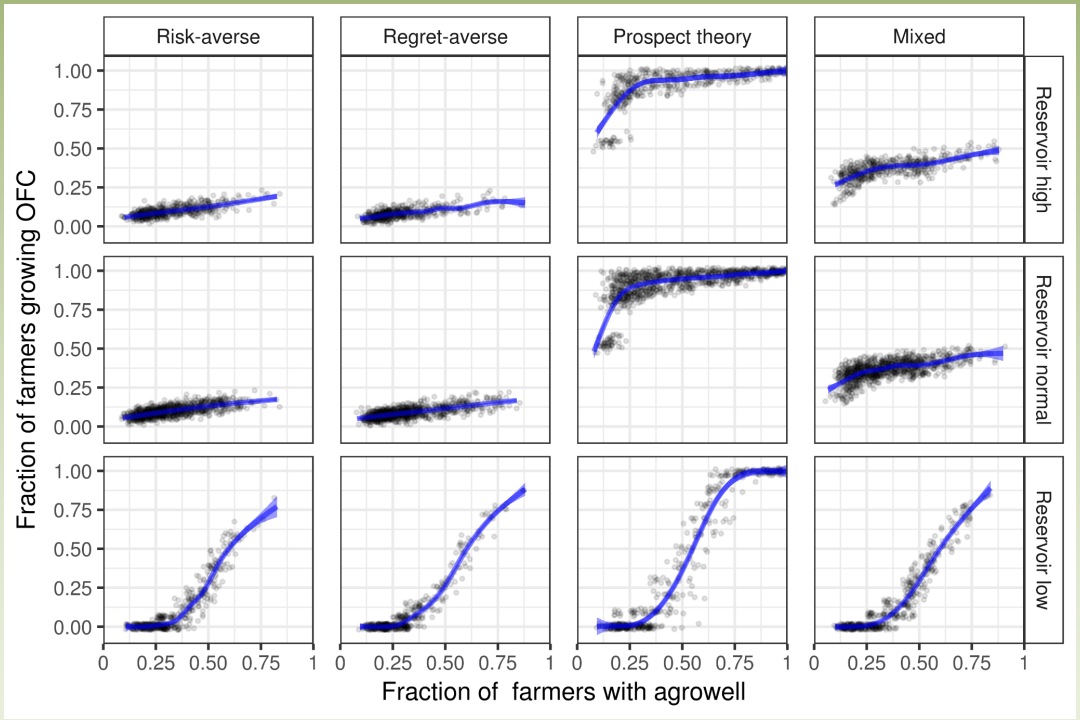
CSDMS Annual Meeting
26 May 2017

The value of applying simple models to complex problems

- Black-box versus glass-box modeling
  - Large, complex models are difficult for others to understand, even when source code is available.
  - Simple models may sacrifice fidelity to observations in favor of transparency:
- Simple models to identify important dynamics
  - Identify what to study in greater detail
- Case Studies:
  1. Participatory agent-based simulations for public engagement on flood hazards
  2. Coupled human natural systems:
     - Tidal river management in Bangladesh

Simple models to identify important questions

- Crop-choice by farmers in Sri Lanka
  - Rice vs. green vegetables
  - Variation by reservoir condition and private irrigation wells
- Different results for different decision models
- Implication: Further research to understand farmers' decision processes under risk & uncertainty

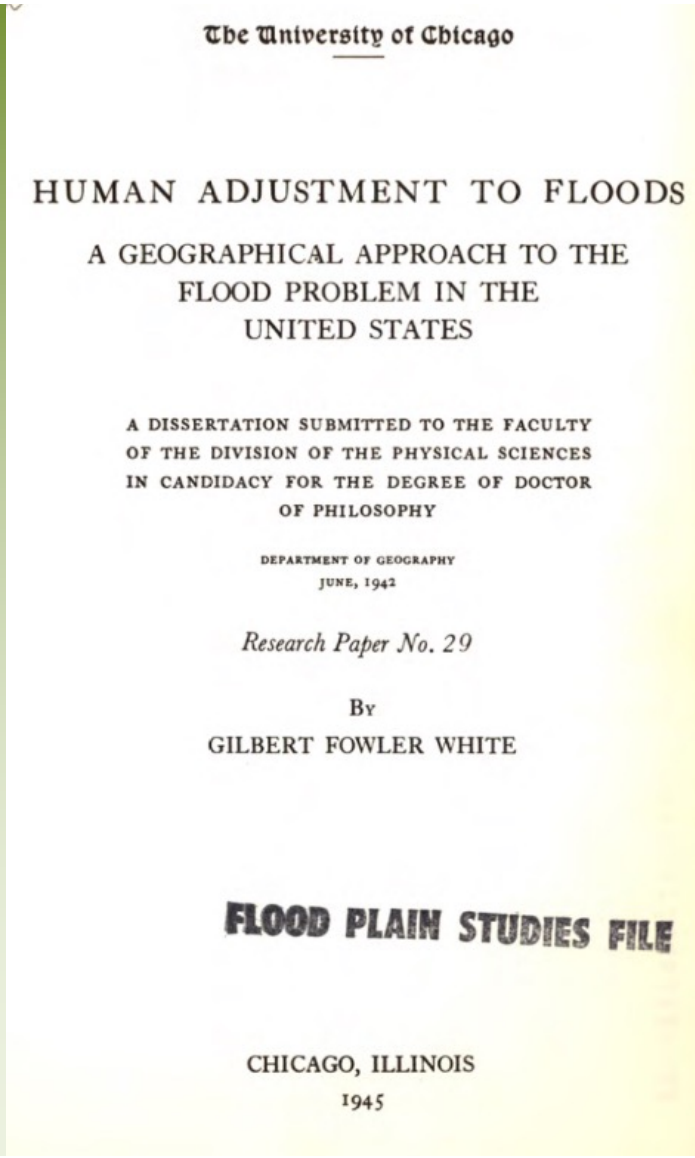


Participatory Agent-Based Simulations for Public Engagement with Flood Control

Floods are "acts of God," but flood losses are largely acts of man.

