WHERE ARE WE GOING?

Resilience to Extreme Events in Social Ecological Systems of the Lake Champlain Basin

(Basin Resilience to Extreme Events, BREE)

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Fig. 1 Tropical Storm Irene floods a Vermont stream, 2011, G. Miller

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BREE Overarching Research Question

What are properties within the Lake Champlain Basin that drive hydrologic and nutrient responses to extreme events, and what are strategies for increasing resilience to protect water quality in the social ecological system?

BREE IAM Research Question

What strategies for resilience can be implemented to manage the risk from extreme events and what are the trade-offs for prioritizing public sector investments?

BREE IAM Scenario Development and Multi-Objective Optimization Plan

BREE Basin Resilience to Extreme Events in the Lake Champlain Basin

- Two stakeholder/advisory group meetings per year & numerous focus groups for:
  - **Cascading IAM development (calibration & validation)**
  - **Identification of "resilient" strategies**
  - **Multi-objective optimization and elicitation of trade-offs among alternate policy and investment portfolios**

Table 2 **Examples of Policy Interventions from Workshops**	**Hypothetical Scenario A** High emission climate scenario leading to more frequent and intense extreme events; centralized governance network; high economic growth rate	**Hypothetical Scenario B** Low emission climate scenario leading to no change in the frequency and intensity of extreme events; decentralized governance; low economic growth rate
1. Incentivize green infrastructure investments through subsidies and tax exemptions	*Increased agriculture and urban BMP adoption rate; Lower net damages from extreme events; moderate water quality*	*Moderate increase in agriculture and urban BMP adoption rate; Minimal net damages from extreme events; high water quality*
2. Strengthen wetland, riparian and forest conservation regulations	*Lower agriculture and urban BMP adoption rate; higher net damages from extreme events; poor water quality*	*Lower agriculture and urban BMP adoption rate; lower net damages from extreme events; poor water quality*

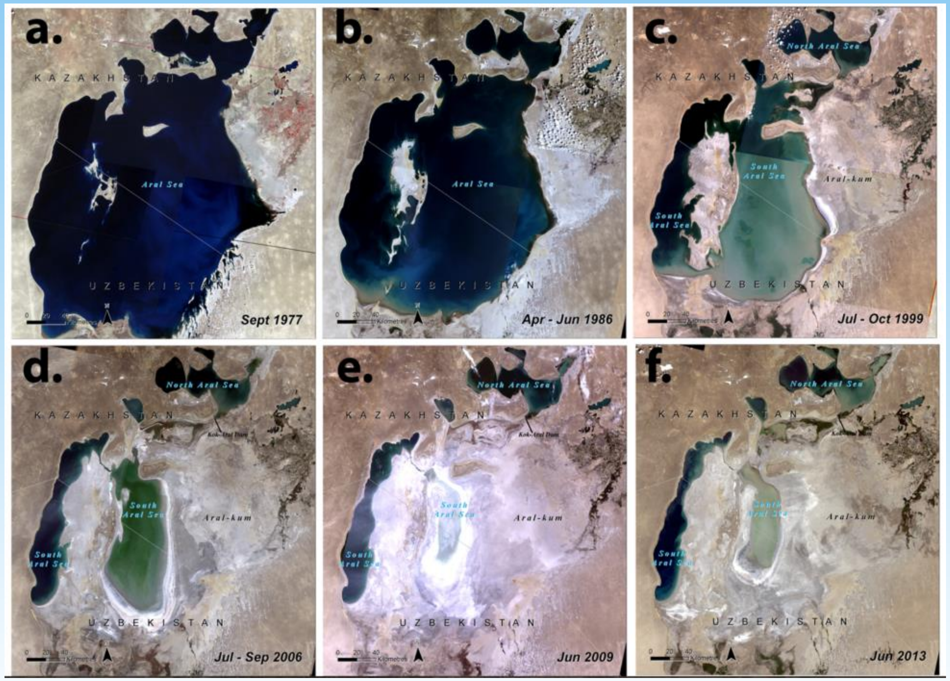
Top-down (benevolent basin planner) vs bottom-Up (distributed) multi-objective optimization

Definition of “Resilience” in Social Ecological Systems (SES) theory (Walker and Salt 2012)

- Resilience is “the capacity of a system to absorb disturbance and reorganize so as to retain essentially the same function, structure, and feedbacks—to have the same identity. Put more simply, resilience is the ability to cope with shocks and keep functioning in much the same kind of way.”

SES of Bali: Farming vs Water

SES of Aral Sea: Cotton vs Water



Walker and Salt (2012)

