# NEXT GENERATION MODELS FOR PLANETARY MANAGERS
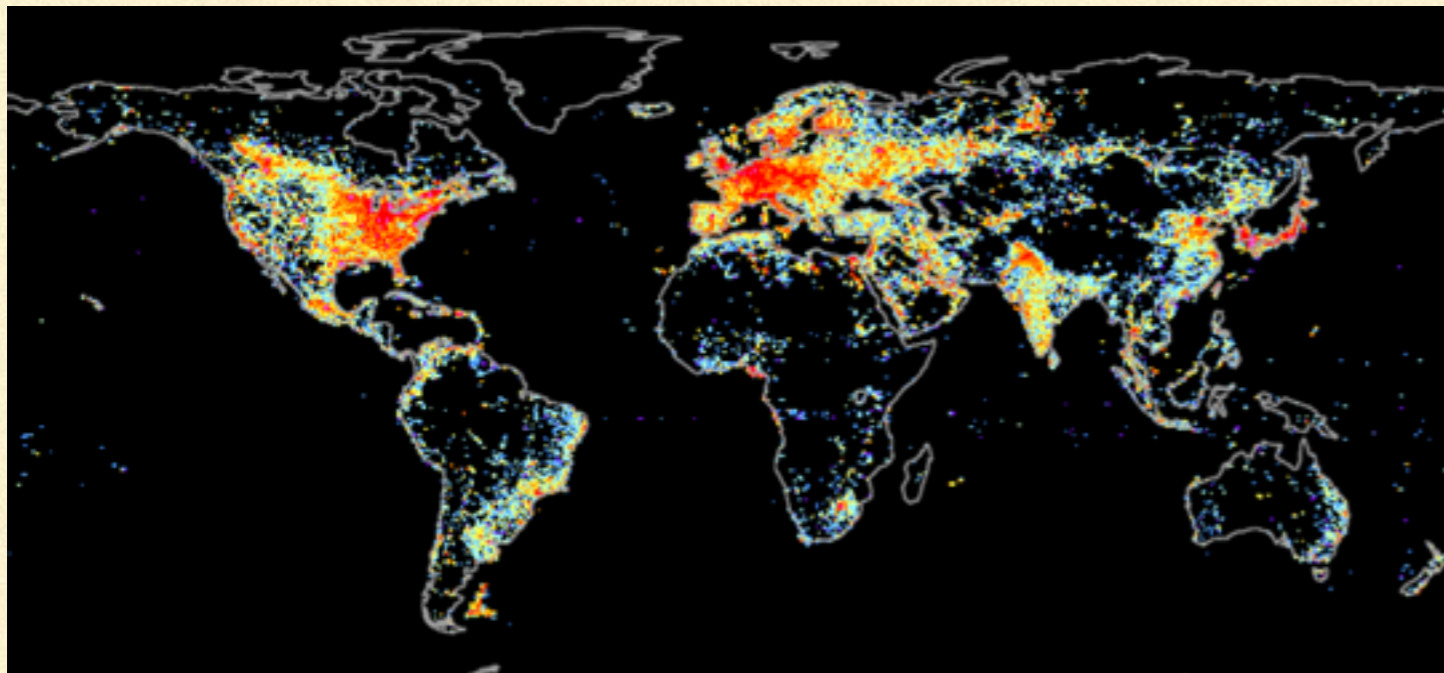
Michael Barton - May 2016

ARIZONA STATE UNIVERSITY

# A HUMANIZED PLANET



- > 50% of land in crops or pasture
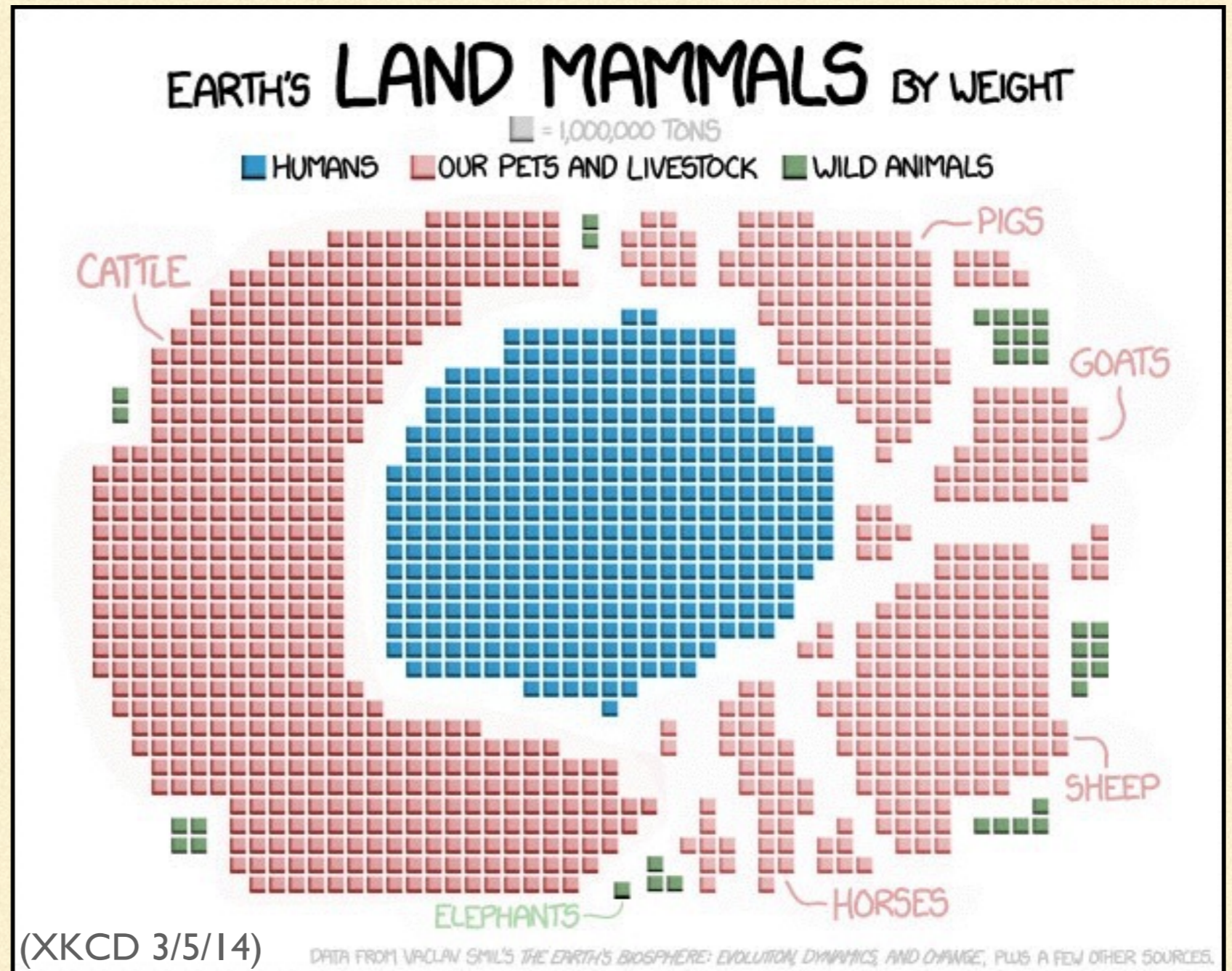
# A HUMANIZED PLANET



