System dynamics across three scales in the Brahmaputra River Basin- Exploring a Himalayan social-hydrological system

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Relevance of Research

- A methodology for policy design for issues of disaster risk management & natural resource governance in HKH region

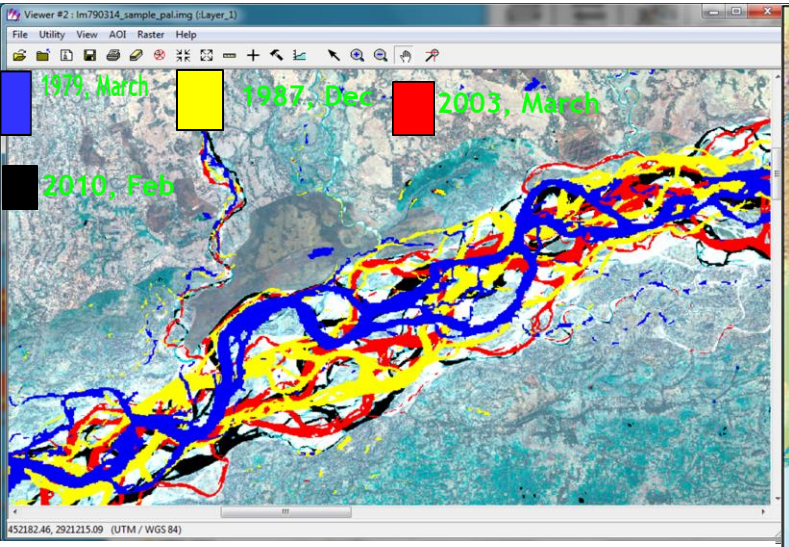
- Conceptualizing a Cross-Scale in a complex social-hydrological system
  - Conceptualizing a River System
  - Quantitative Modelling on multi-scale and cross-scale

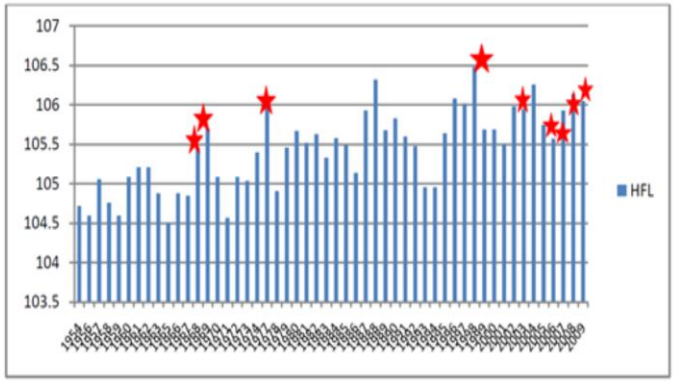
Content Flow

- Conceptualization
  - Context
  - Formulation and Validation
- Scenario Analysis
- Policy Testing
- Key Insights for Governance and Future Research

Conceptualization

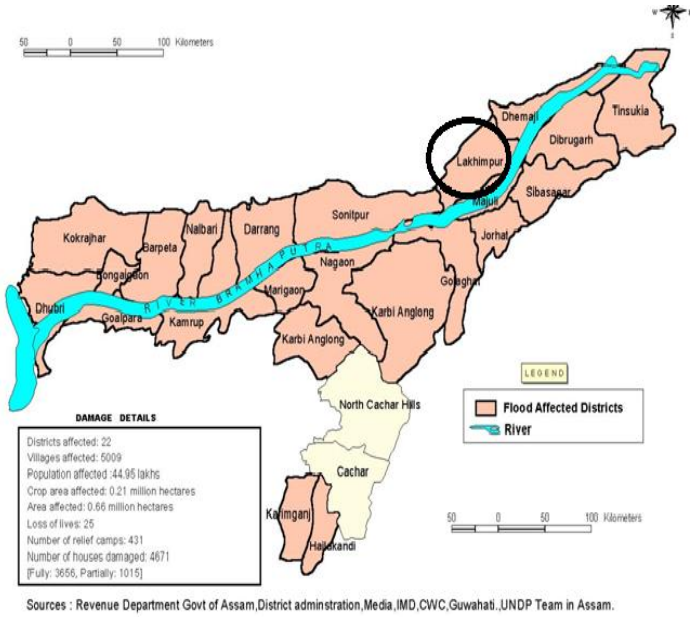
3 Subsystems and Identifying the System Structure





Source- Records of Dibrugarh gauze site (records of 1955, 64, 75 and 76 not present) as in Flood reports of Chief Engineer's Office, Water Resources Department, GoA, (1954-2009).

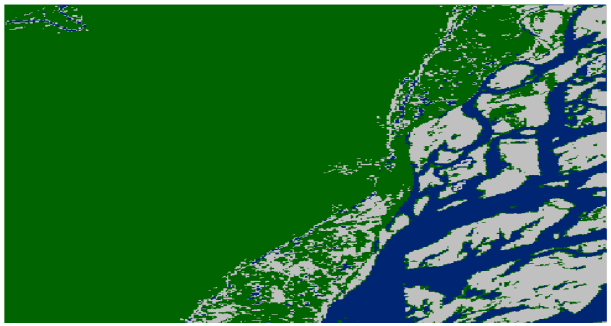
Assam Valley



Sources : Revenue Department Govt of Assam,District adminstration,Media,IMD,CWC,Guwahati.,UNDP Team in Assam.

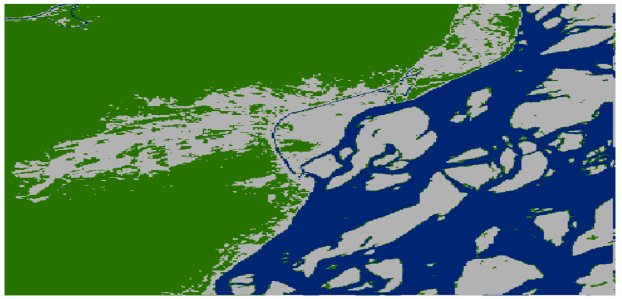
Varma and Mishra (2017)

