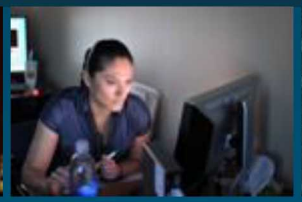
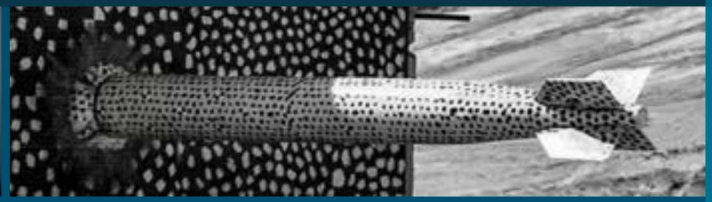
Sandia National Laboratories

SAND2018-10037PE

Modeling (Resilient) Communities





PRESENTED BY

Thushara Gunda

UNM Guest Lecture: CE 491/CE 598

September 10, 2018

U.S. DEPARTMENT OF ENERGY NNSA

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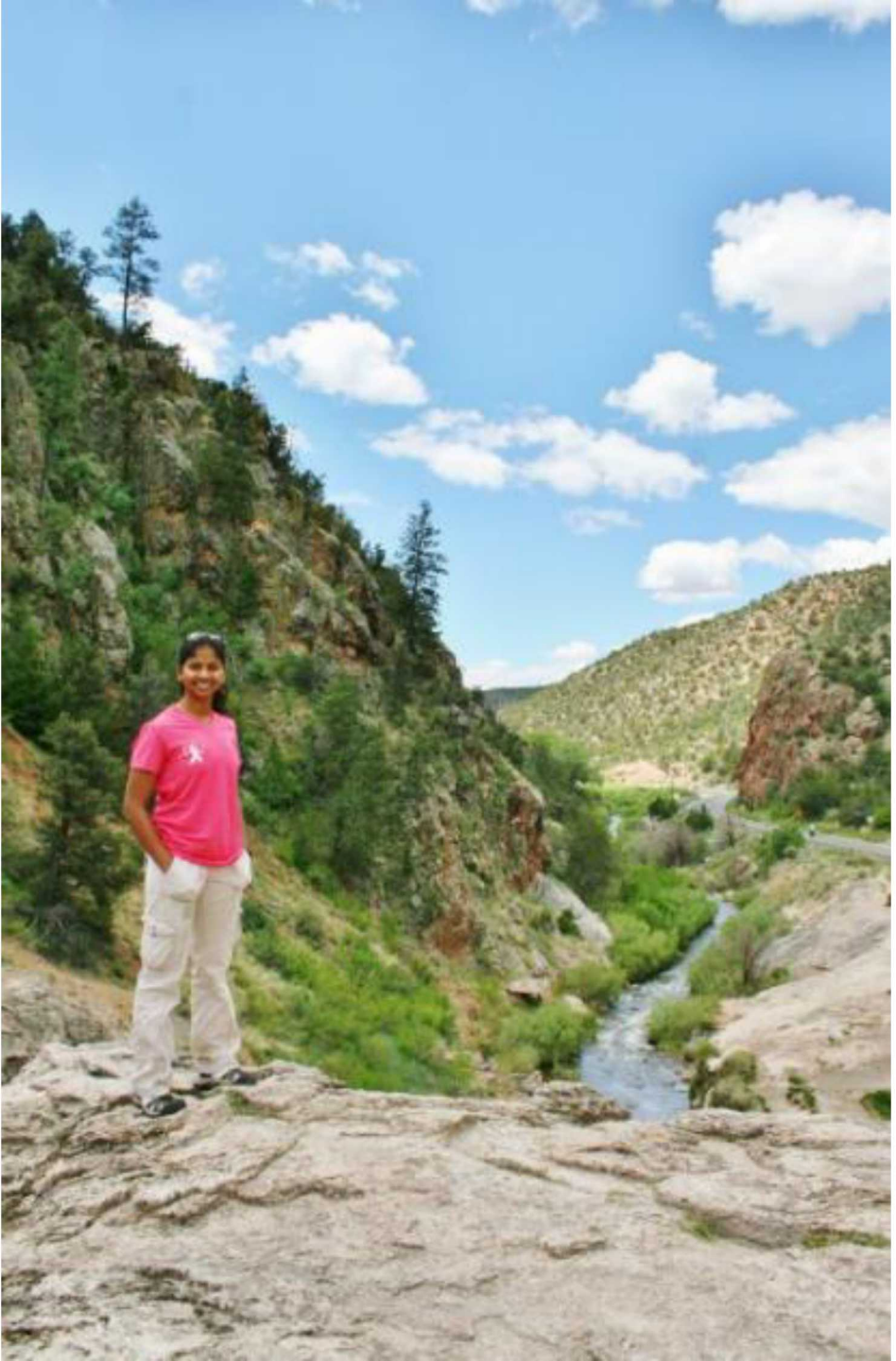
Outline

- Brief Bio
- Coupled Natural & Human Systems
- Conceptual Maps
  - Exercise
- Primary Modeling Techniques
- Data Sources
- Model Validation
  - POM
  - Counterfactuals



About me

- South Indian
- Northern Virginian
- Cavalier (UVA)
- Commodore (Vanderbilt)
- NSF Fellow