— Gilbert F. White

Collaborators: C. Brady (VU), J. Camp (VU), J.J. Nay (VU), P. Sengupta (U. Calgary)



The University of Chicago

HUMAN ADJUSTMENT TO FLOODS

A GEOGRAPHICAL APPROACH TO THE FLOOD PROBLEM IN THE UNITED STATES

A DISSERTATION SUBMITTED TO THE FACULTY OF THE DIVISION OF THE PHYSICAL SCIENCES IN CANDIDACY FOR THE DEGREE OF DOCTOR OF PHILOSOPHY

DEPARTMENT OF GEOGRAPHY
JUNE, 1942

Research Paper No. 29

By
GILBERT FOWLER WHITE

FLOOD PLAIN STUDIES FILE

CHICAGO, ILLINOIS
1945

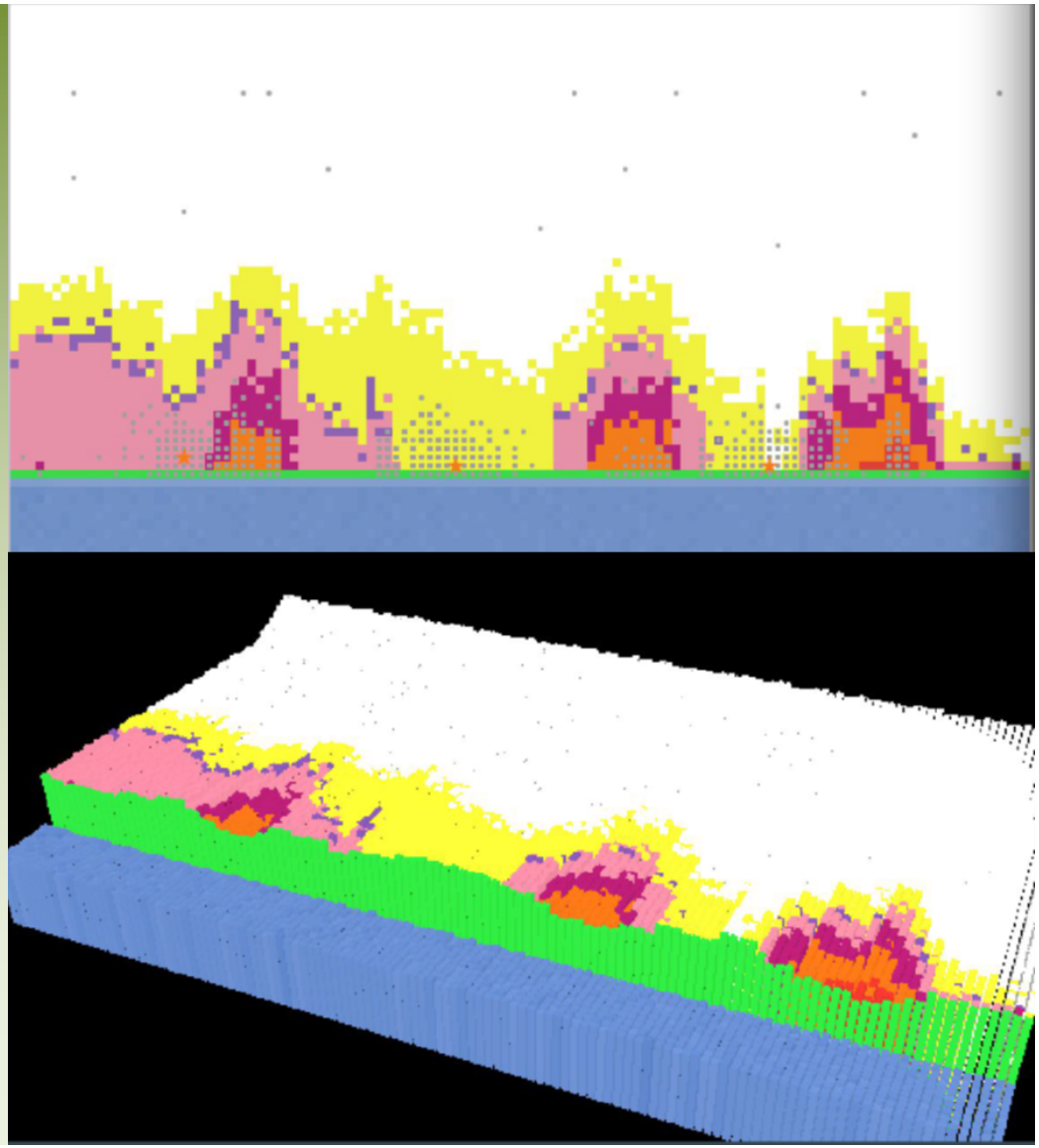
Participatory Agent-Based Simulations

- Interactive simulations:
  - Trial and error with prompt feedback.
  - Learning from experience
- Participatory simulations:
  - Multiple players interacting,
    explore social aspects of emergent phenomena.
- Integrate participatory and agent-based approaches:
  - Players control high-level policy decisions.
  - Automated agents simulate low-level response by population