1990



2001

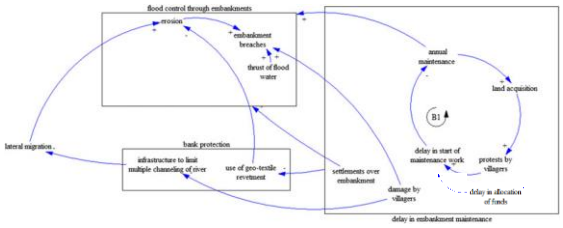
2014



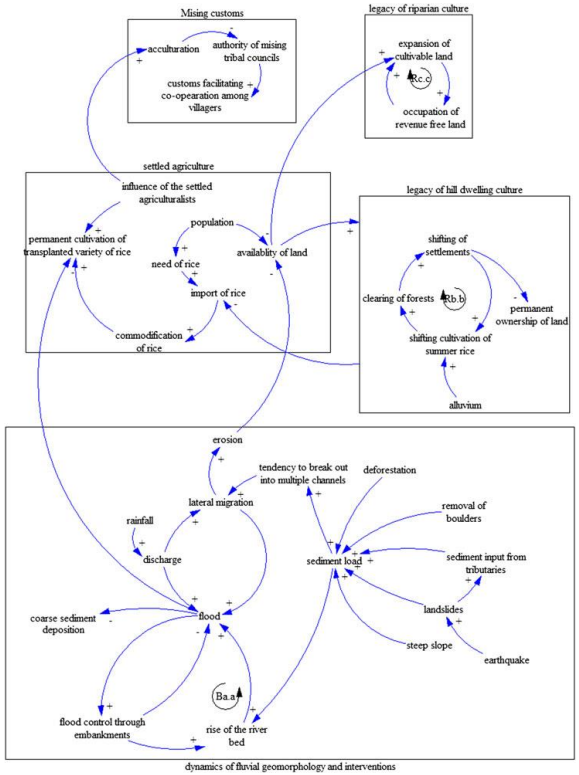
Legend

- Water
- Sediment
- Vegitation

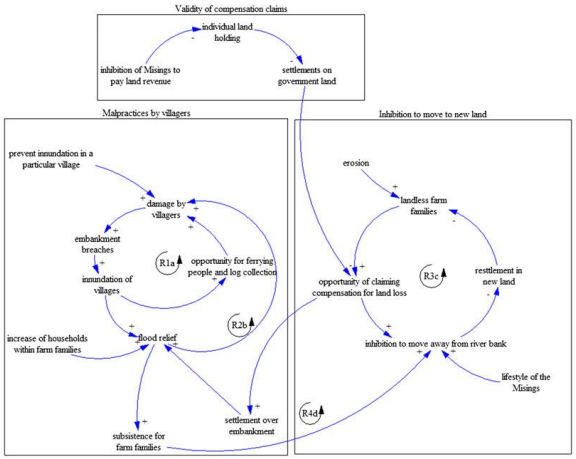
WRD



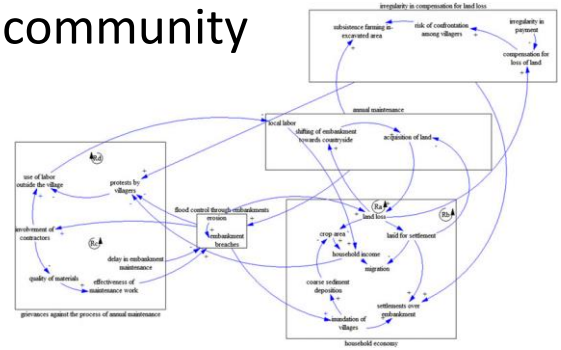
Academia



RDM



Mising community



Spatial and temporal boundaries of narratives

Narrative	Stakeholder group	Spatial scale	Temporal scale
We are doing it right	CEO, WRD	State/Province of Assam	1955onwards
We are neglected	Mising Community	Villages of Lakhimpur District	1998 onwards
Villagers are the problem	Employees of local offices of R&DM	Upper Brahmaputra Valley	19th century onwards
Cultural and geomorphological dynamics	Academia	Brahmaputra Basin	19th century onwards

Varma, N. and Mishra, A. (2017). Discourses, narratives and purposeful action – unravelling the social–ecological complexity within the Brahmaputra basin in India. *Env Pol Gov*. Vol (27), pp:207–228

2014/5 Workshops supported by Asia Pacific Network for global change research (APN)

Varma N, Kelkar U, Bhardwaj S, Singh P and Mishra A. (2015). Climate change, Disasters and Development-Testing the waters for adaptive governance in India**.** Vision