Resilience Assessment Approach Under SES framework

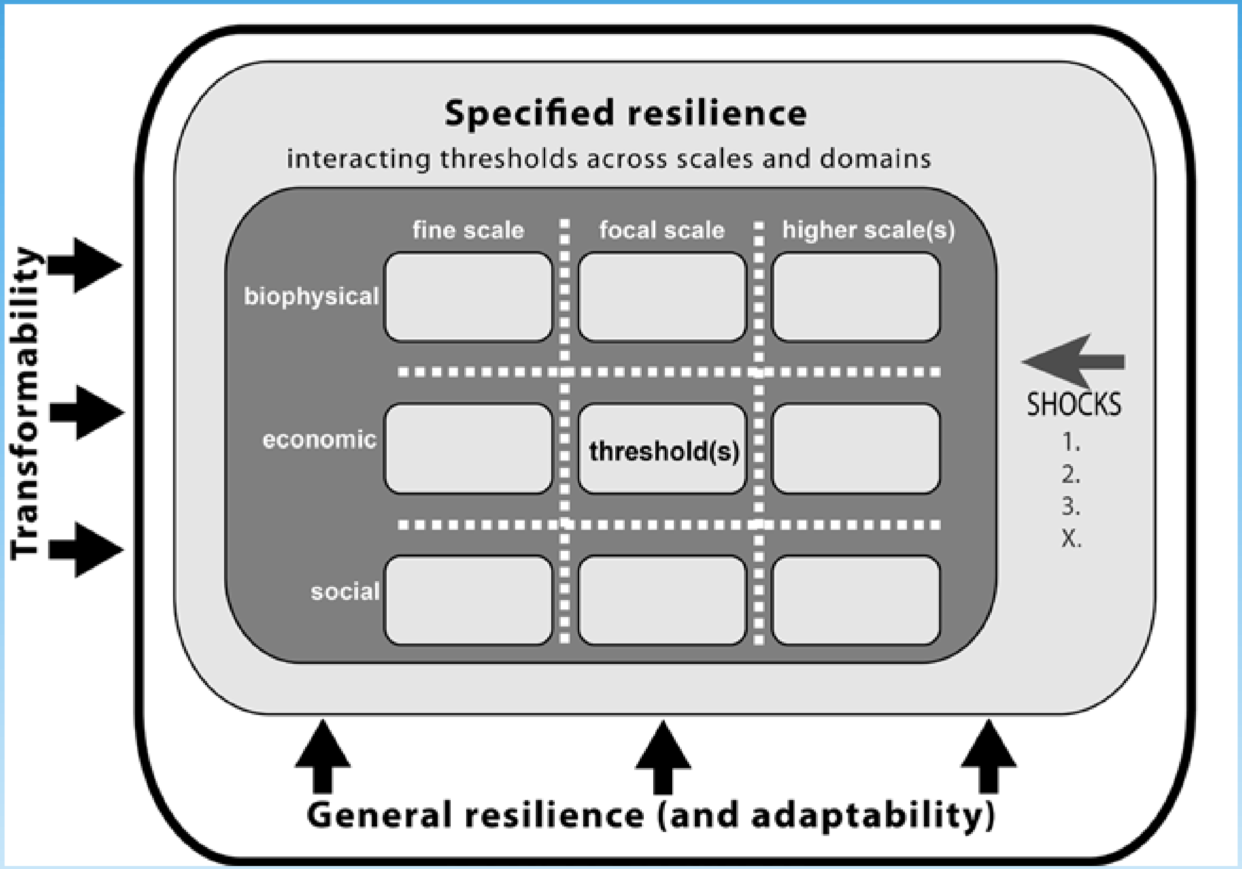


Figure 11: Specified Resilience, General Resilience, and Transformability

These are different but interacting capacities of the system. Assessing a system's resilience requires an accounting of all three.

Walker and Salt (2012)

Transformability in SES framework

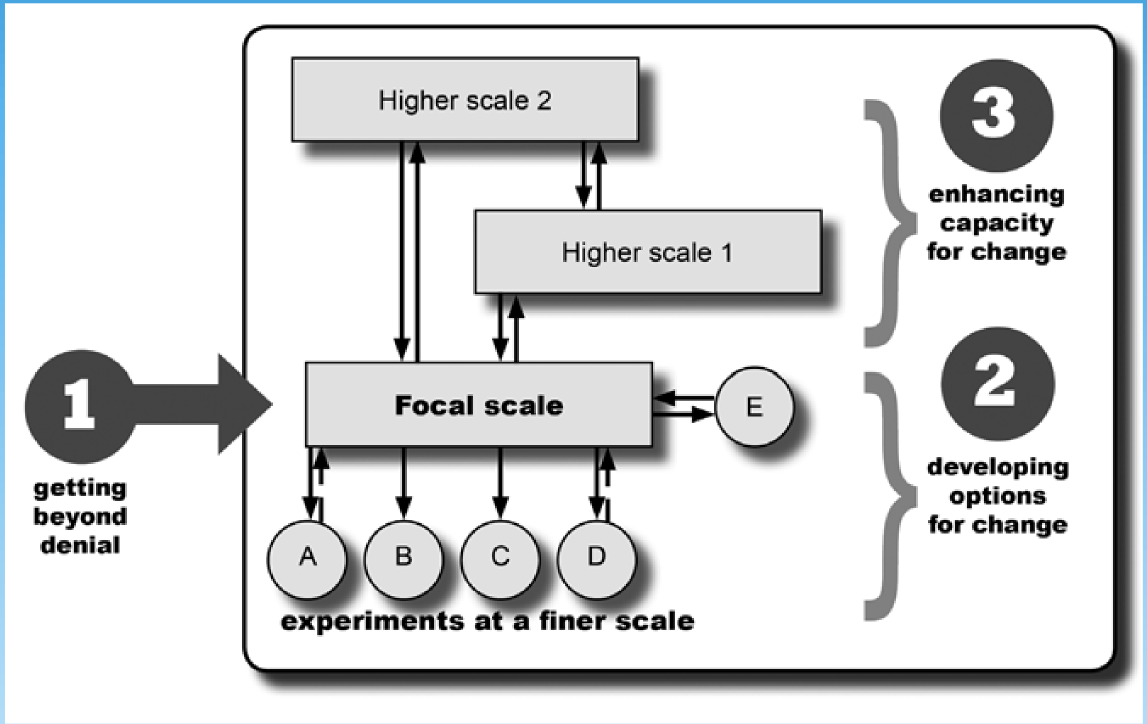


Figure 10: The Components of Transformability

Transformability requires (1) getting beyond a state of denial, (2) creating options for change at the focal scale, and (3) capacity for transformation, which relates to connections between the focal scale and higher scales. Creating options for change at the focal scale requires experimentation at a finer scale (A, B, C, D, and so on), though in some circumstances a trial at the whole focal scale may be appropriate (E). Many of these experiments won't work but some will, as indicated by the dashed arrows from A and D, feeding back to the focal scale.

