Portfolio Decision Technology for Designing Optimal Syndemic Management Strategies

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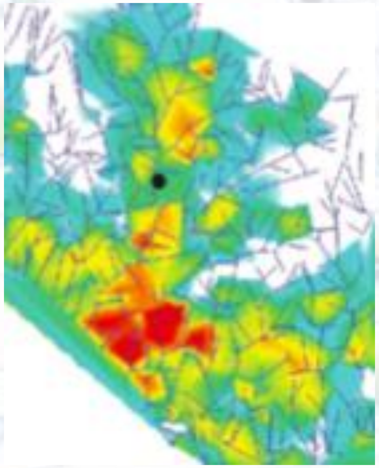
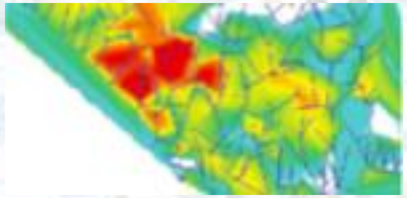
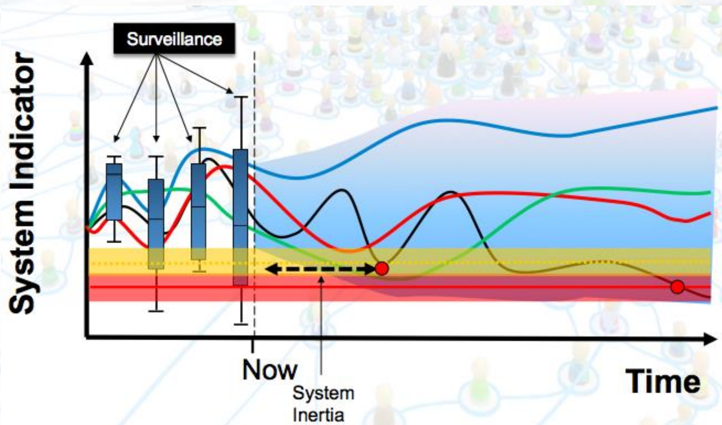
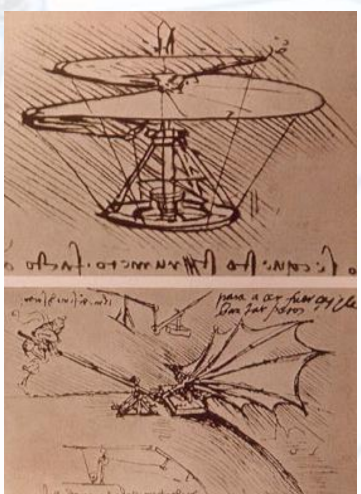
Three Pillars


Scalability and Universality
(Endemic/Epidemic Characterization & Macro Prediction)

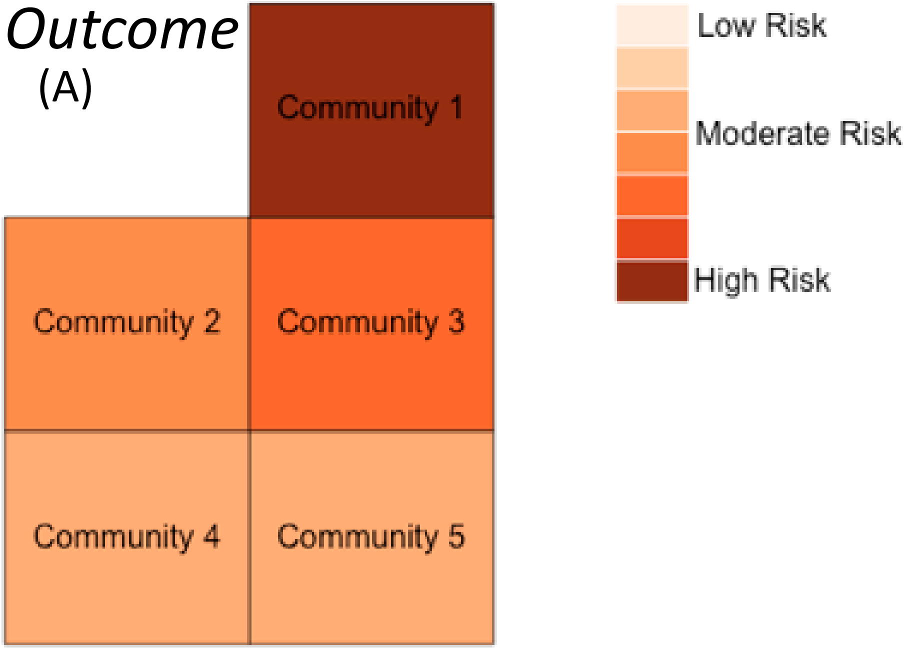


Environmental Dynamics
(Early Warning and Real-time Fine Scale Forecasting)

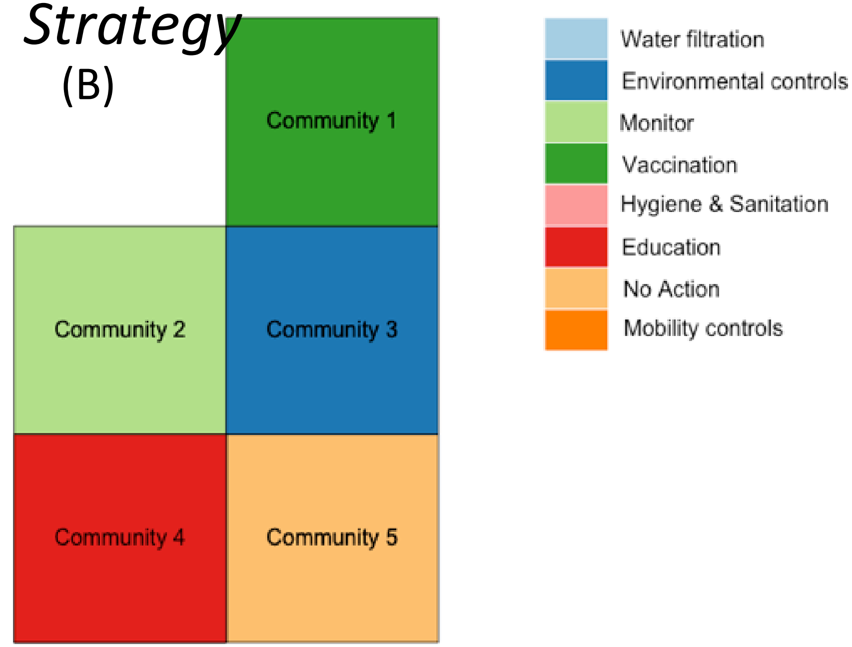


Systemic and Value-based Optimal Ecosystem Design
(Portfolio Decision Model)

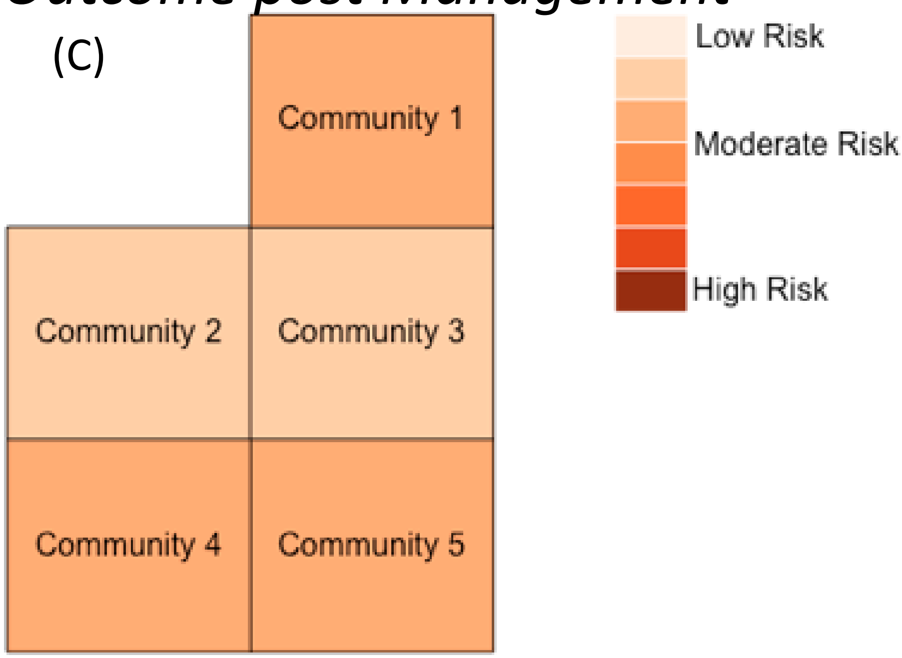
Outcome
(A)



Strategy
(B)



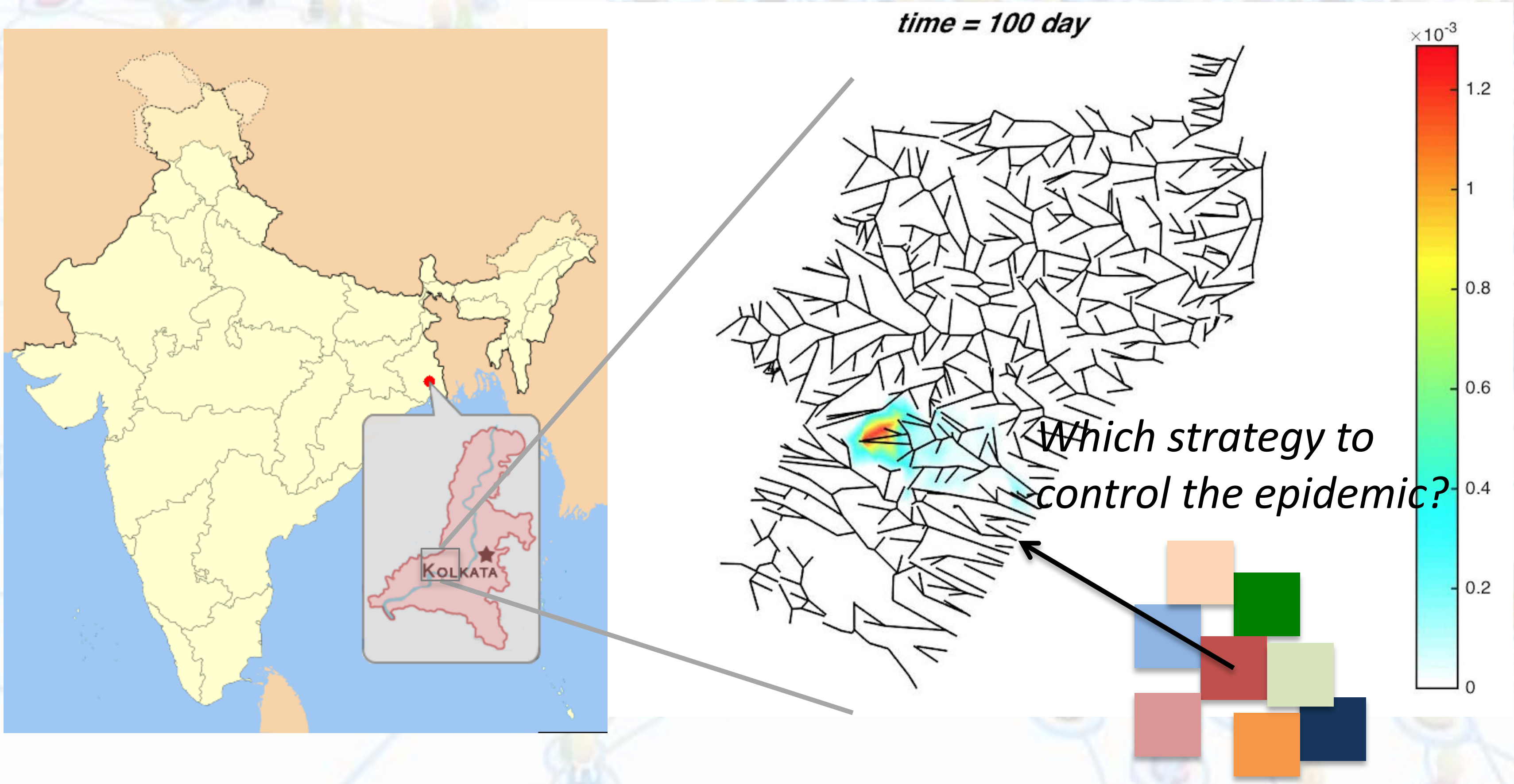
Outcome post Management
(C)