…

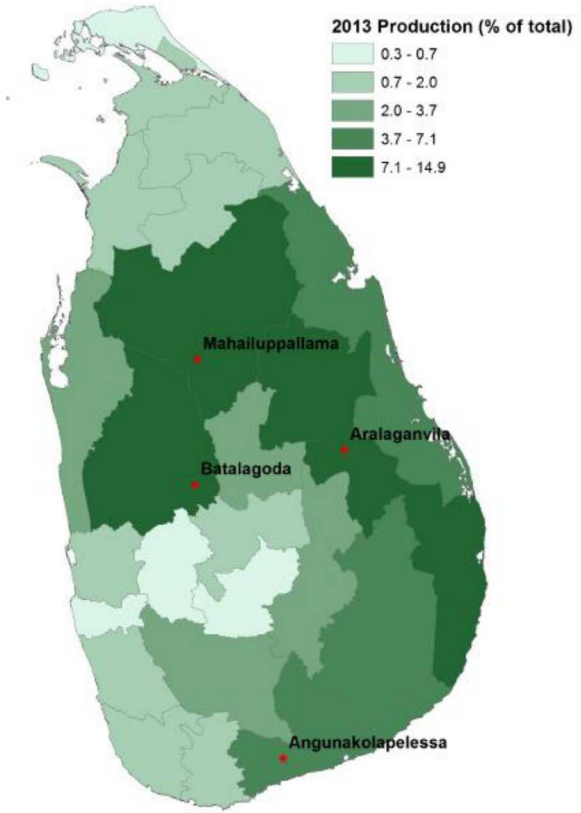
- Local Government
- Env Consultant
- Academic
- Sandian