Walker and Salt (2012)

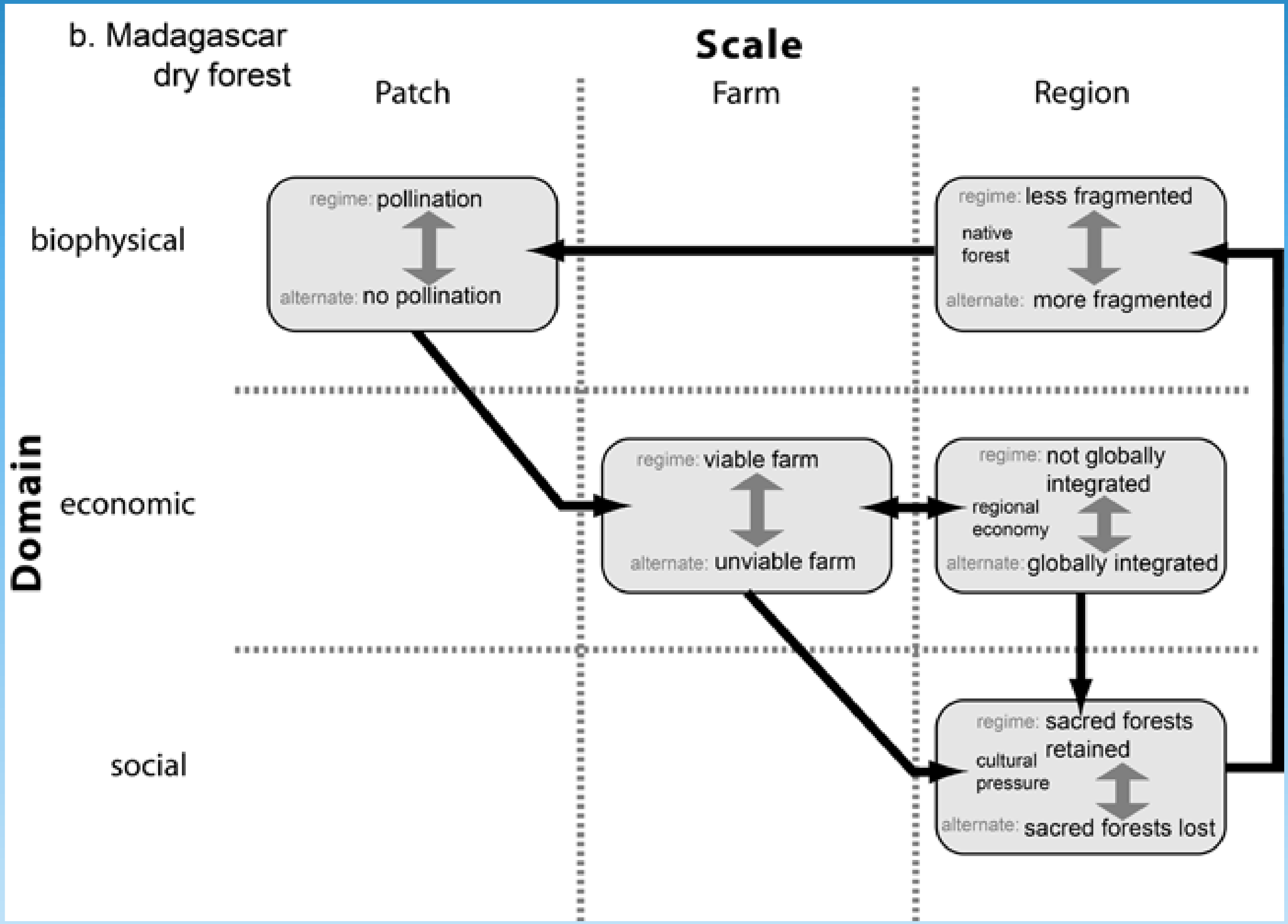
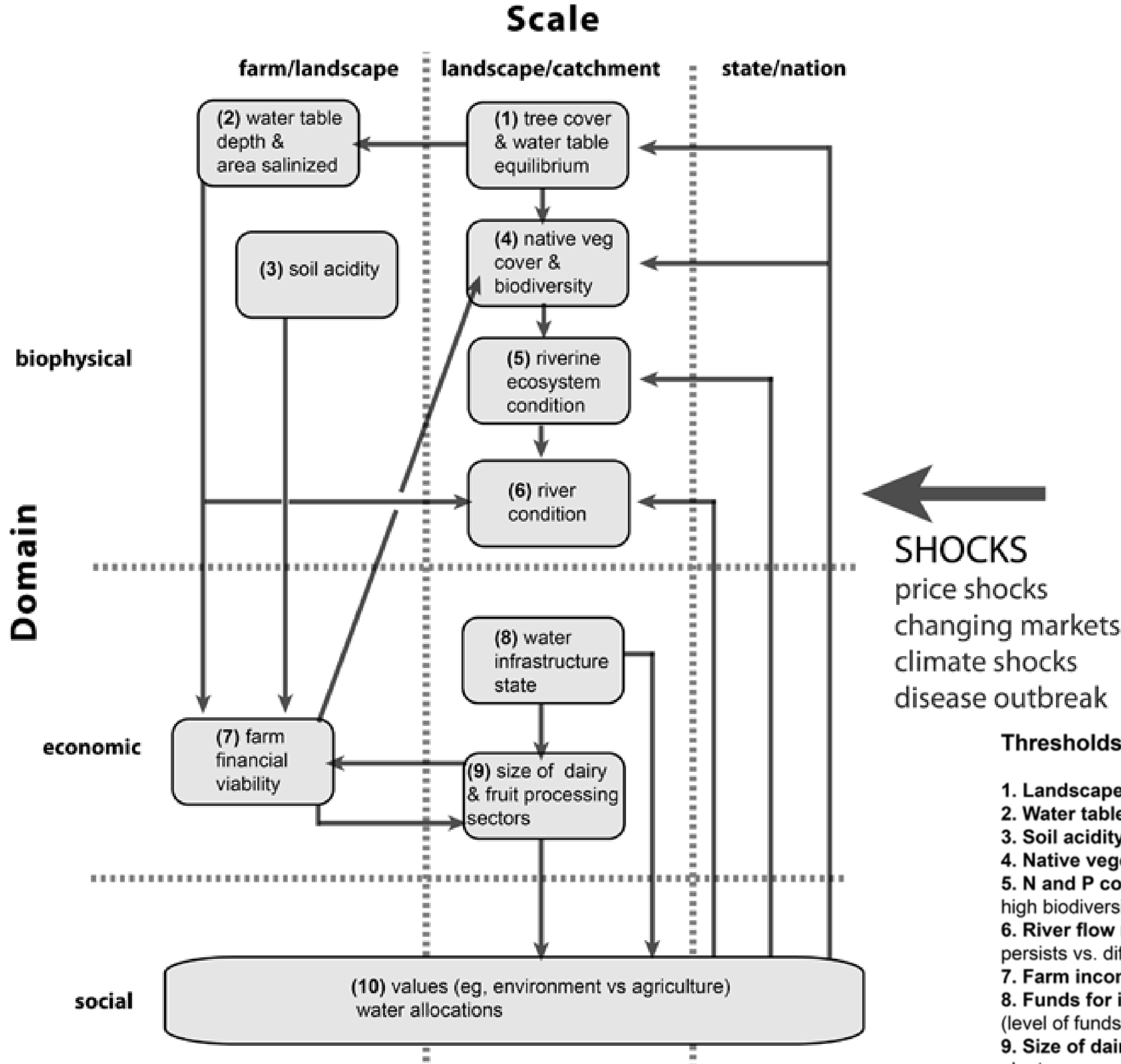