Conceptual Idea

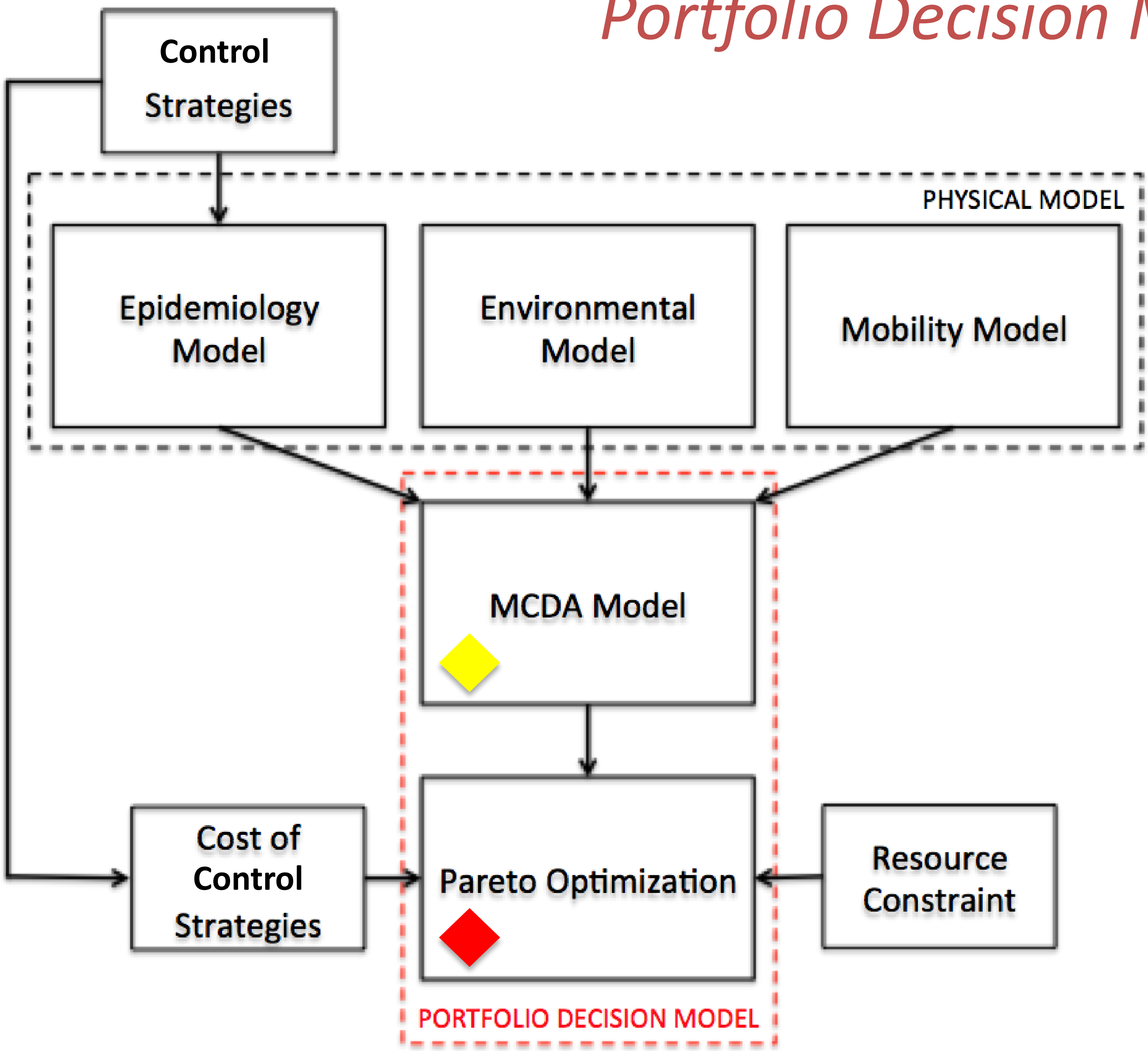
(A) Output of the physical model" expected system risk based on the epidemiology model, environmental and mobility model
(B) Output of the portfolio decision model, selection of the optimal control set at the community scale
(C) Portfolio controlled solution: Lowest systemic risk.

Portfolio Decision Modeling: Kolkata Case Study

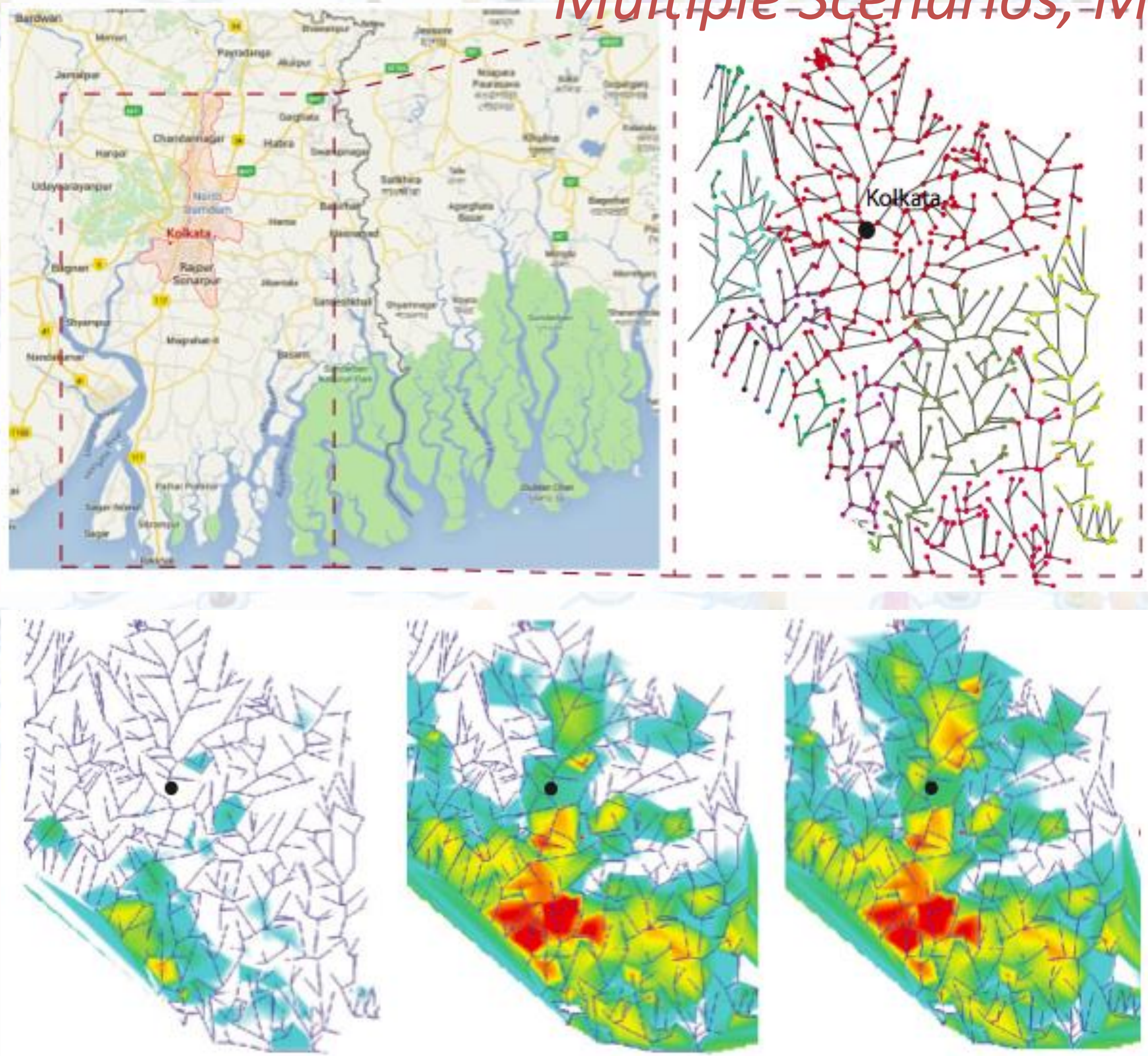


You et al., 2013, PLoS ONE
Convertino and Valverde, 2013, PLoS ONE
Convertino and Nardi, 2015, Nature Clim. C.