…

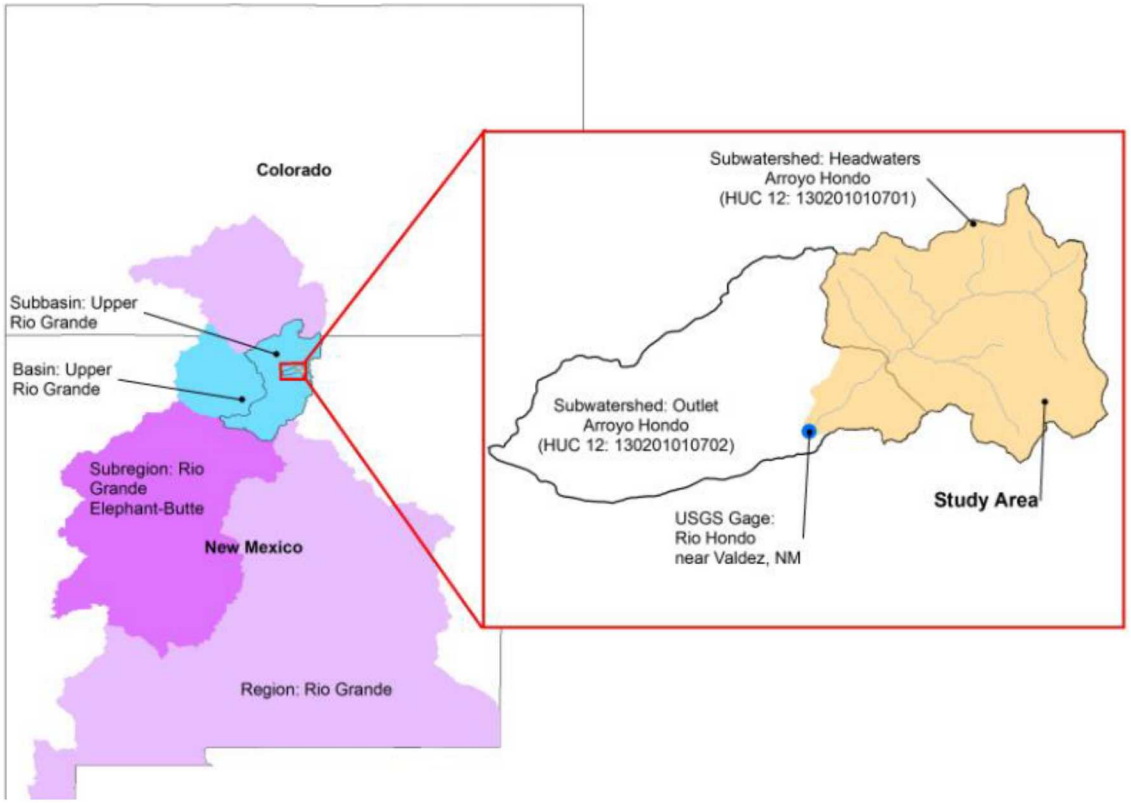
- Hiker
- Dancer
- Climber

Experience

Sri Lanka

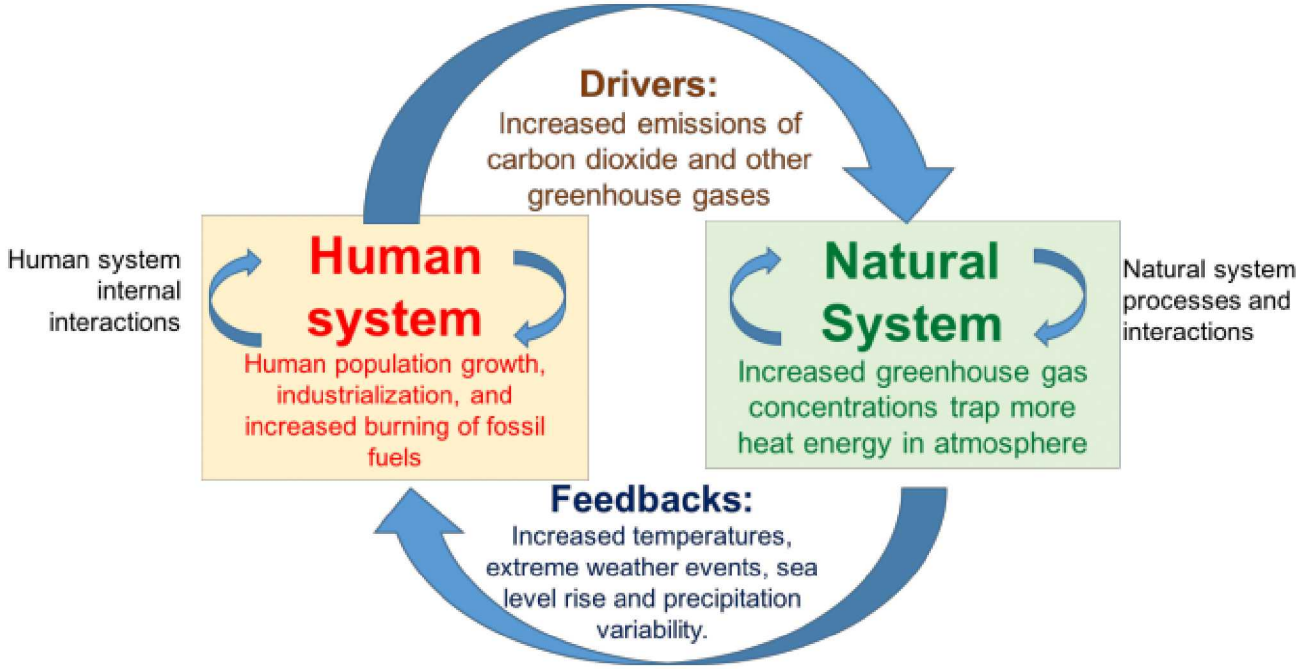


Valdez Acequia



Coupled Natural & Human Systems

- Emphasize feedbacks between two dynamic systems
  - Natural (e.g., hydrologic, atmospheric, biological, geological)
  - Human (e.g., economic, social, institutional, cultural)
- Focuses on the idea that the evolution of these two systems can no longer be treated in isolation
- By definition: interdisciplinary & cross-scalar
- Complementary to SES



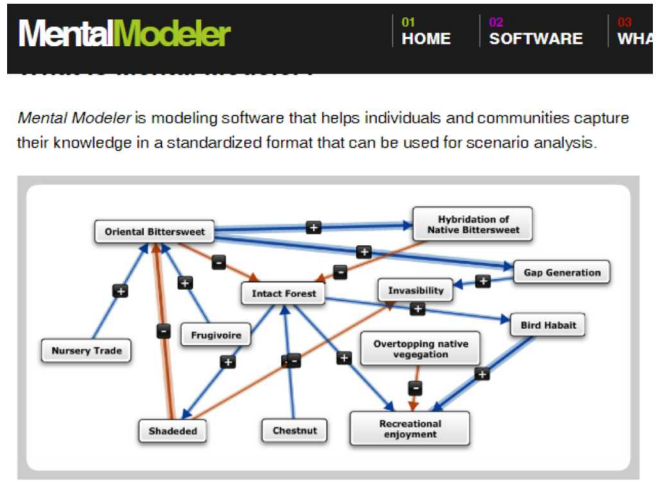
CHANS-Net
International Network of Research on Coupled Human and Natural Systems

http://chans-net.org/

Conceptual Map

- Tool to visually organize primary concepts and interactions between them
- Used in various settings, including teaching and research, to communicate common understanding of key knowledge of a system
- Particularly helpful in stakeholder engagement

- Few different approaches for drawing them
  - By hand
  - Powerpoint
  - Vensim
  - Mental modeler (http://www.mentalmodeler.org/)



What would a conceptual map of a community look like?

Class Brainstorming Time

Acequias

- NSF-funded CNH study
- "Acequia Water Systems Linking Culture and Nature: Integrated Analysis of Community Resilience to Climate and Land-Use Changes"
- Interdisciplinary team: hydrology, livestock and rangeland science, agronomy, economics, rural development and planning, and cultural anthropology)
- Lots of different foci: groundwater recharge from agricultural practices, land use change over time, etc.