Conceptual Lens
of Cross-Scale Interactions

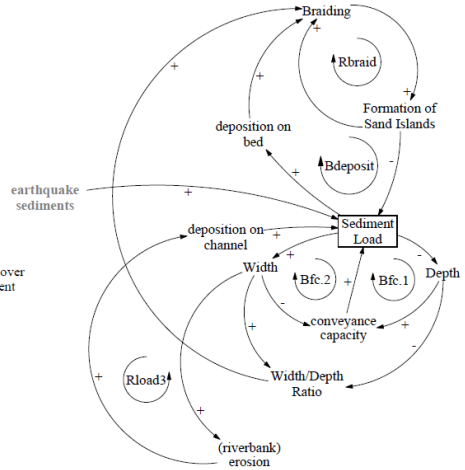
Large Scale

Small Scale

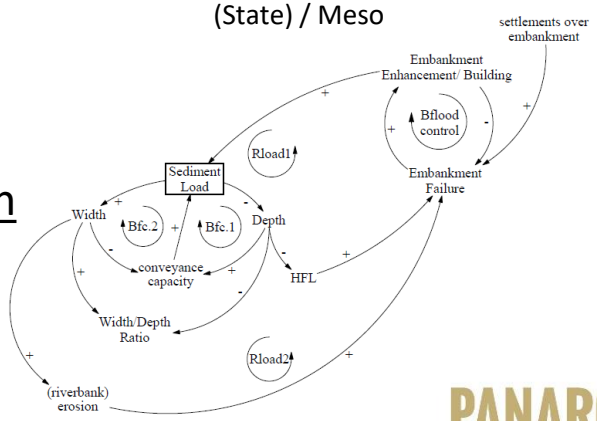
Short/Fast Cycles

Long/Slow Cycles

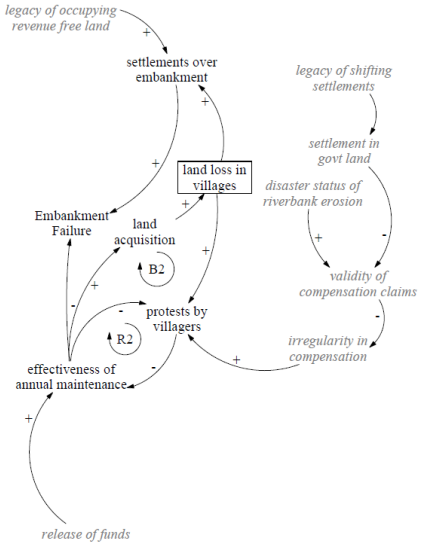
Geomorphology
(Basin) / Macro

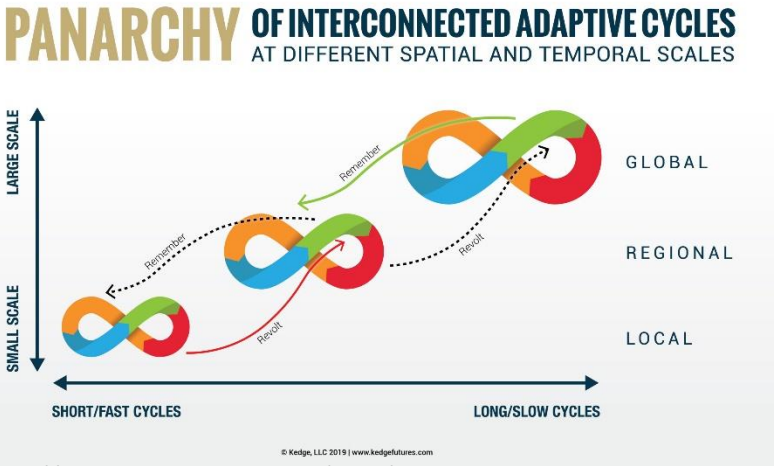


Flood Control Policy
(State) / Meso



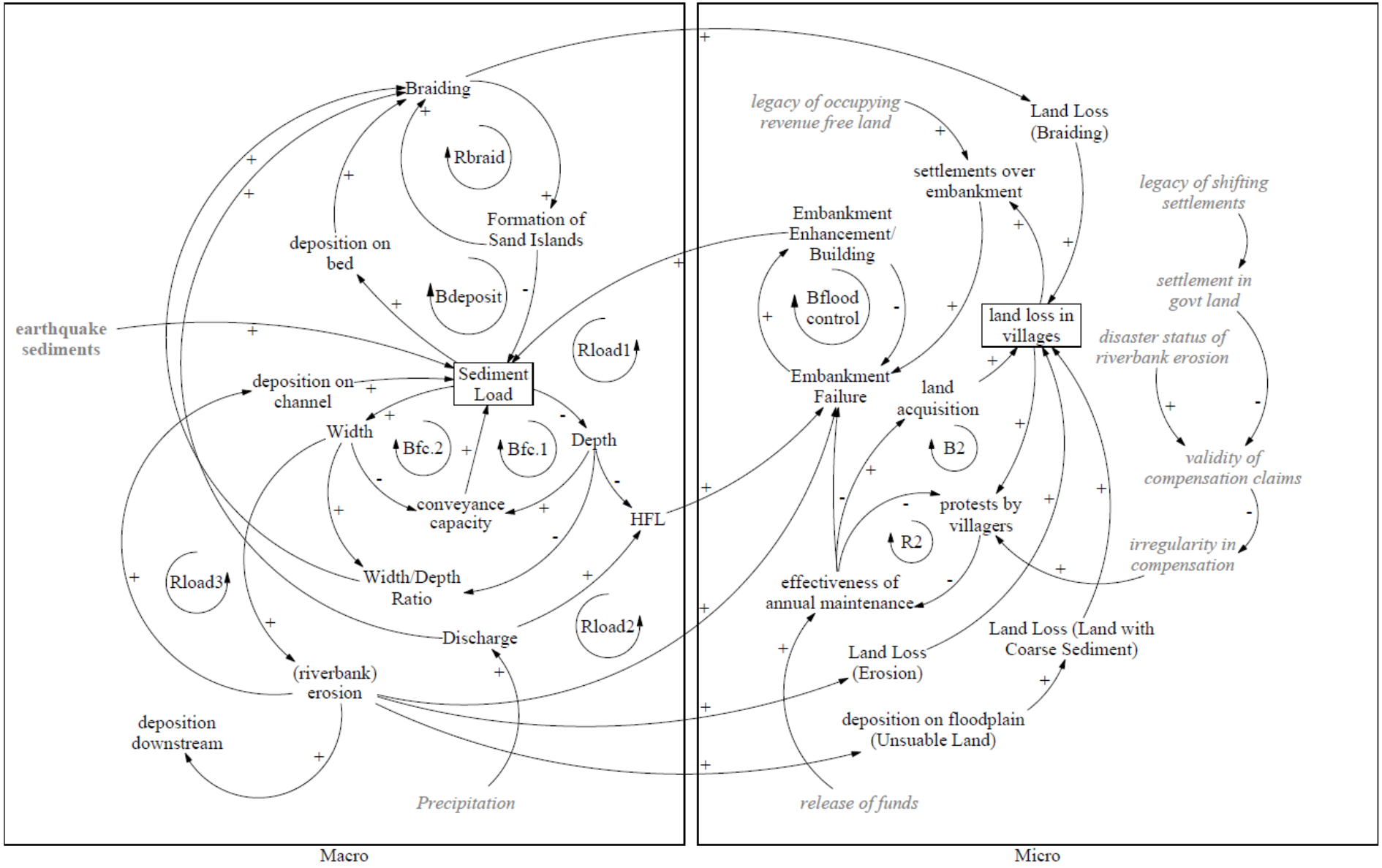
Socio-economic Situation
(Villagers) / Micro



