Theme III: Effects of Global Change on Terrestrial Ecosystems and Freshwater Resources

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Global Change Drivers

(a) Altering the chemistry of air and water

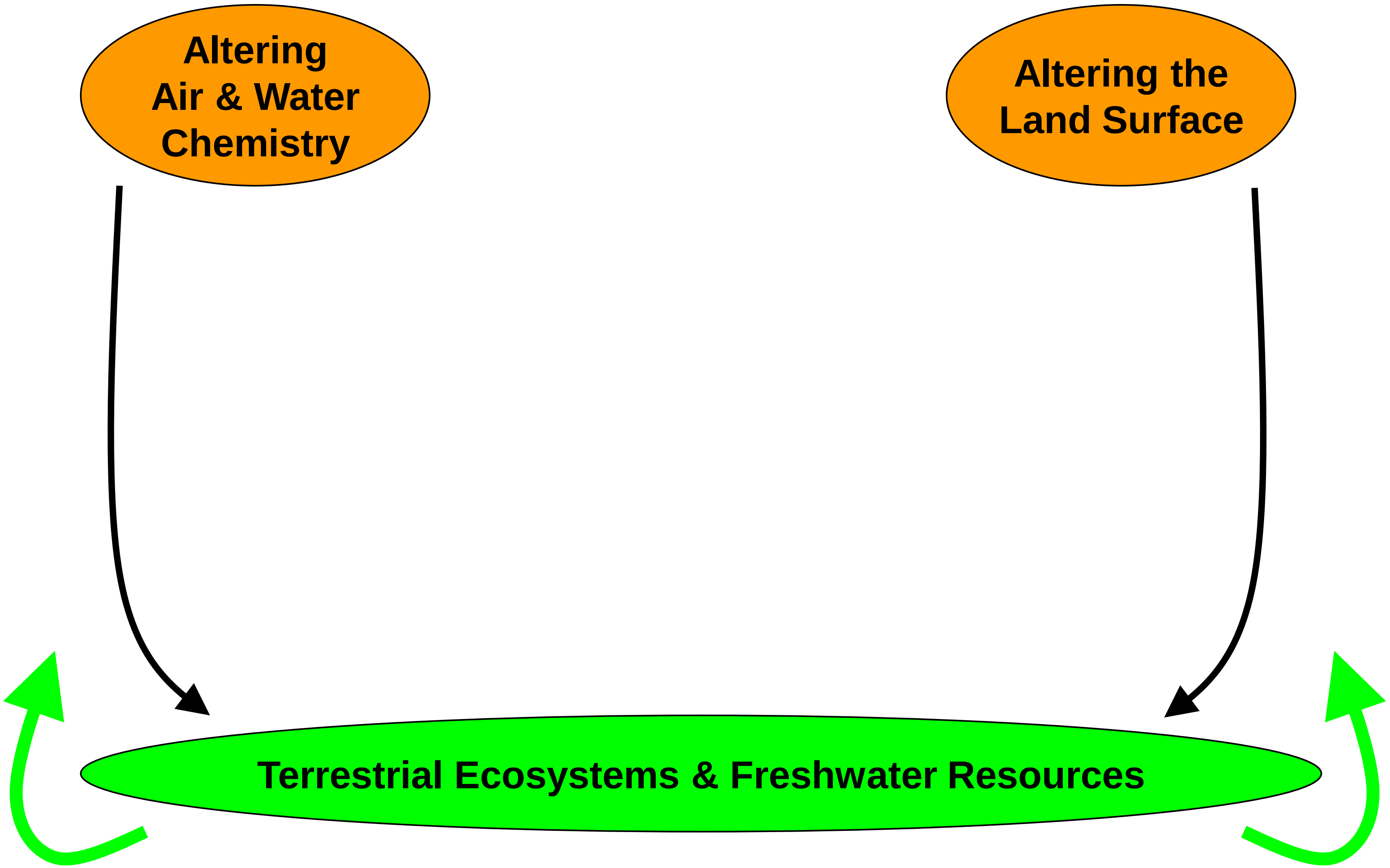
(b) Land use change

(c) Climate change as a result of (a) and (b)

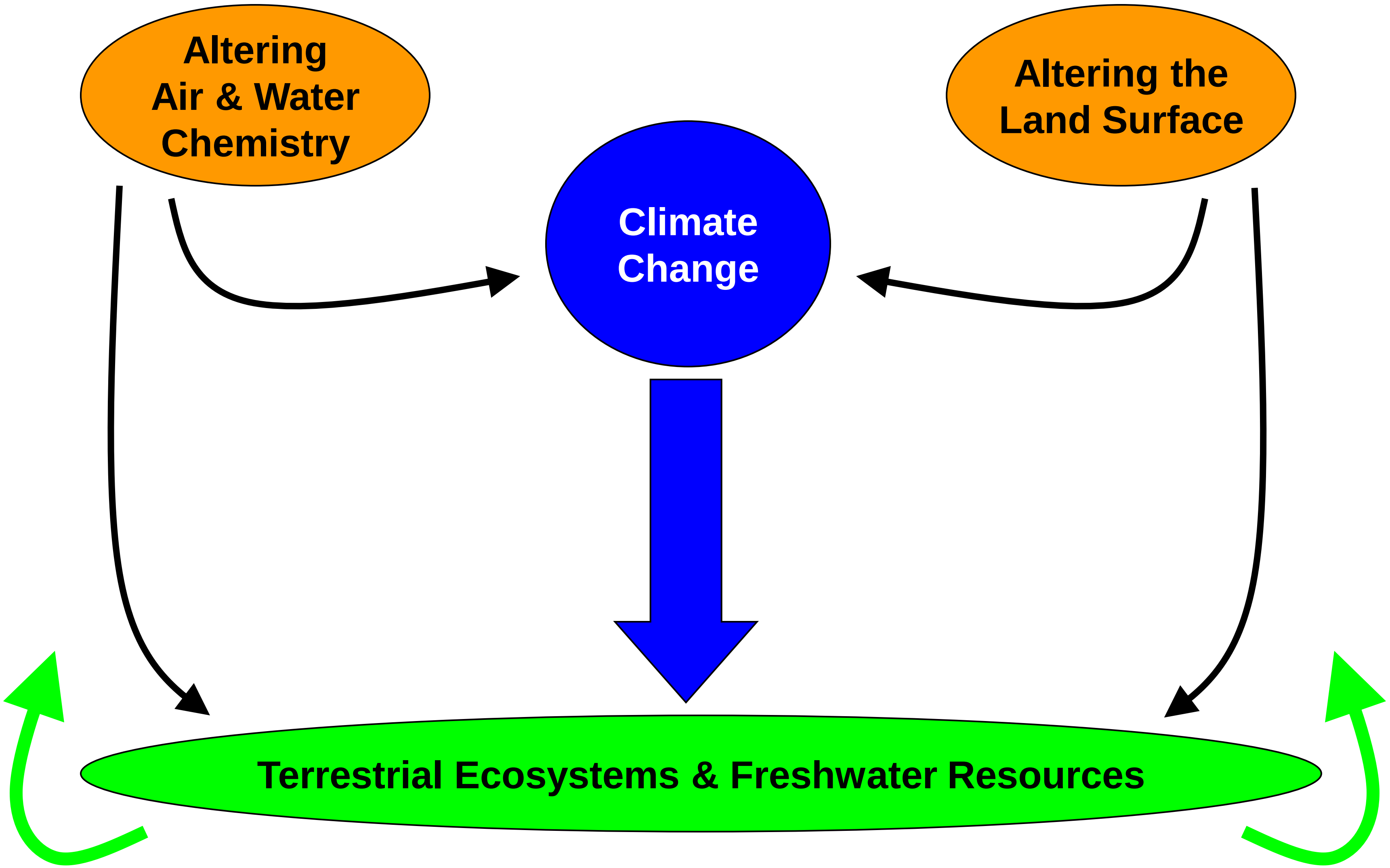
(d) Production of scientific knowledge – societal response in anticipation of change

(e) Natural climate system variability

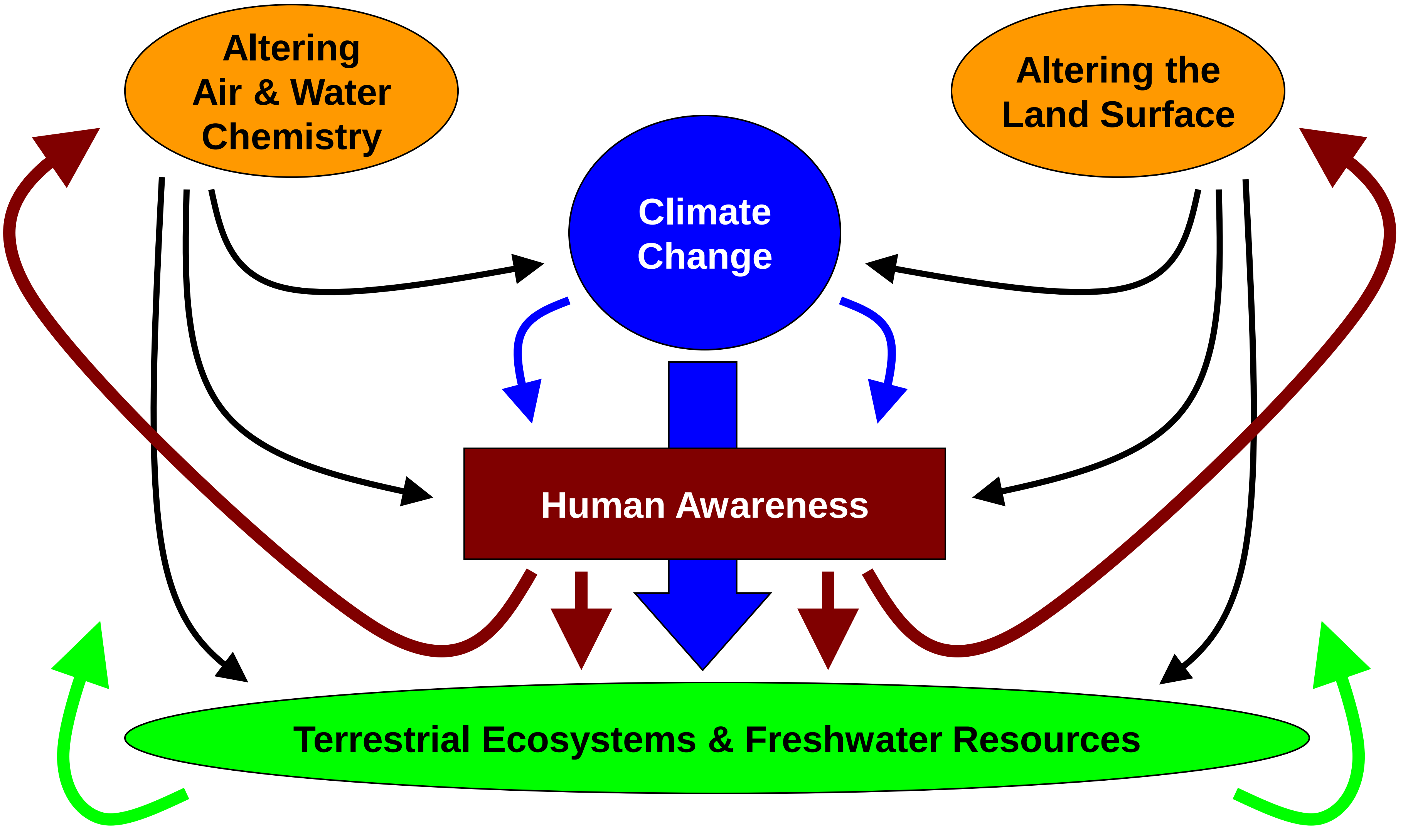
Global Change Drivers



Global Change Drivers



Global Change Drivers



Drivers >> Impacts

These global change drivers will affect the ecosystems and fresh water upon which human society depends for its existence.