- > 50% of land in crops or pasture

- > 50% of forests cleared; more reforested

# A HUMANIZED PLANET

- Humans plus agro-biomass >3 billion tons

- More than all other vertebrates combined (land and sea)



EARTH'S LAND MAMMALS BY WEIGHT

□ = 1,000,000 TONS

■ HUMANS ■ OUR PETS AND LIVESTOCK ■ WILD ANIMALS

CATTLE · PIGS · GOATS · SHEEP · HORSES · ELEPHANTS

(XKCD 3/5/14)

DATA FROM VACLAV SMIL'S *THE EARTH'S BIOSPHERE: EVOLUTION, DYNAMICS, AND CHANGE*, PLUS A FEW OTHER SOURCES.

# A HUMANIZED PLANET

- Coastlines engineered

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- > 50% of fresh water used and 6x more water stored
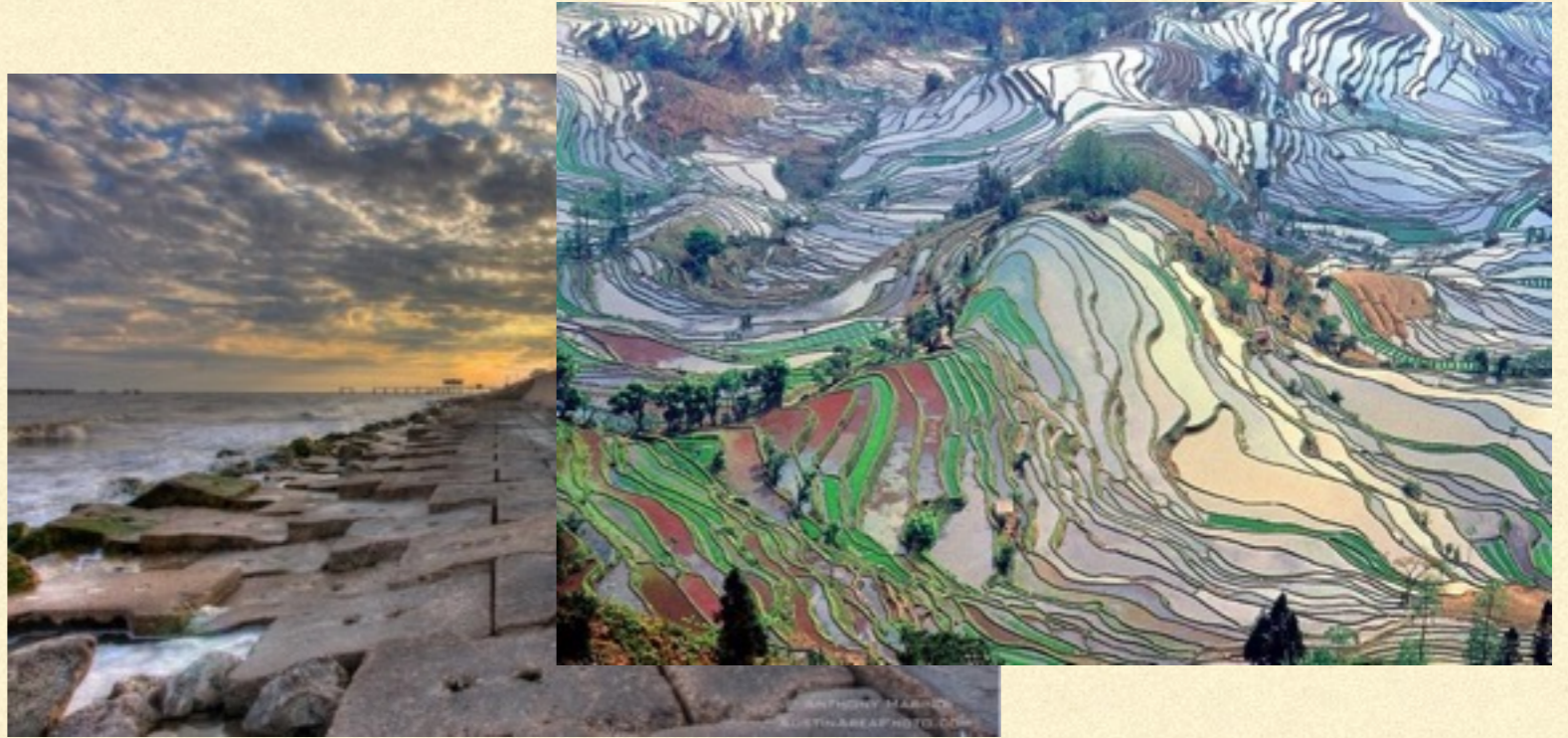
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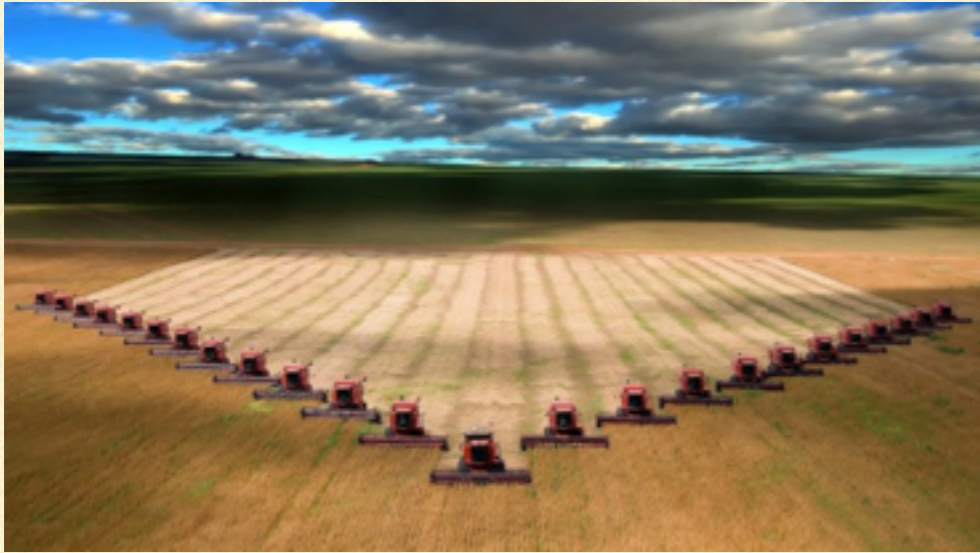
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# A HUMANIZED PLANET