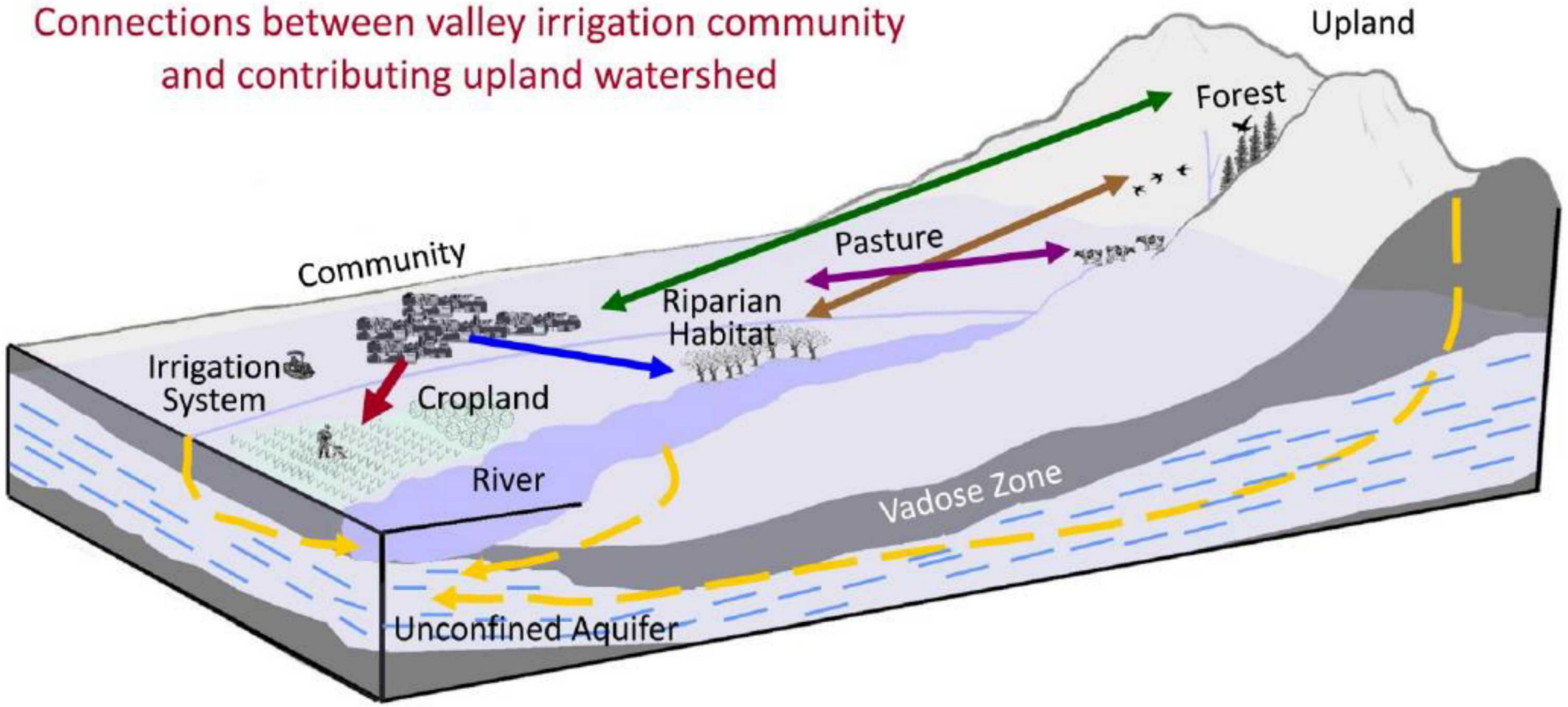

Ancient Traditions Keep Desert Waters Flowing

New Mexico's acequias—communal irrigation canals—still function as a tool to preserve and share scarce desert water.

(ACEQUIAS)

ANCIENT TRADITIONS KEEP DESERT WATERS FLOWING

Our subgroup focus: surface water



Exercise

Full Model

- Two models: upland (blue dashed box) and valley
- Shapes indicate whether a variable is an exogenous input (parallelogram and diamond) or process within a model (oval).
- Text color of the variable indicates the general dynamics they capture:
  - interconnecting variables (black),
  - sociocultural dynamics (purple),
  - biophysical (green),
  - socioeconomic (orange),
  - sociohydrological (light blue), and
  - hydrological (dark blue).
- The colors of the shapes indicate the variables modified for the different scenarios: upland pressures simulated by changes in the climate conditions (filled in yellow) and the additional downstream pressures simulated by changes in headgate closures (filled in gray).
- Not all linkages in the models are presented in the influence diagram (e.g., return flow from irrigation and impact of population demographics on domestic pumping).
- For a full list of equations governing model linkages, see Turner et al. (2016) for the valley model and the supplementary information for the upland model