Changes in water supply, demand, and quality: high/low flows, storm water, floods, droughts, impervious surface

Changes in biogeochemical cycling: nutrients (C, N, P), soil and plant ecology

Changes in ecosystem structure and function: land clearing, species composition, succession, invasives, services, restoration, agricultural yield

Changes in public perceptions and the political environment: mitigation and adaptation policies with their own future (unintended?) consequences

Scientific Assessment: Looking Ahead

Intergovernmental Panel on Climate Change (IPCC)
Millennium Ecosystem Assessment (MEA)
Strategic Plan of the U.S. Climate Change Science Program (CCSP)
First U.S. National Assessment
Etc …

Shifting biomes as a function of changes in temperature and precipitation

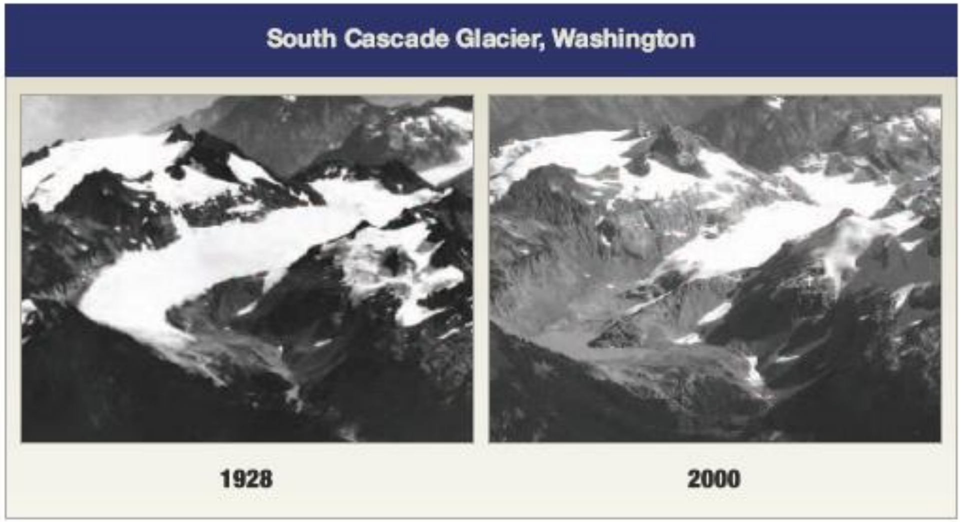
Reduction in potential crop yields in most tropical, sub-tropical, and mid-latitude regions for projected increases in temperature of more than a few °C

Decreased water availability for populations in many water-scarce regions, particularly in the sub-tropics and in regions dependent on snow melt runoff

Widespread increase in the risk of flooding for many human settlements from heavy precipitation events

Increased fragmentation and destruction of ecosystems by development

Decreased water availability for populations in many water-scarce regions, particularly in the sub-tropics and in regions dependent on snow melt runoff



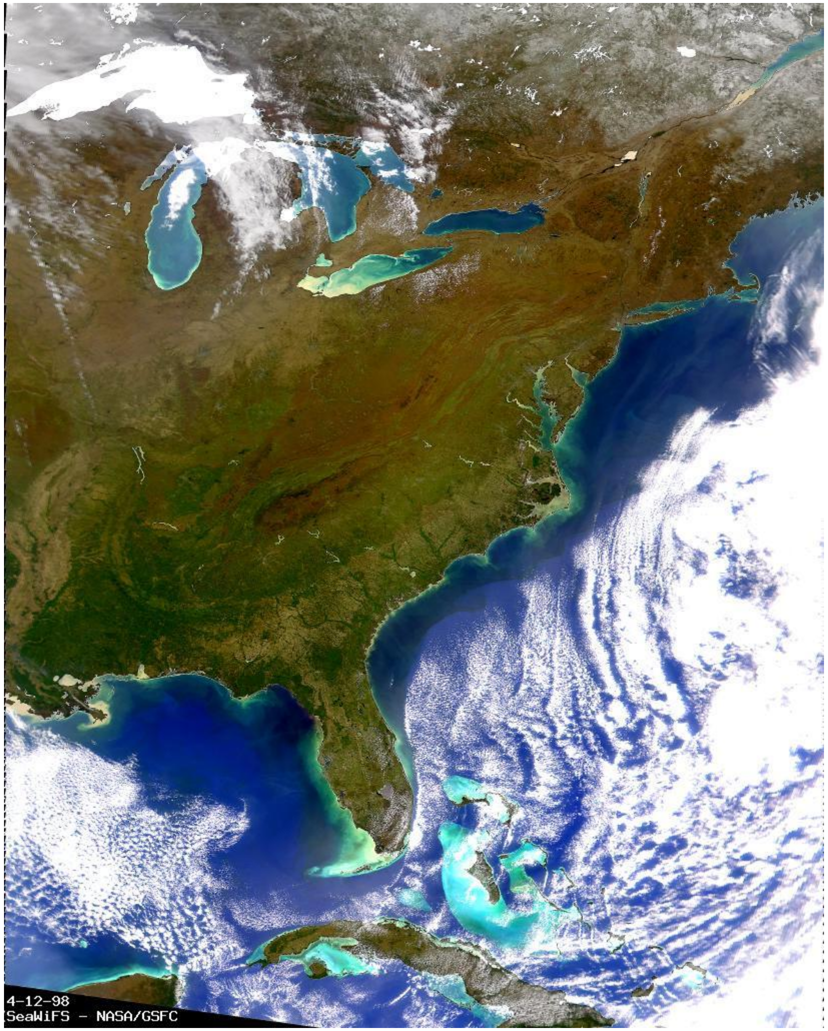
"Approximately 1.7 billion people, one-third of the world's population, presently live in countries that are water-stressed … This number is projected to increase to around 5 billion by 2025, depending on the rate of population growth. The projected climate change could further decrease the streamflow and groundwater recharge in many of these water-stressed countries—for example in central Asia, southern Africa, and countries around the Mediterranean Sea"

IPCC 2001 WG II Report

Eastern Seaboard

Northeast US and Eastern Canada
- Decreased snow cover amount/duration
- Possible large reductions in streamflow
- Changes in amount, timing of ice freeze-up/break-up, with impacts on spring flooding
- Possible elimination of certain wetlands

Southeast, Gulf, and Mid-Atlantic US
- Heavily populated coastal floodplains at risk to flooding from extreme precipitation events
- Possible lower base flows, larger peak flows, longer droughts
- Possible increases and decreases in runoff/river discharge, increased flow variability

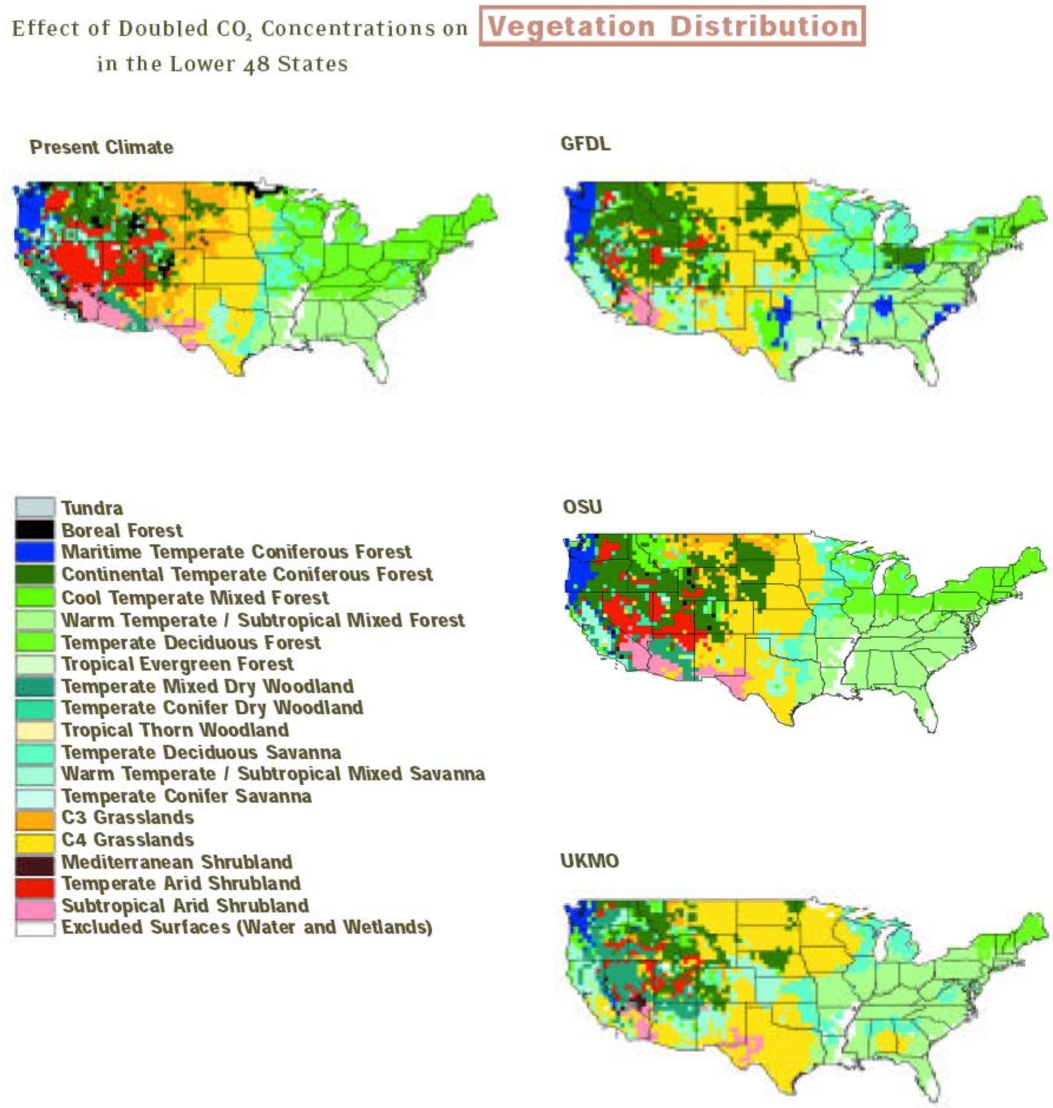


IPCC 2001 WG II Report

"Climate is the single most important factor determining the geographic distributions of species and major vegetation types. It also influences the properties of ecosystems and the flows of energy and materials through them."

Ecosystems and Global Climate Change: A Review of Potential Impacts on U.S. Terrestrial Ecosystems and Biodiversity

Pew Center on Global Climate Change



The effect of climate change and doubled atmospheric CO_2 concentration on vegetation distribution in the lower 48 states. Results are shown for one vegetation model (MAPSS) run under four climate scenarios (present climate and three scenarios of doubled atmospheric CO_2 concentrations: GFDL, OSU, and UKMO). Notice the general shift of vegetation types to the north, especially in the eastern part of the country. Patterns of change in the West are more complex because of greater topographic variation. In the complete set of VEMAP simulations, three vegetation models were used, as summarized in Table 1.

Implications for ecosystem services, agricultural yields.

And don't forget the direct clearing and paving over of land …

Human Modification of the Land Surface

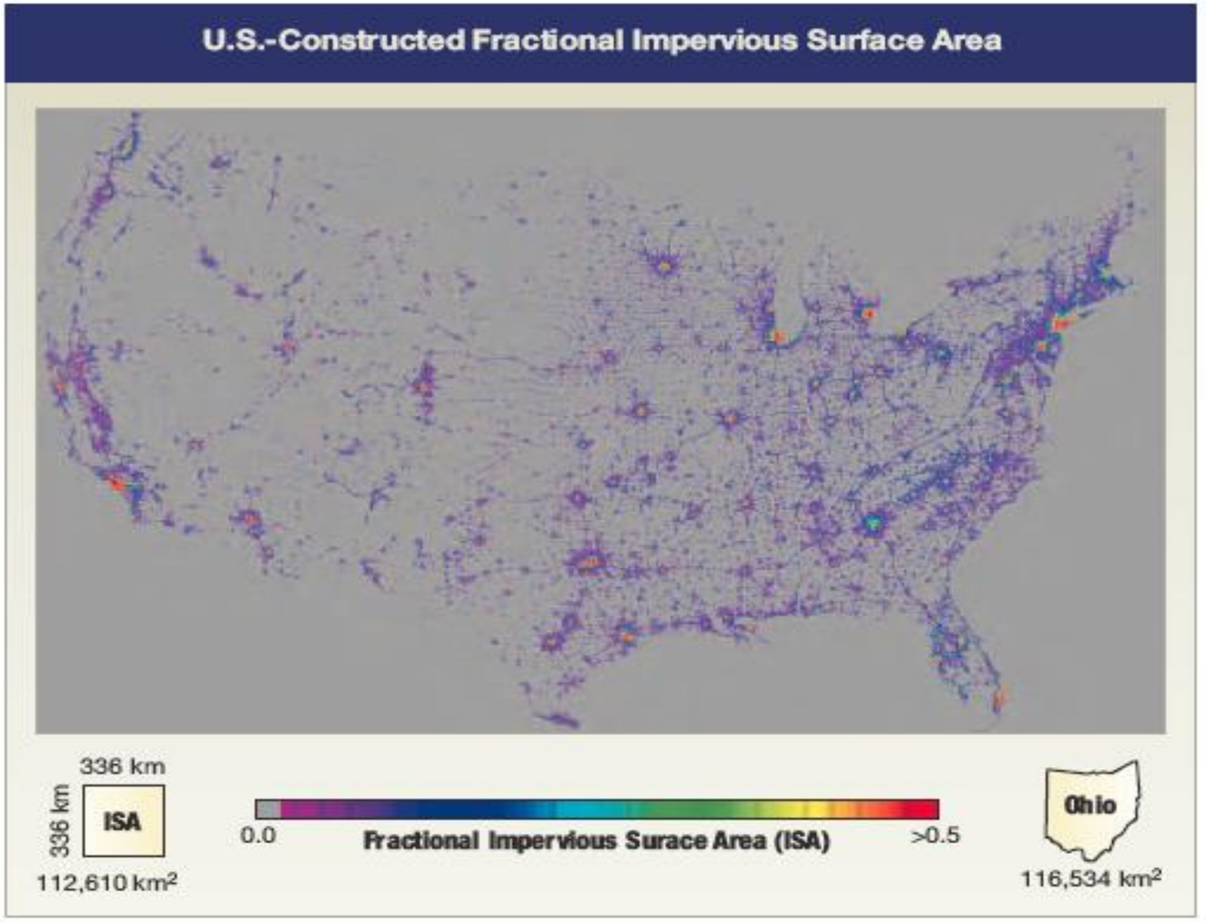


Figure 16: Fractional Impervious Surface Area. The U.S.-constructed impervious surface area (ISA) in 2000 was nearly the size of Ohio. Population is increasing at a rate of 3 million people per year. Annual U.S. public and private sector construction spending is greater than US$480 billion. This includes more than a million new single-family homes and more than 10,000 miles of new roads per year. *Credit: C.D. Elvidge, NOAA/National Geophysical Data Center.*