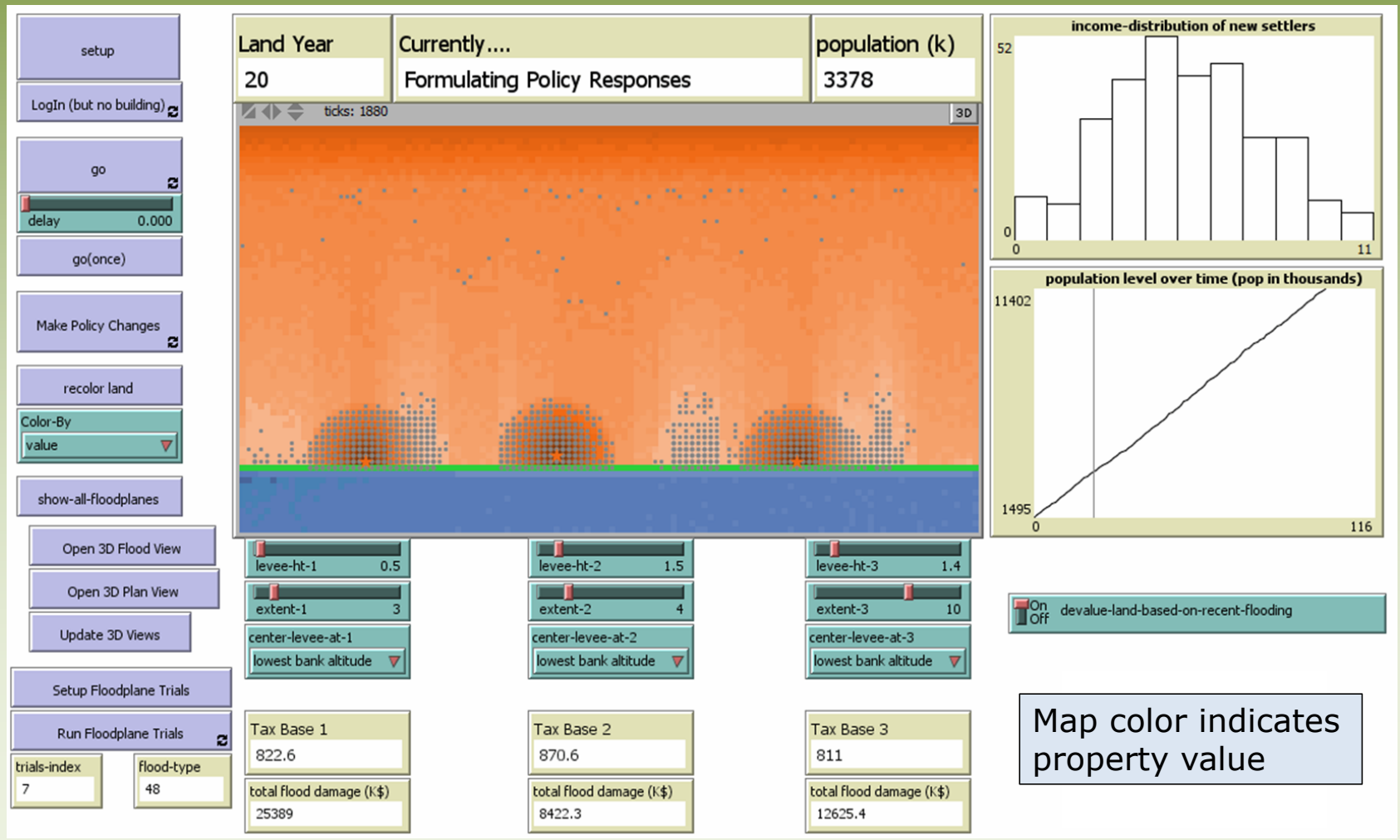
The Model

- Cities along a stylized river
  - Choice **not** to use real geography
- Particle hydrodynamics for channel & overland flow
- Agent-based land markets for development, property value
- Nonlinear time:
  - Slows down during flood events
- Players:
  - Planners for neighboring cities
  - Receive tax revenue
  - Decide on flood wall construction