AGU100 ADVANCING EARTH AND SPACE SCIENCE

Water Resources Research

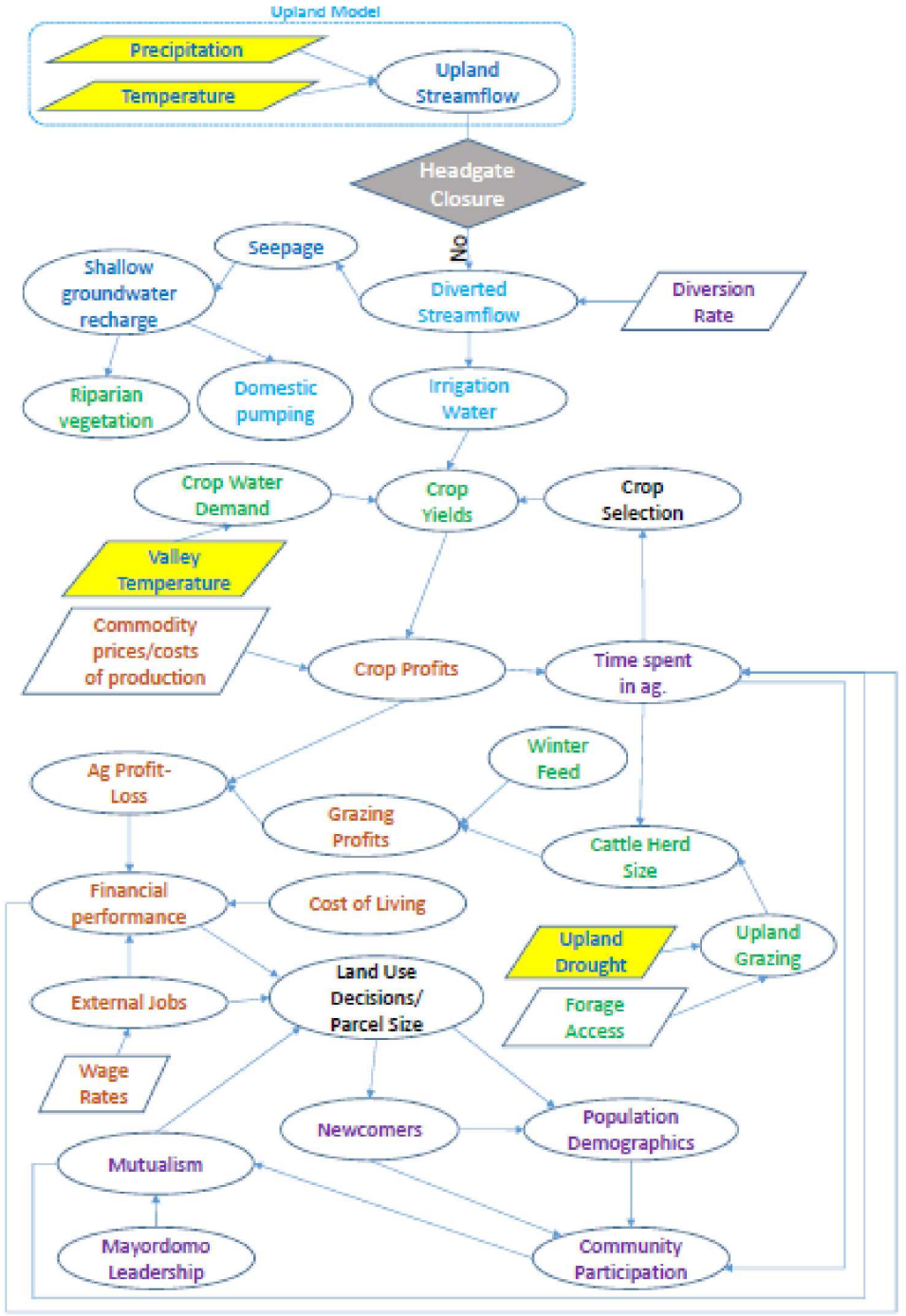
RESEARCH ARTICLE
10.1002/2017WR021223

Special Section:
Socio-hydrology: Spatial and Temporal Dynamics of Coupled Human-Water Systems

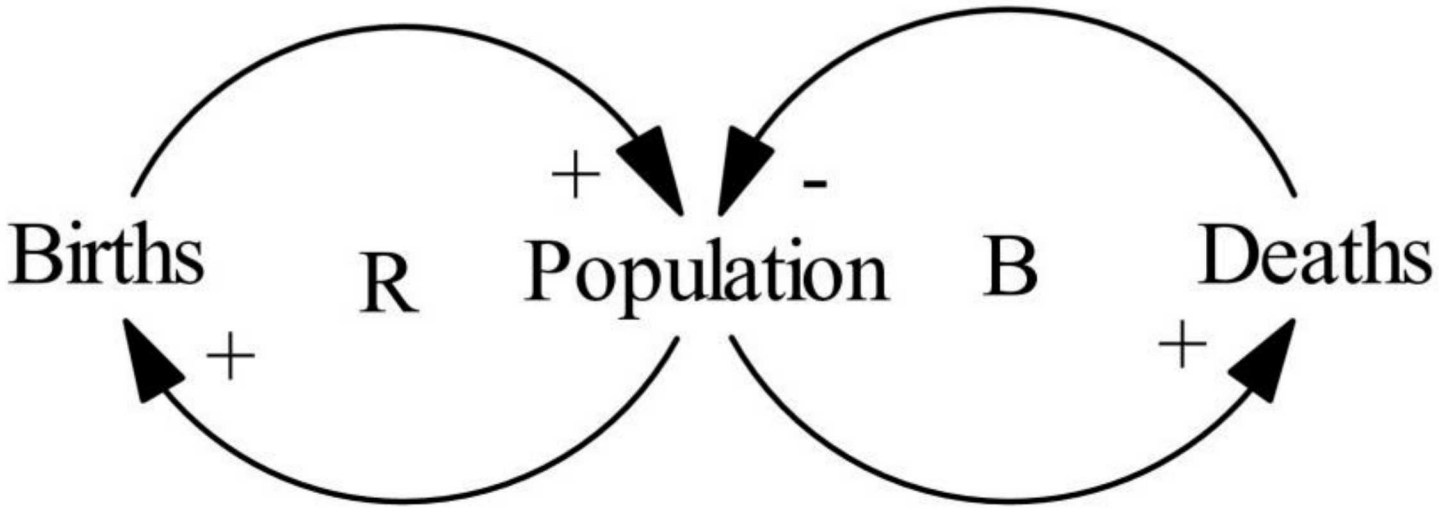
The Influential Role of Sociocultural Feedbacks on Community-Managed Irrigation System Behaviors During Times of Water Stress

T. Gunda[1], B. L. Turner[2], and V. C. Tidwell[1]

[1]Sandia National Laboratories, Albuquerque, NM, USA, [2]Department of Agriculture, Agribusiness & Environmental Sciences, Texas A&M University-Kingsville, Kingsville, TX, USA



Causal Loop Diagrams



- Focused on directions of interactions
  Signs on arrows indicate direction of influence
  - +: same direction
  - -: opposite direction

  Labels within feedback loops indicate direction of overall influences
  - R: reinforcing
  - B: balancing
- Hash marks (||) indicate time delay