- Coastlines engineered

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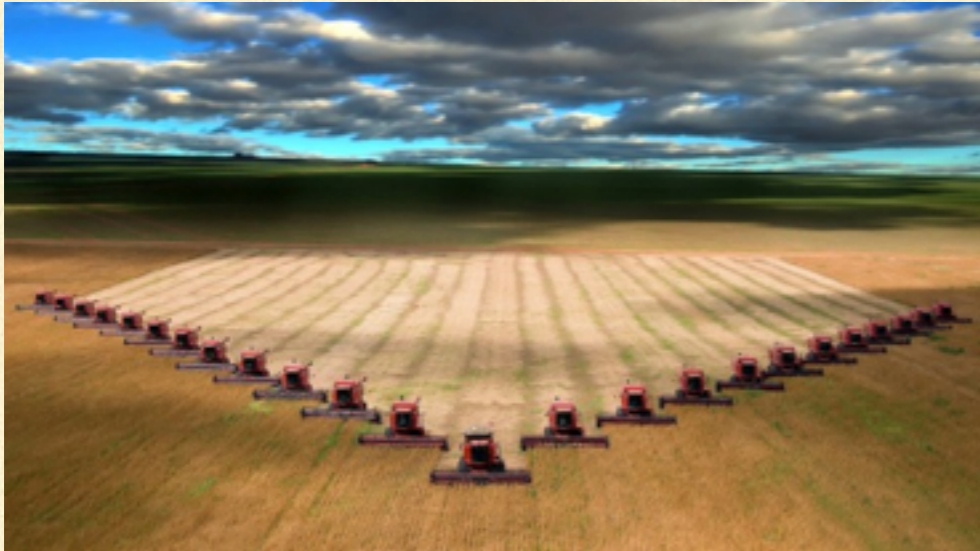- More N cycled

- More sediment transported

# A HUMANIZED PLANET



Ruddiman et al 2016

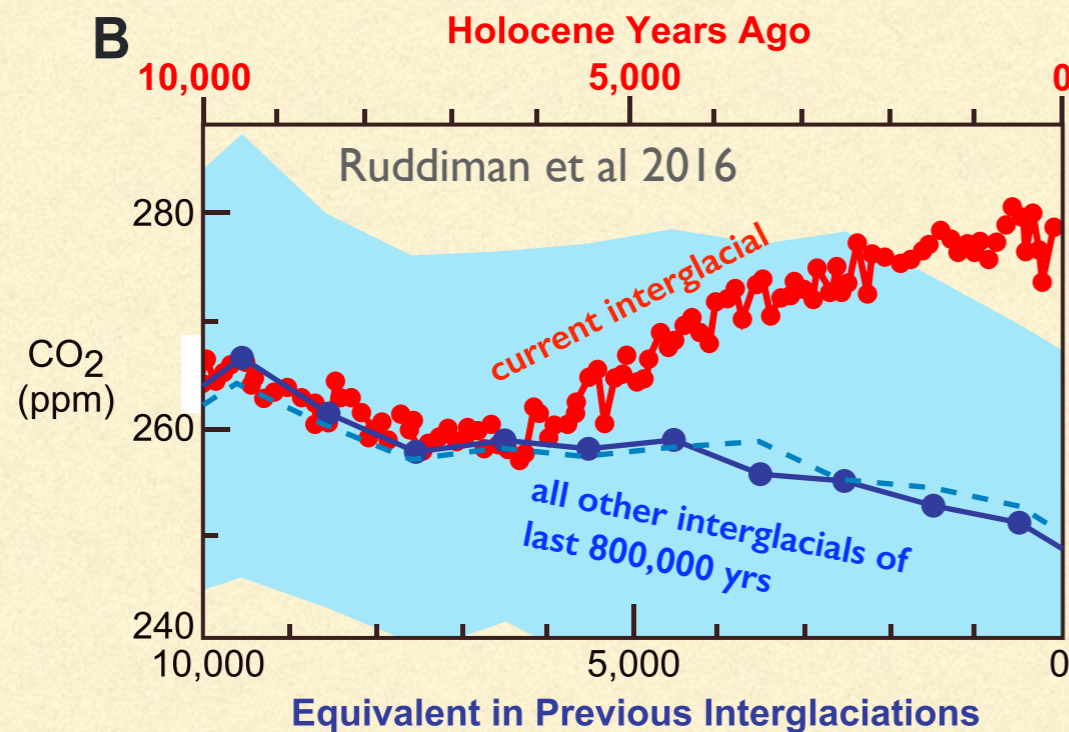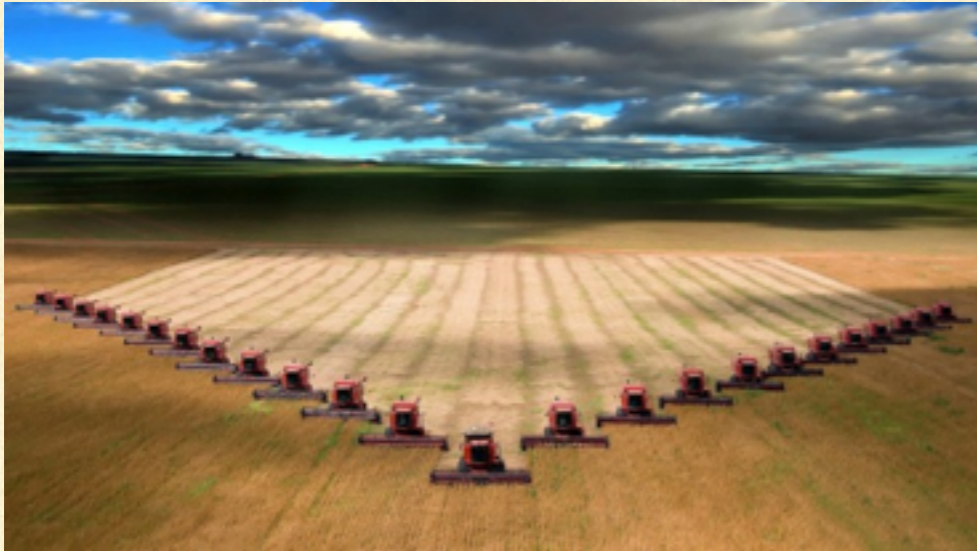- Humanity is more than a global keystone species