Figure 6: A Representation of a Thresholds Matrix

(a) A generalized 3x3 grid of potential thresholds over three scales and three domains. Each box identifies a potential threshold on a controlling variable that leads to a regime shift. (Modified from Kinzig et al. 2006). (b) How researchers believe thresholds might be interacting in a system of dry forests in Madagascar. (Based on Bodin et al. 2006, modified from Kinzig et al. 2006.)

Walker and Salt (2012)



Thresholds & alternative regimes

1. **Landscape tree cover** (10 - approx 15%) water table deep vs. water at surface
2. **Water table depth** (approx 2m under surface) fertile top soil vs. salinized soil
3. **Soil acidity** (approx pH 5.5) high crop production vs. crop failure
4. **Native vegetation cover** (5%, 30%) fauna groups present vs. absent
5. **N and P content in water bodies** (concentration level threshold) clear water, high biodiversity vs. eutrophic, low biodiversity
6. **River flow regime** (flow level threshold) wetland/floodplain biodiversity persists vs. different species
7. **Farm income:debt ratio** (debt ratio threshold) farm viable vs. non-viable
8. **Funds for infrastructure from water sales** (level of funds threshold) infrastructure good vs. declining, non-viable
9. **Size of dairy & fruit processing** (level of industry activity) viable processing plants vs. non-viable
10. **Balance of values for water for environment vs agriculture** (availability of water threshold) farmer income: debt positive vs. negative

Figure 7: A Thresholds Matrix for the Goulburn-Broken Catchment

The matrix presents ten slow variables with identified thresholds. The arrows between boxes indicate possible cascading threshold effects. The list provides more details on each threshold: each item names the slow variable, the threshold in parentheses, and the regime and alternate regime that lie on either side of the threshold. (Modified from Walker et al. 2009.)

Walker and Salt (2012)

BREE IAM Model Structure

Intellectual merit: Exploration of SES couplings and feedbacks through novel application of deep learning and agent cognition!