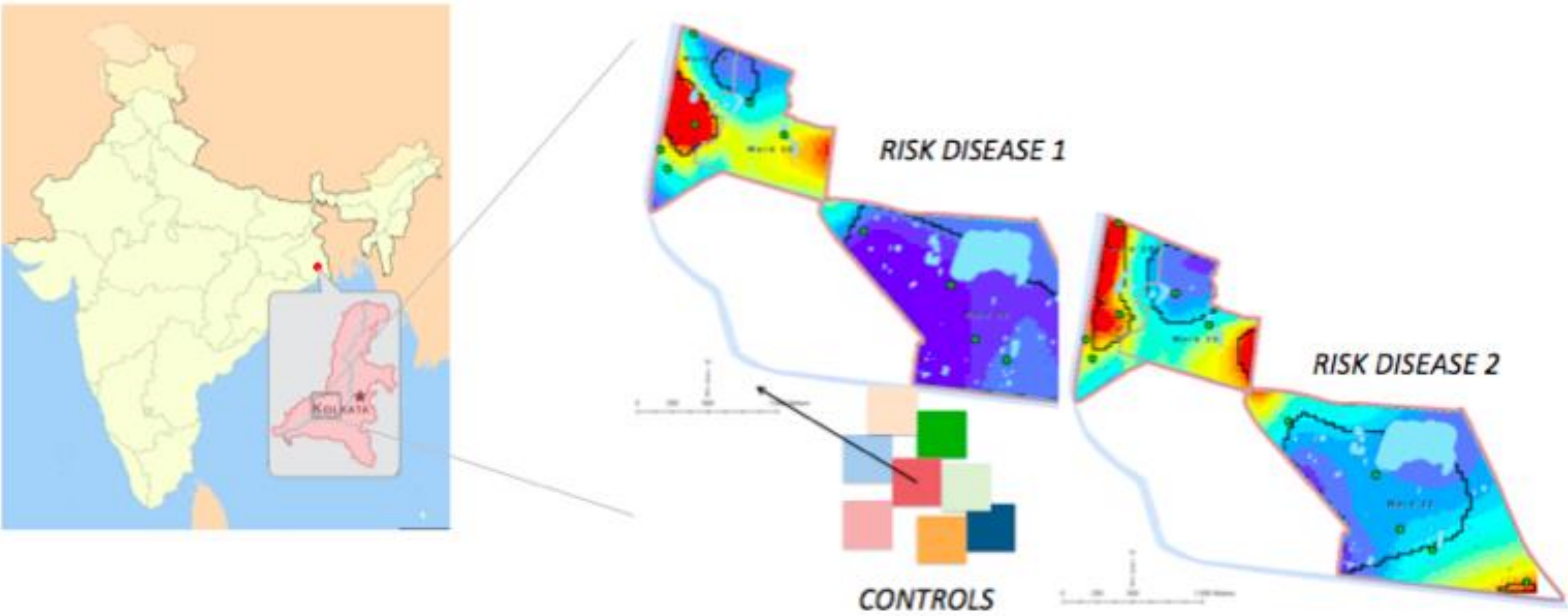
Portfolio Decision Model



Multiple Scenarios, Multiple Risks

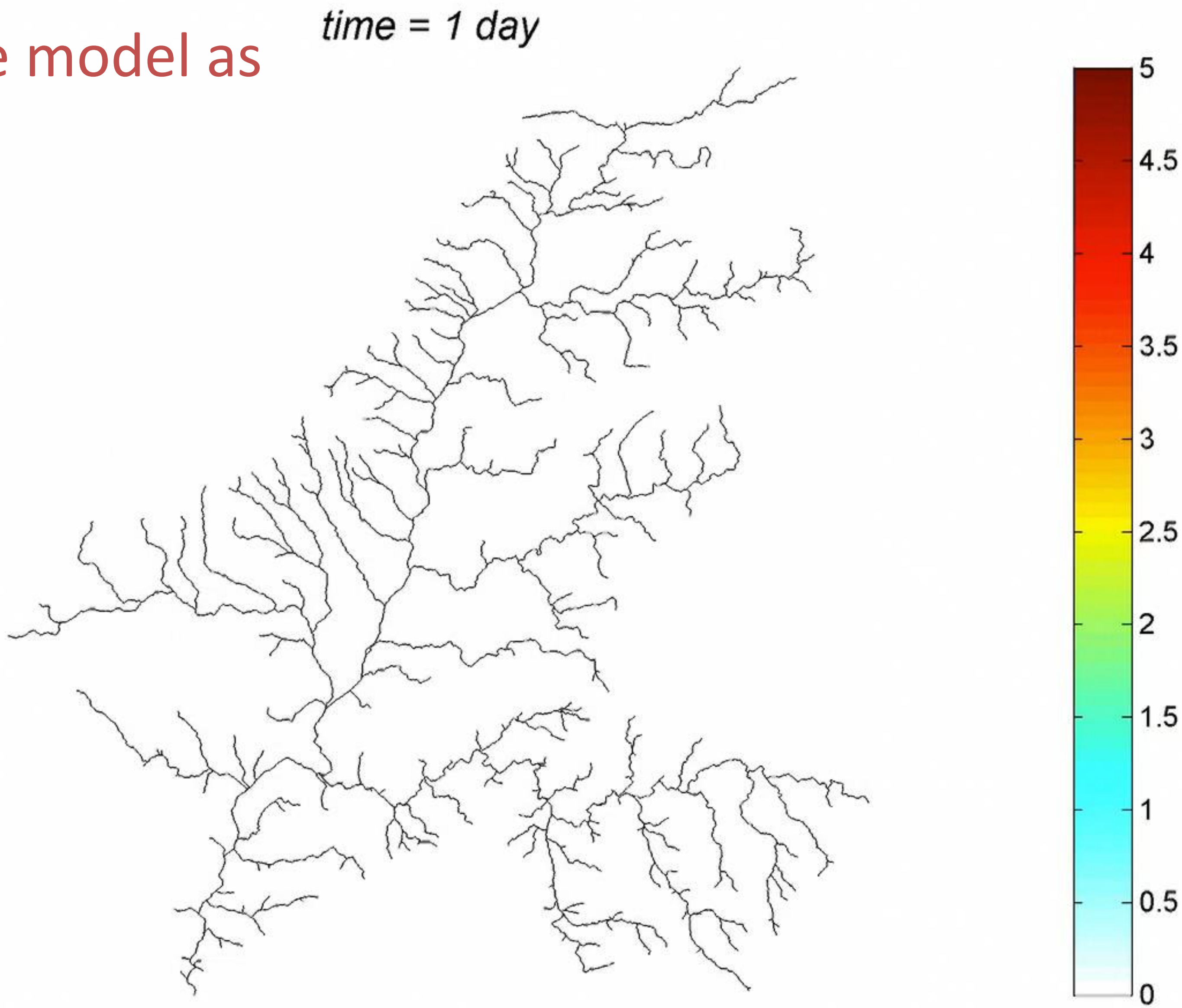


Portfolio Decision Modeling: Multiple Scales



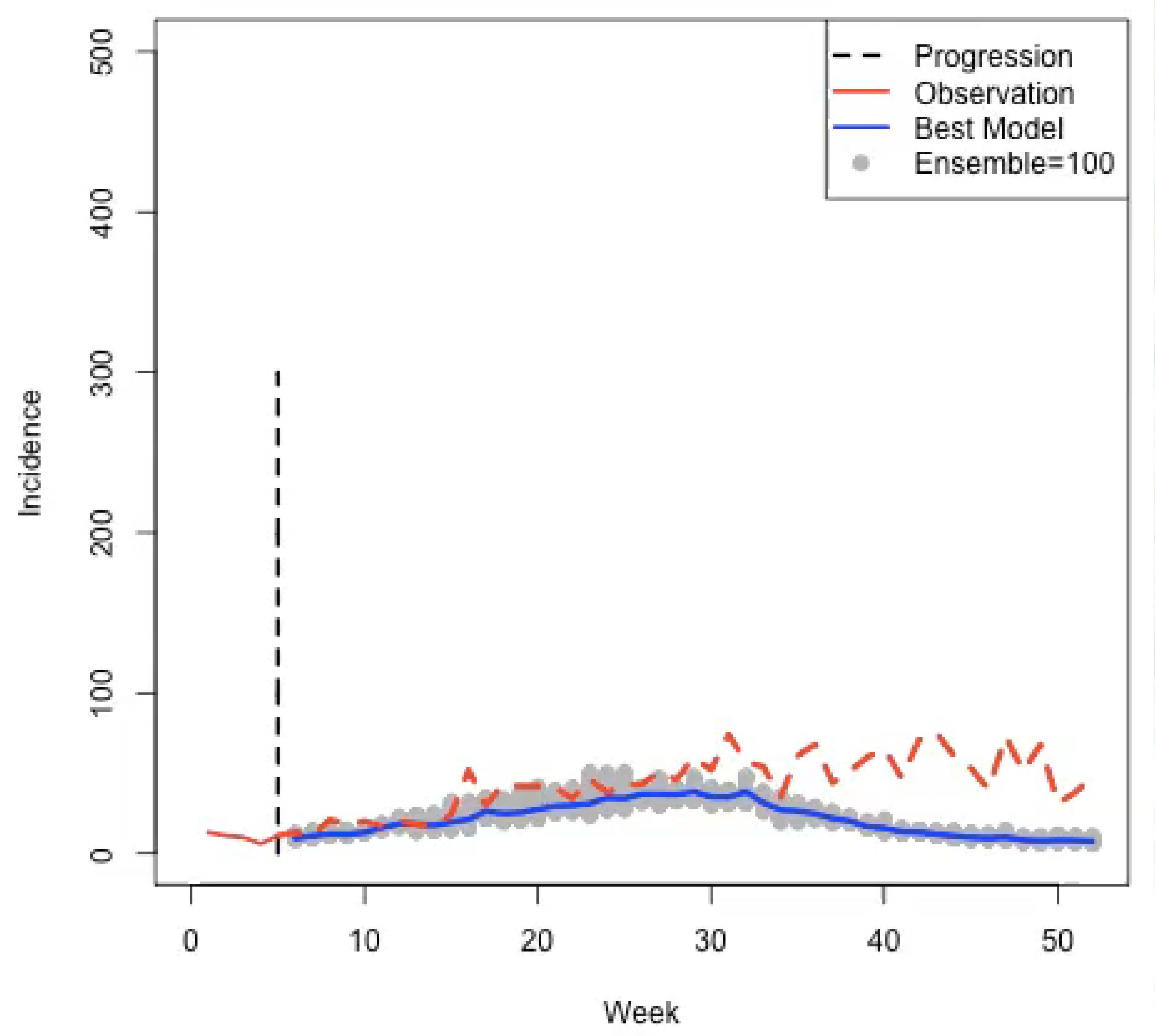
A predictive model as the core

Subbasin with the largest incidence →

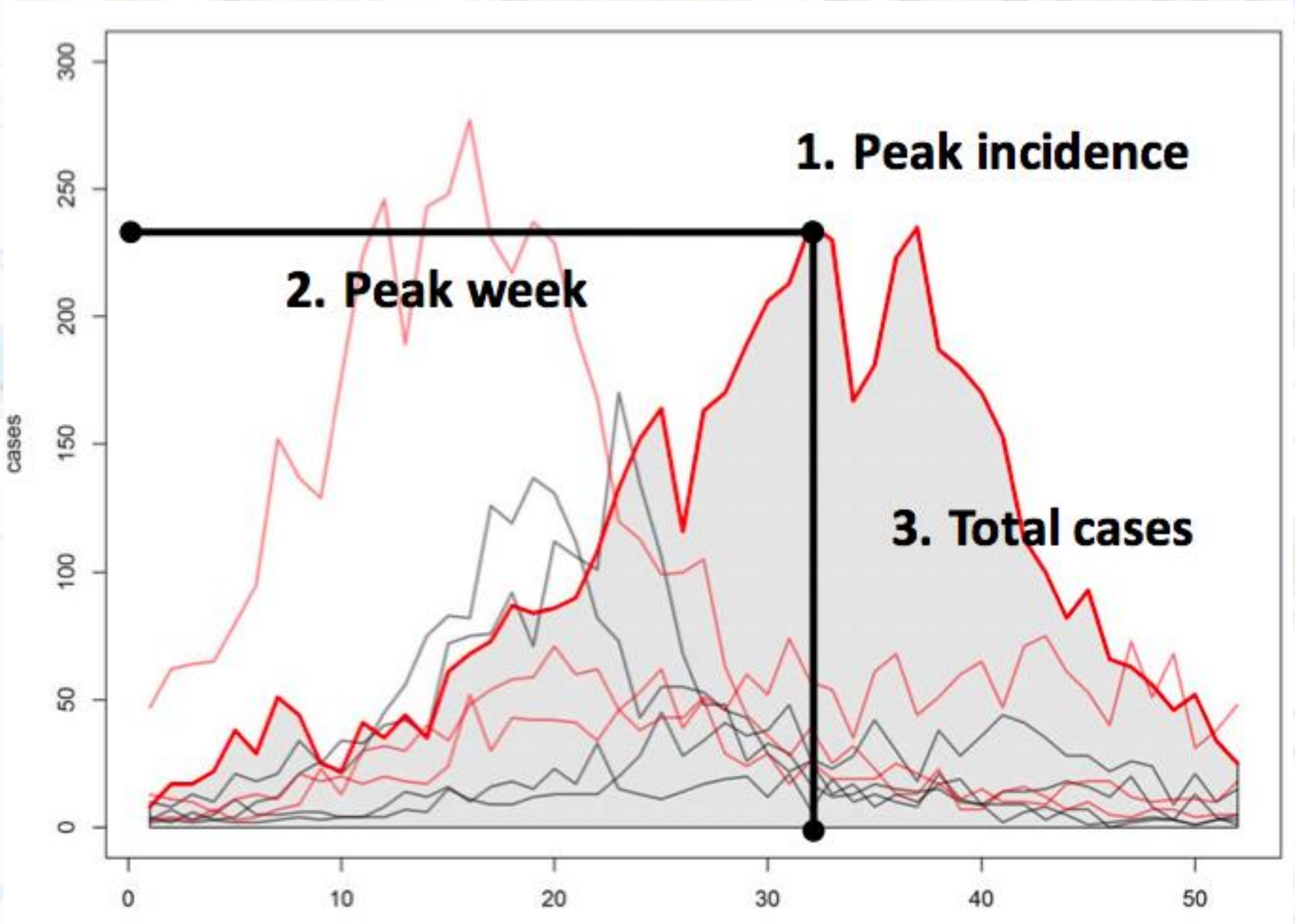


Reddy et al., 2015, submitted to JRS-Interface

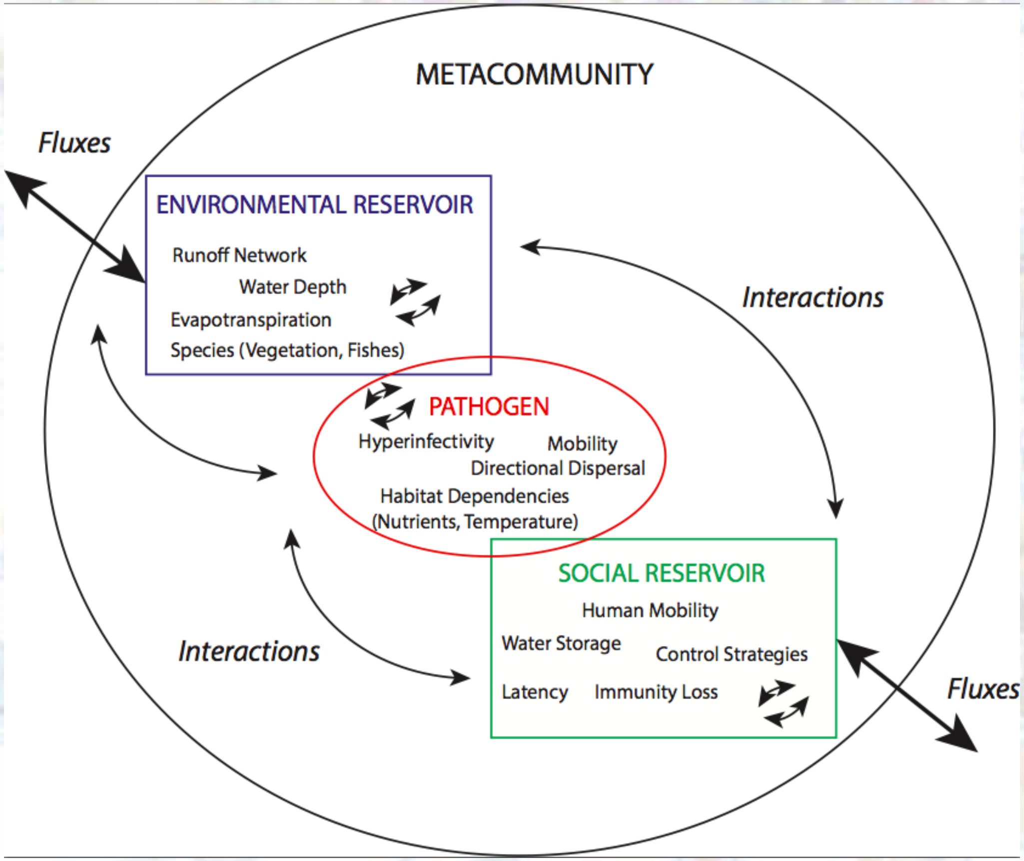
Temporal Forecasts and Predictions

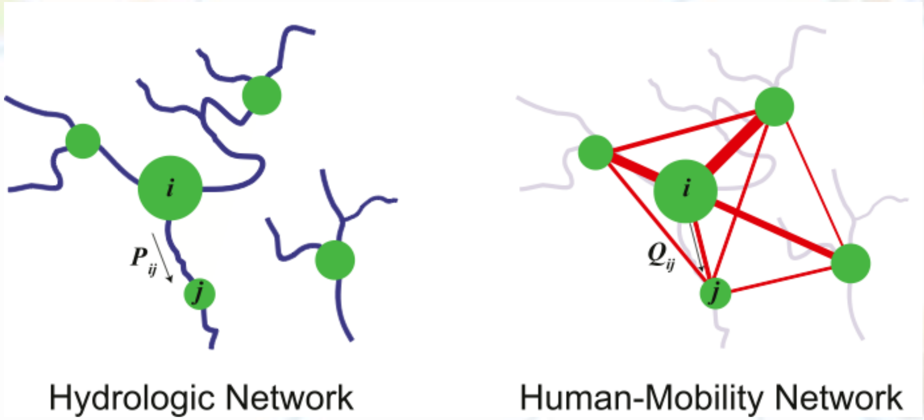


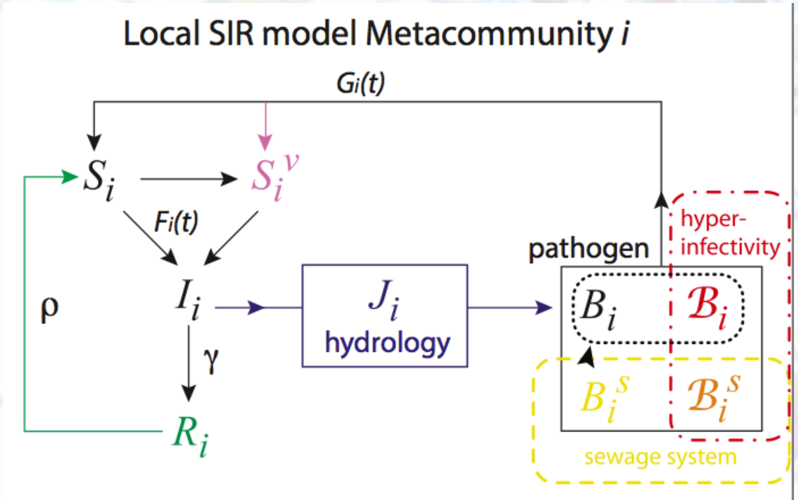
Forecasting Model



Convertino et al., 2014, WRR







Connectopathies, Factorgenicity and Population Outcomes: A Morphological Effective Systemic EpiGraph model (MESE)