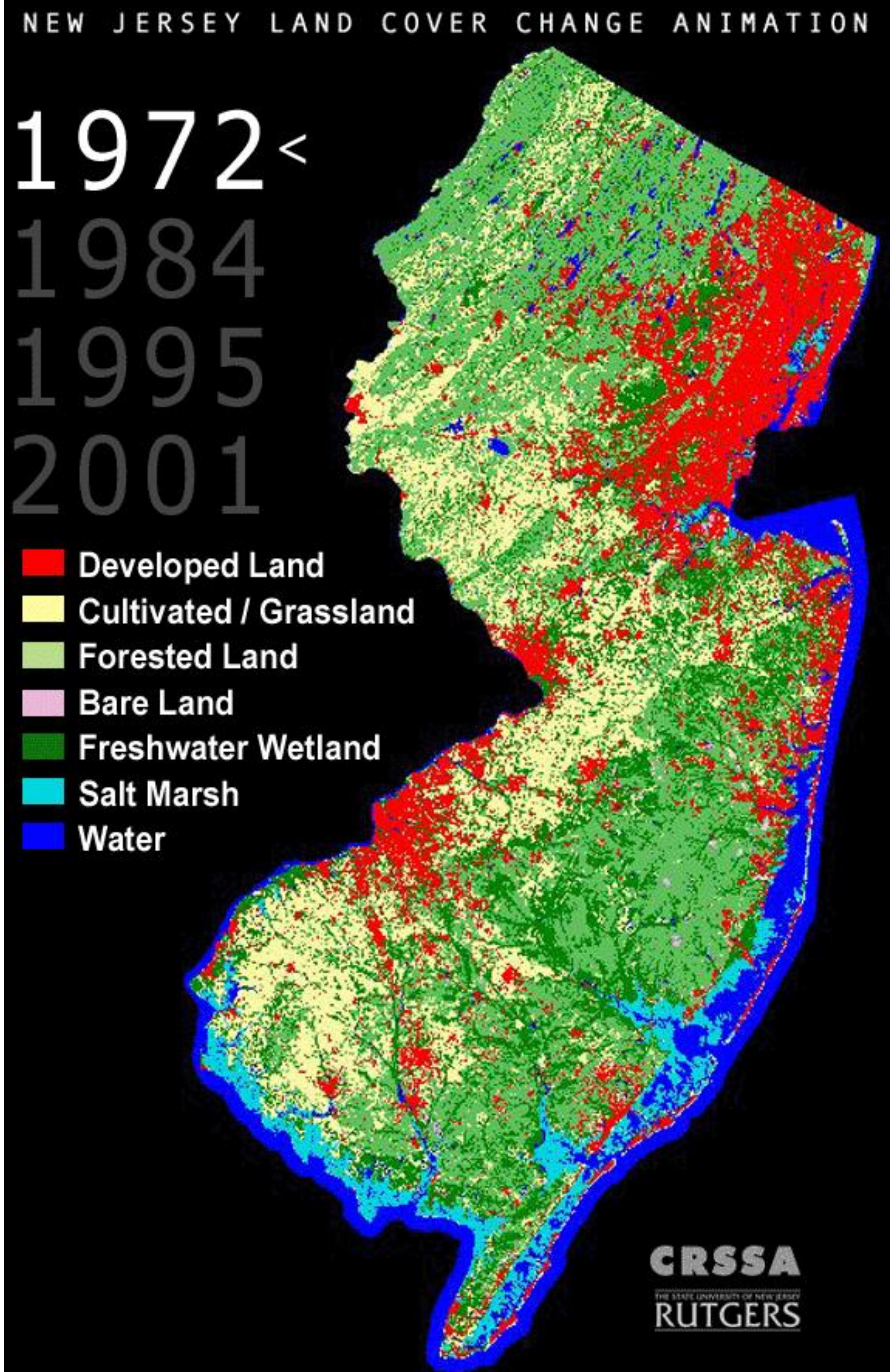
Impacts on runoff and recharge, displacement and fragmentation of habitats

Local Changes

Global Impacts

Urbanization and associated land use and land cover change is a major force driving environmental change here in New Jersey as well as globally.

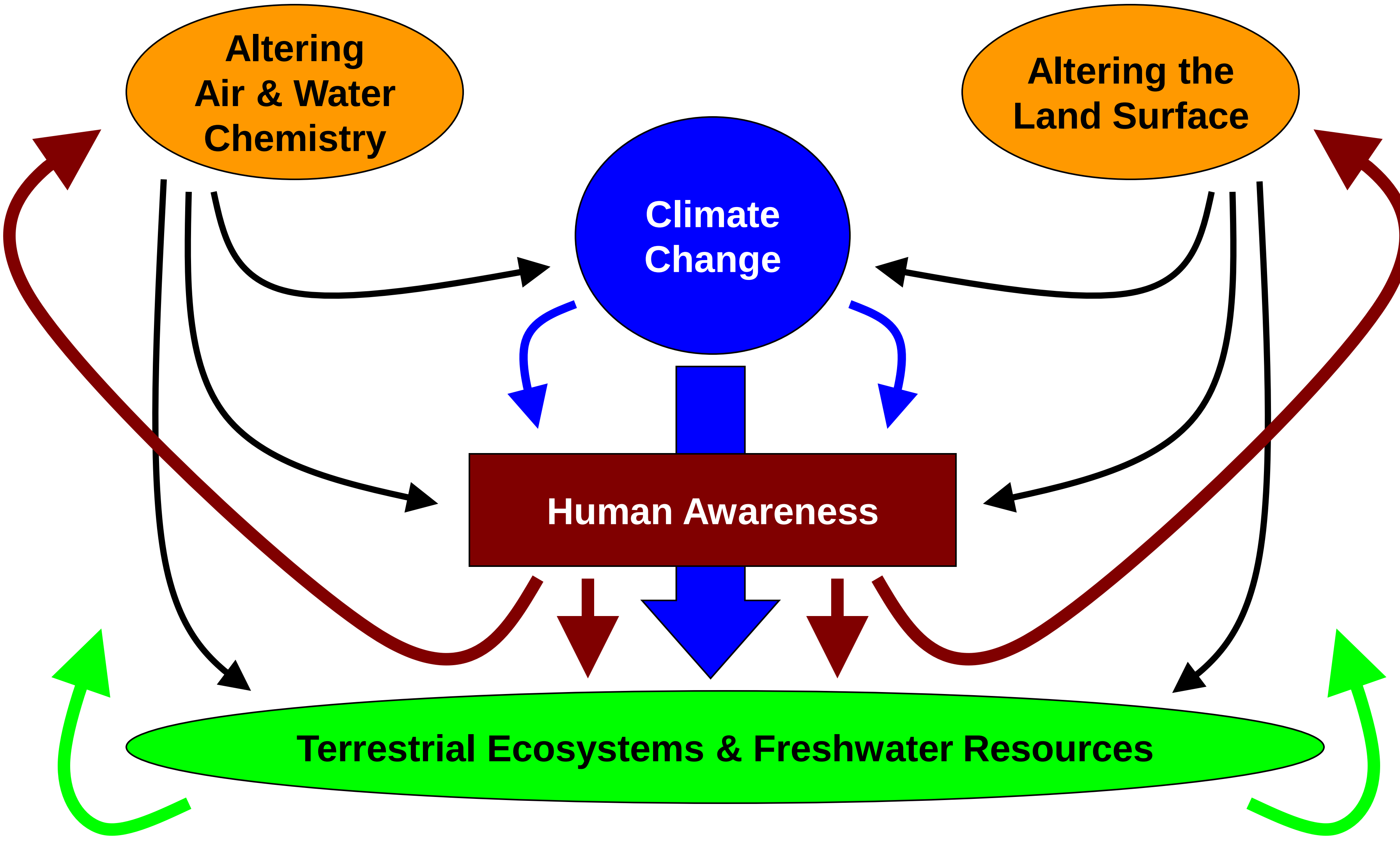
Provided by R. Lathrop



Summary of Mid-Atlantic Impacts	Negative Impact	Positive Impact
Most Certain		
• *Agricultural production*	tobacco	soybeans, possibly corn and treefruits
• *Coastal zones*	erosion, saltwater intrusion	
• *Temperature related health status*	heat stress	
Moderately Certain		
• *Forestry production*	extreme events	more growth, different mix
• *Temperature related health status*		less cold stress
Uncertain		
• *Biodiversity*	migration barriers, invasive species	warmer temperatures
• *Fresh water quantity*	more variability	more average steamflow
• *Fresh water quality*	runoff	
• *Ecological functioning*	forest composition, cold water fisheries	warm water fisheries
• *Vector and water-borne disease health status*	Cryptosporidiosis	
• *Environmental effects from agriculture*	nutrient leaching, runoff	

Arrow length and thickness shows the relative size of potential impacts: bigger arrows mean bigger impacts. Arrows in the lower sections of the table have lighter shading because those impacts are less certain.