https://github.com/pratim/Floodpartsim



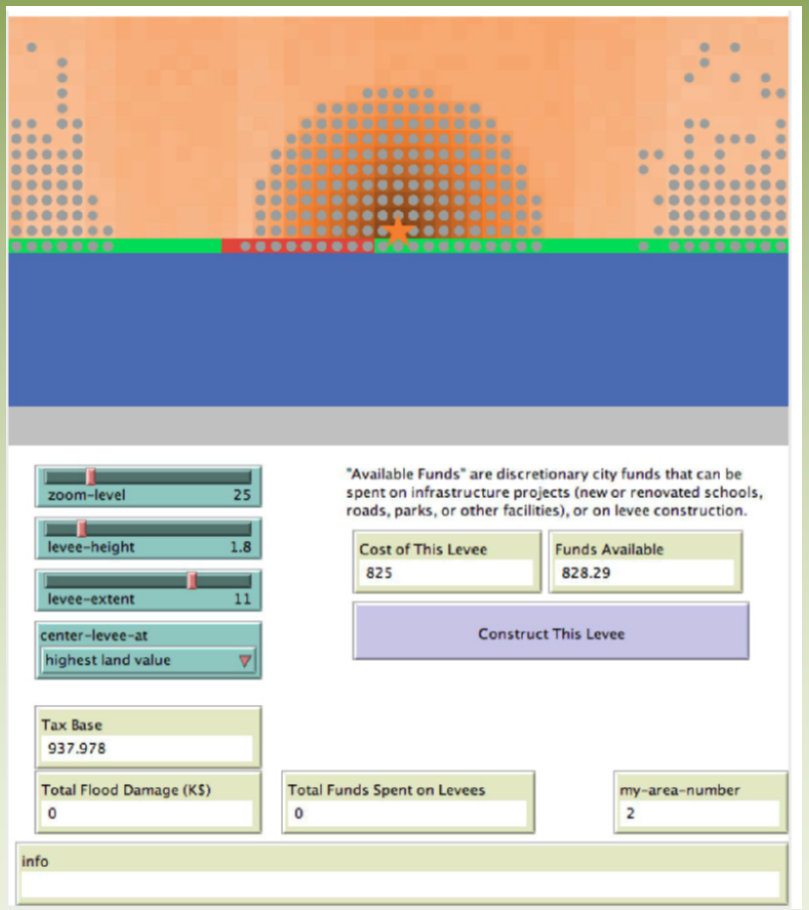
Master Interface



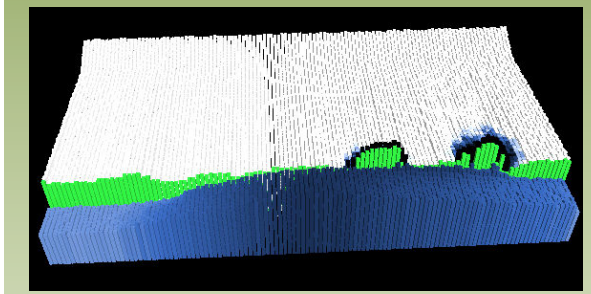
Map color indicates property value

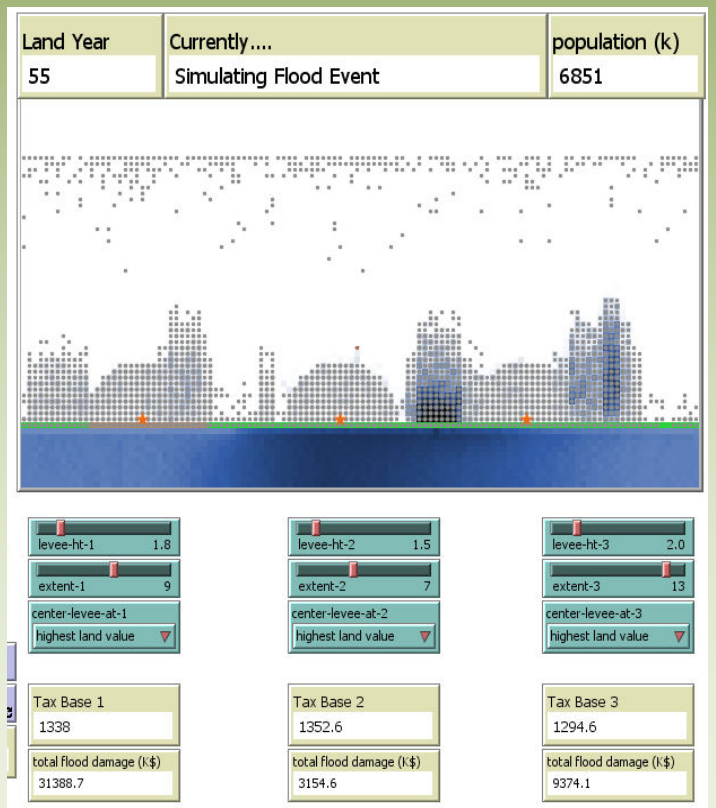
Sequence

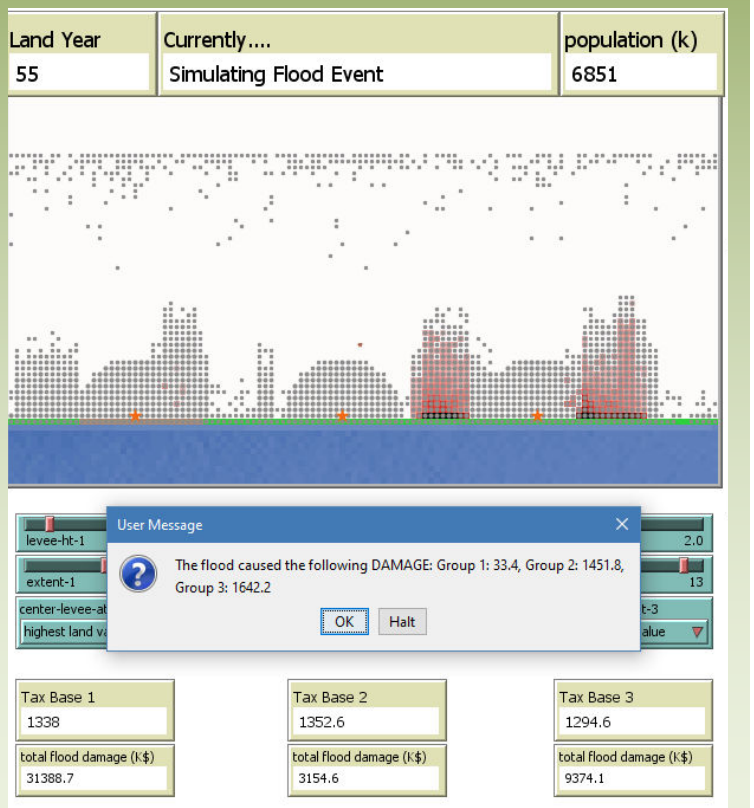
- 20-year run
  - Stochastic rain, river discharge
  - Automated land development
  - Slow time for floods (20+ year stage)
- Every 20 years:
  - Discussion, levee building
- After 100 years:
  - Generate 200-year flood