EPI (STATIC; RISK) TRANSPORT (DYNAMICS; OUTCOME)

$$I(\tau) = A \int j_e(\tau) [p_\gamma (f_{\gamma_1} * f_{\gamma_n})]_{t-\tau} d\tau$$

$$I(\tau) = A \int j_e(\tau) W(t-\tau) d\tau$$

$$f_\gamma = pdf(L_\gamma) pdf(T_{L_\gamma})$$

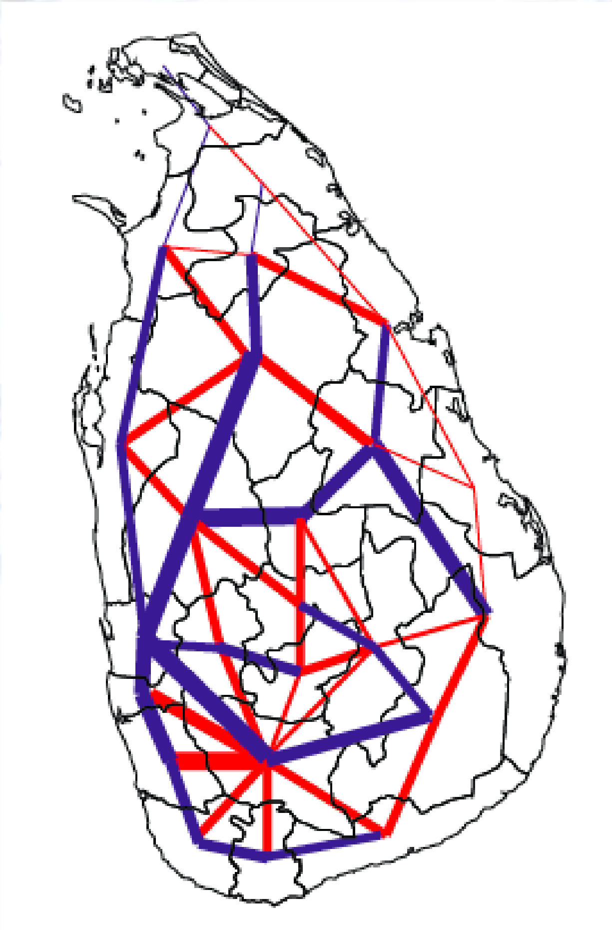
L=network length

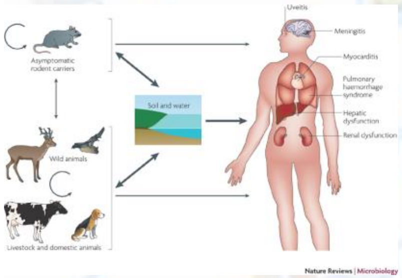
Travel Time distribution ~ Arrival Time distribution (of Cases) ~ (Residence Time)$^{-1}$

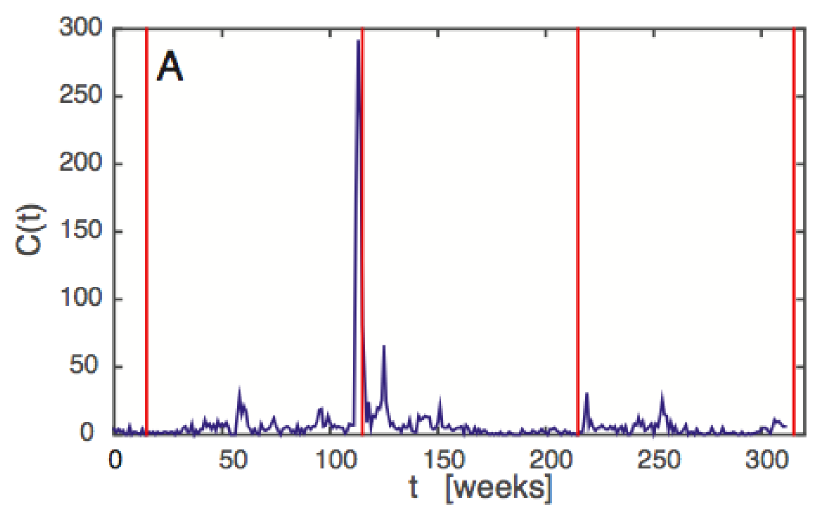
Convertino, Huang, Liu, 2014, WRR, submitted

… GIUH from Rodriguez-Iturbe and Valdes, 1979

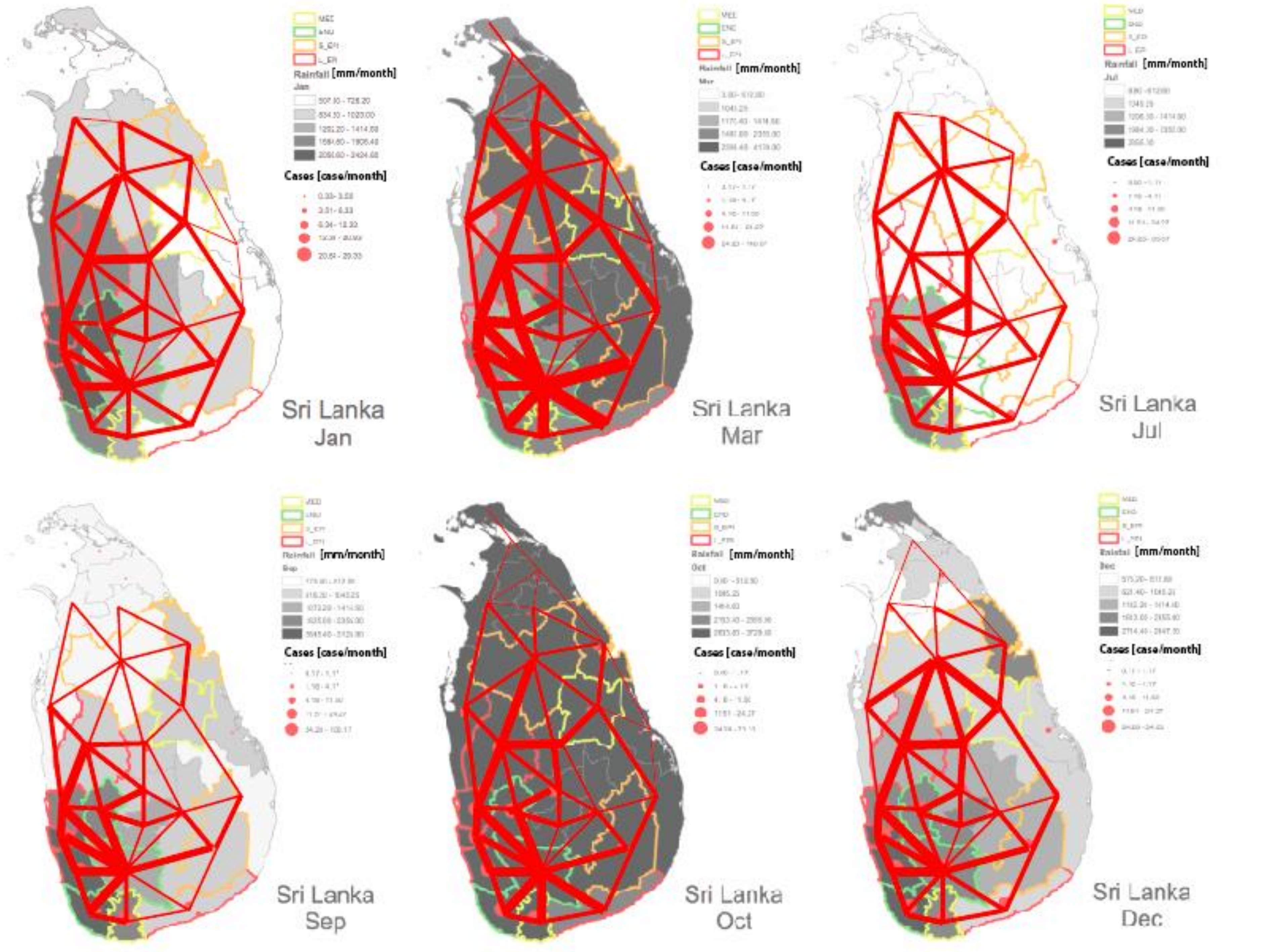
Scaling and Early Warning Models: Application to Leptospirosis in Sri Lanka







Reddy et al., 2015, submitted to PNAS


Rainfall [mm/month]
Cases [case/month]
Sri Lanka
Jan
Rainfall [mm/month]
Cases [case/month]
Sri Lanka
Mar
Rainfall [mm/month]
Cases [case/month]
Sri Lanka
Jul
Rainfall [mm/month]
Cases [case/month]
Sri Lanka
Sep
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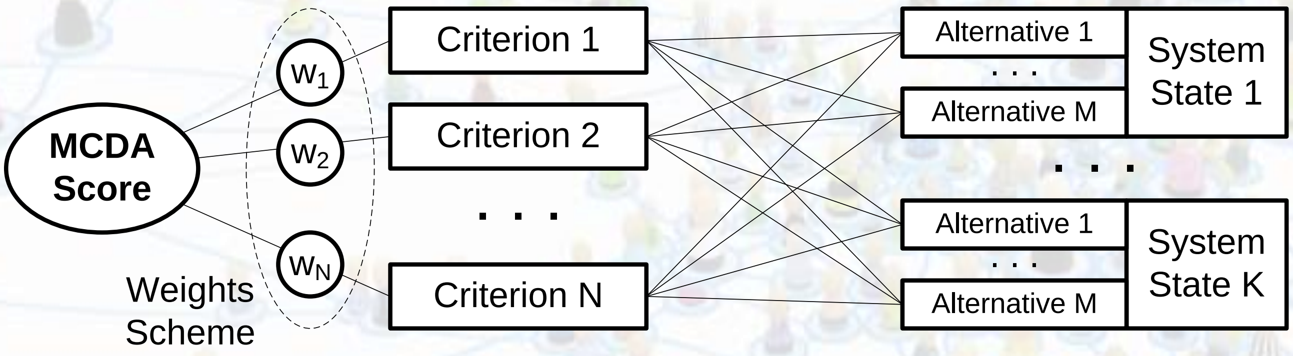
Sri Lanka
Oct
Rainfall [mm/month]
Cases [case/month]
Sri Lanka
Dec

MCDA



Alternatives	Criteria	System States			
		State 1	**State 2**	**. . .**	**State K**
Alternative 1	Criterion 1	$X_{1,1,1}$	$X_{2,1,1}$	. . .	$X_{K,1,1}$
	Criterion 2	$X_{1,1,2}$	$X_{2,1,2}$	. . .	$X_{K,1,2}$
	. . .	. . .	. . .	. . .	. . .
	Criterion N	$X_{1,1,N}$	$X_{2,1,N}$	. . .	$X_{K,1,N}$
. . .	. . .	. . .	. . .	$X_{k,m,n}$	. . .
Alternative M	Criterion 1	$X_{1,M,1}$	$X_{2,M,1}$	. . .	$X_{K,M,1}$
	Criterion 2	$X_{1,M,2}$	$X_{2,M,2}$	. . .	$X_{K,M,2}$
	. . .	. . .	. . .	. . .	. . .
	Criterion N	$X_{1,M,N}$	$X_{2,M,N}$	. . .	$X_{K,M,N}$