# A HUMANIZED PLANET



Ruddiman et al 2016

- Humanity is more than a global keystone species

- Our planetary environment shaped by human decisions, technology, and nature

# A HUMANIZED PLANET



- Humanity is more than a global keystone species

- Our planetary environment shaped by human decisions, technology, and nature

- Human impacts can exceed non-human forces



B

Holocene Years Ago

10,000      5,000      0

Ruddiman et al 2016

280

$CO_2$ (ppm)

260

240

current interglacial

all other interglacials of last 800,000 yrs

10,000      5,000      0

Equivalent in Previous Interglaciations

# A HUMANIZED PLANET

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- The human species has transitioned from individuals harvesting wild resources

- To communities managing local ecosystems

- And now are confronted with the need to manage our planetary systems
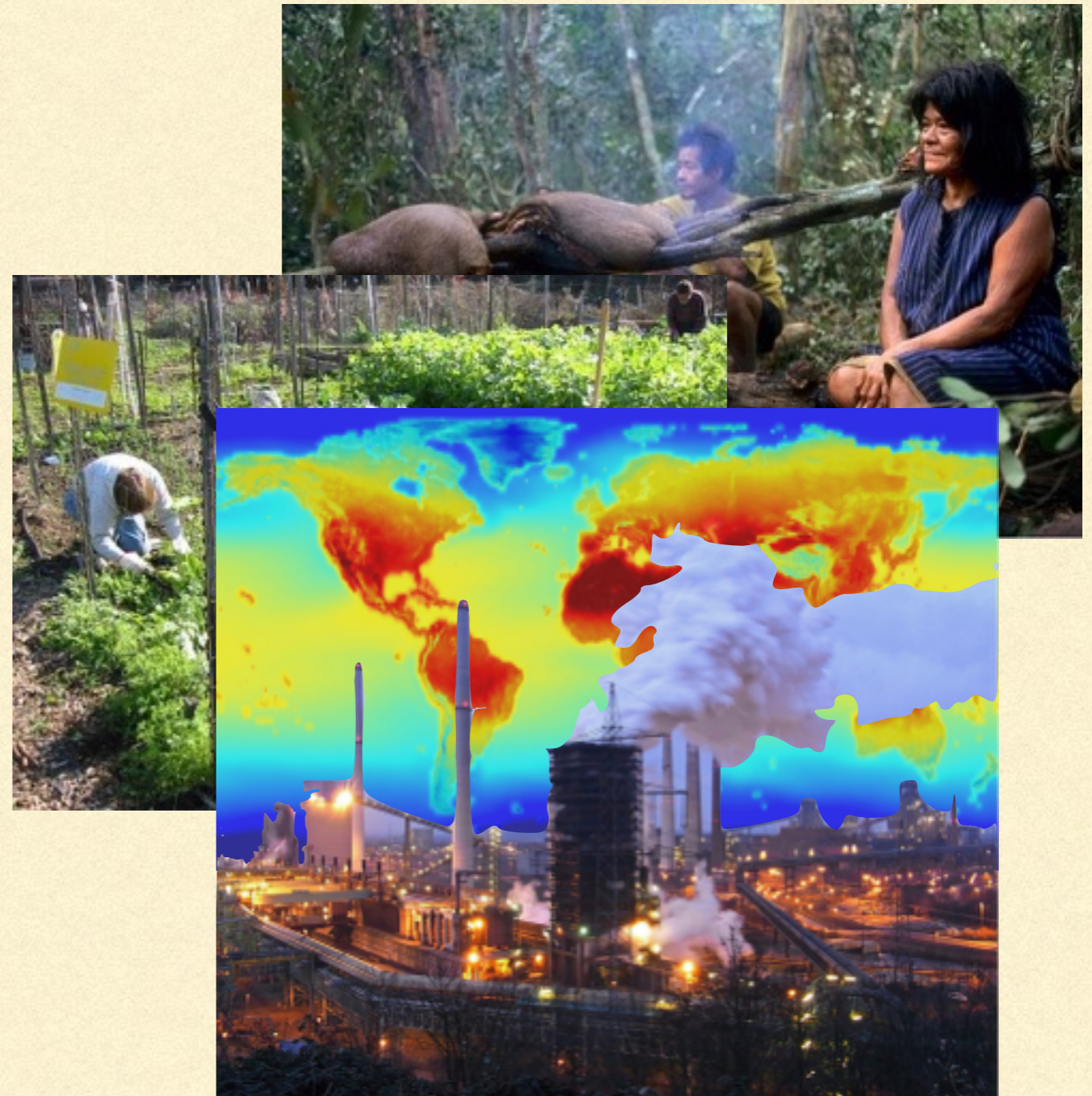
# A NEW SOCIAL REALITY