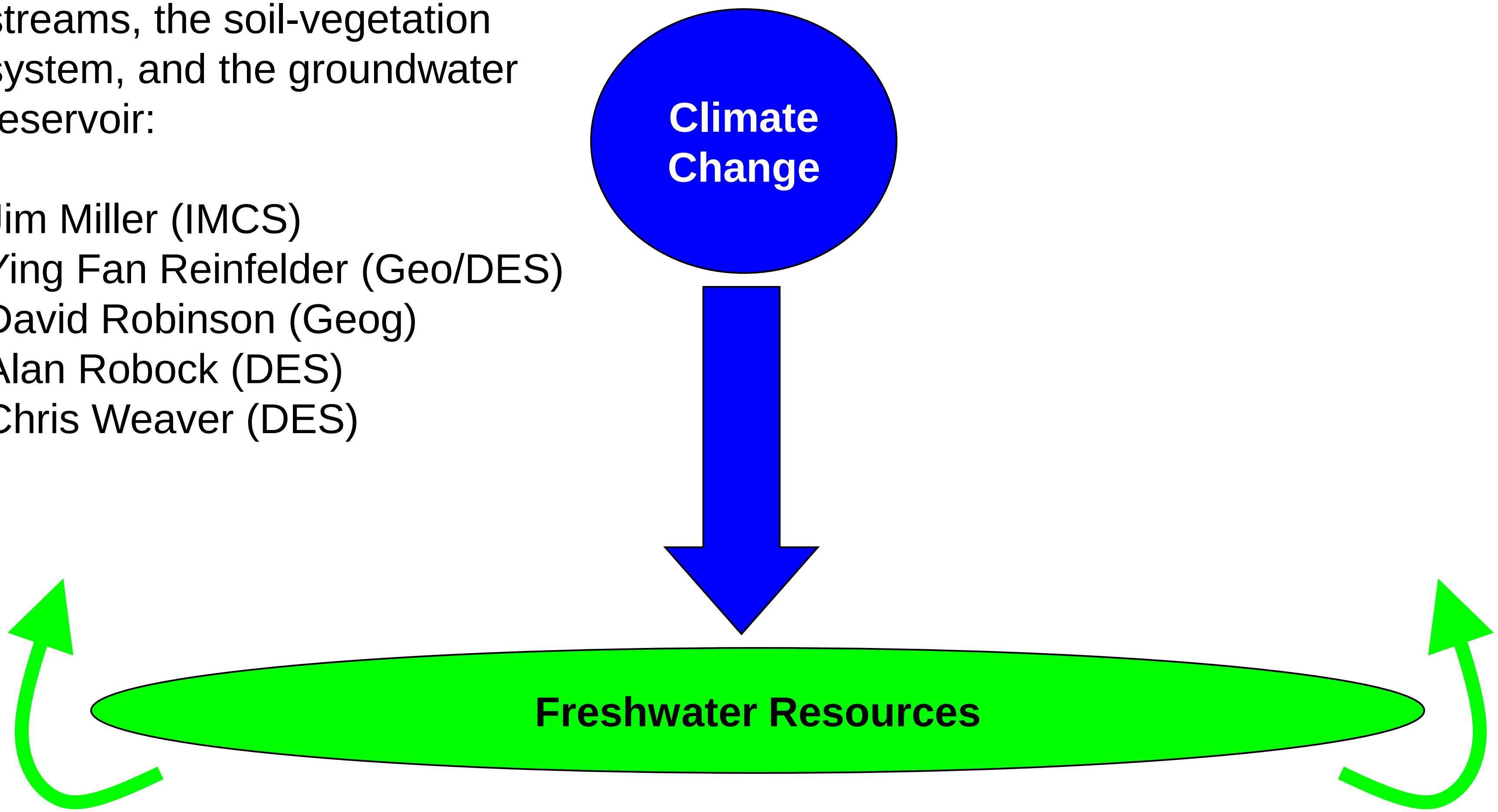
Global Change Drivers



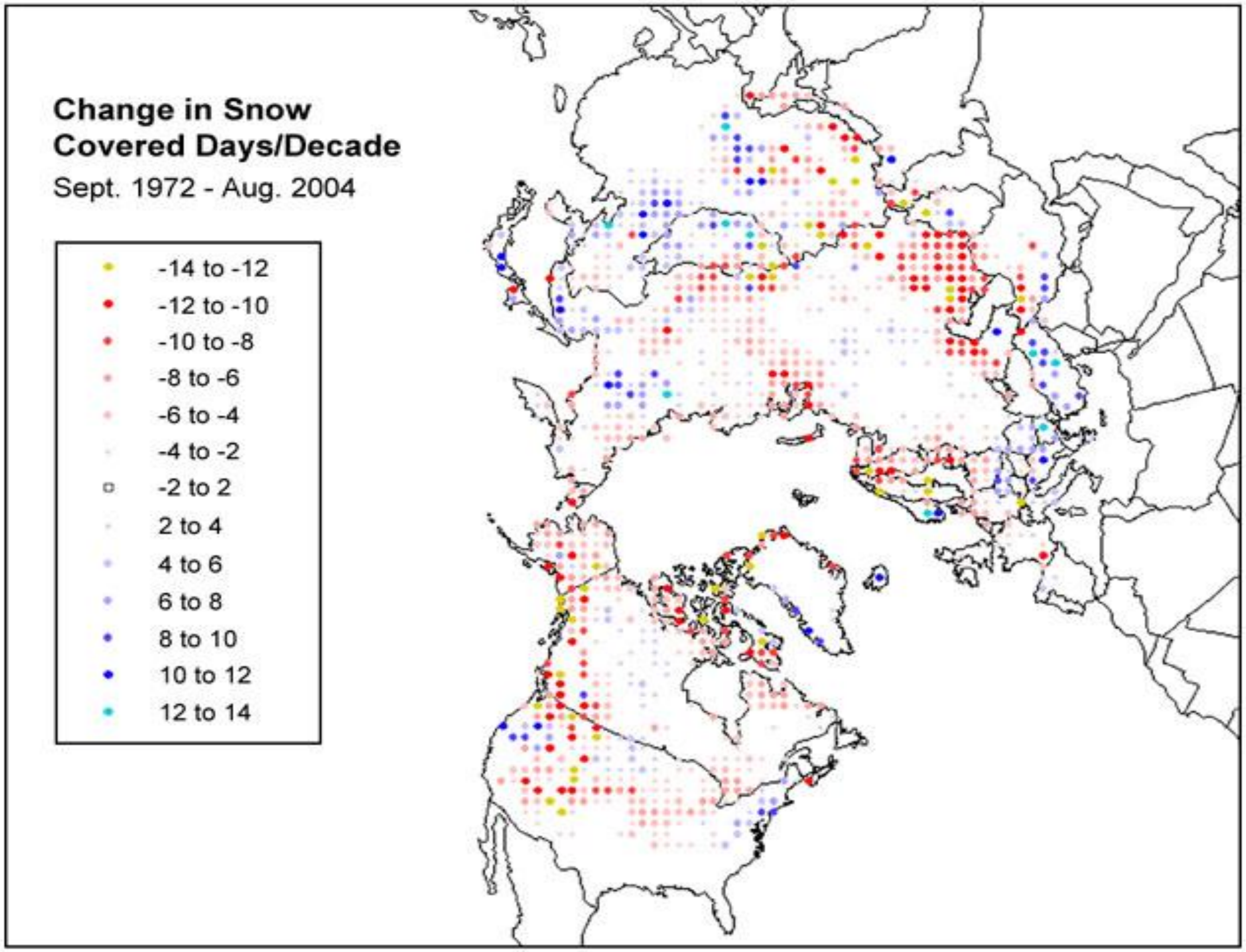
Global Change Drivers

Impact of climate change on water cycling through rivers, streams, the soil-vegetation system, and the groundwater reservoir:

Jim Miller (IMCS)
Ying Fan Reinfelder (Geo/DES)
David Robinson (Geog)
Alan Robock (DES)
Chris Weaver (DES)



Observed historical changes



Provided by D. Robinson

Projected future changes

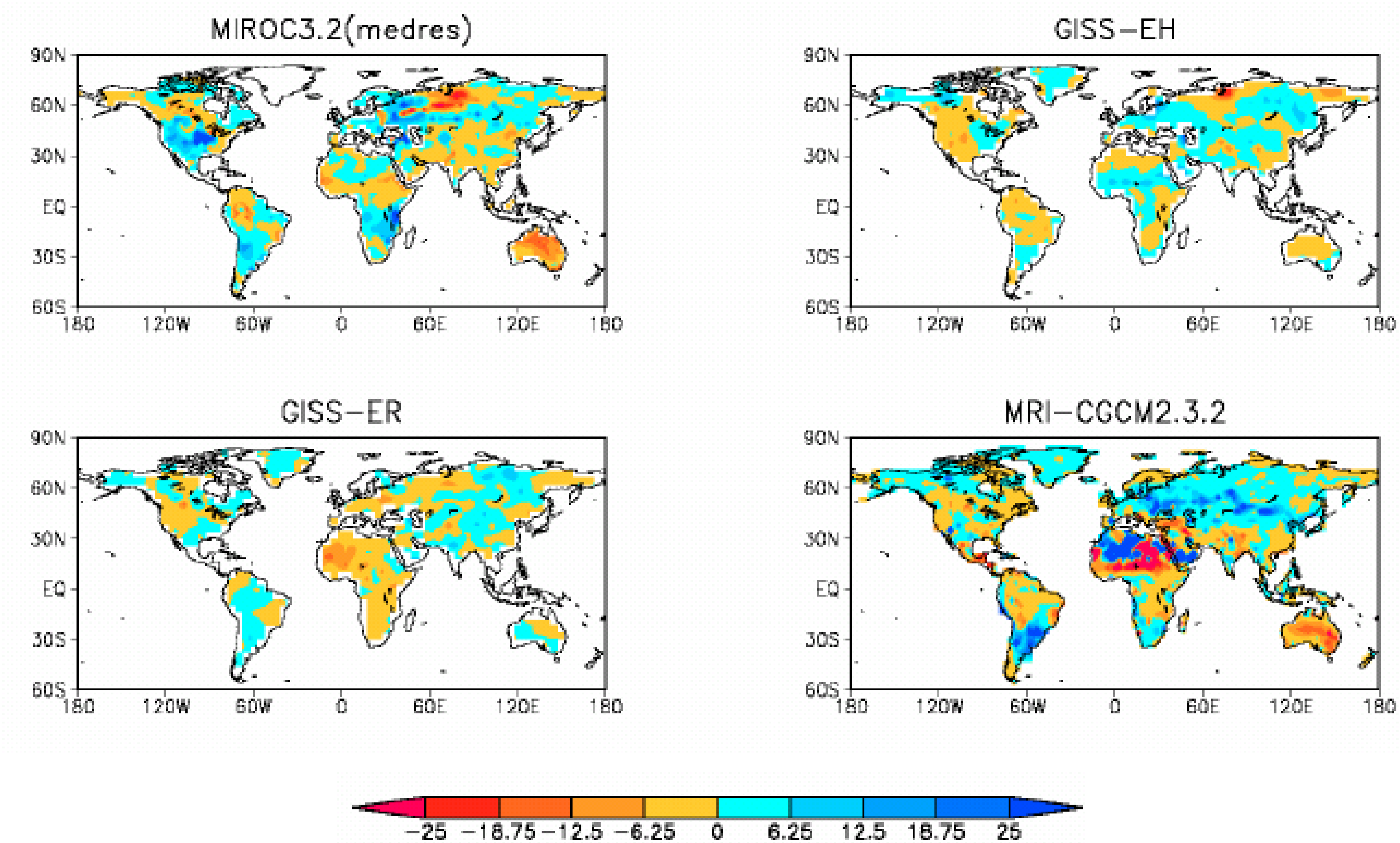
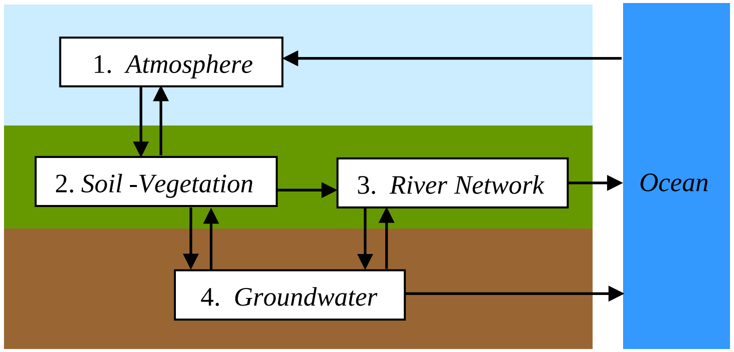
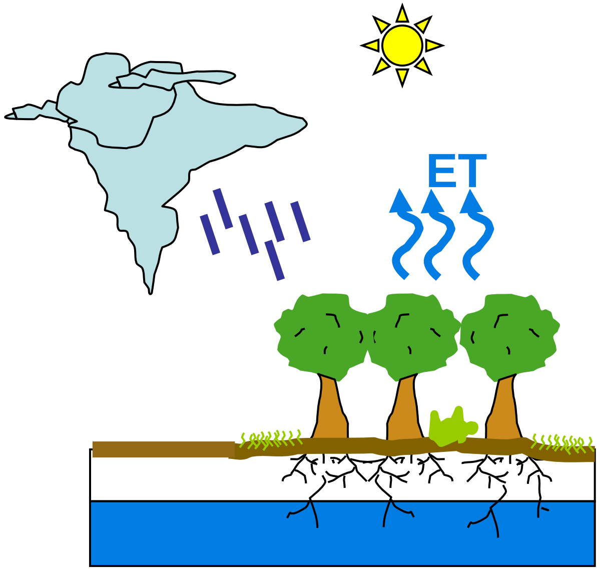


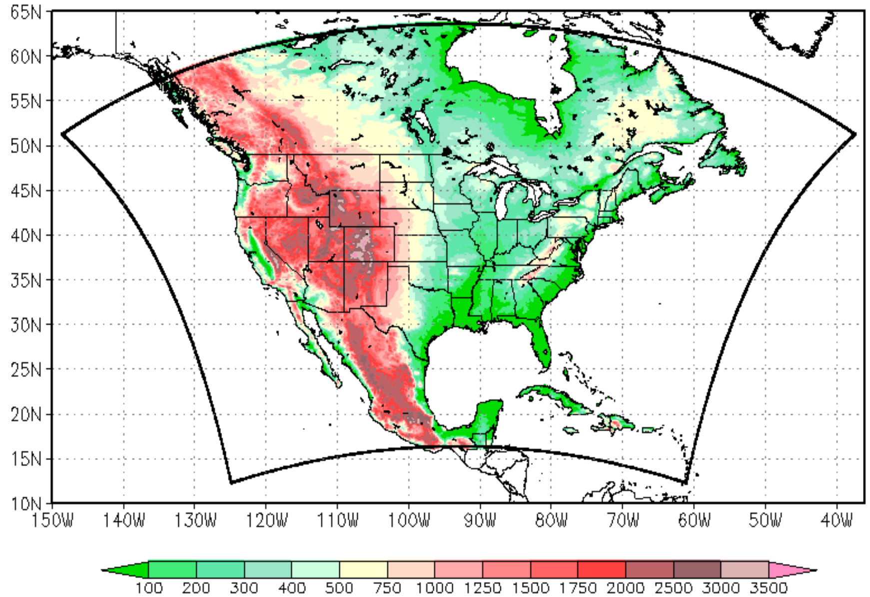
Figure 12. Relative change of soil moisture in summer (JJA) between 2060-2999 and 1960-1999 for models forced with the SRES A1B scenario, normalized by the average of 1960-1999. Units are in percent.