Local Population-adjusted Risk

Alternative Effectiveness ~Efficacy

$$V^*_{m,j}(\underline{R}) = (1 - v_j(\underline{R}))\, f_{i(j)} R_{i(j),m}\, V_{m,j}(\underline{R})$$

Population Vulnerability (if available and meaningful)

Systemic Risk

Stakeholder Preferences

$$V_T(\underline{R}) = \sqrt{\sum_{m=1}^{M} \sum_{j=1}^{J} \left(V^*_{m,j}(\underline{R})\, w_j\right)^2} = $$

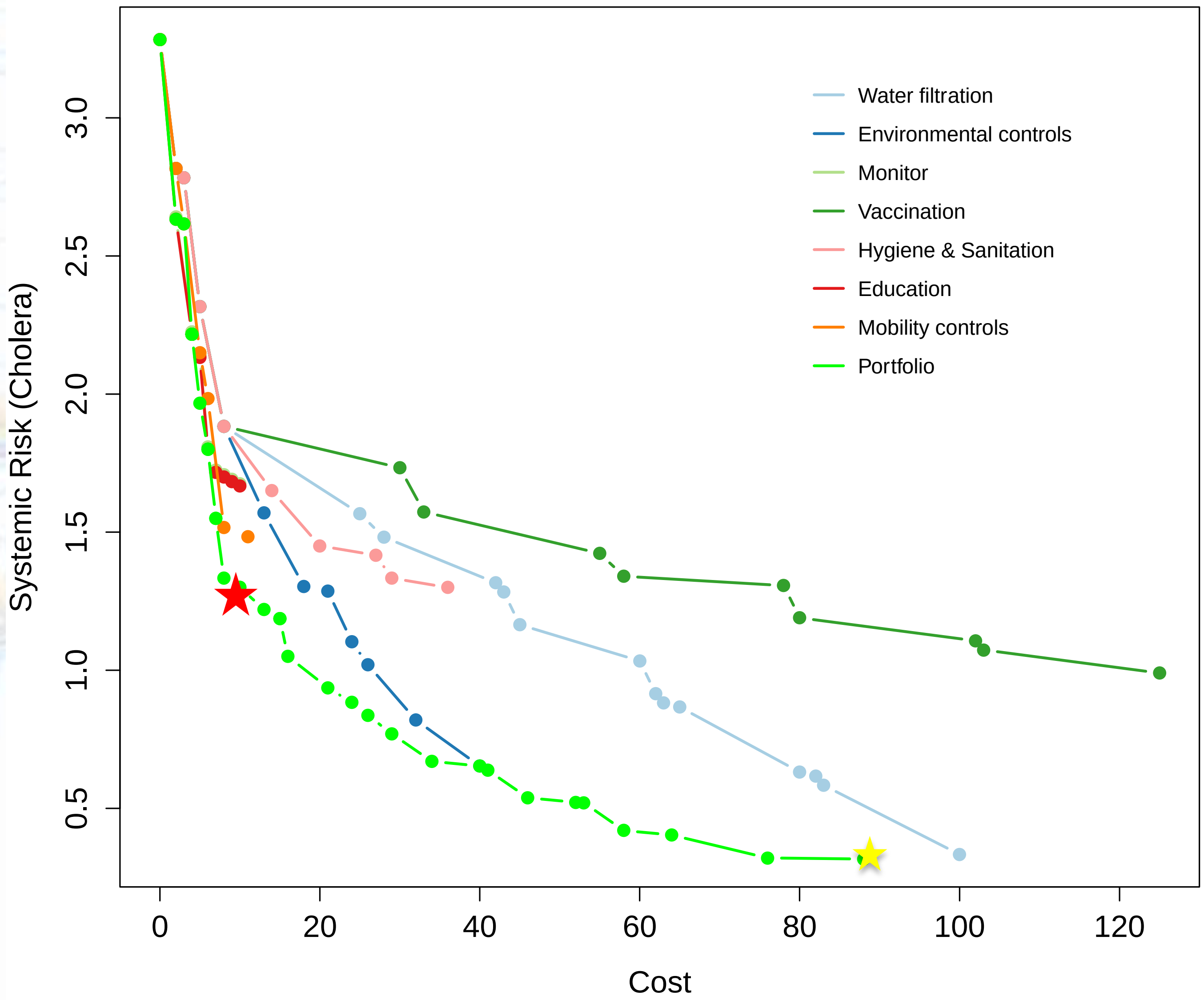
$$= \sqrt{V_N(\underline{R})^2 + V_H(\underline{R})^2}$$

m=disease management alternative

i=site

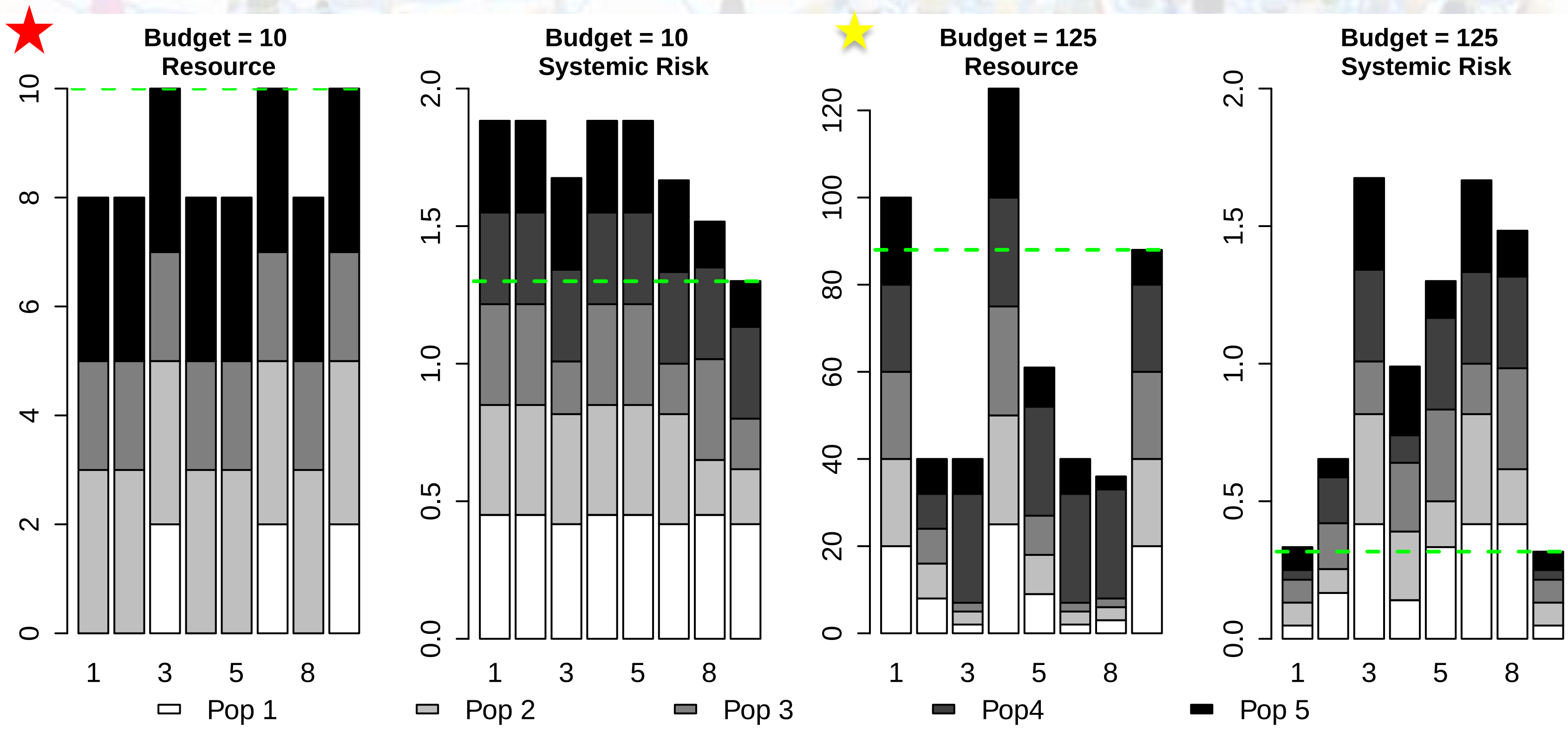
j=criteria or ecosystem services (e.g., incidence, water quality)

Portfolio Optimality



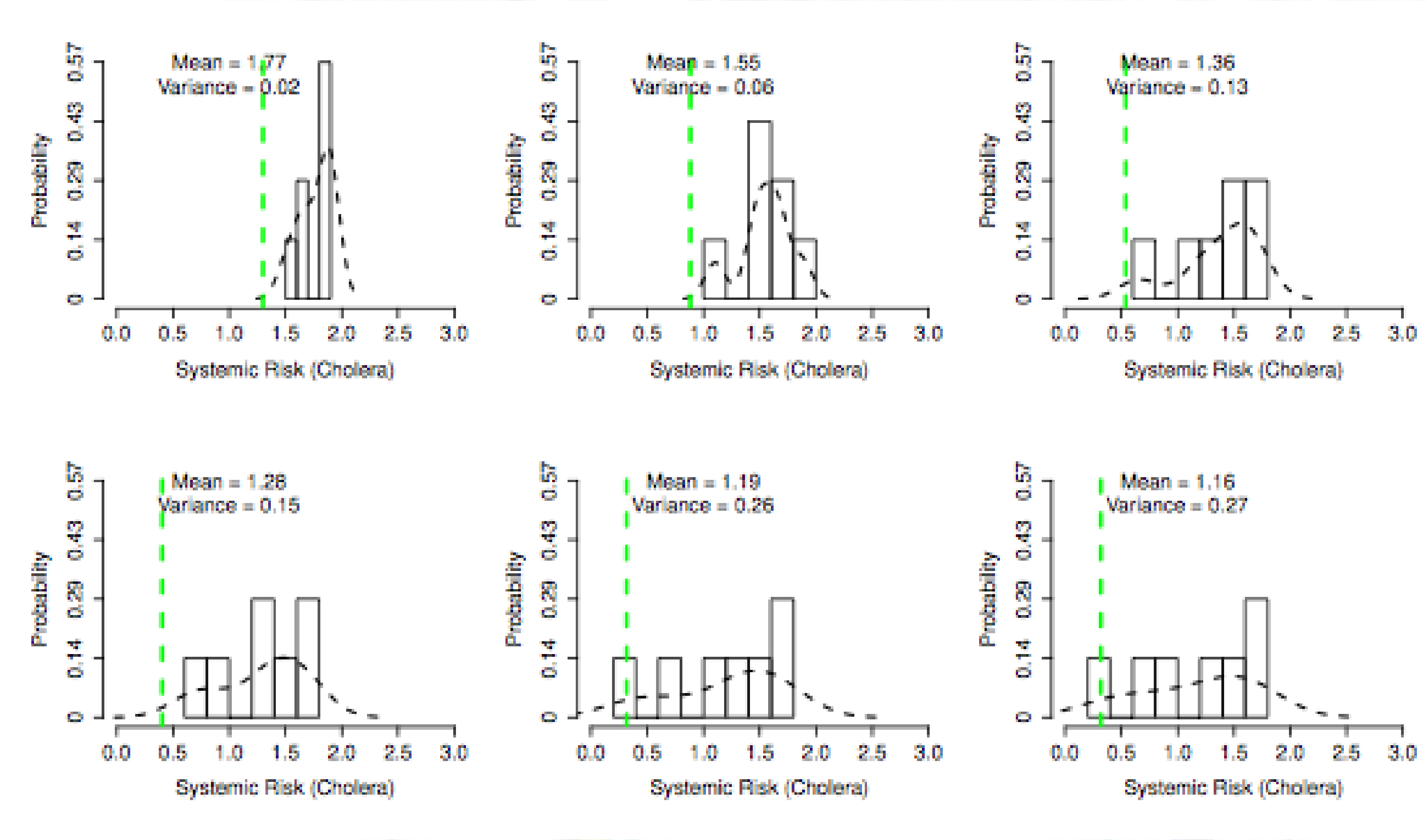
Yang et al., 2015, in prep

Budget and Risk Diversification



The lower the budget the lower the expense of the portfolio and the higher the risk