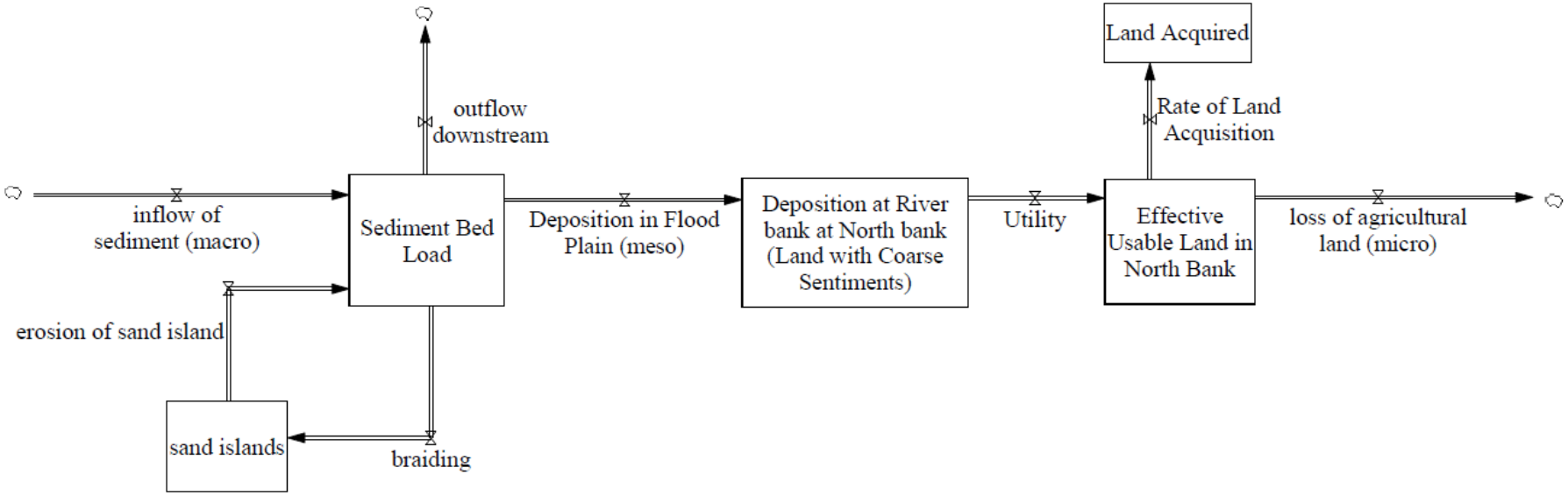


https://thefuturesschool.com/blog/natural-foresight-as-a-panarchy/

Overview of Causal Loop Diagram



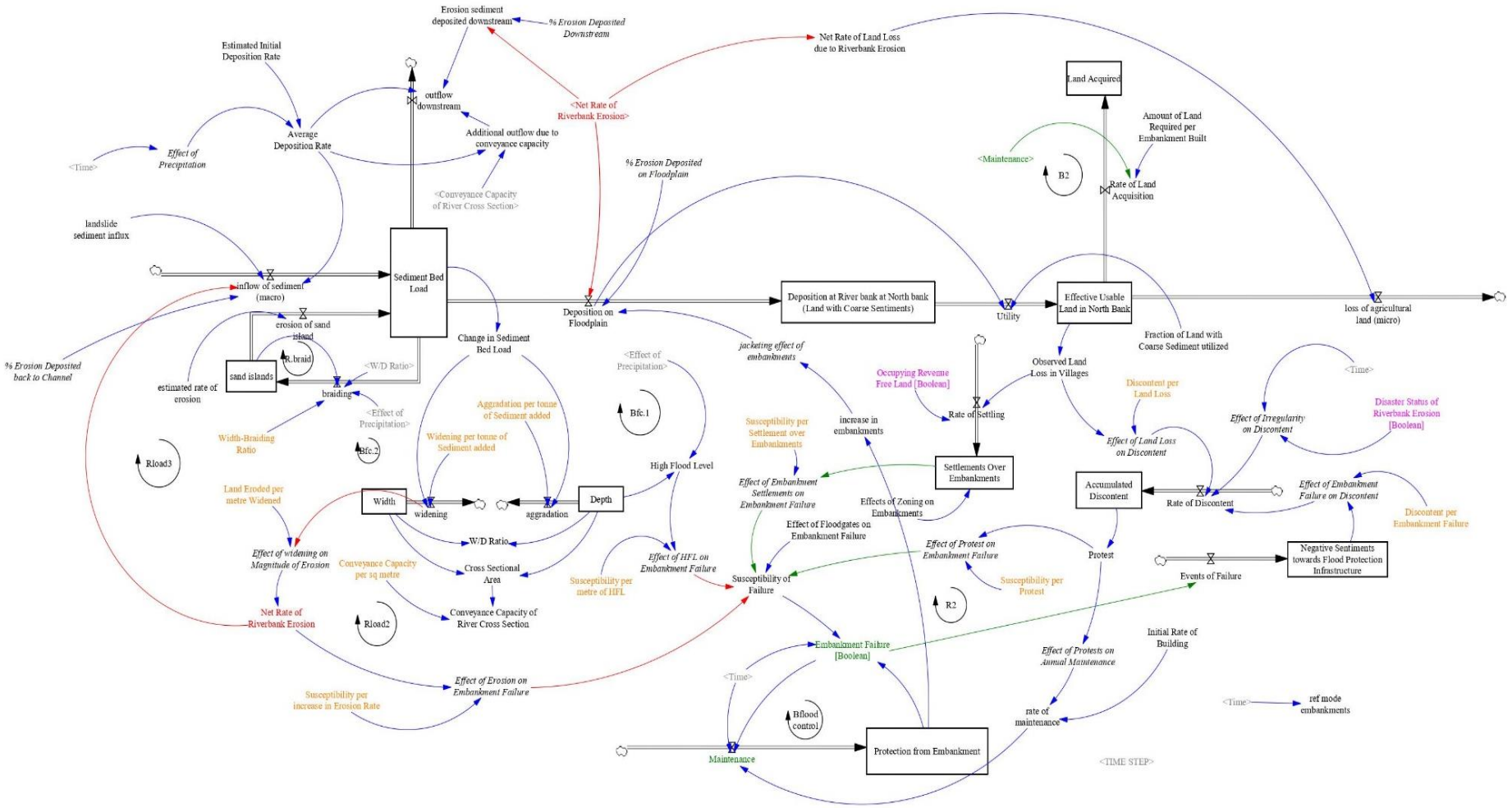
Overview of Stock and Flow Diagram



Geomorphology: Flow of Sediment from Macro to Micro

Difficulties of the Quantitative Model

- Linking physical quantities of variables from various scale
  - Focus on tracking the sediment flow
- Unit scaling of physical variables poses are rather difficult
  - Arbitrary Units (tonnes, metres), Scaling Parameters (Dmnl)
- Quantitative data is scarce when involving politically sensitive transboundary issues
  - Focus on system structure; Focus on behavioural trends


Erosion sediment deposited downstream
% Erosion Deposited Downstream
Net Rate of Land Loss due to Riverbank Erosion
Land Acquired
Estimated Initial Deposition Rate
outflow downstream
<Net Rate of Riverbank Erosion>
Amount of Land Required per Embankment Built
<Time>
Effect of Precipitation
Average Deposition Rate
Additional outflow due to conveyance capacity
<Maintenance>
B2
% Erosion Deposited on Floodplain
Rate of Land Acquisition
<Conveyance Capacity of River Cross Section>
landslide sediment influx
Sediment Bed Load
inflow of sediment (macro)
Deposition at River bank at North bank (Land with Coarse Sentiments)
Effective Usable Land in North Bank
loss of agricultural land (micro)
Deposition on Floodplain
Utility
erosion of sand island
Change in Sediment Bed Load
jacketing effect of embankments
Fraction of Land with Coarse Sediment utilized
% Erosion Deposited back to Channel
R.braid
sand islands
<W/D Ratio>
<Effect of Precipitation>
Occupying Reverne Free Land [Boolean]
Observed Land Loss in Villages
Discontent per Land Loss
<Time>
estimated rate of erosion
braiding
Rate of Settling
Effect of Irregularity on Discontent
Disaster Status of Riverbank Erosion [Boolean]
Aggradation per tonne of Sediment added
Bfc.1
Susceptibility per Settlement over Embankments
increase in embankments
Effect of Land Loss on Discontent
Width-Braiding Ratio
Widening per tonne of Sediment added
Bfc.2
High Flood Level
Settlements Over Embankments
Accumulated Discontent
Effect of Embankment Failure on Discontent
Rload3
Land Eroded per metre Widened
Width
widening
aggradation
Depth
Effect of Embankment Settlements on Embankment Failure
Effects of Zoning on Embankments
Rate of Discontent
Discontent per Embankment Failure
Effect of Floodgates on Embankment Failure
W/D Ratio
Effect of widening on Magnitude of Erosion
Conveyance Capacity per sq metre
Effect of Protest on Embankment Failure
Protest
Negative Sentiments towards Flood Protection Infrastructure
Effect of HFL on Embankment Failure
Cross Sectional Area
Susceptibility per metre of HFL
Susceptibility of Failure
Susceptibility per Protest
Events of Failure
Net Rate of Riverbank Erosion
Rload2
Conveyance Capacity of River Cross Section
R2
Embankment Failure [Boolean]
Initial Rate of Building
Effect of Protests on Annual Maintenance
Effect of Erosion on Embankment Failure
<Time>
Susceptibility per increase in Erosion Rate
Bflood control
rate of maintenance
<Time>
ref mode embankments
Maintenance
Protection from Embankment
<TIME STEP>