- Our social life has also become global

- Humankind has transformed from a normal terrestrial animal to a unique global phenomenon

- Nearly 8 billion people

- Over half live in urban hives of millions of individuals

# A NEW SOCIAL REALITY



- Digital media and rapid transportation now connect humanity economically, socially, and culturally in a global network of multiple, cross-cutting ties

- This has created *complex social-ecological-technological systems* (CSETS) at planetary scale

# A NEW SOCIAL REALITY

- A few millennia ago, all people lived in small communities

- An individual could observe social and natural phenomena and extrapolate the consequences of their actions on fellow humans and the natural world

- This is no longer the case

# PLANETARY CSETS
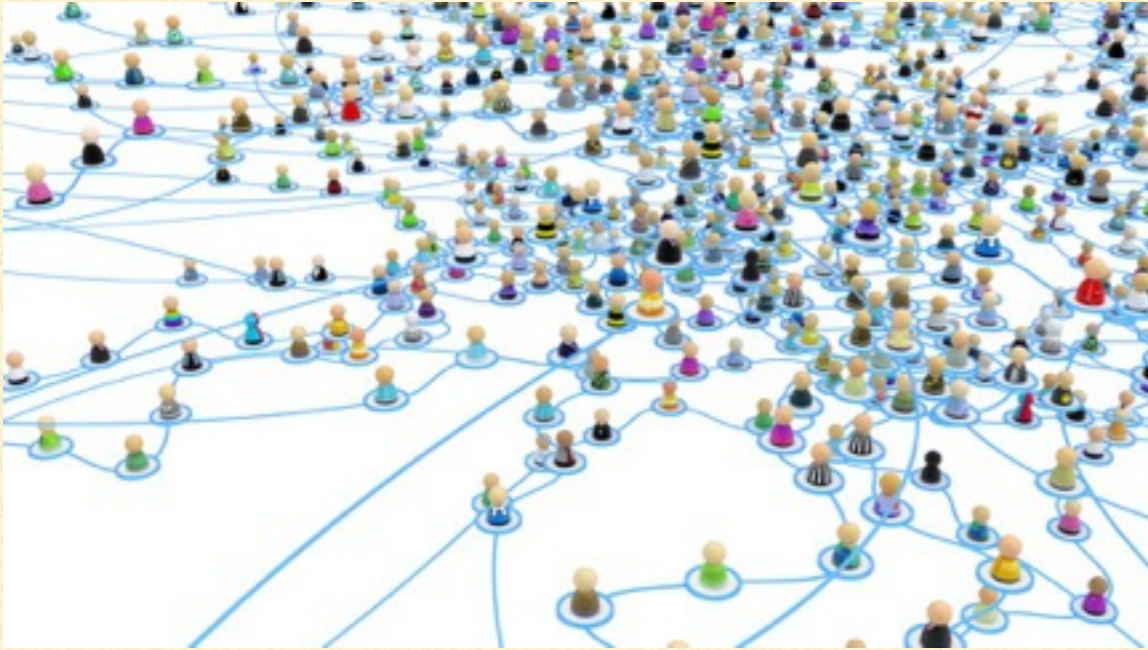


- Scale and complexity of our global CSETS *unprecedented for any organism in earth's history*

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# PLANETARY CSETS

- Scale and complexity of our global CSETS *unprecedented for any organism in earth's history*

- CSETS multi-dimensional, multi-scale causality and non-linear dynamics *exceed our innate abilities* to anticipate the consequences of decision-making

- And human system dynamics are *major drivers of Earth's biophysical environment*

# NEXT GENERATION SCIENCE FOR PLANETARY SOCIOECOLOGICAL SYSTEMS



- In an Earth dominated by rapidly changing, telecoupled human and biophysical processes…

- we need next generation data-driven science and modeling to enable us to sustainably manage dynamics of a planetary socio-ecological system

# NEXT GENERATION SCIENCE FOR PLANETARY SOCIOECOLOGICAL SYSTEMS

- Building new capacity in data science and modeling of human systems at planetary scales poses significant challenges

- Require coordinated, community-wide efforts

- Need to build on existing research and also be willing to explore new directions

- Briefly outline some of the relevant issues and challenges
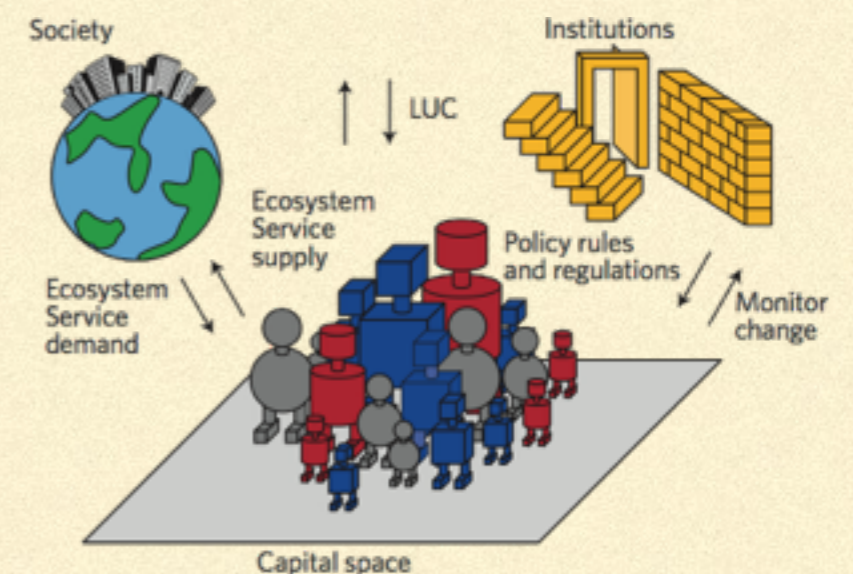
# MODELING GOALS

- All models are wrong but some are useful (G. Box)

- What kind of models are most useful - produce the most value - for scientific understanding and for planetary management?