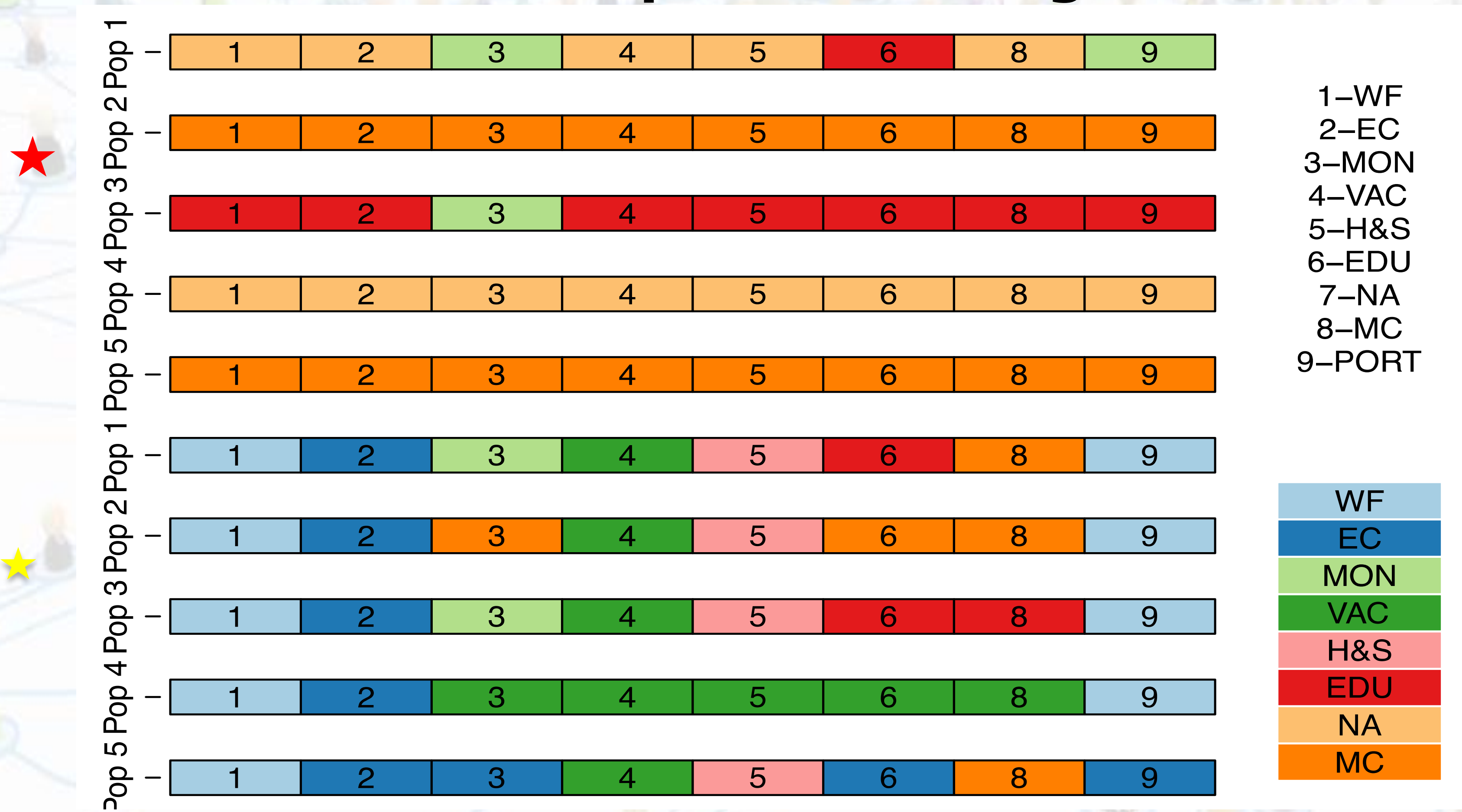
For high budget the effectiveness of each control is higher for a single and all subpopulations



Green=portfolio solution

The higher the budget the more platykurtic the pdf is

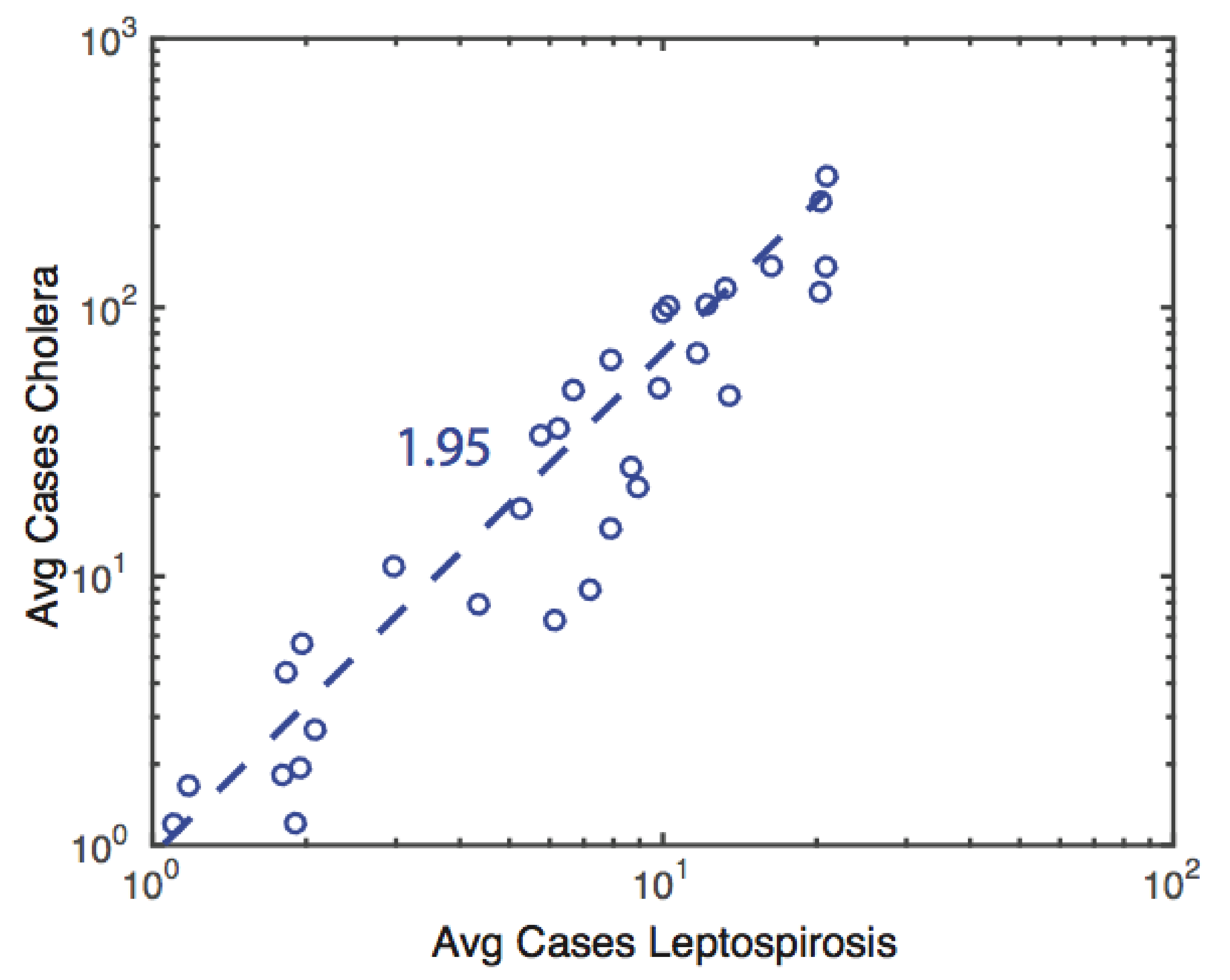
Pareto Optimal Strategies



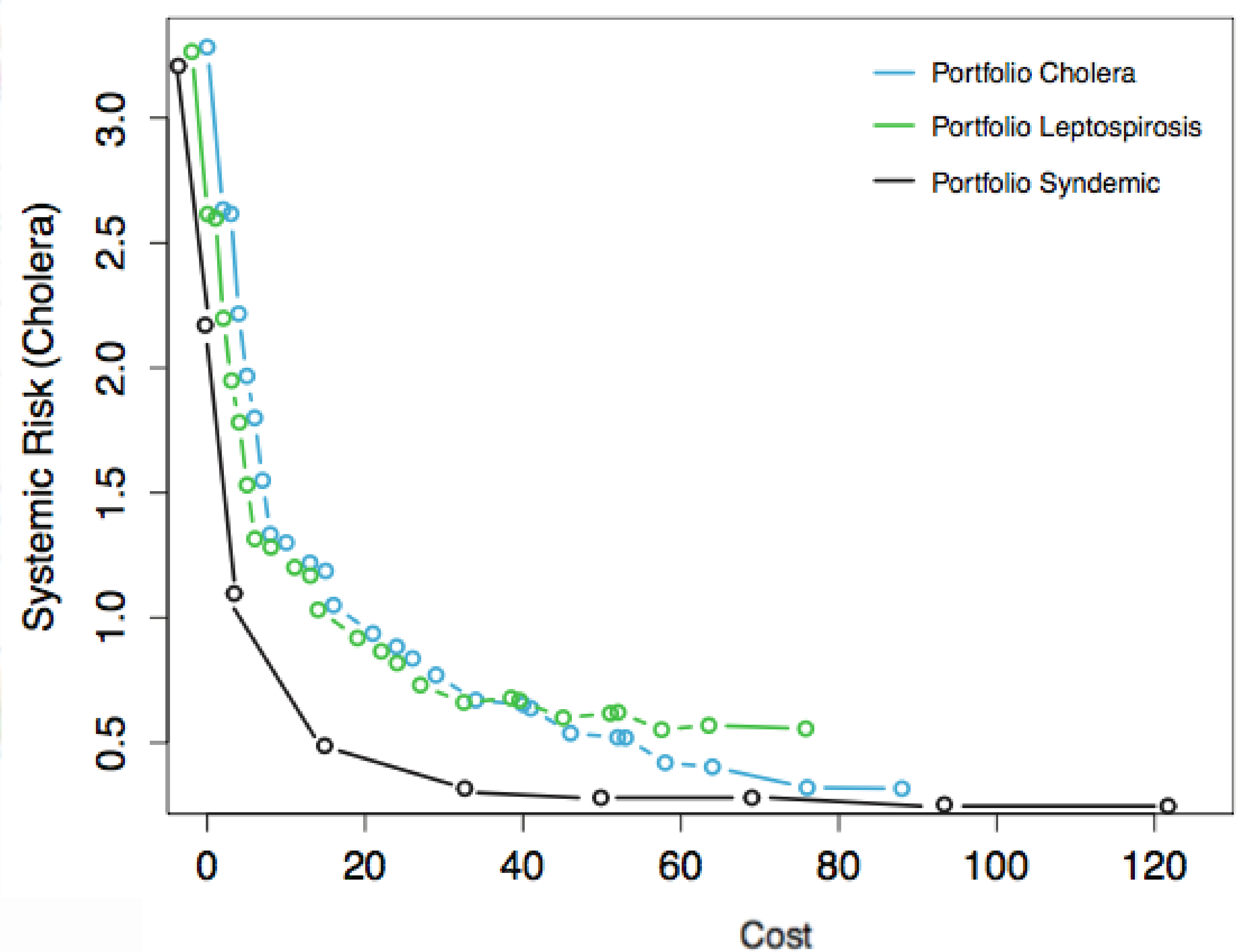
Monocontrol Strategy is not selecting one alternative a priori vs. a priori selected alternatives (in the latter scenario budget constraint may not allow to select the imposed alternative)