Provided by A. Robock

Building new modeling tools





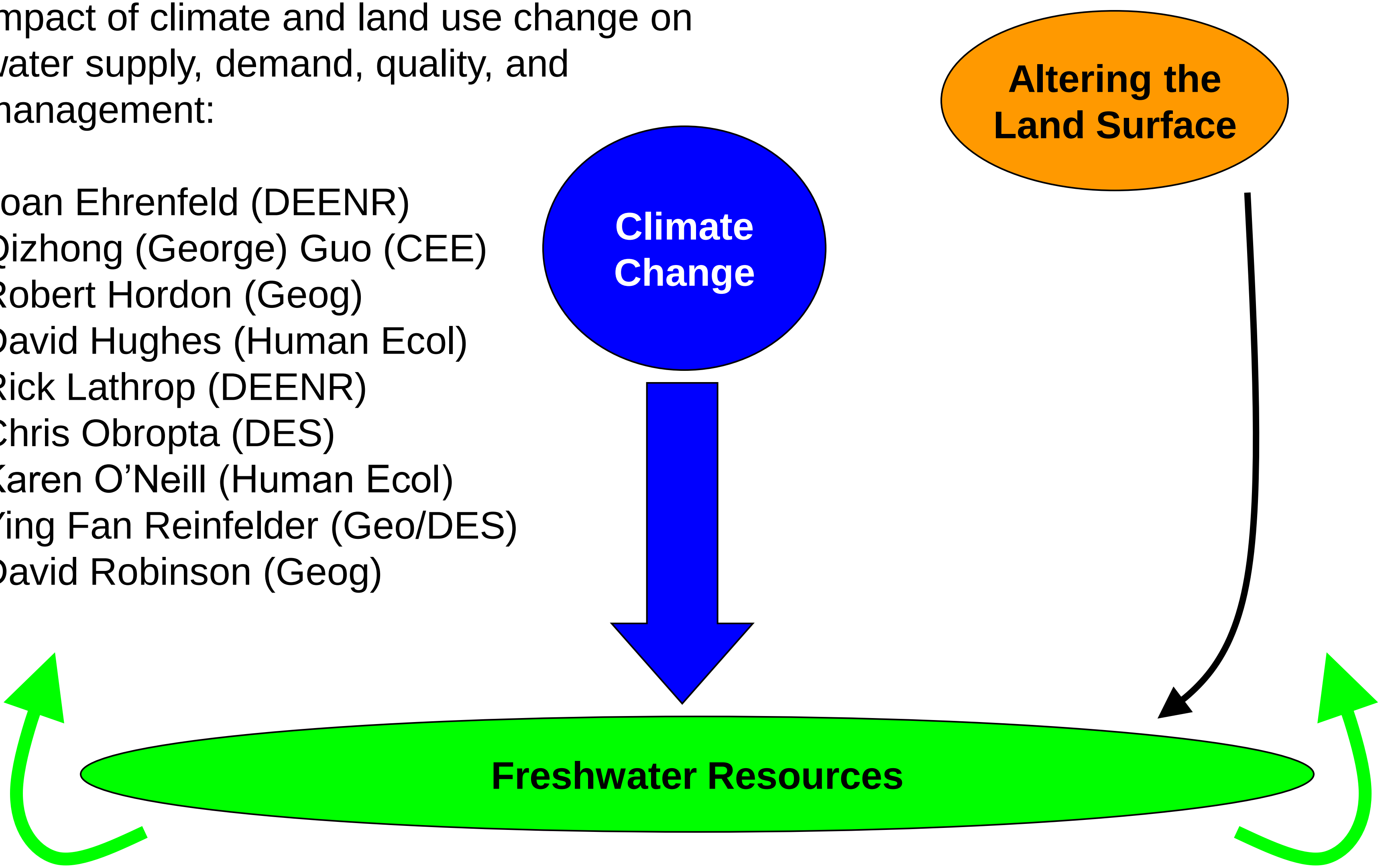


Provided by Y. Fan Reinfelder

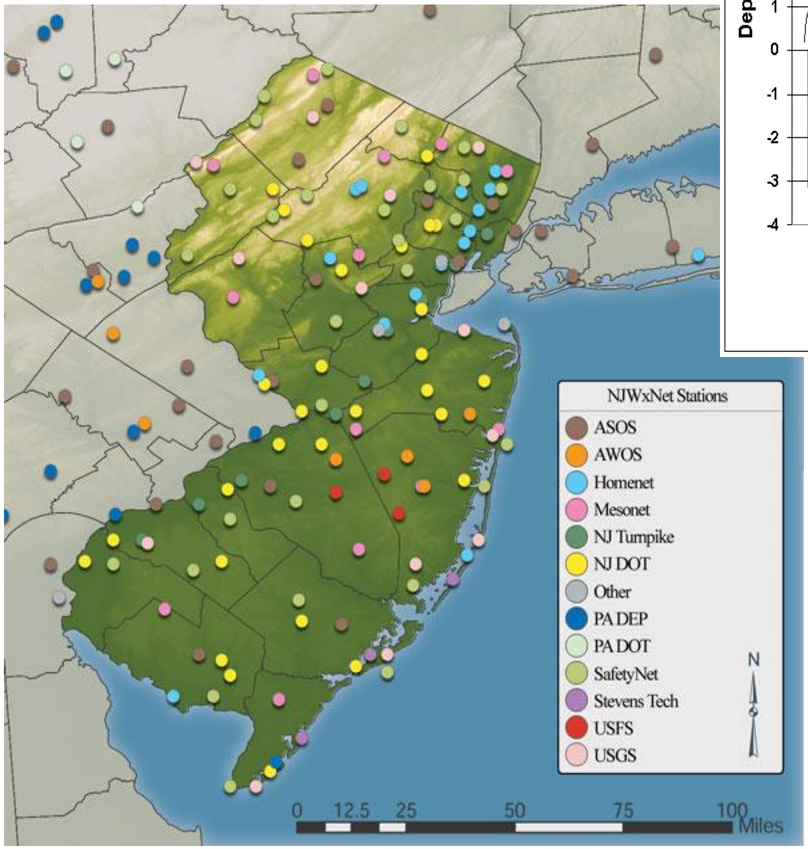
Global Change Drivers

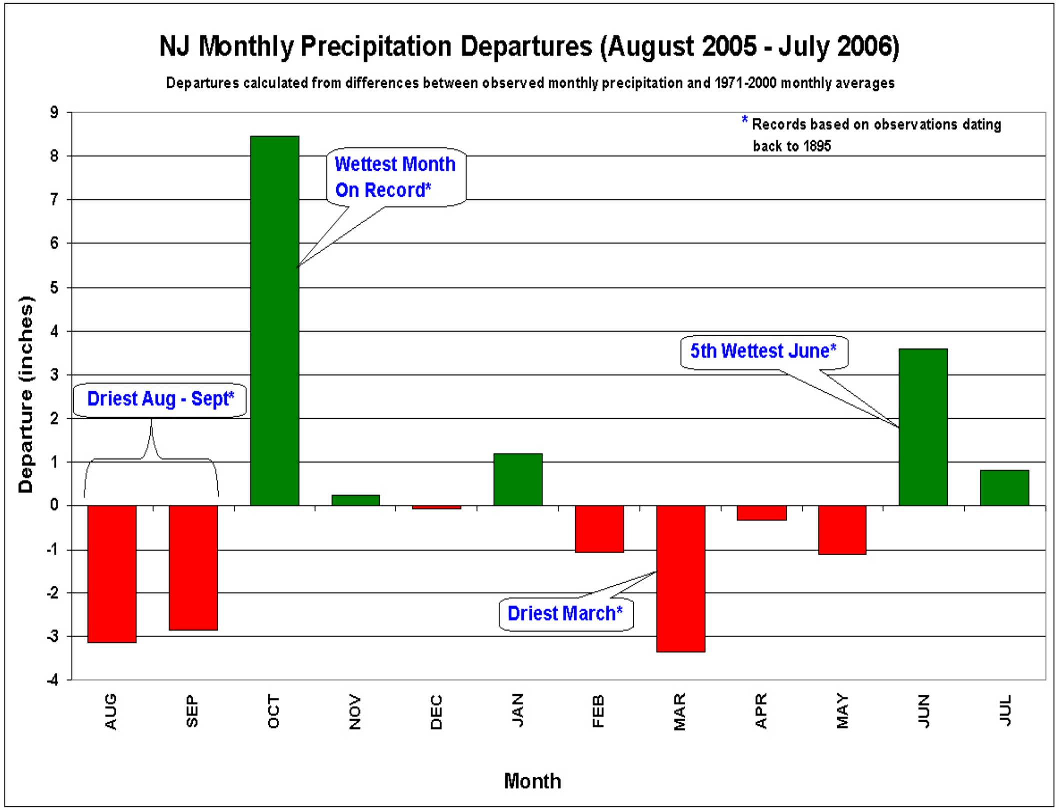
Impact of climate and land use change on water supply, demand, quality, and management:

Joan Ehrenfeld (DEENR)
Qizhong (George) Guo (CEE)
Robert Hordon (Geog)
David Hughes (Human Ecol)
Rick Lathrop (DEENR)
Chris Obropta (DES)
Karen O'Neill (Human Ecol)
Ying Fan Reinfelder (Geo/DES)
David Robinson (Geog)



Drought monitoring: The Office of the New Jersey State Climatologist





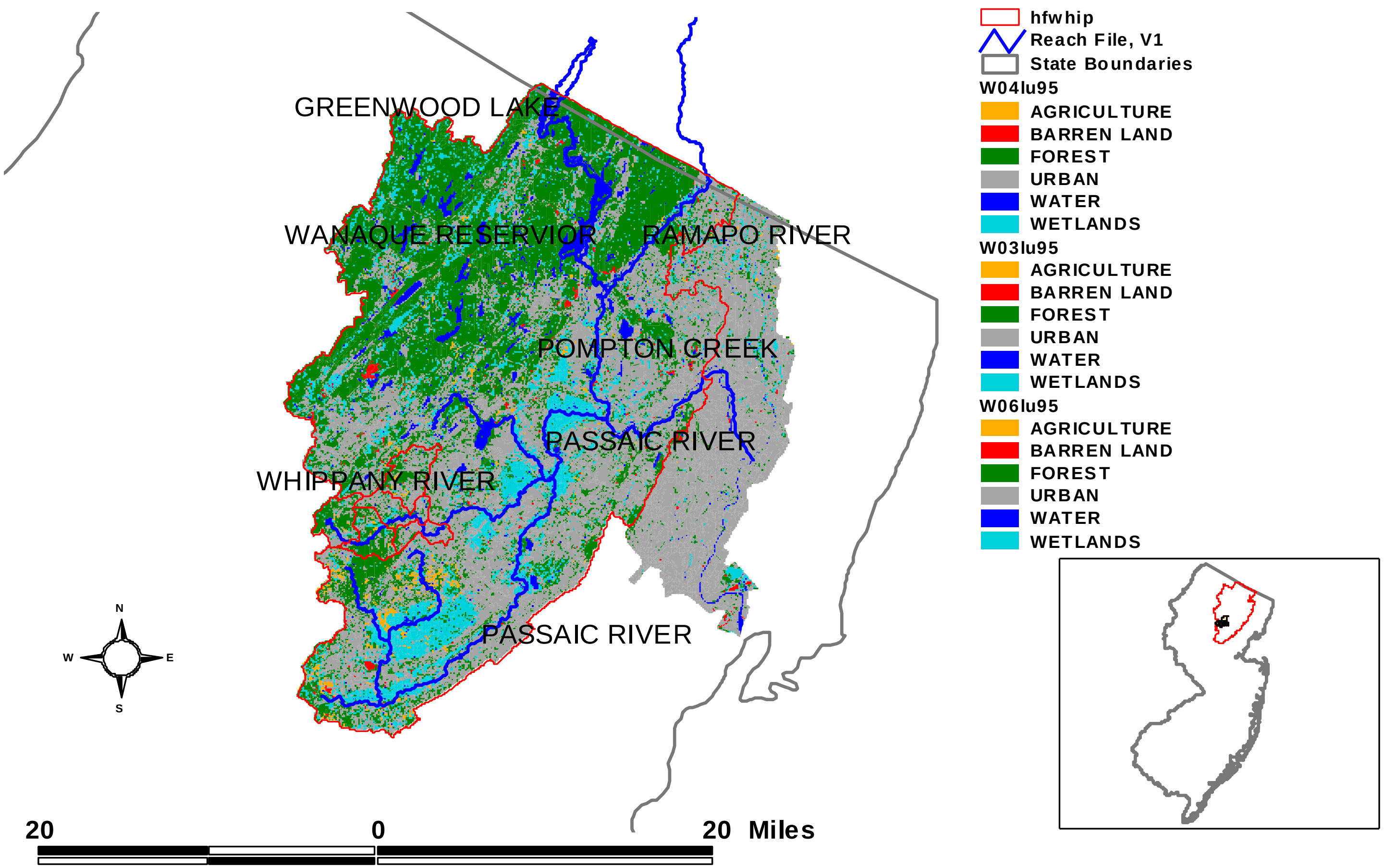
Provided by D. Robinson

Climate change implications for urban stormwater management: runoff quantity, runoff quality, and groundwater recharge

Impacts of changes in rainfall on flooding and contaminant concentrations …

Provided by Q. Guo

Non-tidal Passaic River Basin and Modeled Whippany Watershed



Research, training, and outreach:

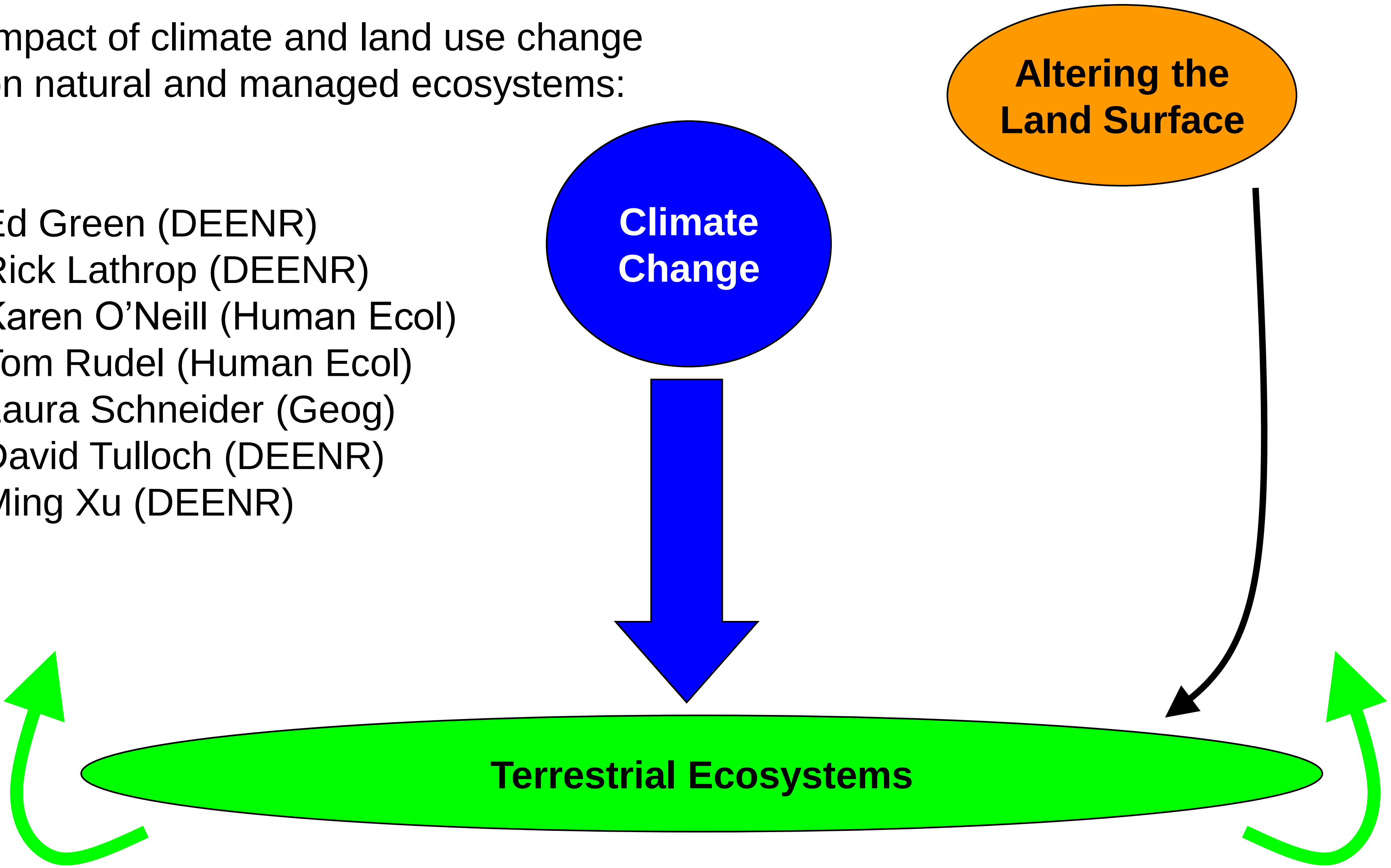
The New Jersey Water Resources Research Institute