Primary Modeling Techniques

System Dynamics

Discrete Event Simulations

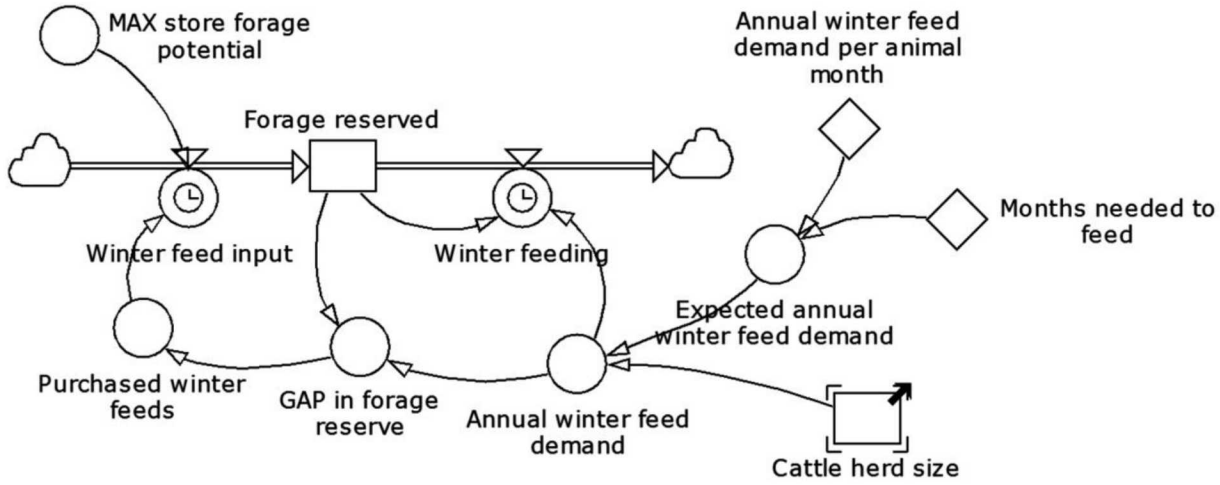
Agent-Based Modeling

Social Networks

Data Analytics (ML, DL)

System Dynamics

- Typically use a stock and flow approach
- Connect model components with feedback loops
- Generally focus on aggregate or macroscopic behavior
- Continuous time step
  - Tend to use differential equations
  - Account for time delays
- Resources for further information:
  - Vensim software: free license for educational use: http://vensim.com/vensim-software/
  - Powersim Software AS' instructional videos: http://www.powersim.com/main/services/simulation_services/get-started/
  - MindsEye Computing, LLC (models on Resources page): http://www.mindseyecomputing.com/Resources.html



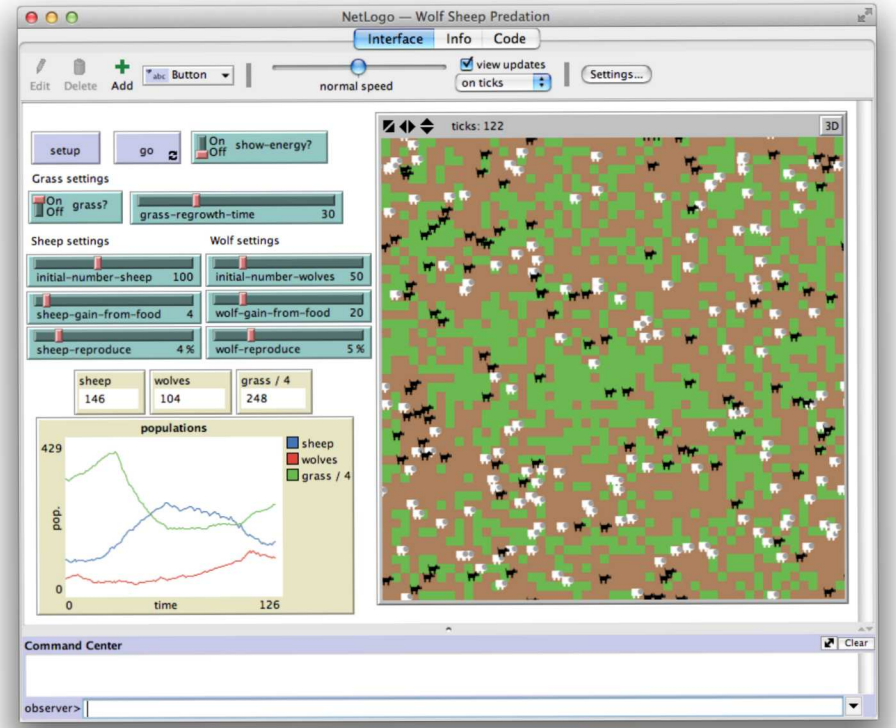
Stock and flow structure for forage inventory
from Turner et al (2016): http://www.mdpi.com/2071-1050/8/10/1019/htm

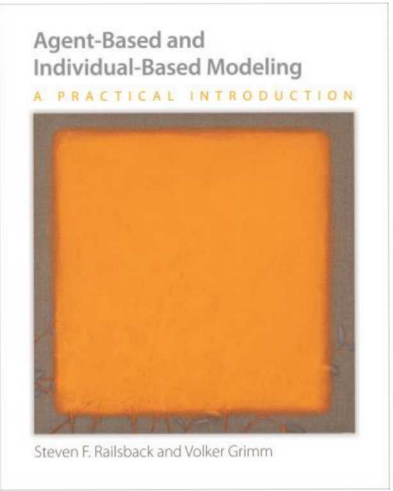
Vensim
VENTANA systems, inc.