Portfolio does allow multiple alternatives

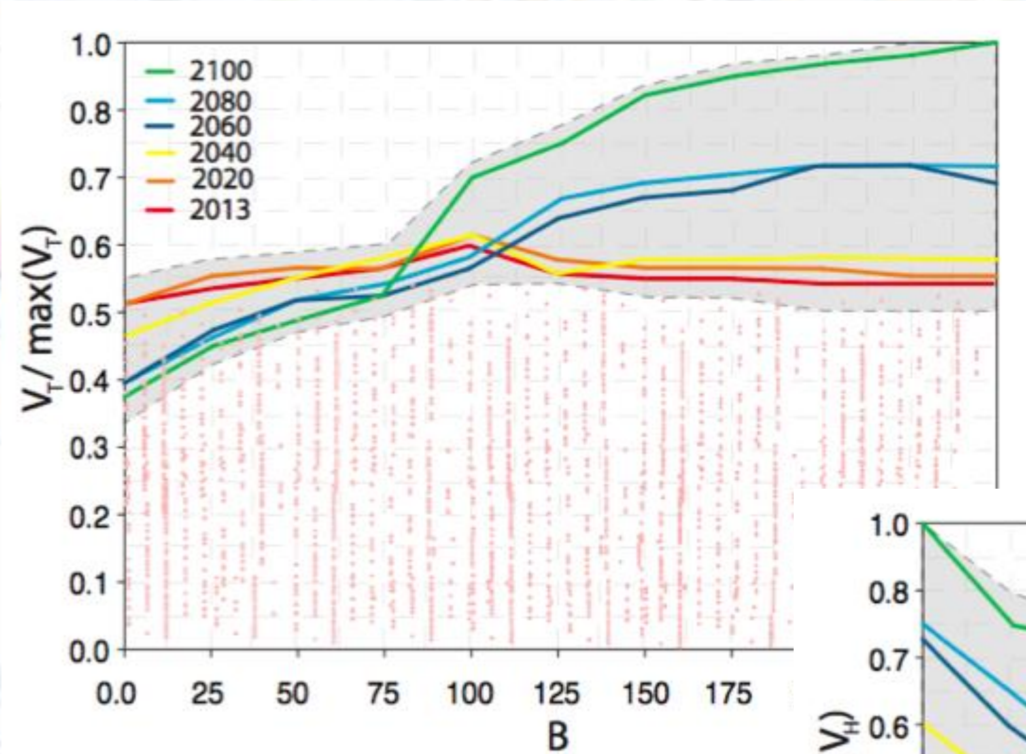
Syndemic Scaling

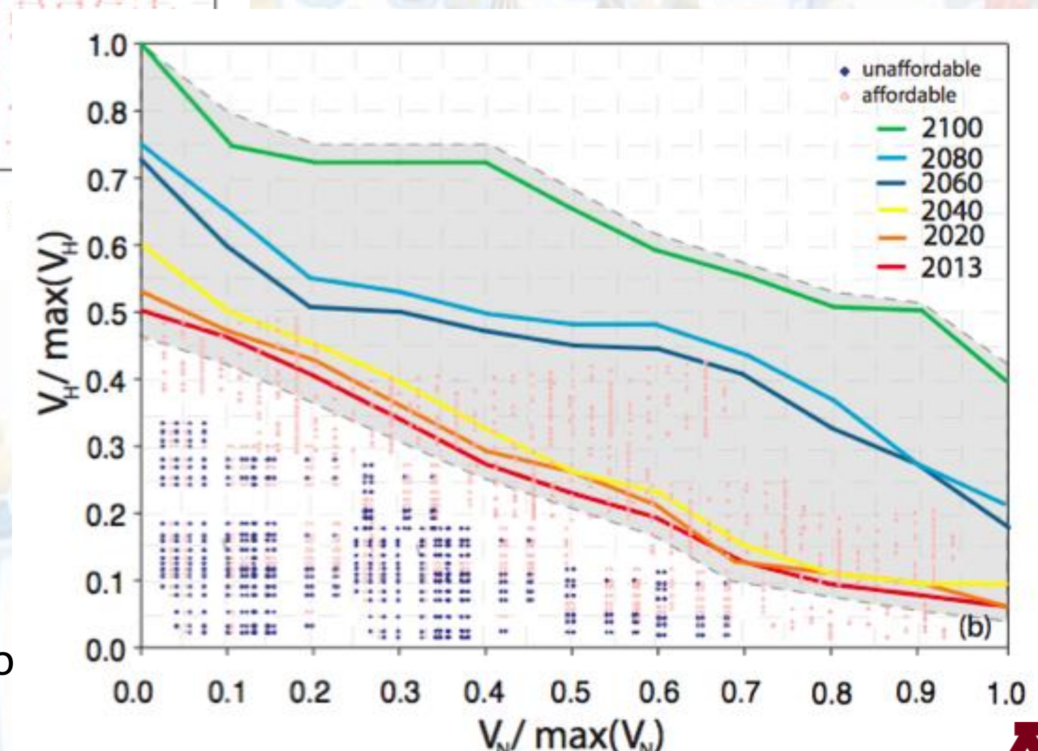


Optimizing Syndemic Management



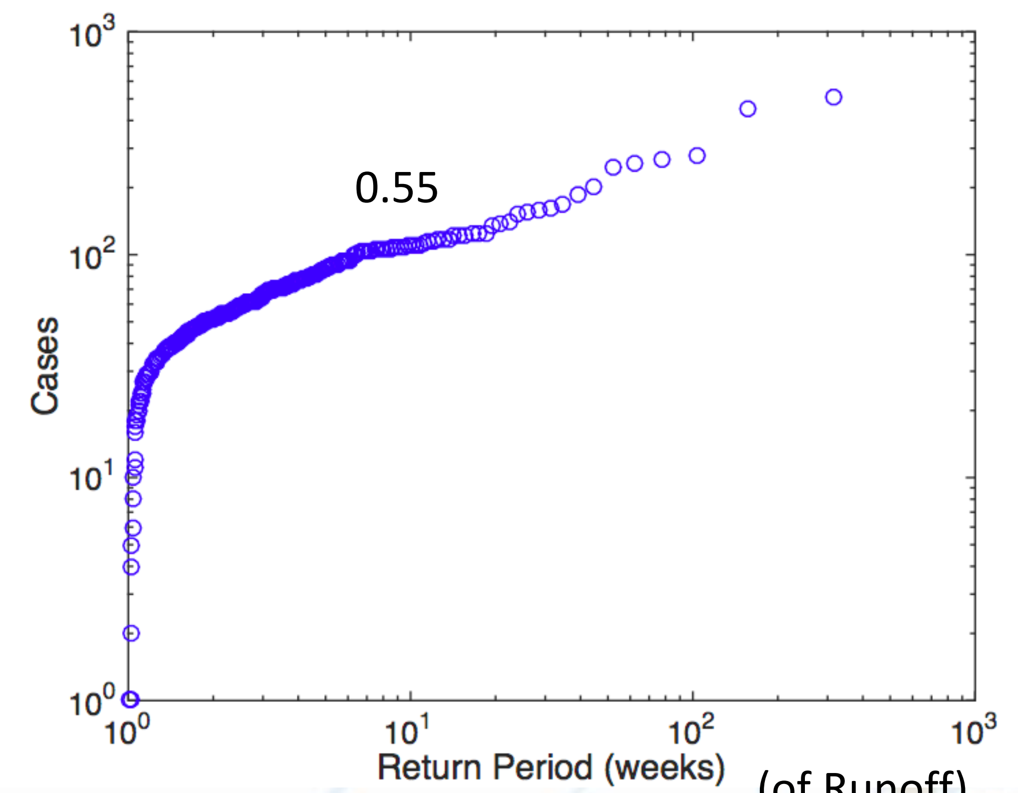
Pareto Frontiers considering urban and rural benefits



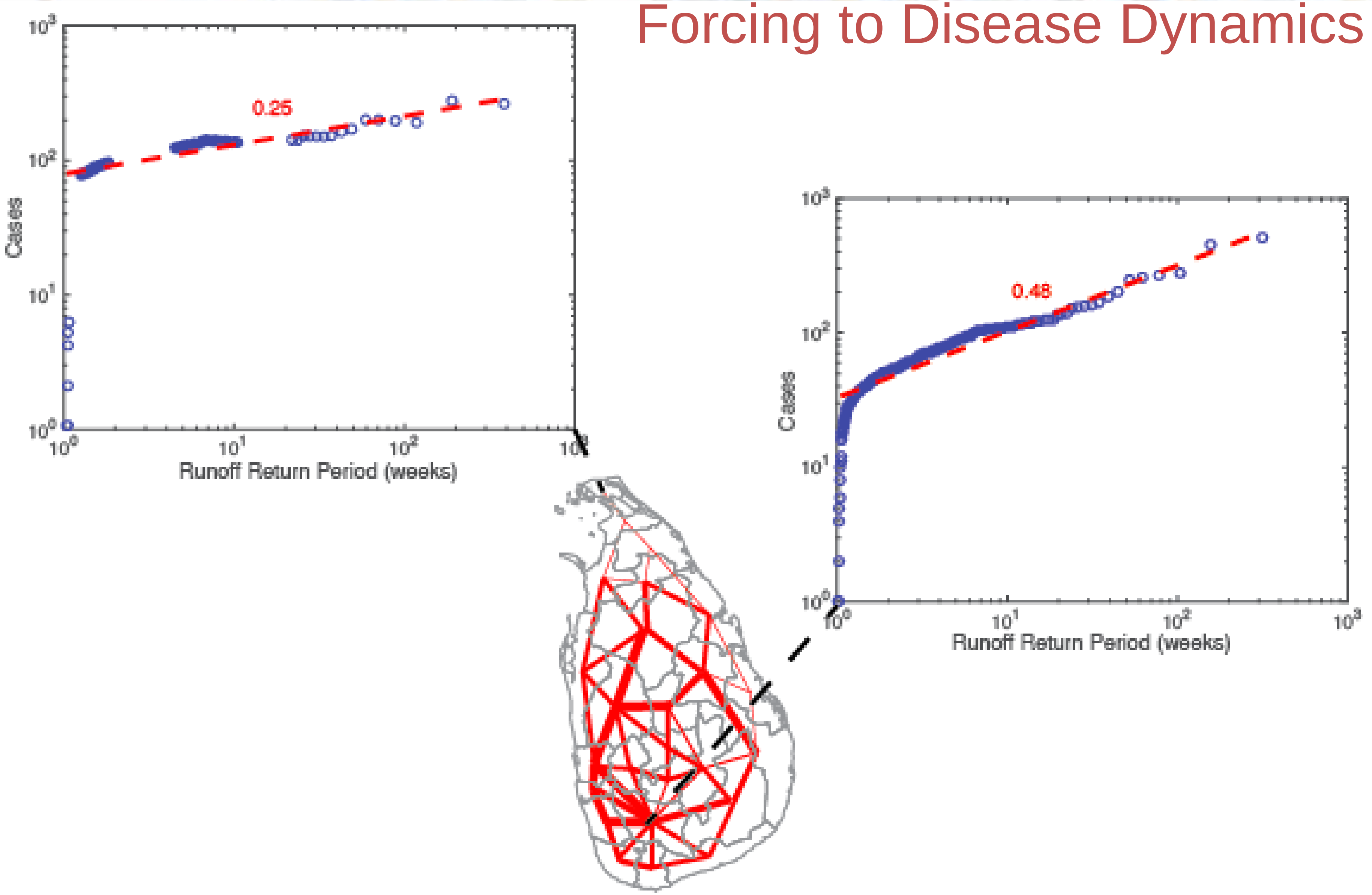


The relative values of urban and rural populations are assessed in the portfolio considering stakeholder preferences

Scaling Epidemiology

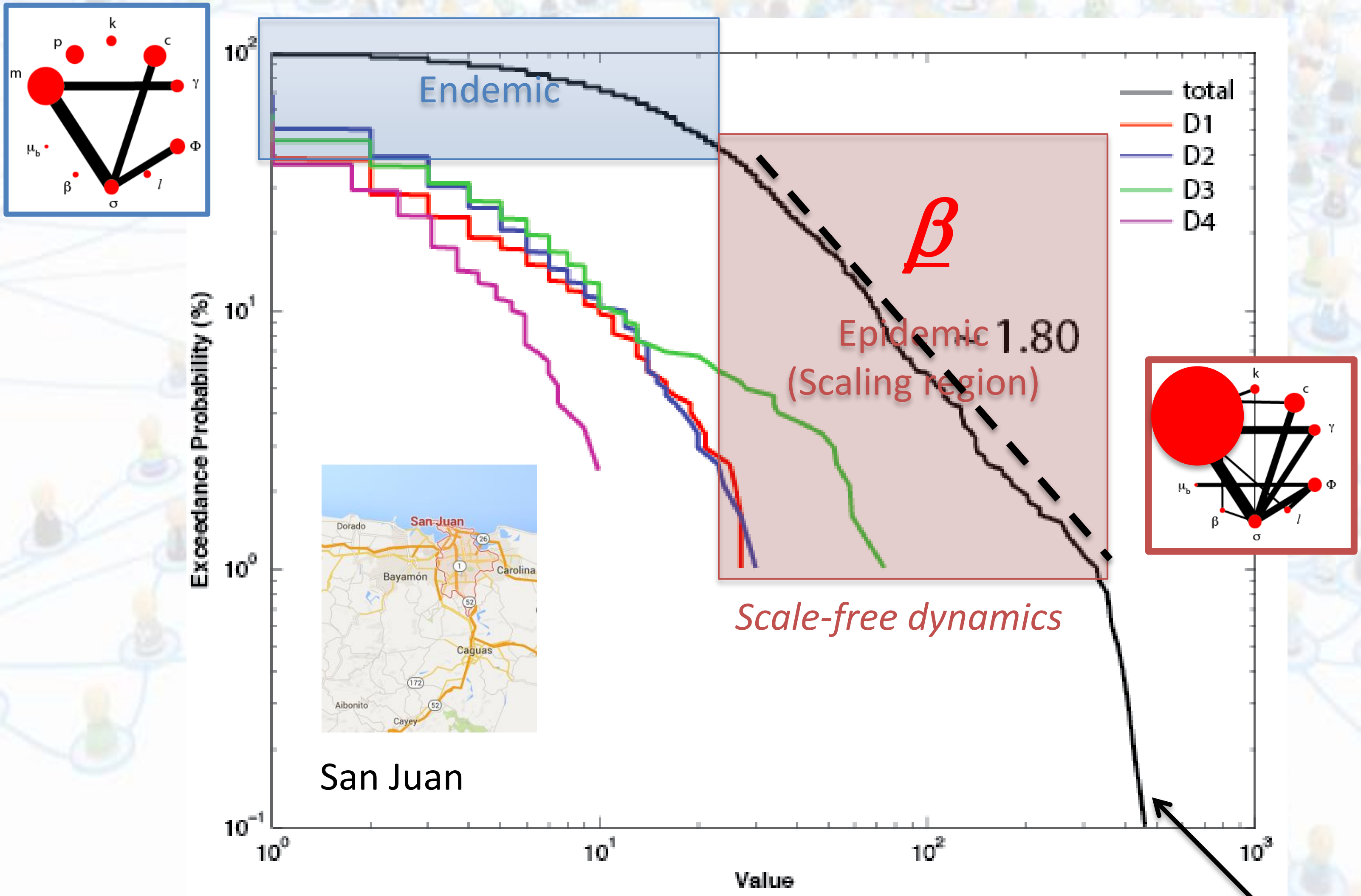


From Large Scale Forcing to Disease Dynamics



Distribution of EHL Outcomes

Exponential dynamics



$$P(I>i) \sim i^{-\beta}$$

Finite-size effects

Portfolio Conclusions

The portfolio management approach, by combining environmental and decision models, provides the most efficient allocation of resources in a quantitative sustainability perspective