RCE Water Resources Program

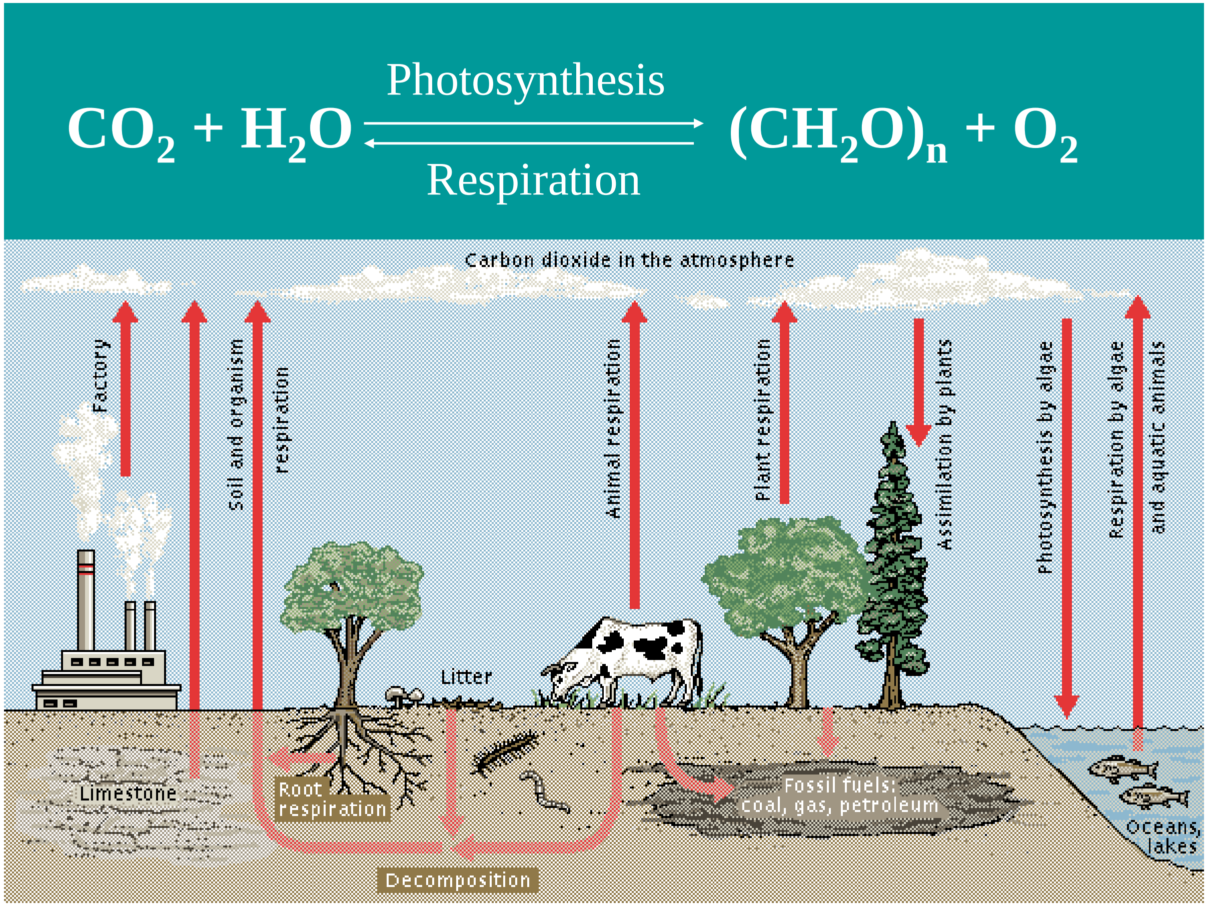
Global Change Drivers

Impact of climate and land use change
on natural and managed ecosystems:

Ed Green (DEENR)
Rick Lathrop (DEENR)
Karen O'Neill (Human Ecol)
Tom Rudel (Human Ecol)
Laura Schneider (Geog)
David Tulloch (DEENR)
Ming Xu (DEENR)



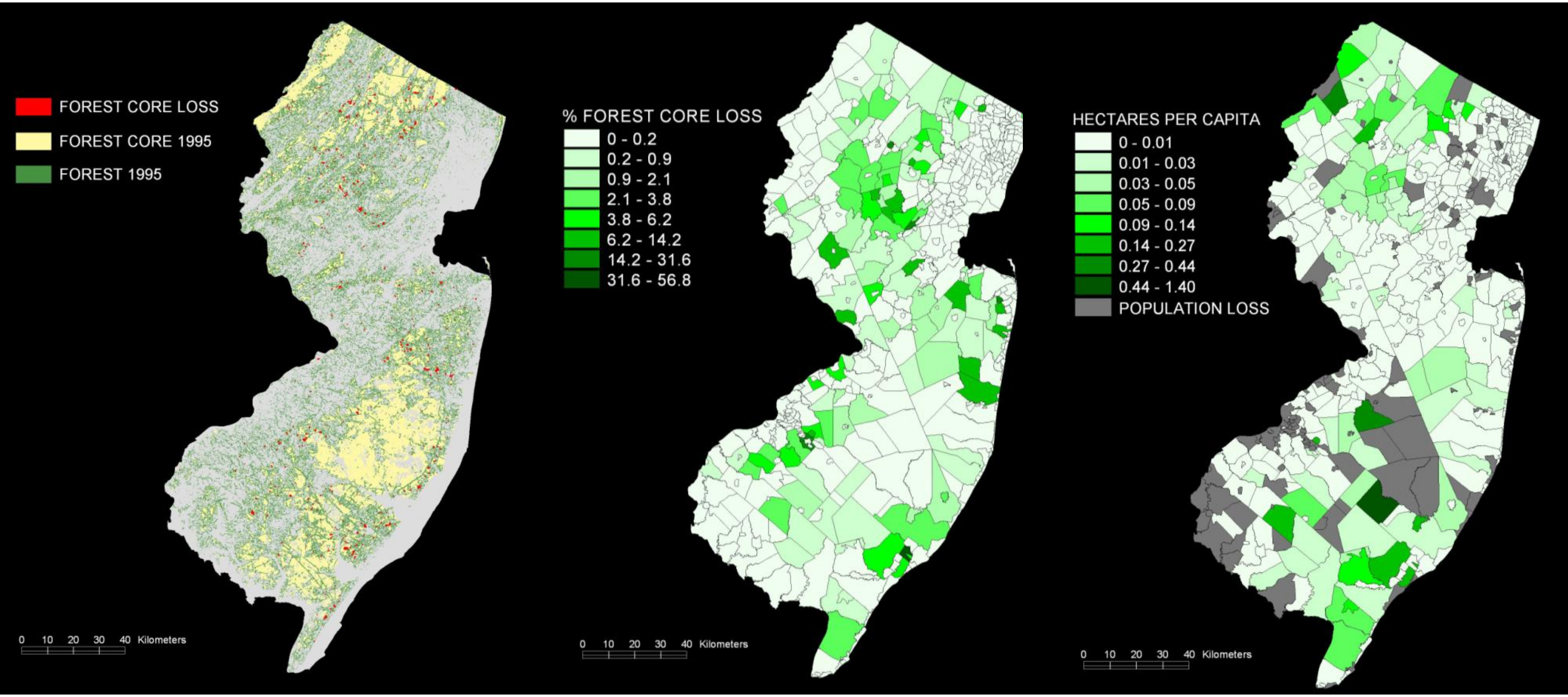
Climate change impacts on ecosystem processes:
carbon and water cycling



Provided by M. Xu

Core Forest Change

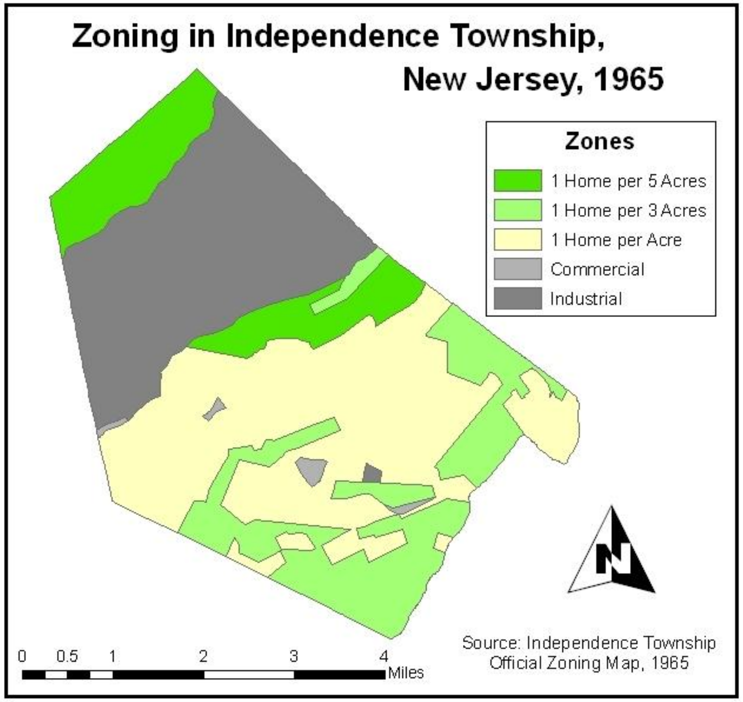
Overall Forest Loss to Development: 1995-2000 3,880 ha/yr