- Generative/process models vs. descriptive/empirical models

- Models as experiment & scenario creation vs. replicating the planet *in silico*

  - Which behaviors or phenomena are controlled or boundary conditions?

  - Which are simulated?

  - Which can be ignored?
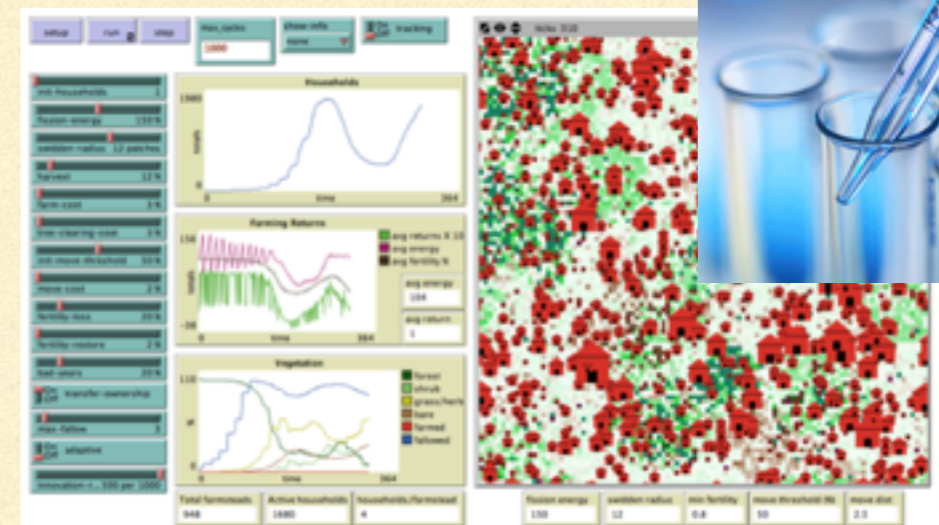
# FEEDBACKS ARE CRUCIAL
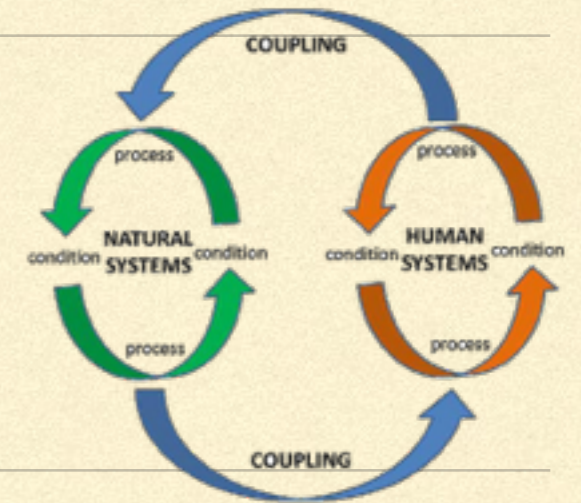


- We know from abstract models and small-scale realistic simulations that…

    - Insignificant differences can have enormous consequences in complex systems due to cascades of interaction effects and feedbacks

    - Powerful forces can have negligible consequences for the same reasons

- Feedbacks in CSETS should be equally important at global scales.

- How can we create modeling environments that simulate feedbacks between human and biophysical processes?

# SPACE MATTERS…EXCEPT WHEN IT DOESN'T
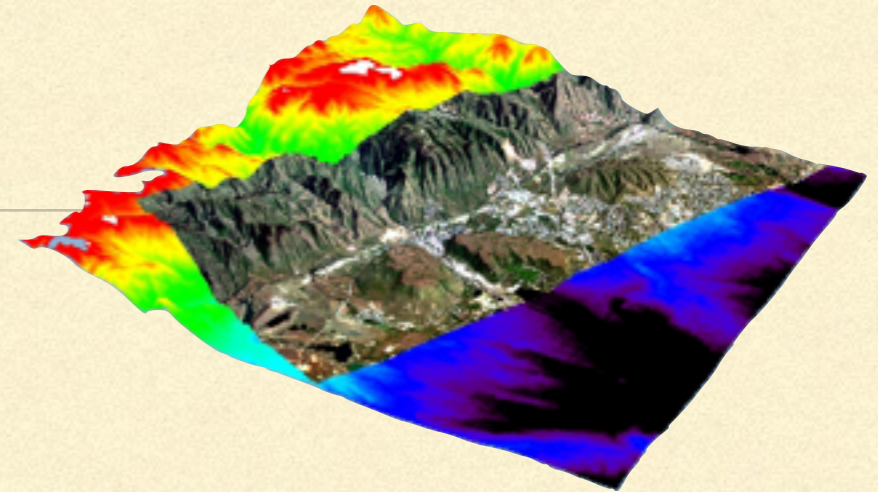


- Much current social science is aspatial

    - e.g.: individual cases studies, social networks, national surveys, economic indicators

- Human action and impacts on biophysical systems are local and vary across space

    - But interaction effects change across scales

    - And electronic media have created global interaction networks where distance is irrelevant—though consequences may still be local.

- How can we represent interactions of spatially-explicit social actors and distance-irrelevant information networks?

# DYNAMICS CROSS MULTIPLE SCALES

- Climate is global, weather is local. Policies and institutions are top down, human action is bottom up.

  - Combined effects of many individual actions are changing climate

  - Climate imposes boundary conditions on weather which affects human actions

- Interaction effects and feedbacks cause CSETS dynamics operate across multiple scales.