Flood Event and Damage Map



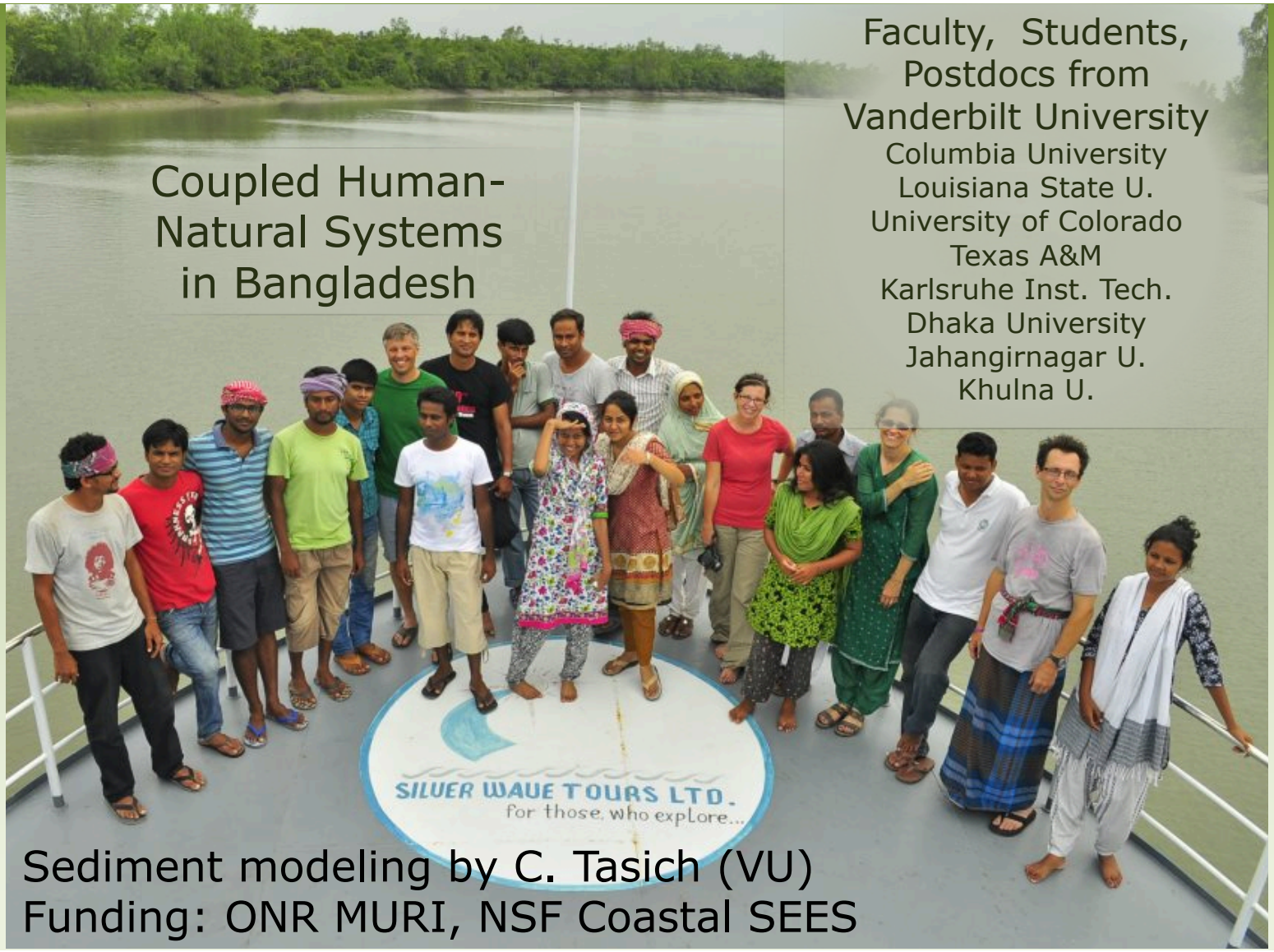




Experiments

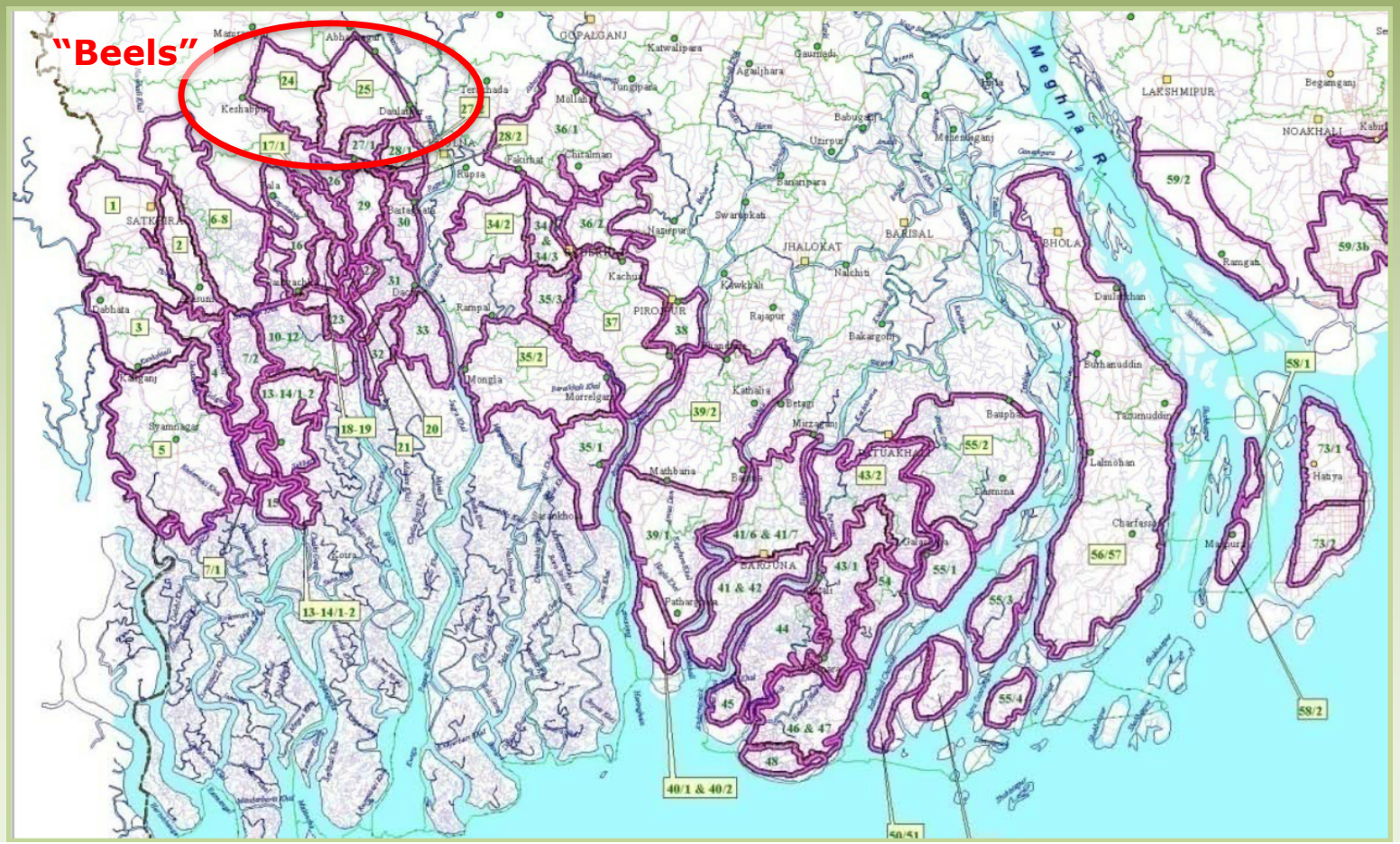
- Pre-service social studies teachers
  - Groups of 2-3
  - Sequence:
    - Pre-questionnaire and briefing
    - Participatory simulation exercise
    - Post-questionnaire and debriefing

- Unexpected results:
  - Students became very emotionally engaged
    - "This is terrifying!" (covering mouth and gasping)
  - Emotional engagement may facilitate learning
    - Damasio, Slovic
  - Interactive simulations facilitate emotional engagement
    - Weizenbaum, "Eliza" (1966)


Coupled Human-
Natural Systems
in Bangladesh
Faculty, Students,
Postdocs from
Vanderbilt University
Columbia University
Louisiana State U.
University of Colorado
Texas A&M
Karlsruhe Inst. Tech.
Dhaka University
Jahangirnagar U.
Khulna U.
SILVER WAVE TOURS LTD.
for those who explore...
Sediment modeling by C. Tasich (VU)
Funding: ONR MURI, NSF Coastal SEES

Coastal Embankment Project: 1960s-70s

123 enclosed "polders"