Free license for educational use
http://vensim.com/vensim-software/

Agent-Based Modeling

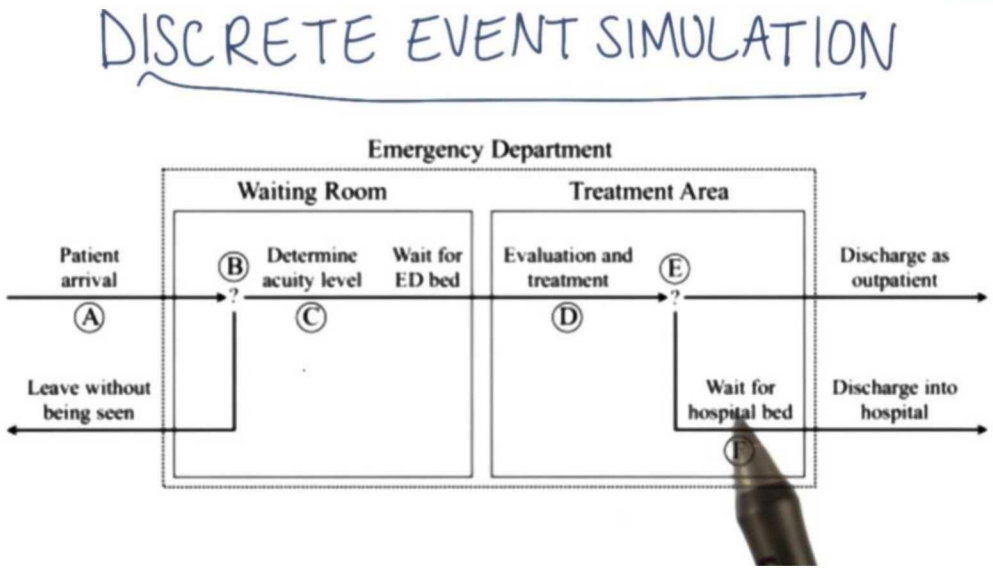
- Focus on emergent behavior of microscopic elements
- Driven by 'simple' individual (or "agent") behavior rules (e.g., birds in a flock)
- Account for agent interactions and heterogeneity in agent characteristics
- Applied to a range of domains, from translational biology to agricultural decision-making
- Resources for further information
  - Netlogo software: free, lots of example codes
  - Railsback & Grimm's book "Agent-Based and Individual-Based Modeling": best practices, sample Netlogo code
  - https://www.comses.net/resources/ repository of ABMs in other languages)





Discrete Event Simulations

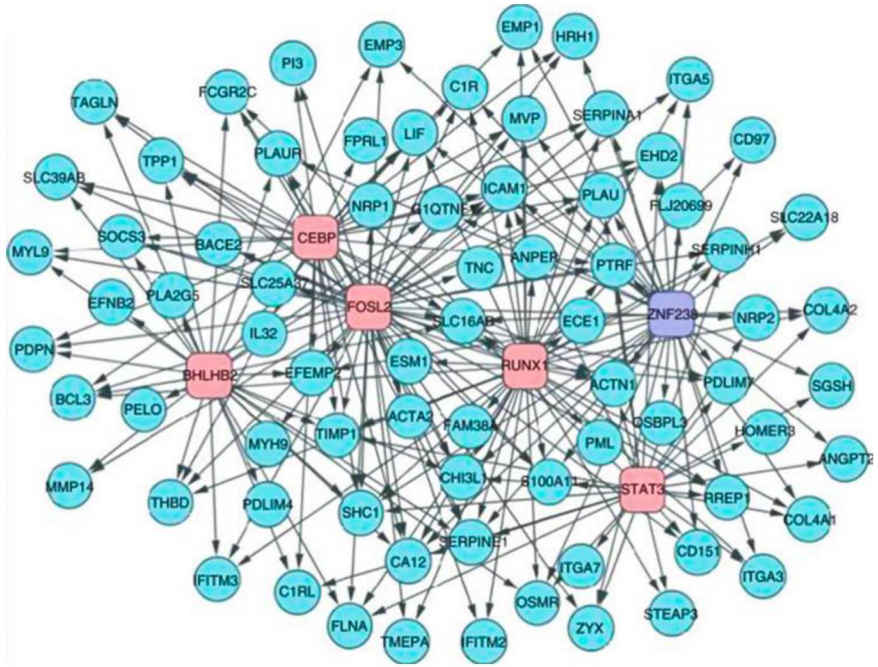
- Primarily focus on event triggers to drive system behavior
- Use entities (i.e., passive agents), gates, cues, and servers to represent events and associated system states to evaluate overall system bottlenecks and resource utilization
- Often optimal for understanding discretized practices such as train loadings, grocery line traffic, volcanic hazard predictions
- Resources for further information:
  - https://www.cs.cmu.edu/~music/cmsip/readings/intro-discrete-event-sim.html
  - MATLAB webinar series (5 videos)