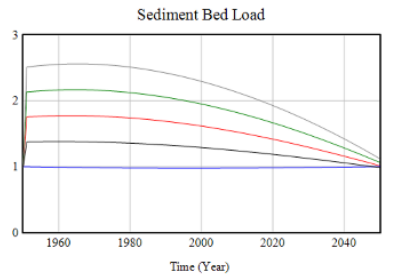
Validation

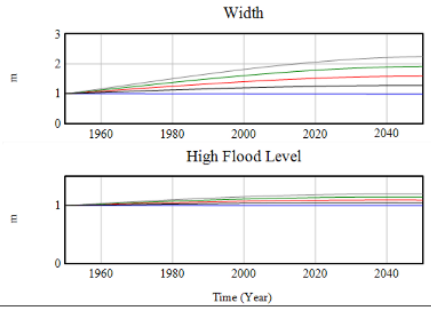
Assuring the Reliability and Robustness of our Model

Extreme Condition Tests

Geomorphology
Landslide Sediment Influx

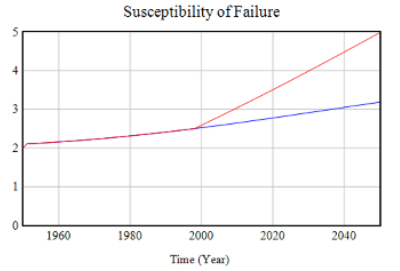
- Landslide 0%
- Landslide 50%
- Landslide 100%
- Landslide 150%
- Landslide 200%

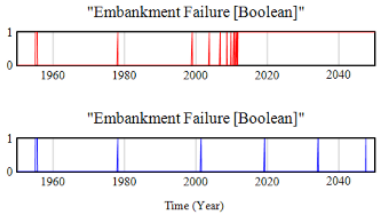




Policy
Disaster Status

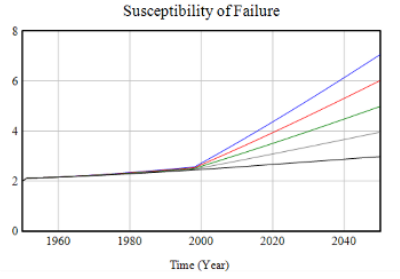
- Disaster Status False
- Disaster Status True

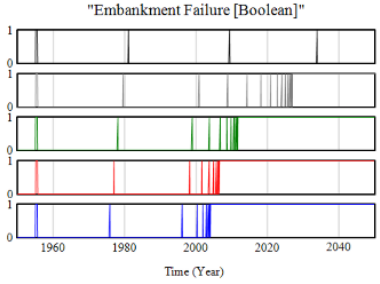




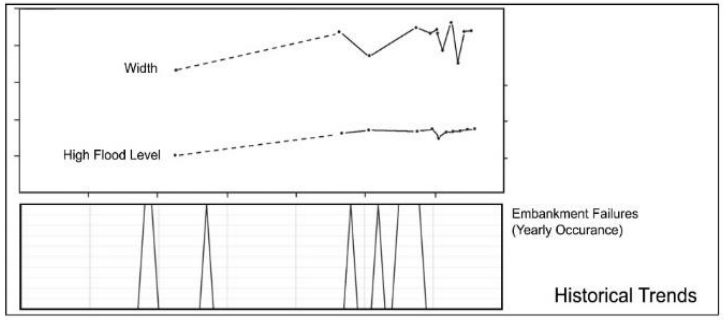
Policy
Protest Occurrence

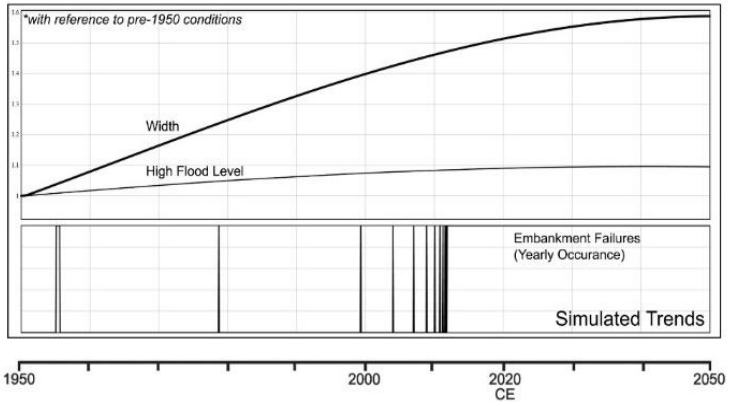
- Protest 0%
- Protest 50%
- Protest 100%
- Protest 150%
- Protest 200%





Reference Mode

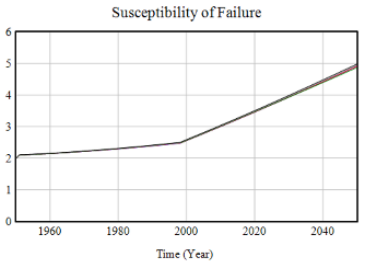


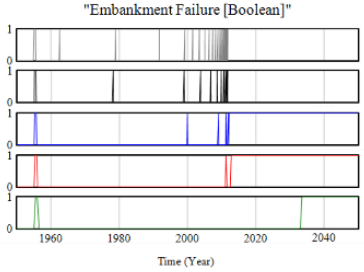


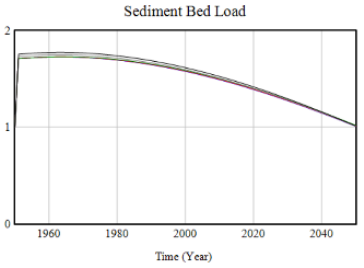
Time Step Tests

Simulation
Model Time Step

- Time Step 0.03125
- Time Step 0.0625
- Time Step 0.125
- Time Step 0.25
- Time Step 0.5