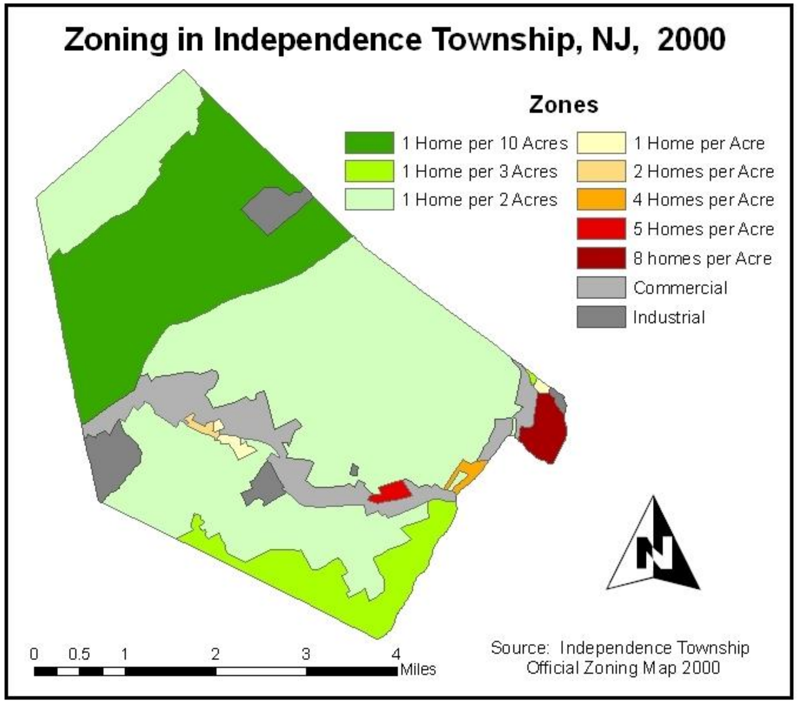


% change vs. per capita change at a municipal level

Provided by R. Lathrop

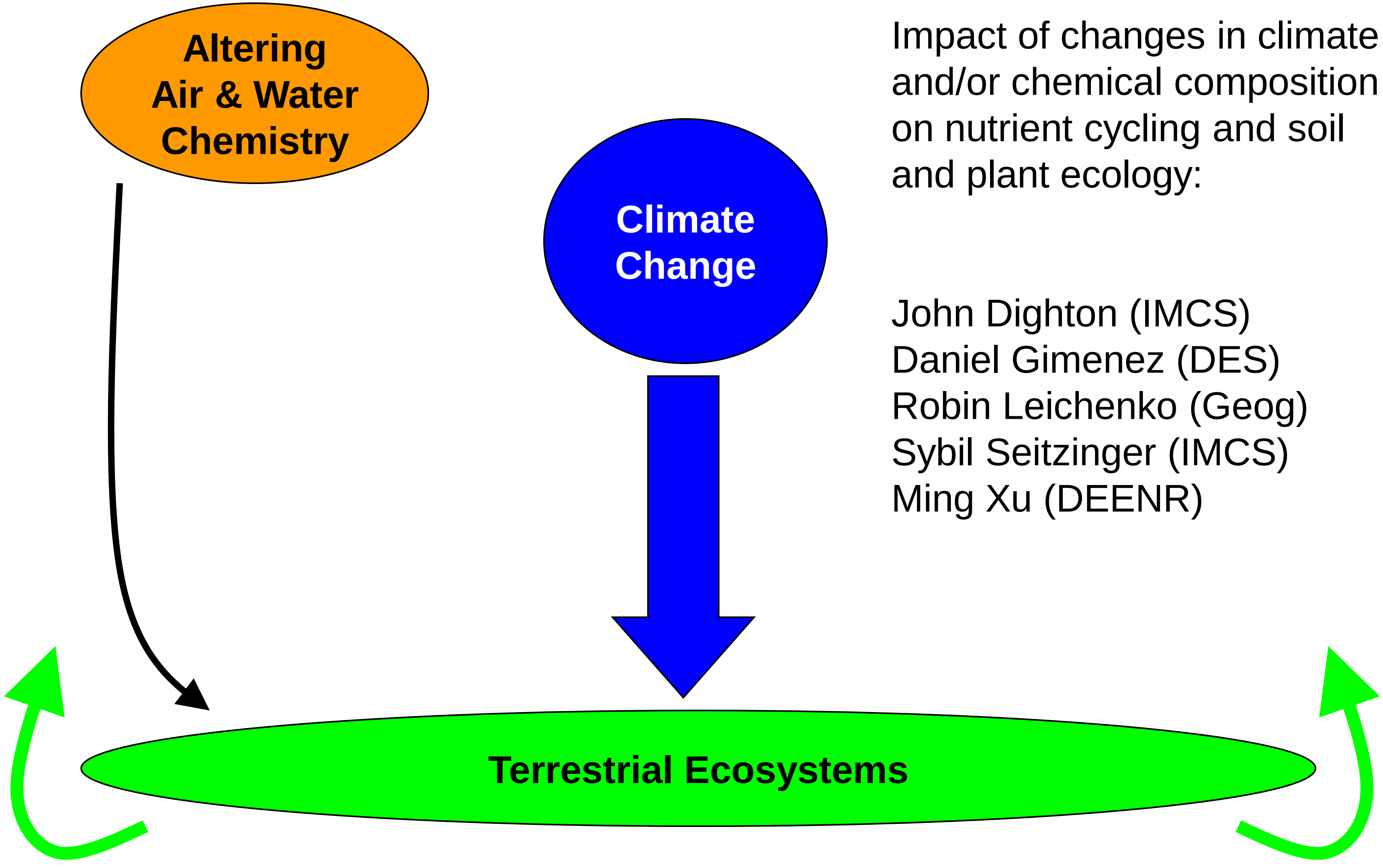
New Jersey Highlands





Provided by T. Rudel

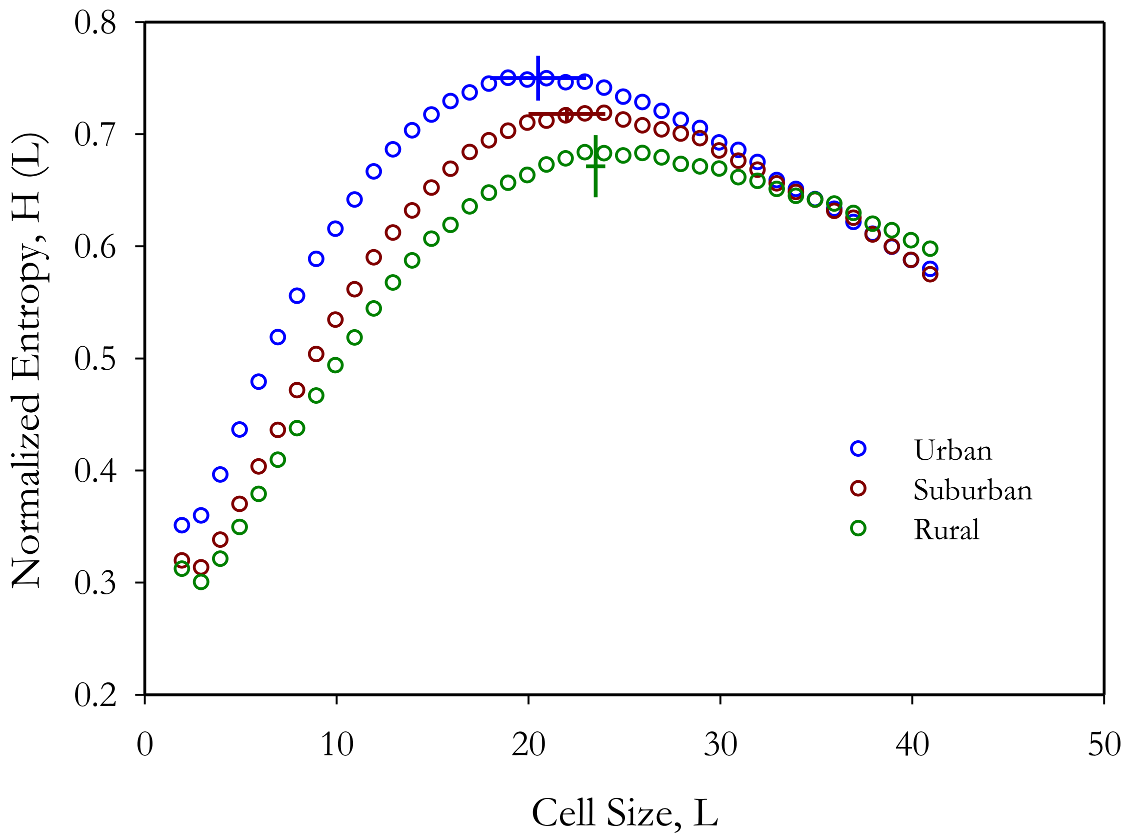
Global Change Drivers

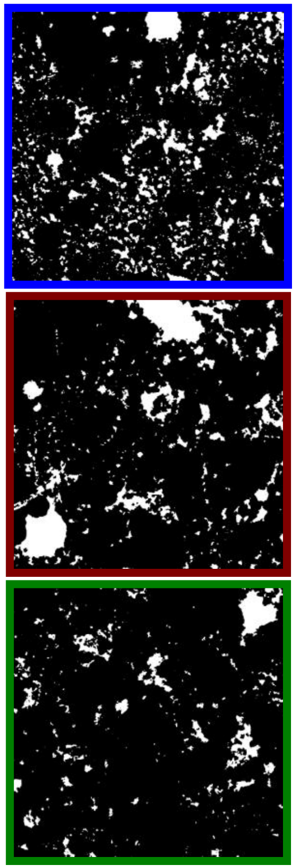


Impact of changes in climate and/or chemical composition on nutrient cycling and soil and plant ecology:

John Dighton (IMCS)
Daniel Gimenez (DES)
Robin Leichenko (Geog)
Sybil Seitzinger (IMCS)
Ming Xu (DEENR)

Entropy of Soil Pore Systems

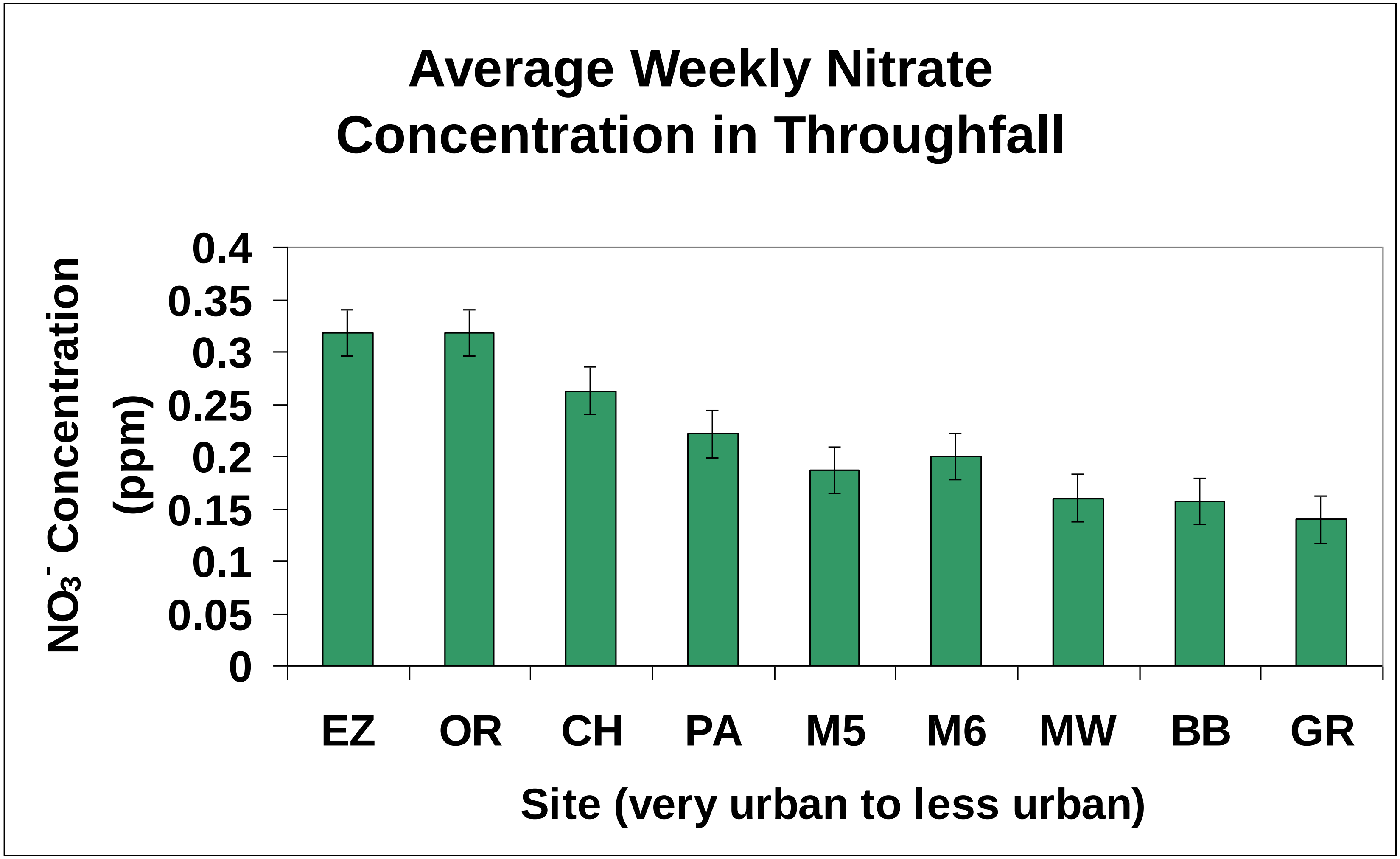




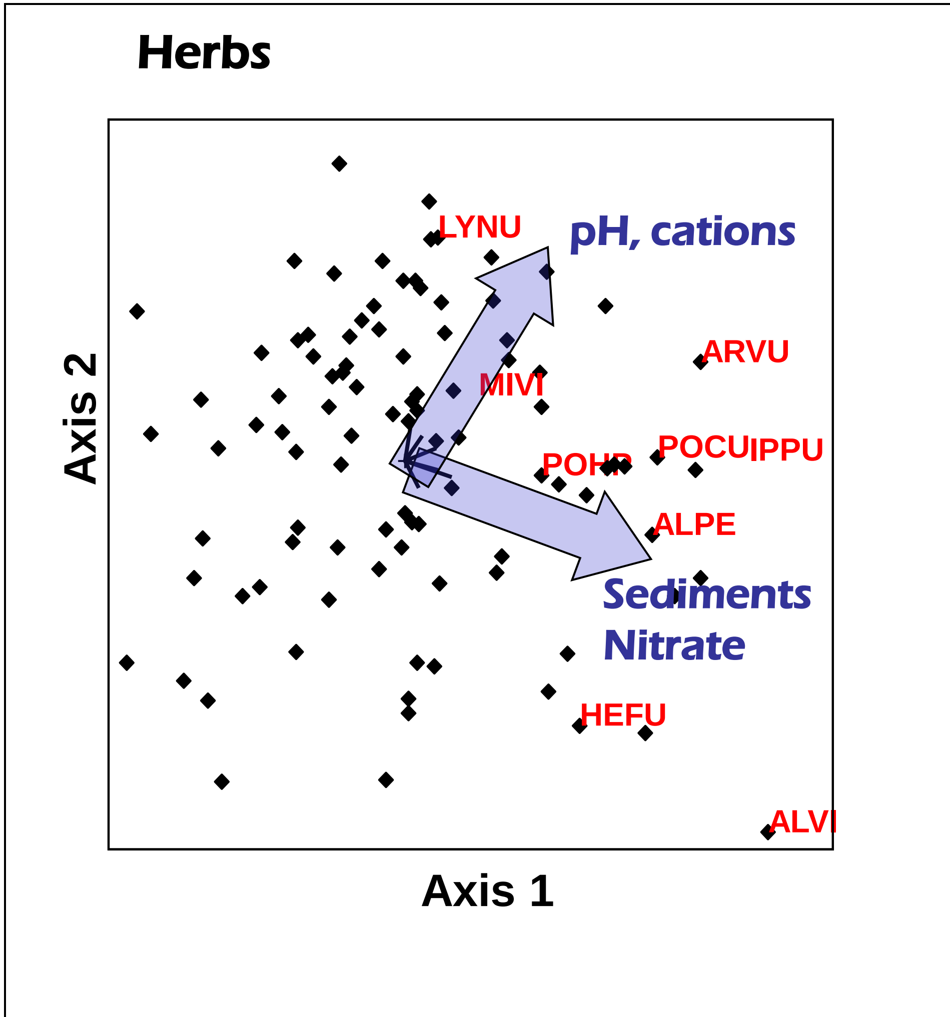
The 3D arrangement of soil pores is affected by CO_2 and temperature, with important potential implications for soil ecological functions and the transport and storage of matter and energy.