Embankments and Sluice Gates

Forgotten Wisdom of the Past

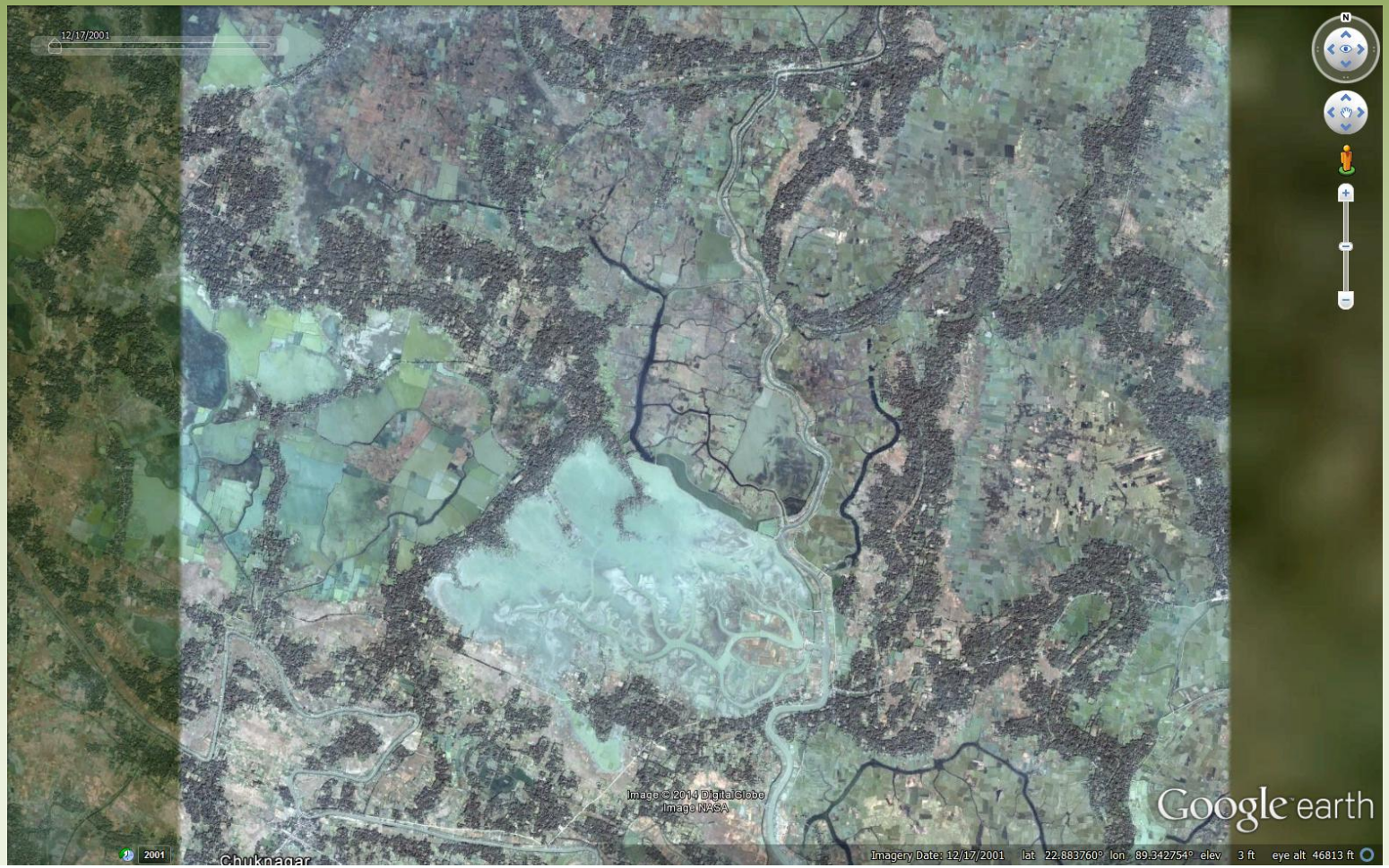
"Embankments … are likely to make the situation far worse in the long run"

—P.C. Mahalanobis (1927)

"If the river could flow properly, then everything will be all right."

— Farmer displaced by floods (Sept. 2011)

Beel Bhaina 2001



Beels Bhaina & Kukshia 2010

Beel Kukshia 2013

Public opposition to Tidal River Management

Photo Credit: BanglaNews24 2 June 2012

Failure of government drainage rehabilitation project

- ADB Project evaluation:
  - No buy-in from local communities
  - Failure to compensate farmers for losses
  - "*Lack of understanding of an indigenous knowledge base*"
- *Local farmer:*

  "The [government] engineer … would not accept our suggestion because he thought it was given by the non-experts!"

Challenges

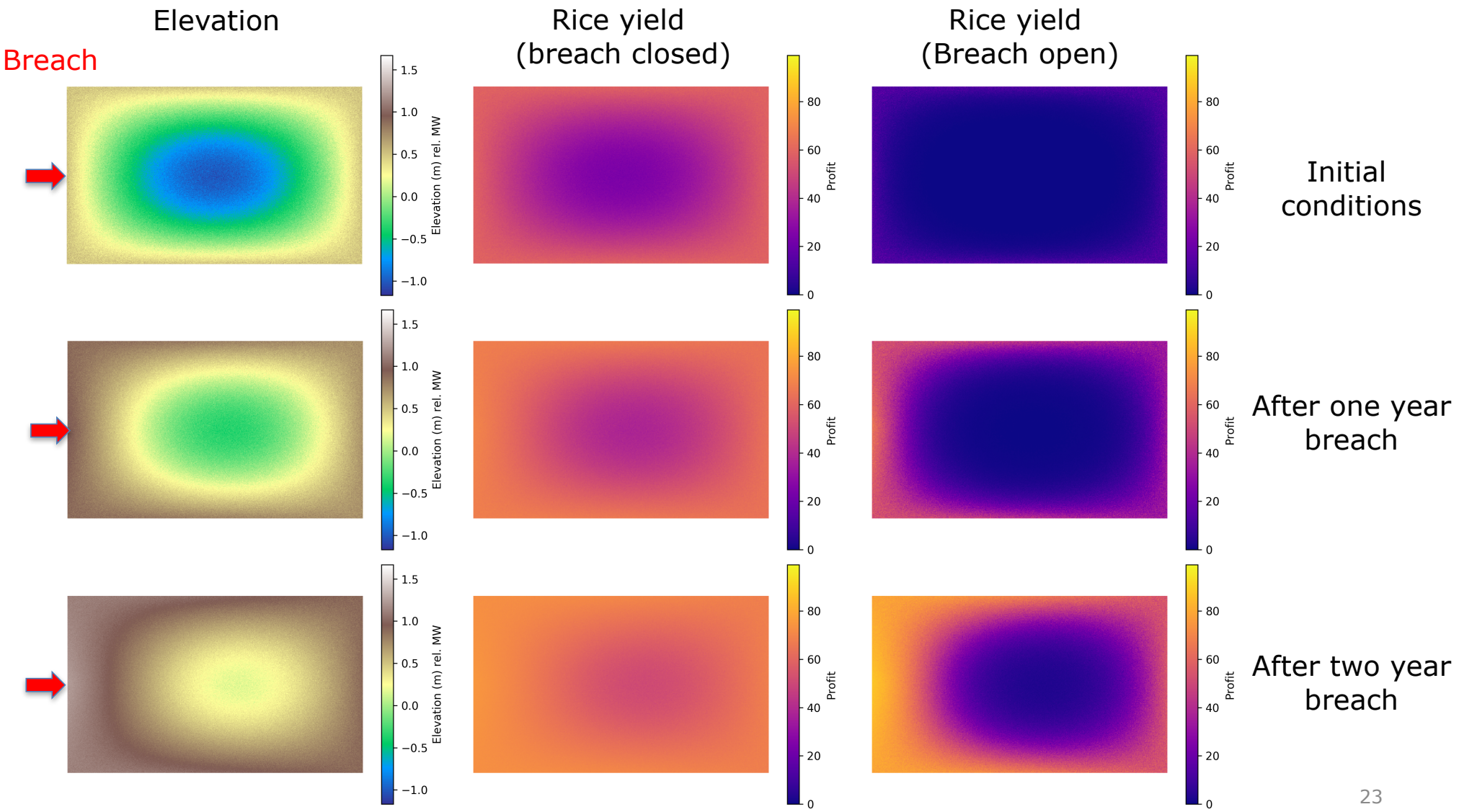
- Representing local decision-making:
  - History: informal grass-roots activism vs. imposed government program
  - Explore role of voting and negotiation for building popular support
- Inequality:
  - Unequal land holdings in size, quality
    - Higher elevation vs. lower elevation
  - Complex land tenure:
    - Tenant farmers, share-croppers, “dummy” owners, etc.