- How do we model cross-scale processes and consequences
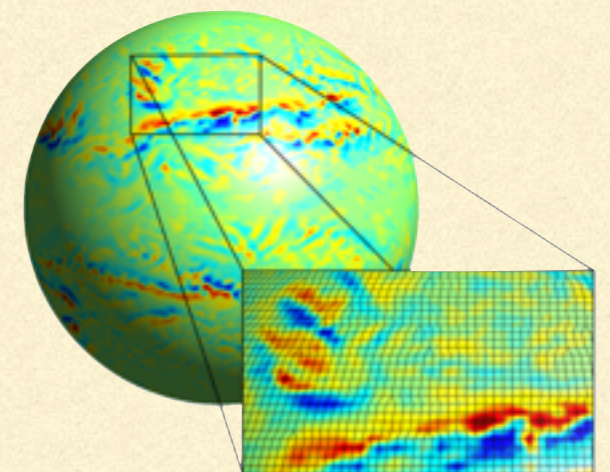
# WHERE & HOW TO COARSE-GRAIN
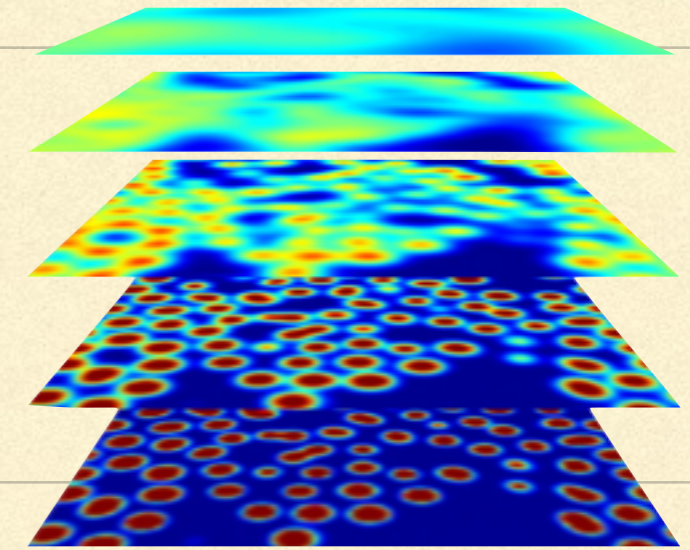


- In all CAS, higher level emergent properties are not easily explained or predicted from properties of individual lower level components

    - All biophysical and human components of CSETS composed of subatomic particles

    - Earth's thermal balance can be represented in a single equation

    - Neither scale of analytical units or processes helpful for understanding and managing most relevant dynamics of global CSETS

- Between the scales of modeling 8 billion individual agents, and aggregating all people into a single variable, what provides the most value and is most tractable?

- How to downscale and coarse-grain up human systems processes and interactions at chosen scales?

# BIG DATA ARE SMALL DATA

- Much current social science focuses on …

    - Few, information rich cases

    - Indices aggregated across a few regions

# BIG DATA ARE SMALL DATA

- Much current social science focuses on …

  - Few, information rich cases

  - Indices aggregated across a few regions

- Need to make much better use of …

  - Many cases with a little information in each

  - High-dimensional data

  - Integrating ontologically diverse and multi-scale data sets

# PRAGMATICS

- How do we intellectually maintain and manage a global scientific agenda for modeling human systems?

- Who writes the code? In what language?

- How does modeling environment evolve?

- How do we maintain standards for API or I/O and integrate them with existing ESMs?

- Where can the code be run?

- How do we decide which modeling experiments to run?

- How do we evaluate results? (HSMIPS?)

# A FIRST STEP FOR NEXT GENERATION HUMAN-EARTH SYSTEMS SCIENCE
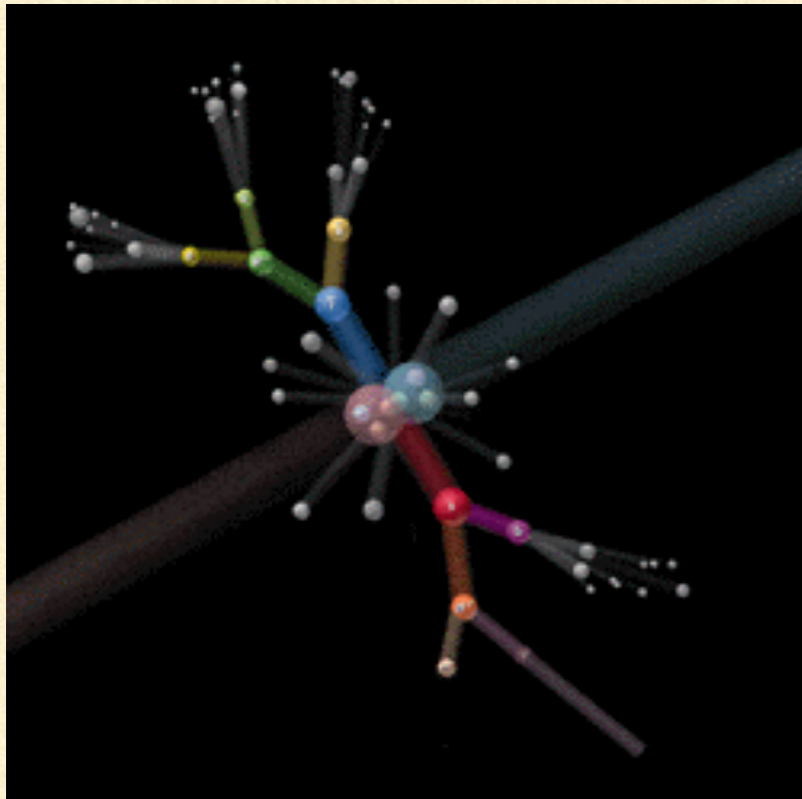
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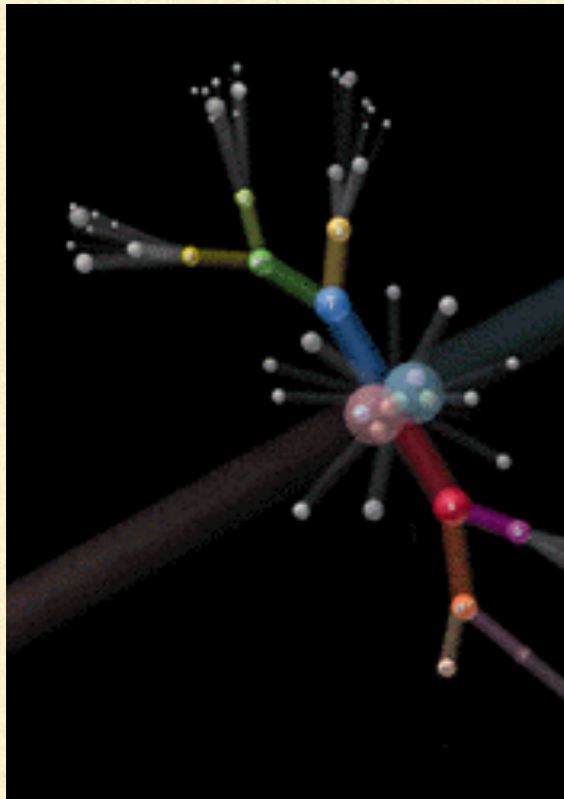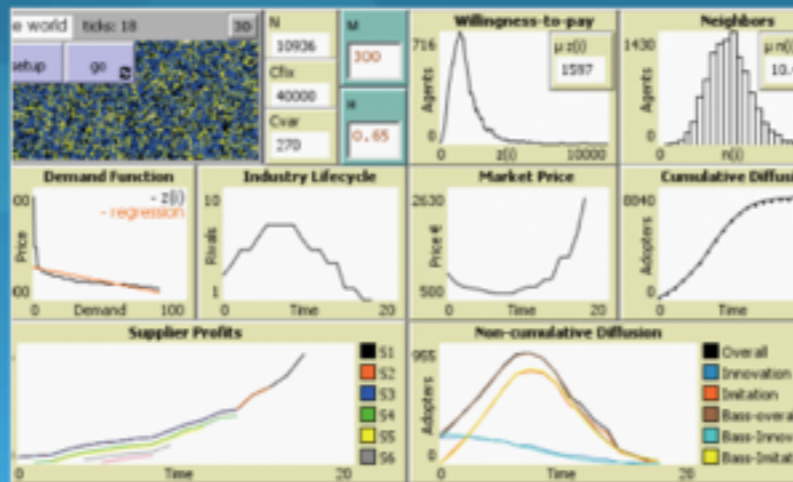
# COMSES NET