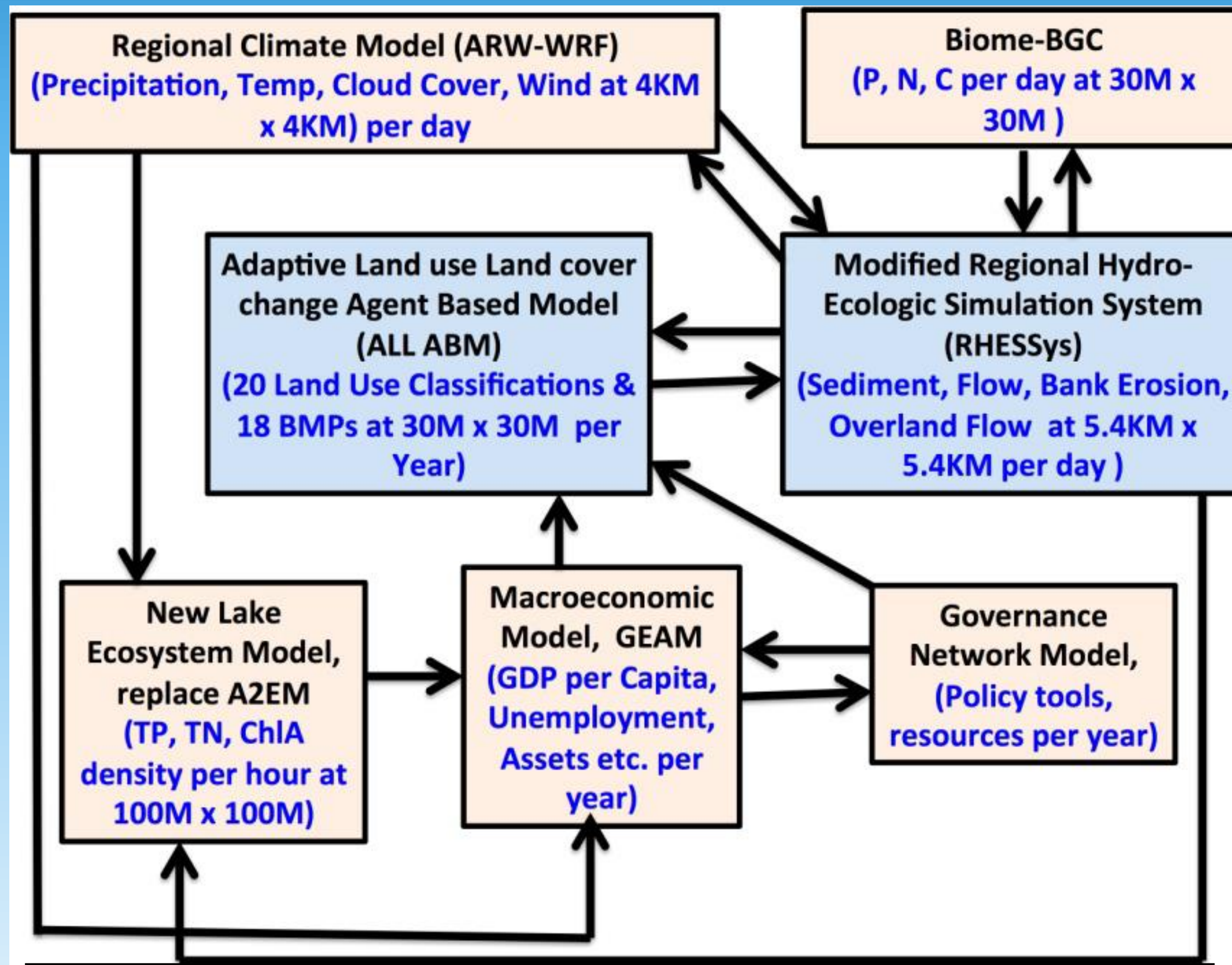
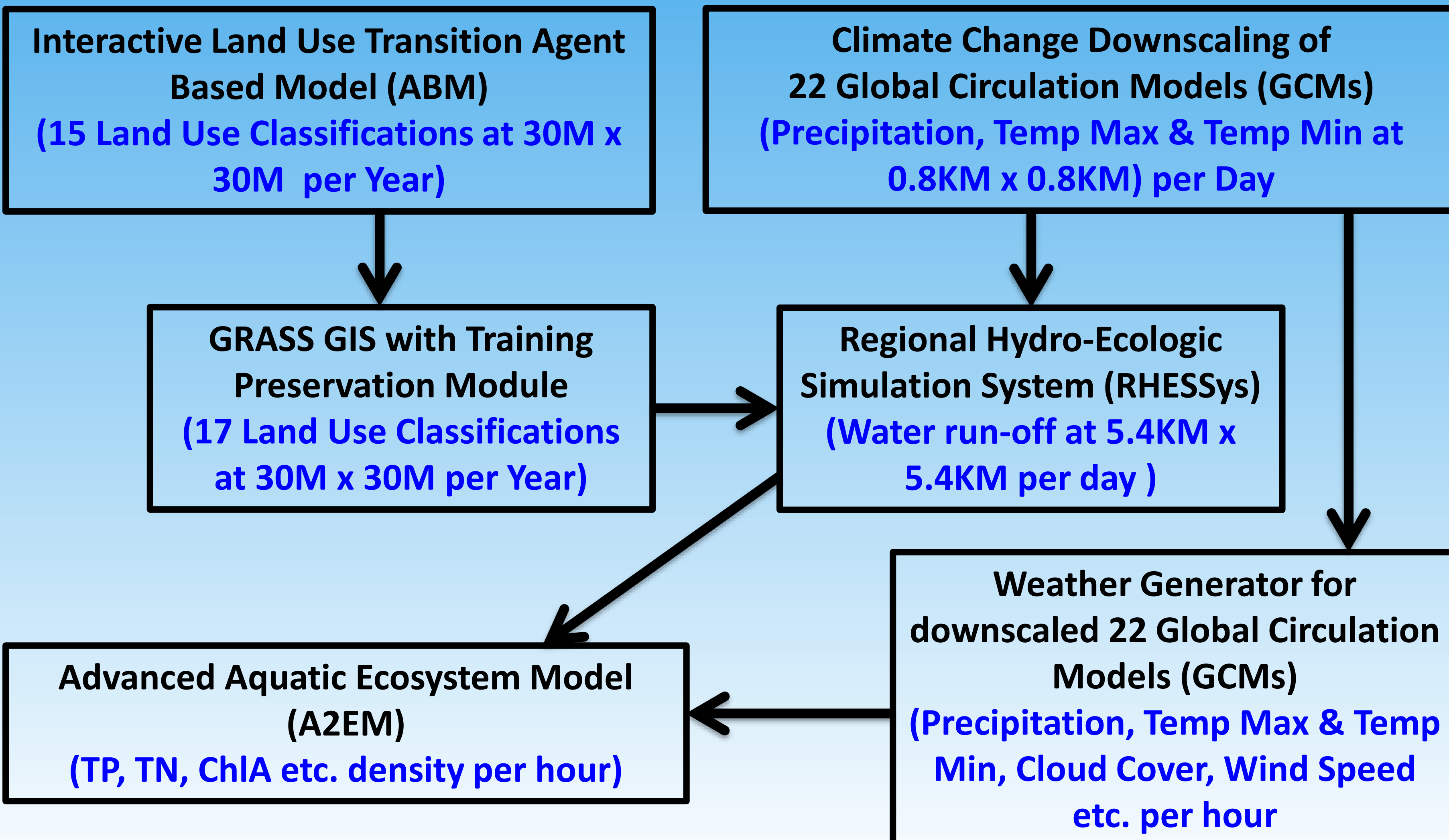