Modeling challenge

- Limited data:
  - Qualitative social-science field-work
    (Key-informant interviews, focus-group discussions)
  - Review of qualitative social-science literature
  - Measurements of physical system elsewhere,
    but not near beels
    (Topographic surveys, tide gauges,
    suspended sediment, sedimentation rates)
- For designing simple models, narratives can be more useful than quantitative survey data

Modeling Tidal River Management

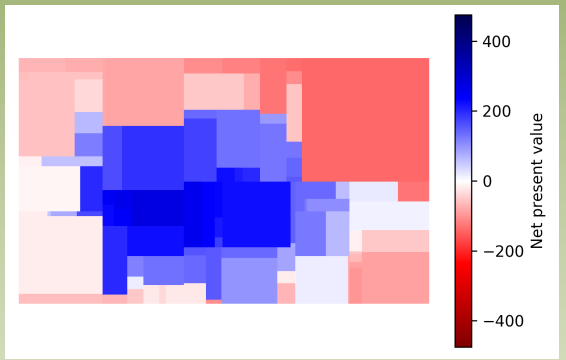
- Simple model of coupled human-natural system
  - Simple model of sediment deposition
  - Stylized representation of agricultural impact
  - Add human dimension: community decision-making
- This work:
  - Stylized models: informed by empirical data, but not calibrated
  - No attempts so far at quantitative validation
  - Basic framework in place
    - Future work will explore social, economic, political dynamics


Elevation
Rice yield
(breach closed)
Rice yield
(Breach open)
Breach
Elevation (m) rel. MW
Profit
Initial
conditions
After one year
breach
After two year
breach

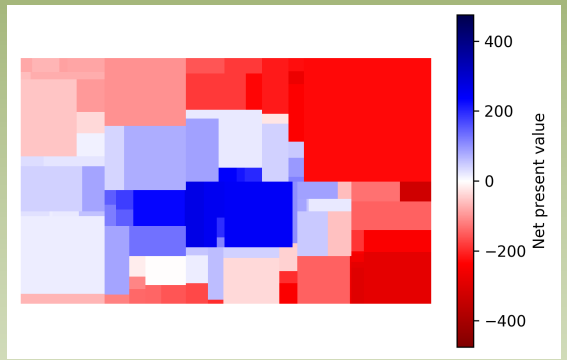
Simulating community decisions

- Simplified:
  - Not based on actual decision procedures
  - Informed by considerations expressed in key-informant interviews
- Voting:
  - Instant-runoff in case of no majority in first round
- Trading:
  - Farmers "trade votes":
    - Winners offer compensation to losers to support choice
    - Continuous double-auction until a majority emerges

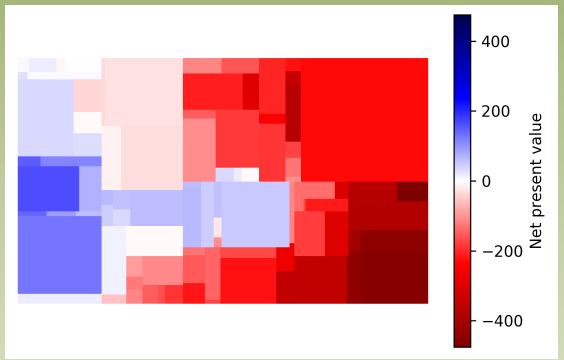
Discounted net-present value of n-years of breaches with 5-year horizon



1 year



2 years



3 years

- No majority for any option
  - Most people are dissatisfied regardless of outcome
- If winners can compensate losers, a majority emerges for 1 year breach, with fewer unhappy farmers