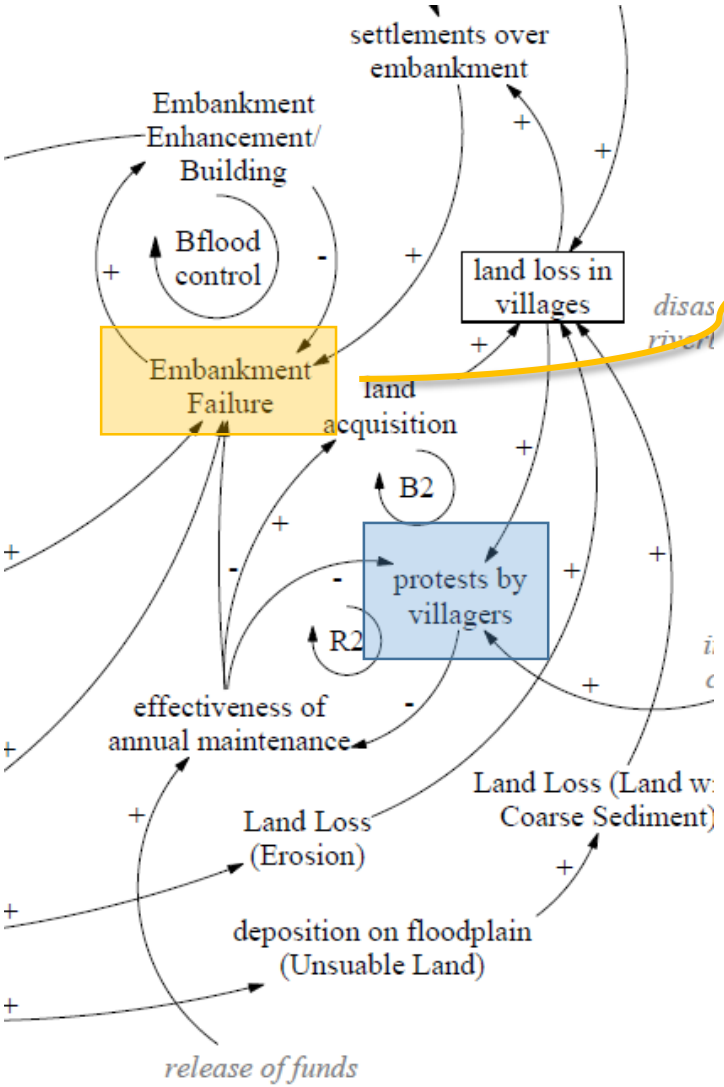


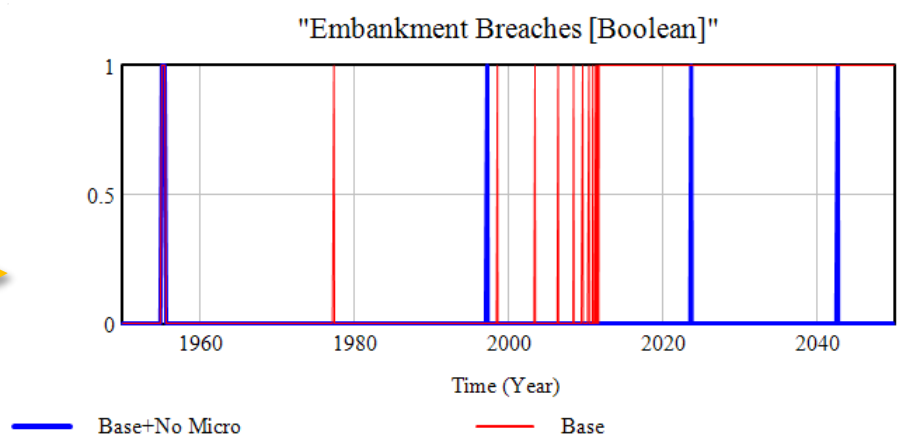




Analysis

Simulation Results and Scenario Testing



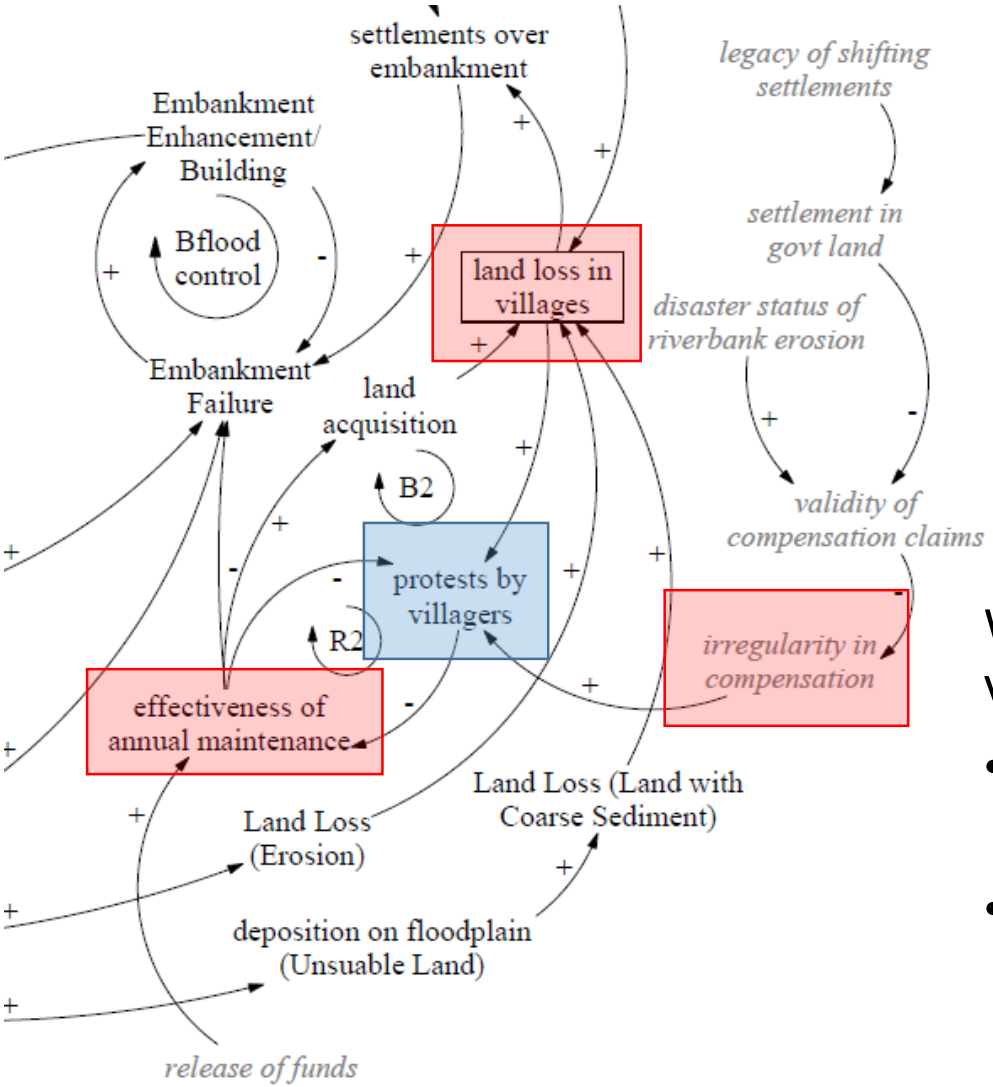


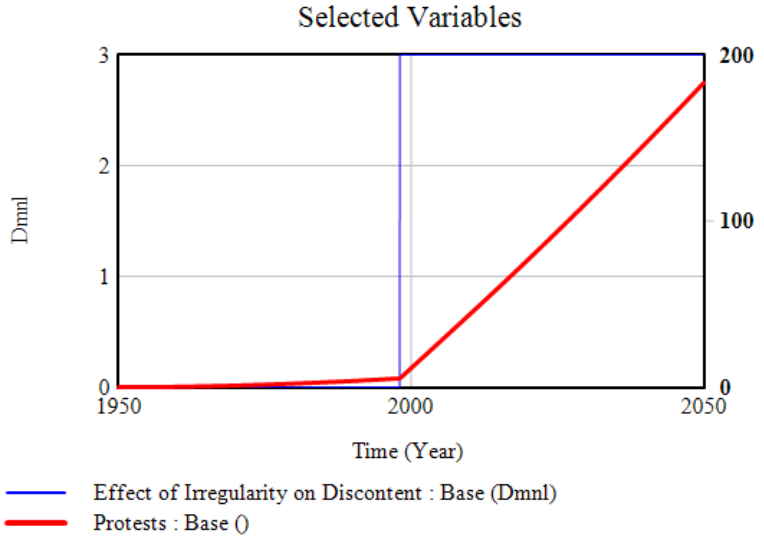
How much do *Protests* (micro) influence the rate of *Embankment Failure* (meso)?

- Quite Substantially – Protests result in the exponential rise in breaches (~2000)
- Unintuitive finding - Awareness of how Village Level Dynamics has a cascading impact on the overall flood control protection

Influence of cross-scale linkage (Meso-Micro):

Impact of village-level dynamics on embankment effectiveness



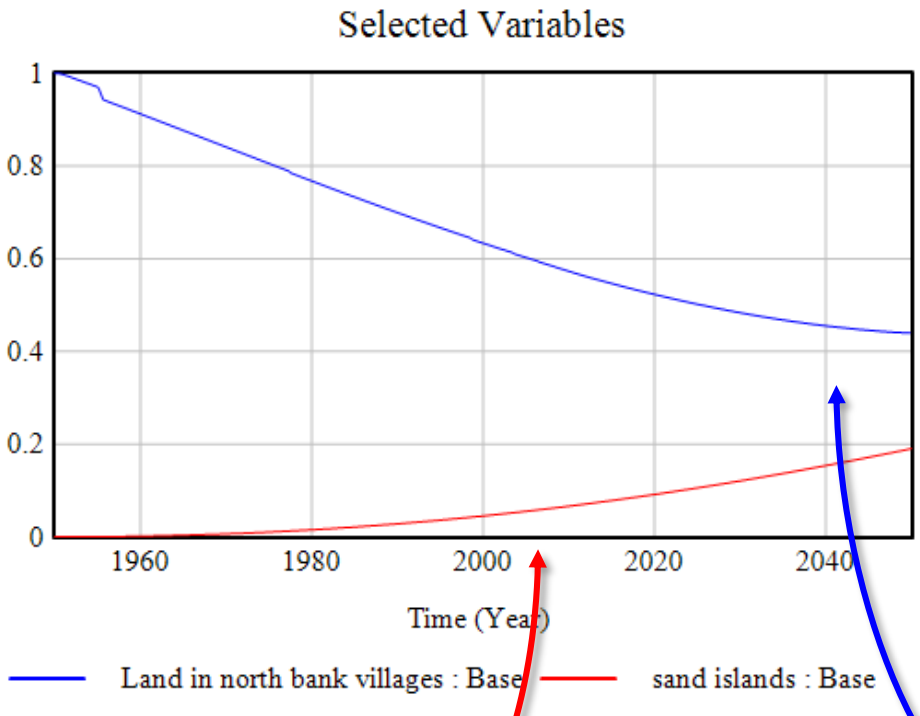