Figure 7: The BREE Integrated Assessment Model (IAM) of coupled social ecological systems for understanding the cascading impacts of climate change induced extreme events at watershed scales; tan = new model; blue = expanded existing model; WRF: Weather Research and Forecasting; ALL: Adaptive Landuse Land cover agent based model: GEAM: General Equilibrium Analysis Model

RACC IAM Status at the Start of the BREE Project



Development Plan for BREE IAM (2016-17)

Adaptive Land Use Land cover change Agent Based Model (ABM)
(15 Land Use Classifications & 10 BMPs at 30M x 30M per Year)

Climate Change Downscaling of 22 Global Circulation Models (GCMs)
(Precipitation, Temp Max & Temp Min at 0.8KM x 0.8KM) per Day

GRASS GIS with Training Preservation Module
(17 Land Use Classifications at 30M x 30M per Year)

Modified Regional Hydro-Ecologic Simulation System (RHESSys)
(Sediment, Flow, Bank Erosion, Overland Flow at 5.4KM x 5.4KM per day)

Advanced Aquatic Ecosystem Model (A2EM)
(TP, TN, ChlA etc. density per hour)

Weather Generator for downscaled 22 Global Circulation Models (GCMs)
(Precipitation, Temp Max & Temp Min, Cloud Cover, Wind Speed etc. per hour

Feedback effects from Lake Model to Land Use Agent Based Model

- **Proactive versus Reactive "Regulator" Agents have been added in the ABM**
  - Regulator agents perceive the signal, either as a forecast or a delayed signal, from the lake and act to change financial and technical assistance policies, which in turn influence the adoption of farmer BMPs and land use transitions
  - Test runs (in progress)

- **Changes in land value from changing water quality**
  - Preliminary machine learning algorithms being tested
  - Cascading "up" effects: decreasing land value may lower the town revenues, which in turn may lower available infrastructure that may lead to population and business flight