*Network for Computational Modeling in Social & Ecological Sciences*

Partner with CSDMS for organizing workshop

# COMSES NET



- NSF sponsored Research Coordination Network

- A community of practice for scientists using advanced modeling to study human and natural systems

*http://www.openabm.org*

# COMSES NET

- Framework for interaction and professional development

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- Overcoming challenges to knowledge dissemination and sharing

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- Overcoming challenges to knowledge dissemination and sharing

- Publishing model code to catalyze innovation in computational modeling
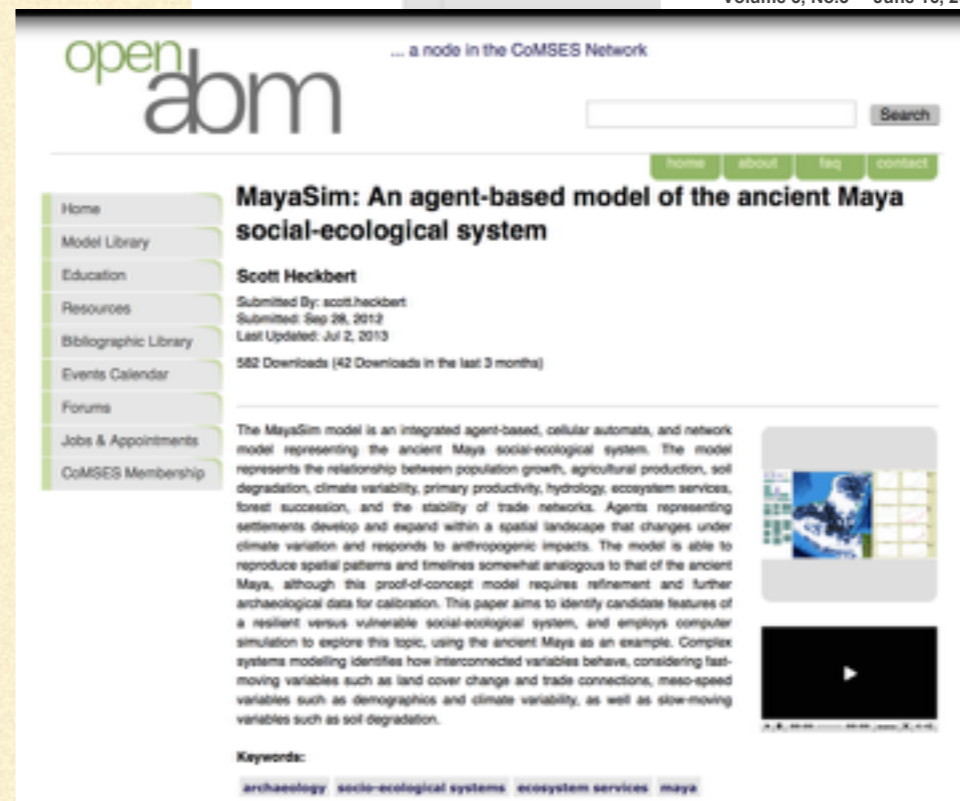
# COMSES NET

- >1600 members

- 348 published models

- >53,000 site visitors in 2015

- >16,000 model downloads in 2015



| | Continent | Sessions ▼ | Sessions ▼ |
|---|---|---|---|
| | | 53,305<br>% of Total: 99.50% (53,573) | 53,305<br>% of Total: 99.50% (53,573) |
| 1. | Americas | 22,255 | 41.75% |
| 2. | Europe | 18,608 | 34.91% |
| 3. | Asia | 9,140 | 17.15% |
| 4. | Africa | 1,712 | 3.21% |
| 5. | Oceania | 1,590 | 2.98% |

*http://www.openabm.org*