What could have escalated these village-level dynamics?

- Was thought to be an equal combination of factors
- From analysis, it was found out that irregularity in compensation was the main source of the escalation of protests

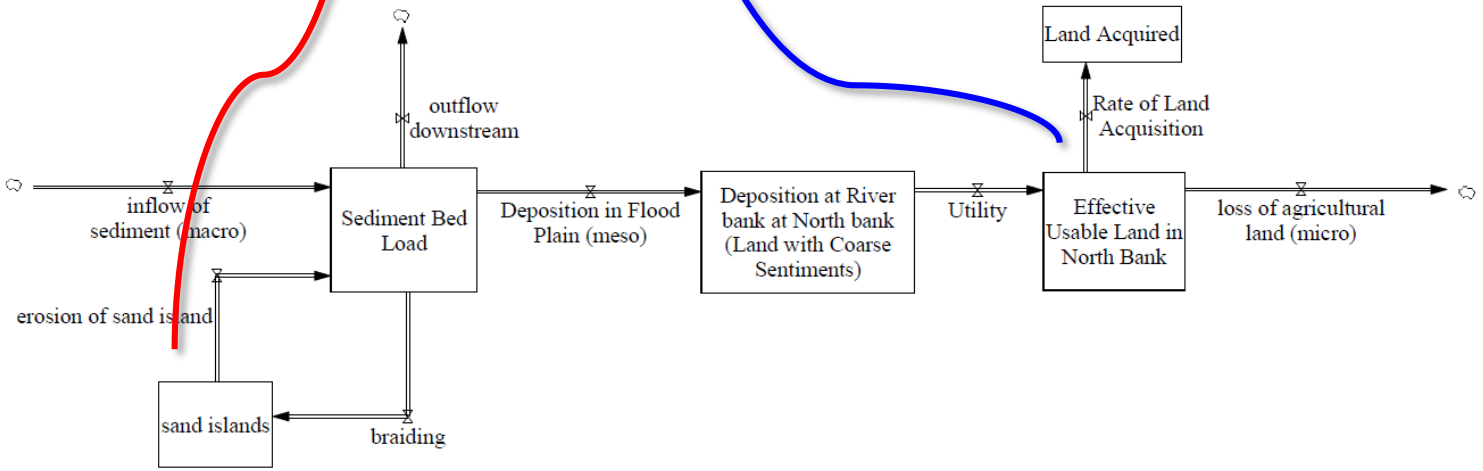
Influence of cross-scale linkage (Meso-Micro):

Impact of village-level dynamics on embankment effectiveness



Can be interpreted as the reconnection of Sand Islands with flood plains

- Aligns with satellite images and field observations
- Creates a need for innovations in land use
  - The community was willing to innovate their practices of land use
- As of 2017, there is still a lack of land surveys to validate on these emerging trends