- **Ecosystem Service approach being planned**

Modeling behavioral change (e.g. BMP adoption) by multiple agents in ALL ABM

ALL ABM

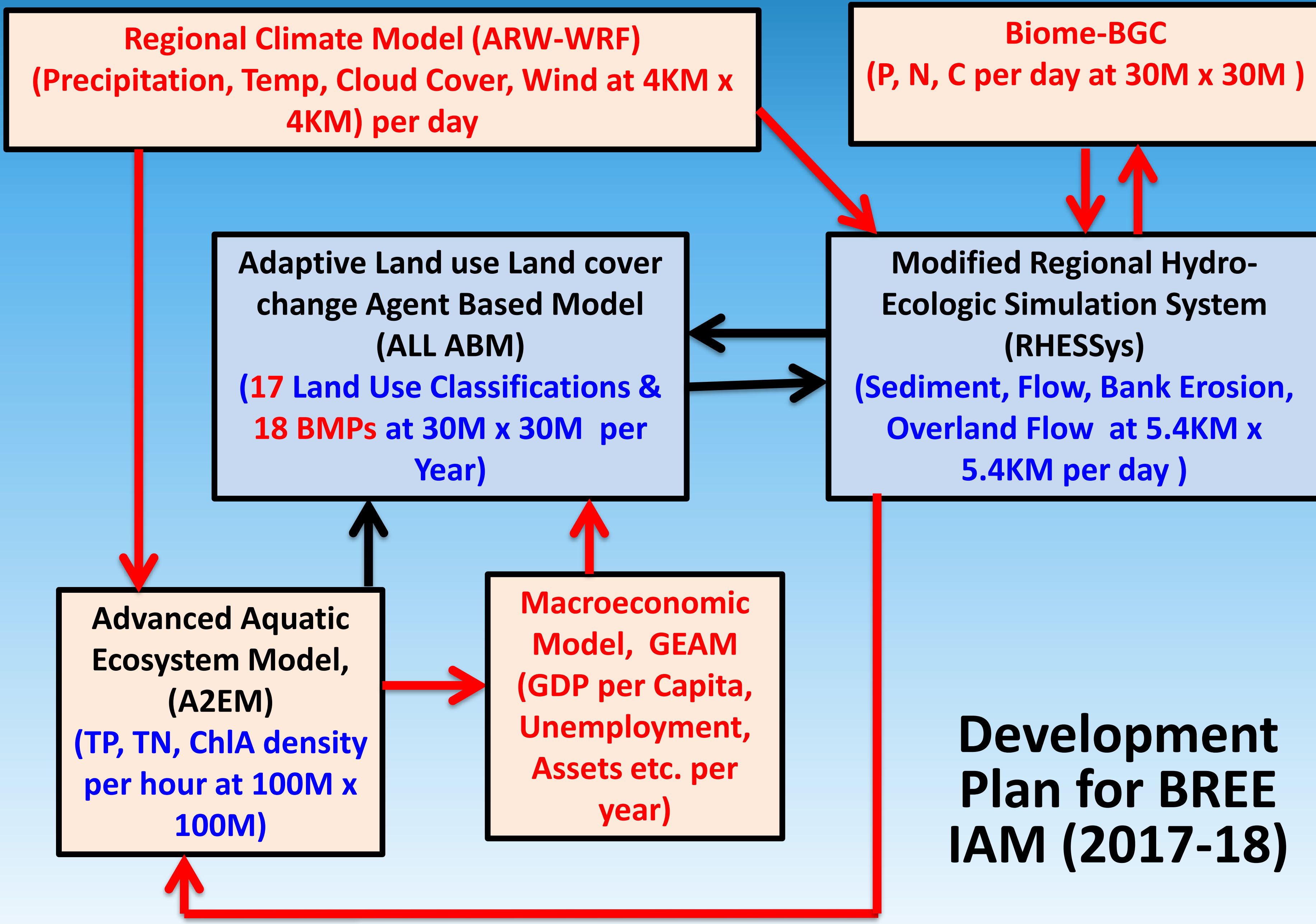
Current Structure & Processes

Planned extensions (2017-2019)

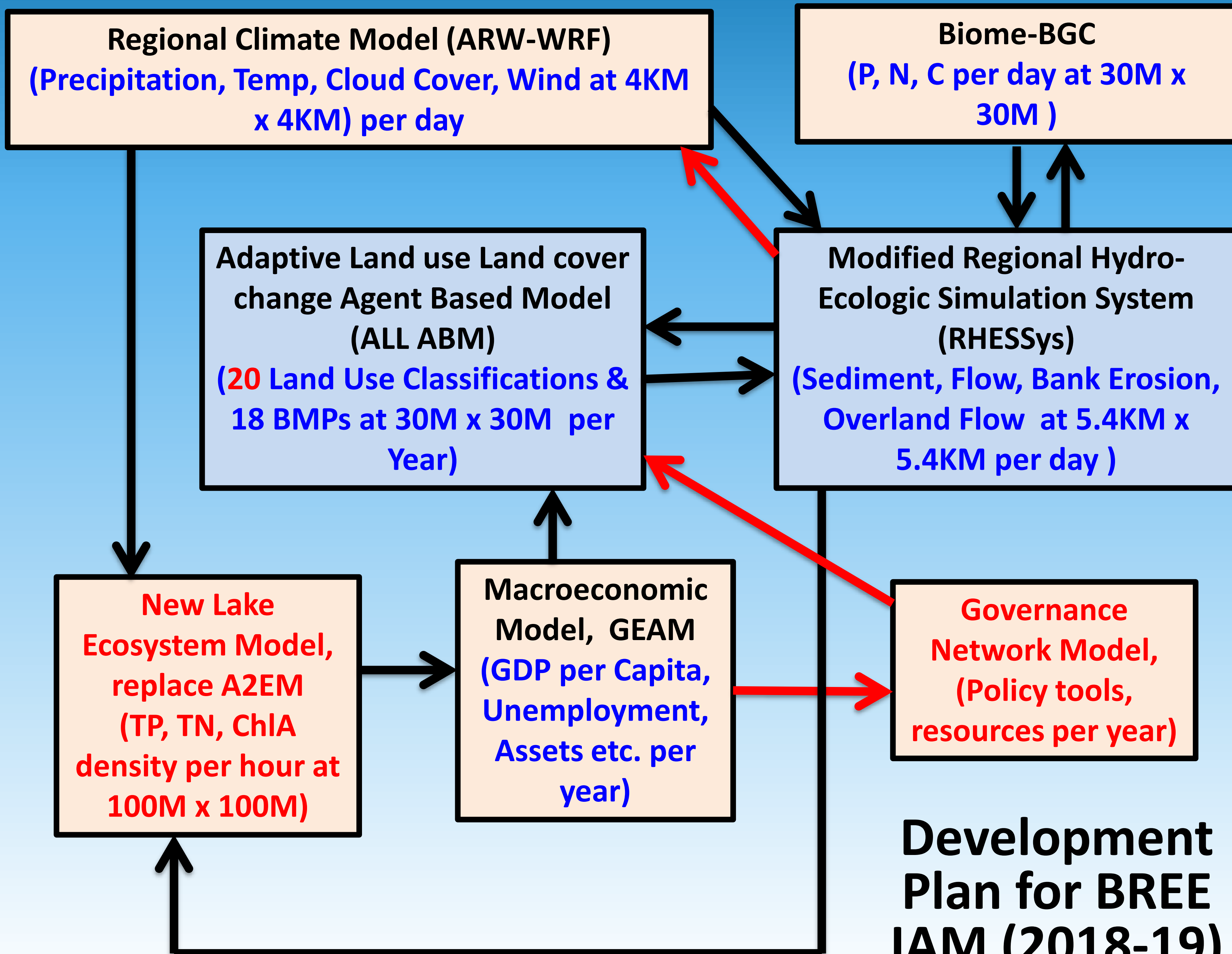
Theory based decision heuristics (e.g. Game Theory, Theory of Planned Behavior etc.)