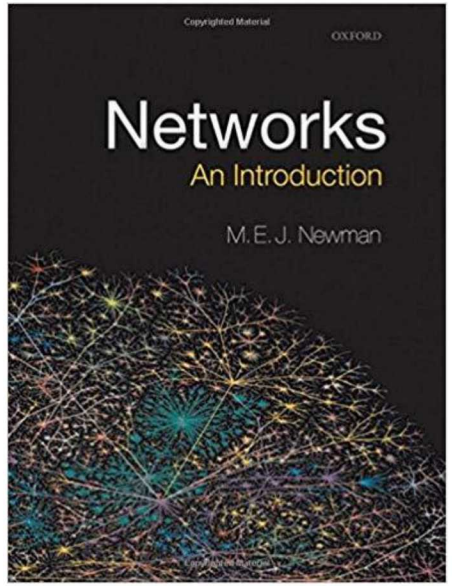


Source: https://www.youtube.com/watch?v=XHGBUO2Q4C0

Social Networks

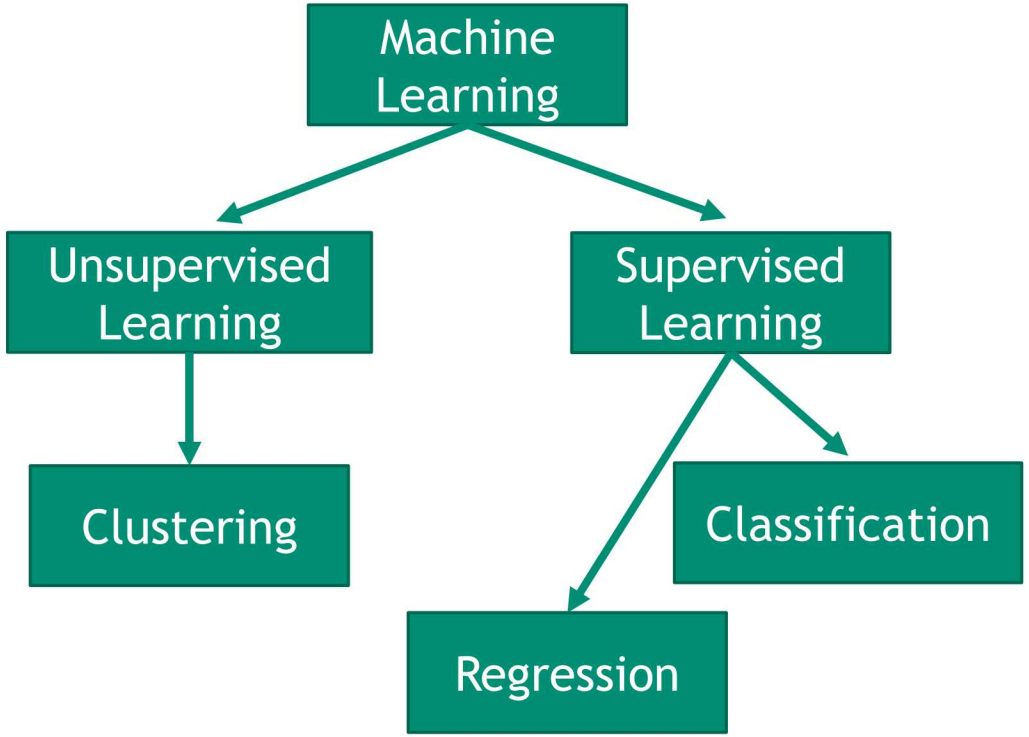
- Investigating social structures through the use of networks and graph theory
- Nodes are entities (people, organization, etc.) while links are relationships (or interactions)
- "Because structure always affection function" (Strogatz, 2001, Nature, pgs 268-276)
- Focused on understanding pathways of influence/critical nodes
- Applies in various domains including sociology, biological , communication studies, and computer science
- Resources for further information:
  - Newman's "Networks: An Introduction"
  - Python's NetworkX package: https://networkx.github.io/
  - Strogatz's 2001 paper: https://www.nature.com/articles/35065725





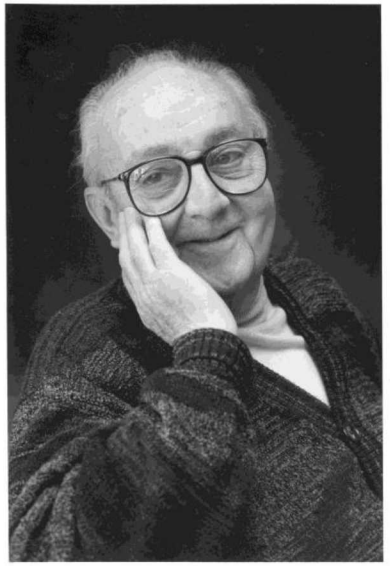
Data Analytics

- Primarily data-driven
- Can incorporate diverse sources of information (including audio files, text documents, etc.)
- Implemented methods dependent on model requirements and data availability
  - Black box vs. causality insights
  - Descriptive vs predictive
  - Machine Learning vs Deep Learning
- Resources for further information:
  - R & Python websites
  - Coursera classes: Intro to R, Python, Data Science, etc.



Which approach do you use?

- Depends on multiple factors
- What question are you interested in?
- What are your model priorities - is black box ok?
- Would a hybridized approach better suit your needs?
- What resources are available (personnel, expertise, time, data, etc.)?



"All models are wrong, but some are useful"
-George P. Box

Data

- Regardless of methodological approach, "natural" or "human" focus, require data in some shape or form
  - Caveat: assuming non-theoretical focus
- 3 primary classes
  - Learn from previous work: literature reviews, books, etc.
  - Collect your own/field work: water samples, interviews (SMEs), workshops, games in the field*, in-depth/ethnographic studies
  - Leverage big data: satellite imagery, social media platforms, etc.

Challenge: Quantitative vs. Qualitative Insights

*can be incredibly valuable if executed well

Source: Gunda et al., (2017)
http://iopscience.iop.org/article/10.1088/1748-9326/aa5ef7

Q&A

Always welcome to contact me:

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