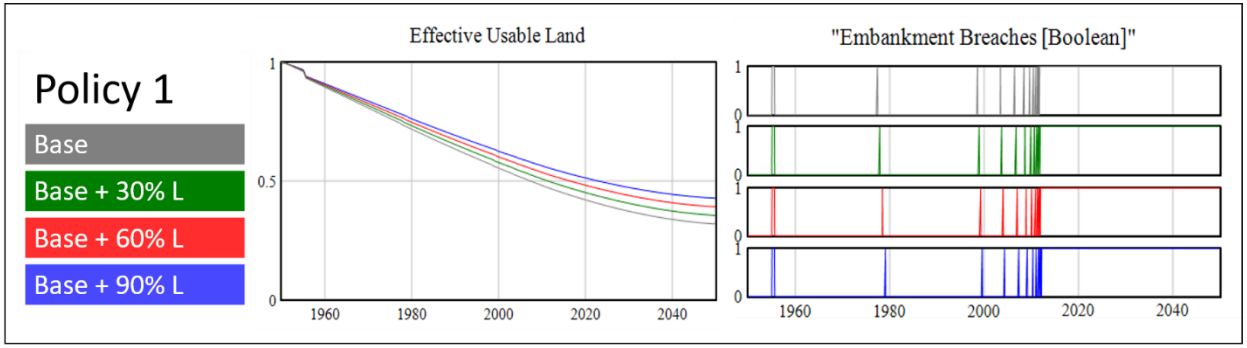


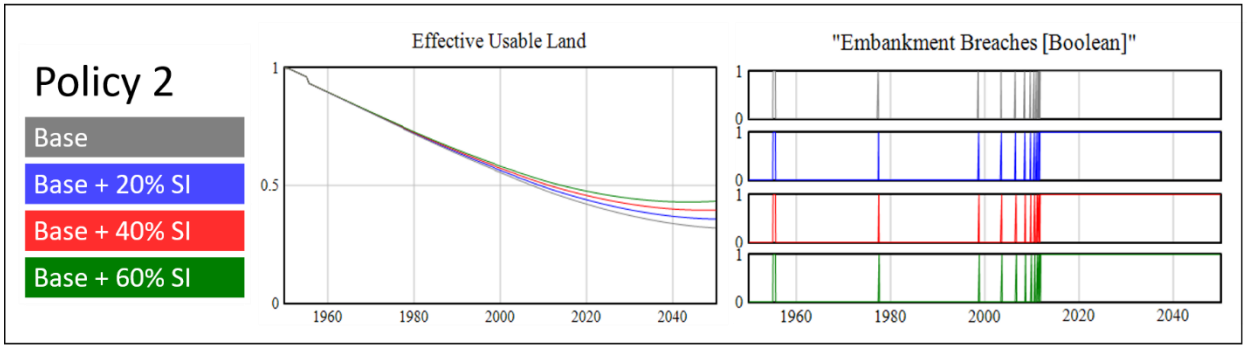
A relook at land in a Riparian Context :

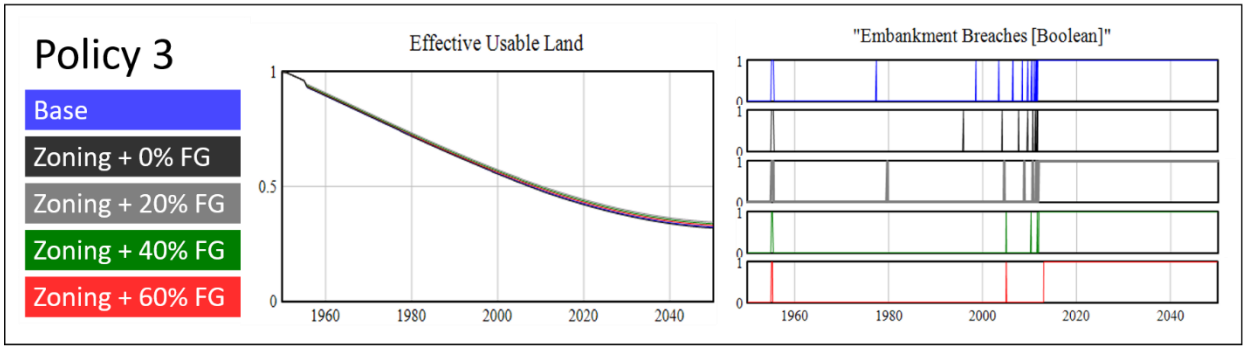
Need for innovations in land use policy

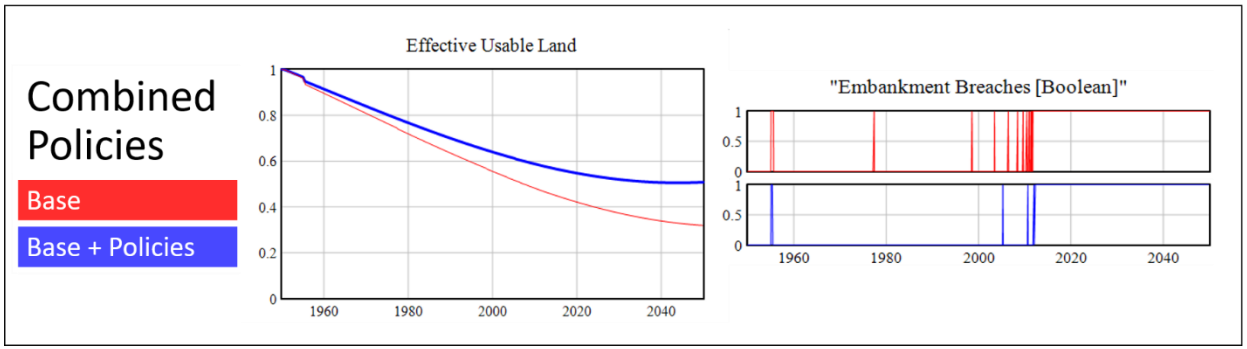
Policy Testing

Policy Alternatives and Insights into Management









Rationale	Scale
Crop Diversification	Micro
Innovations in Land Use	Macro
Floodplain Design	Meso
Combination of Policies	Multiscale

Key Insights

Ways forward for social-hydrological resilience

Key Insights:

- Application of the system dynamics method helped in exploring the cross-scale dynamics of BRB and can be replicated for similar fragile river basin systems
- Findings emphasize the role of feedback between governance issues occurring on the local-scale, and disaster policy implementation
  - Landlessness, Disaster Compensations, Flood Protections
- There is a need for flexibility in disaster management institutions in the BRB to recognize social needs and facilitate adaptation to novel hazards
- Flood disaster policy in fragile river systems like in the Himalaya need to look at interventions in multiple scales and integrate the dynamics of land use, land tenure, water discharge and sediment flow
- Systems thinking and system dynamics can serve as a pedagogic tool in capacity-building programs which can help in the integration of actors' voices as well as lead to change in mindsets and protocols through iterations, dialogue and simulations.

Thank You

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