Machine learning based decision heuristics (e.g. ANNs, DBNNs etc.)

Reinforcement learning based decision heuristics (e.g. Q-learning, SARSA etc.)

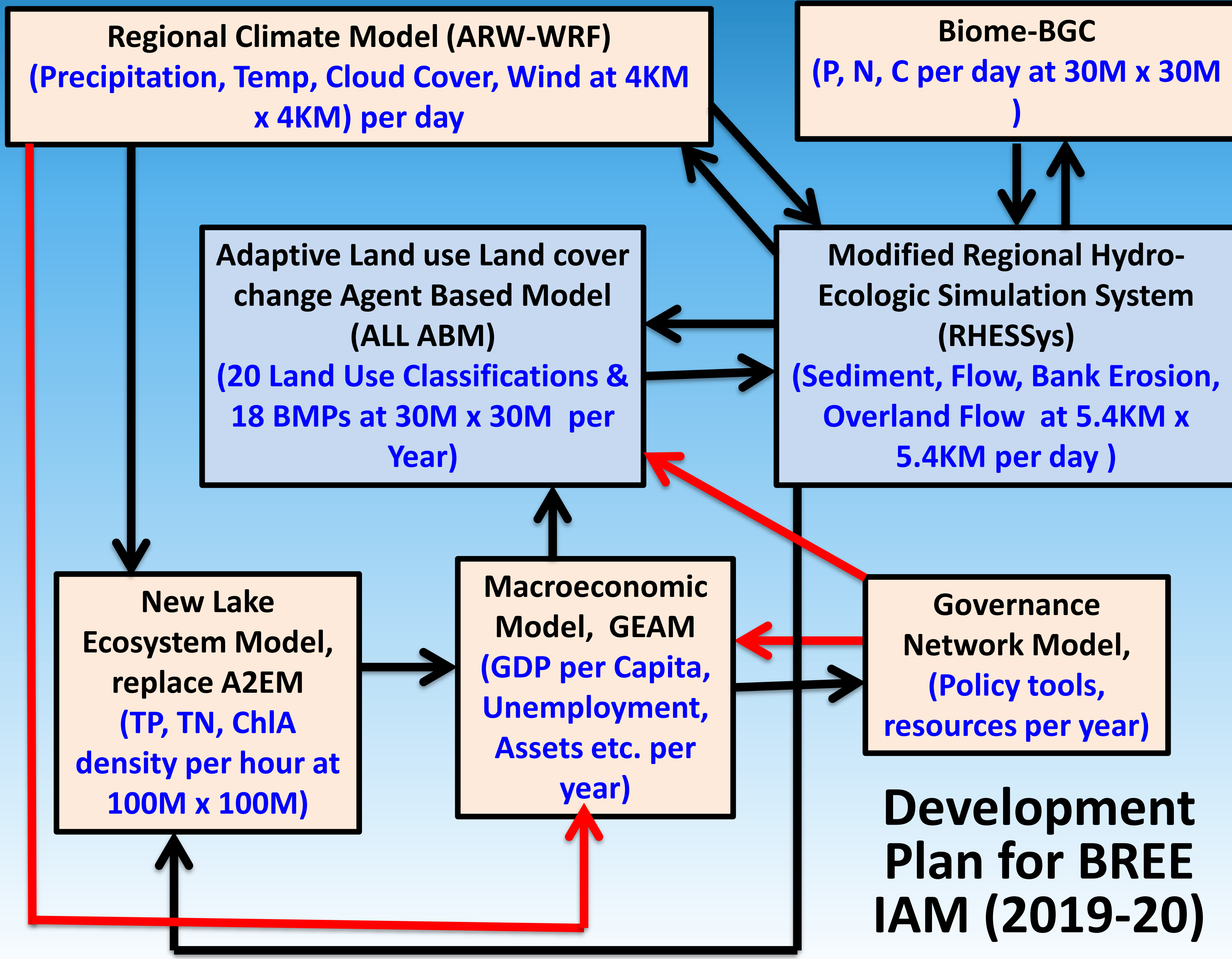


Development Plan for BREE IAM (2017-18)



Development Plan for BREE IAM (2018-19)

Development Plan for BREE IAM (2019-20)



THANK YOU

QUESTIONS?