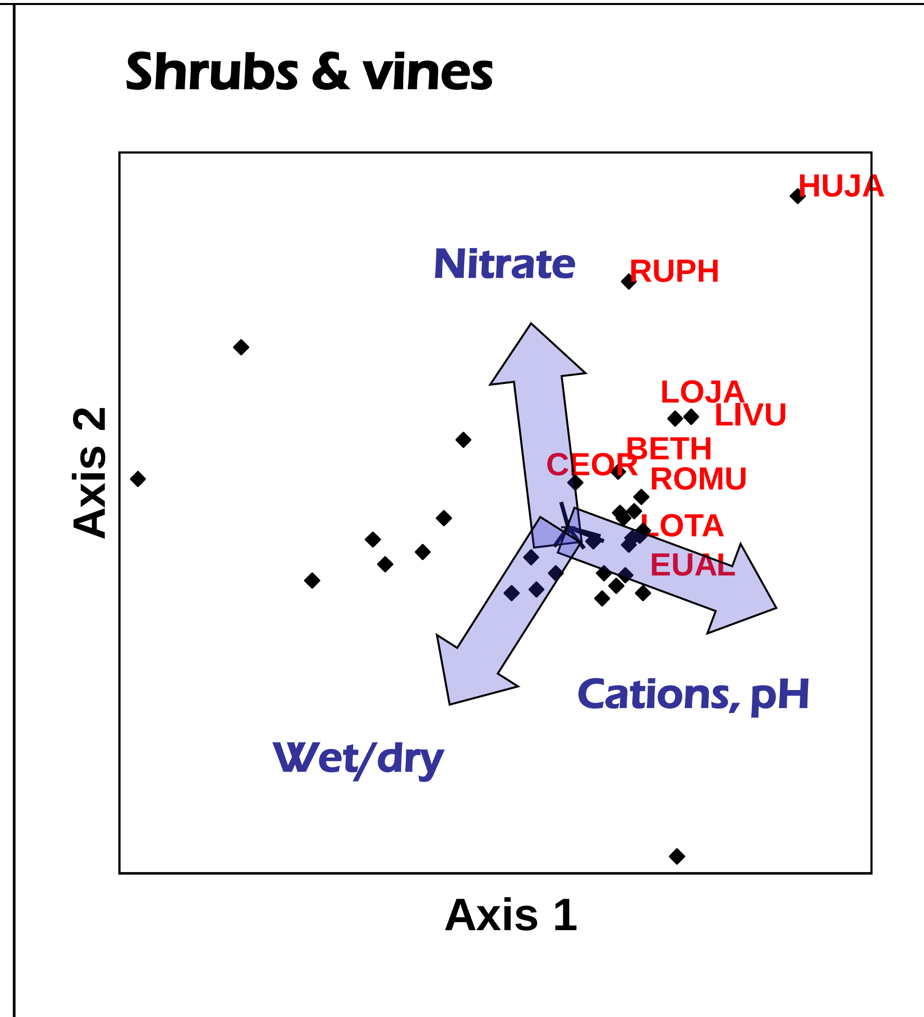
Provided by D. Gimenez

Nitrogen inputs to ecosystems increases with development …



… and exotic species in NJ wetlands are associated with increased availability of nitrogen and other nutrients



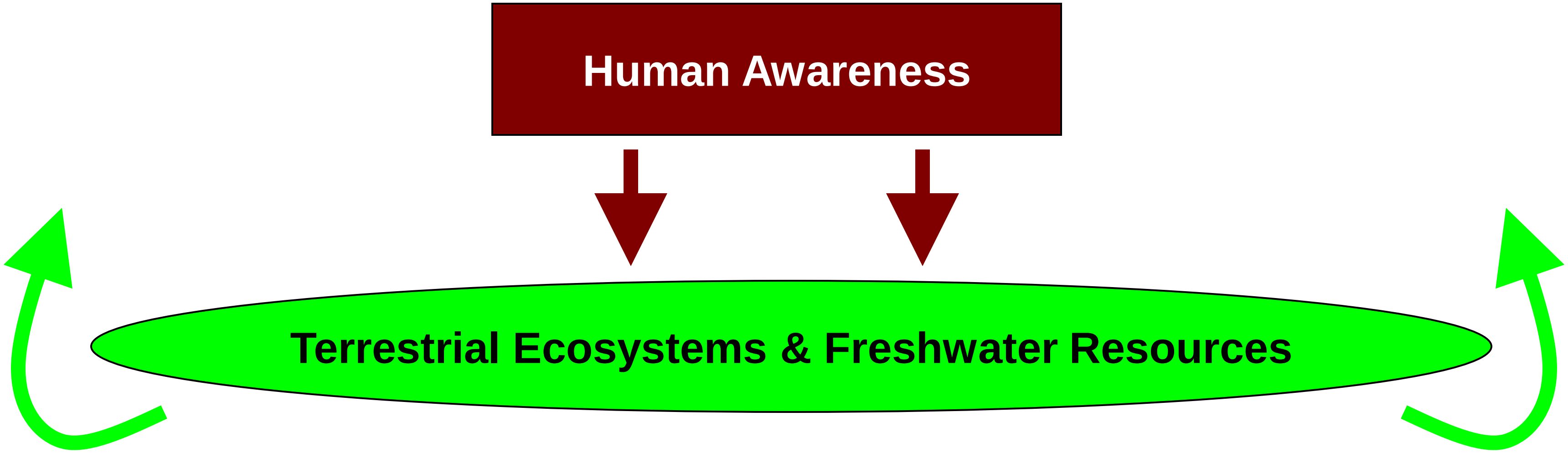


Provided by J. Ehrenfeld

Global Change Drivers

Impacts of new knowledge about global change on ecosystems and water resources - via the consequences of mitigation and adaptation policies:

Paul Gottlieb (DAFRE)
Karen O'Neill (Human Ecol)
Peter Parks (DAFRE)
Carl Pray (DAFRE)
Tom Rudel (Human Ecol)

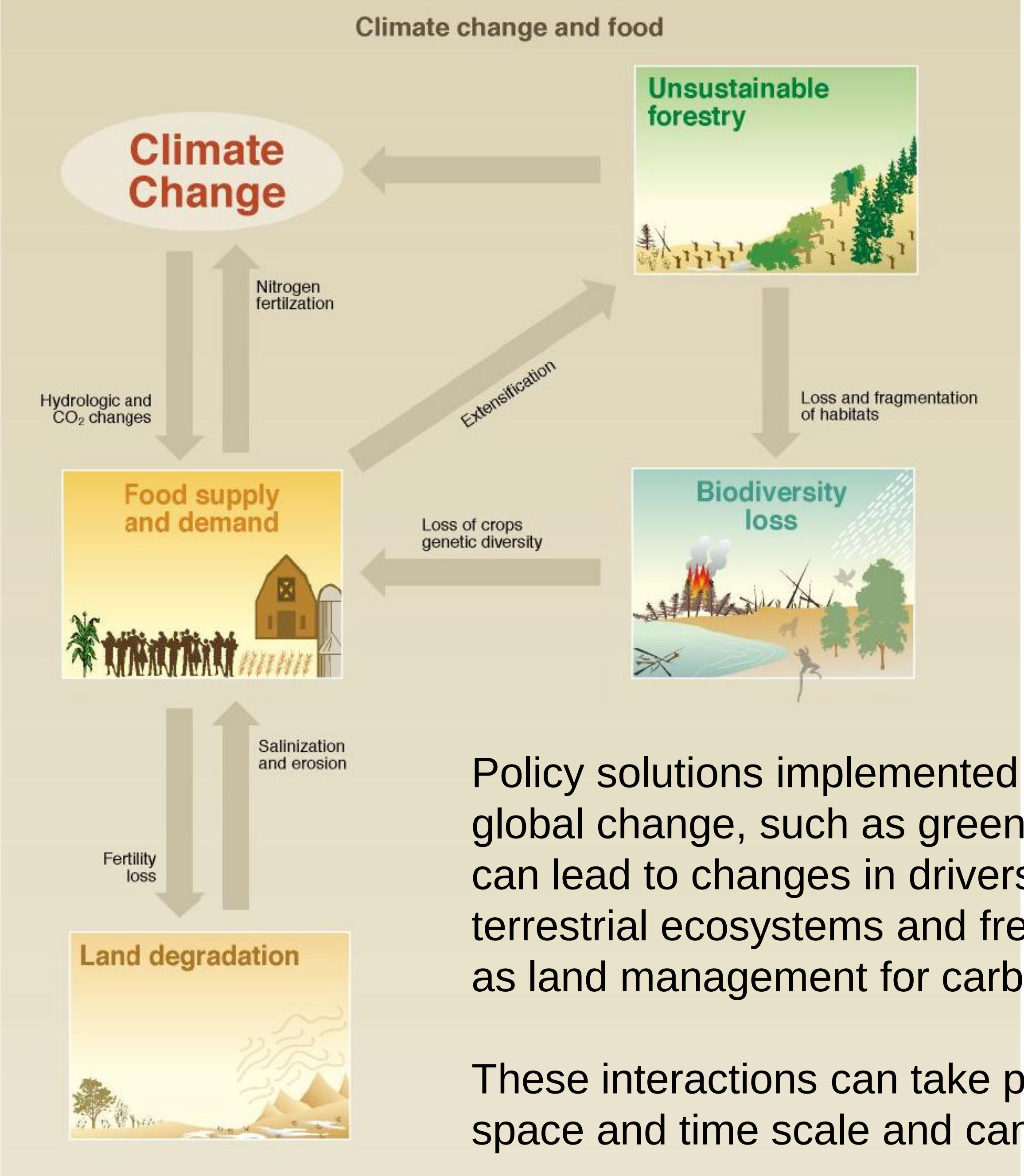


"The Unanticipated Consequences of Purposive Social Action"
Robert K. Merton, 1936

Typology:

The two most common:
Ignorance of conditions that might affect the situation
Errors in analysis, execution of policy

Less common:
Willful ignorance: purposefully ignoring unintended effects
Self-defeating prediction: prediction that prompts people to act to avoid that outcome



Policy solutions implemented to address one aspect of global change, such as greenhouse gas concentrations, can lead to changes in drivers that directly affect terrestrial ecosystems and freshwater resources, such as land management for carbon sequestration.

These interactions can take place at more than one space and time scale and can cross scales.

Gaps, challenges, and initiative-building ...

Barriers: Global Climate System Modeling

Complex, 3-D, dynamical models are unquestionably valuable scientific tools:

- They allow us to explore nonlinearities, feedbacks, threshold effects, and in general surprising behaviors when we increase the number and complexity of the linked components.
- They encapsulate our current level of scientific understanding - they provide a useful snapshot of the state of the science.

But …

We don’t yet know how to use them as effectively to support the research of the global change impacts community, nor as policy-relevant decision support tools.

We need to spend as much time learning how to use climate model output effectively in impacts studies and for policy as we spend on model development - no “overselling” of model usefulness.

Mismatch of scales/resolution - computational resources

Things like crop yield, biodiversity, stream flow etc. are complex integrators of weather and climate over a period of time.

- To understand impacts on these systems, we need additional metrics of climate change from models
- We lack much data about how well our models reproduce these other metrics.

Subject experts with different norms and perspectives: e.g., natural sciences vs. social sciences

The uncertainties in our modeling system may preclude explicit prediction of impacts - their main value may be in improving our understanding of the interconnections and feedbacks in the system - can we distill these types of lessons into heuristics to aid decision-making?

Barriers: Science for Policy

Decision makers must act on best estimates. They must accept the uncertainty present at that moment. They are interested in complex questions requiring aggregation of knowledge across disciplines.

"Science for policy" means being responsive to policymakers' needs for expert judgment at a particular time, given the information currently available, even if those judgments are subjective.

"Public understanding of science" is not a sufficient basis for policy making.

- Creation of new, clever, policy options break political deadlocks.
- There must be feedback between scientist and policy maker– the scientist must help the policy maker formulate questions answerable in terms of the science and identify the limits of the science.

A healthy process is as important as improved information. Weather forecasts have value not because they are perfect but because users have successfully incorporated them into their decision routines.

Institutional and Scholarly Structure