Spatial heterogeneity and connectivity is critical for reproducing infectious disease dynamics and for optimizing health management. Model scale and resolution depends on stakeholder objectives

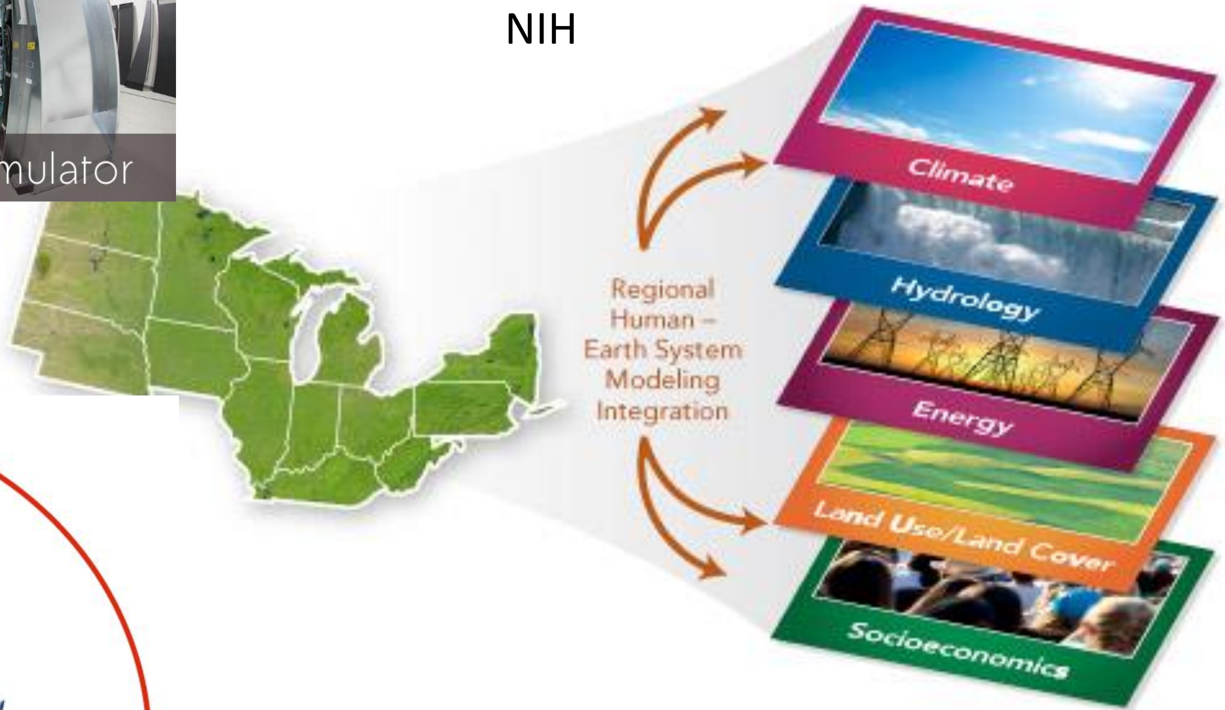
Global sensitivity and uncertainty analyses of the model allows one to capture variability in epidemiological and management factors. It allows also the detection and attribution of transmission pathways as well as to design the system

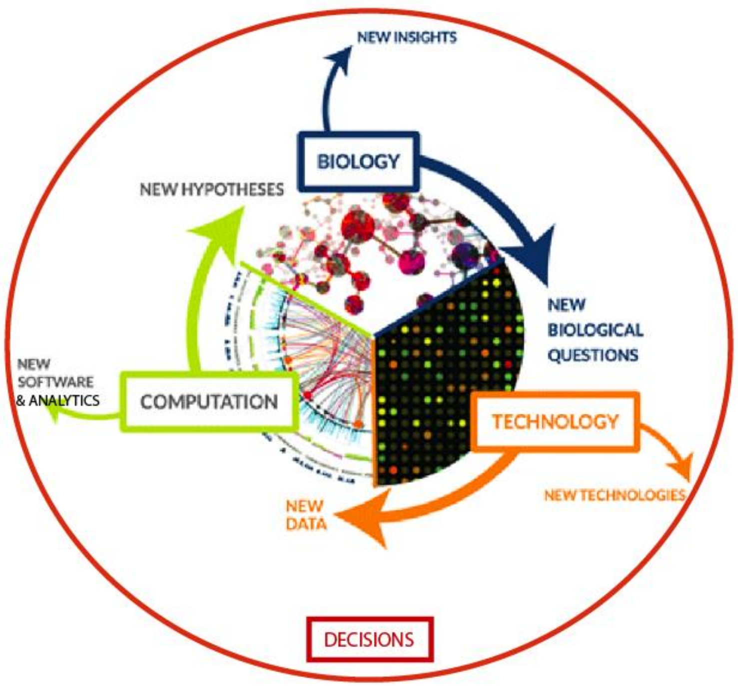
The model directly translates science into optimal practice. The model can be used as a real time technology for other affine syndemics and can formally include stakeholder mental models

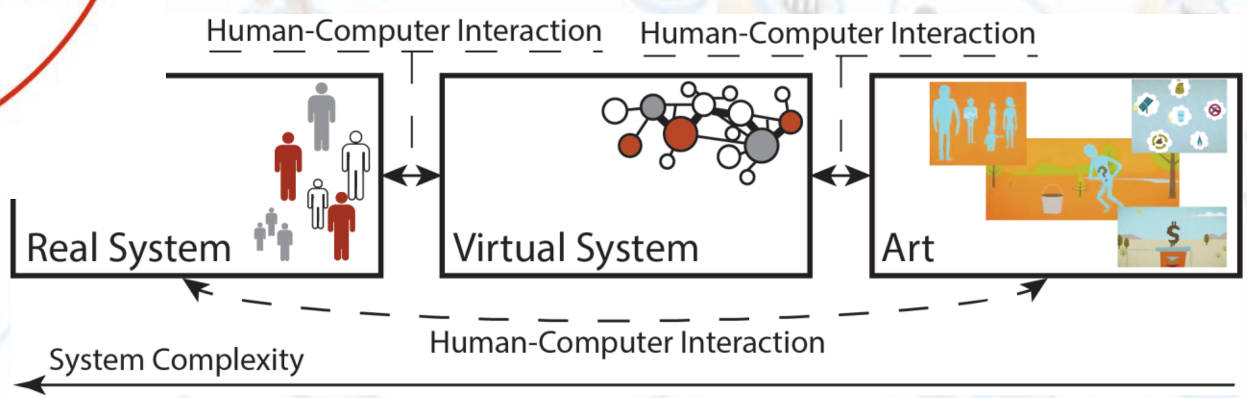
FuturICT
www.futurict.eu

CS4HS

IMAG
NIH







Pan American Health Organization

World Health Organization

REGIONAL OFFICE FOR THE Americas

HHS IDEA LAB

Thanks!

Matteo Convertino, PhD PE
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SMART Solutions

ComplexUS

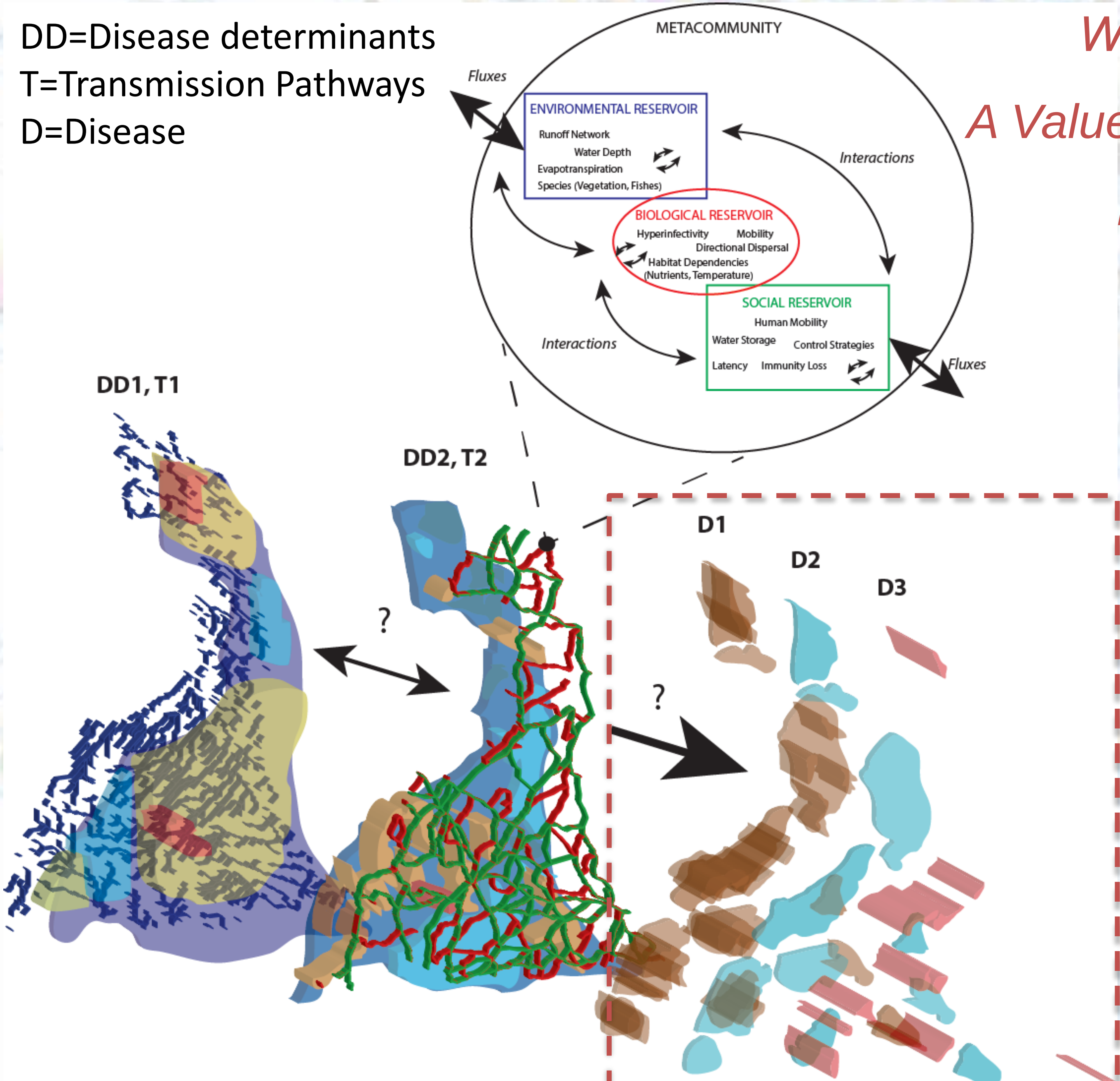
HumNat

Supplementary Material

DD=Disease determinants
T=Transmission Pathways
D=Disease

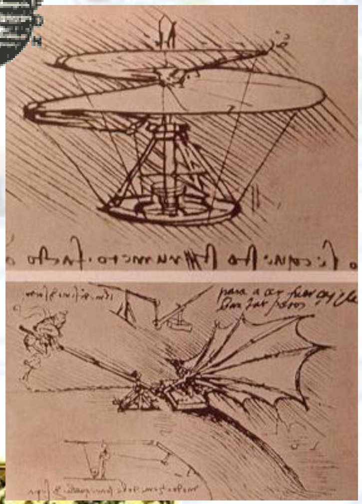
Web of "Causation"

A Value-based Statistical Physics Approach



Syndemics

Philosophical Foundations



Probabilistic Dynamics (Static Analysis) -> Return Period, Magnitude, Decay, and detection of disease regimes -> short term predictions

Mutual Information (Causal Dynamic Analysis) -> "hidden" and diverse functional networks of underpinning factors for different disease regimes -> long term forecasts

Macro-scale evolution (Macro Analysis) -> power-law growth of the disease (derived from the underlying or tendential criticality of disease dynamics) -> macroscopic patterns

Corollary: Mimicking the emergent patterns in nature (biomimicking) is useful for understanding the fundamental processes underlying the observed patterns. This is what models should capture