The Impact of Climate Change on Terrestrial Ecosystems

Climate Damages Workshop

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Washington, DC
January 28, 2011
Outline

- Background
- Descriptions of key ecosystem impacts
  - Vegetation distribution and dynamics
  - Wildfire dynamics
  - Species extinction risks
- Future research needs
Background

- Why do ecosystems matter when assessing economic impacts of climate change?
- Provide critical services to people
  - Provisioning (e.g., food, water, raw materials)
  - Regulating (e.g., air quality, storm protection, waste assimilation)
  - Cultural (e.g., recreation, passive use)
- These services have substantial economic value
Background (cont.)

- Climate change affects:
  - What species are where
  - How productive an ecosystem is
  - Rates of ecosystem processes (e.g., decomposition, denitrification)
  - The disturbance regimes it experiences
    - Drought
    - Fire
    - Pest outbreaks

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Background (cont.)

- Which ecological impacts?
- Given focus on use in integrated assessment models, focus on impacts:
  - Ecologically important
    - Impact is large and relatively widespread
  - Economically important
    - Impact will affect ecosystem services with high values
  - Well understood
    - Need to quantify projected impacts in scientifically robust way
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Key Ecosystem Impacts

- For each impact, will discuss:
  - Why the impact is likely to occur
  - The tools available to estimate the impact
  - What research has shown
  - Key uncertainties or other shortcomings with projecting future impacts
  - What key services are likely to be affected
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Changes in Vegetation

- **How will climate affect vegetation?**
  - Changes in temperature, precipitation, relative humidity affect:
    - What species can live where
    - Ecosystem productivity
    - Wildfire frequency and intensity, a key disturbance agent
  - Will fundamentally alter our environment – where grasslands and forests are, and what kinds of animals we see in different areas (not static)
Changes in Vegetation (cont.)

- **Projecting future vegetation dynamics**
  - Dynamic global vegetation models (DGVMs)
    - Large scale patterns of vegetation change
    - Typically have interacting modules:
      - Biogeography model – potential vegetation given climate and soil parameters
      - Biogeochemistry model, which simulates the movement of nutrients
      - Fire model – disturbance by wildfire
Changes in Vegetation (cont.)

- **Projecting future vegetation dynamics (cont.)**
  - For specified time period and climate scenario, DGVMs can tell you:
    - Potential vegetation type (e.g., temperate deciduous forest, temperate mixed forest)
    - Plant biomass (by life form – trees, shrubs, grasses)
    - Carbon storage (above and below-ground)
    - Burned area/wildfire frequency
Changes in Vegetation (cont.)

- Projecting future vegetation dynamics (cont.)
  - Many DGVMs are available; commonly used:
    - MC1 – United States
    - Lund-Potsdam-Jena (LPJ) – Germany/Sweden
    - SDGVM – United Kingdom
    - Integrated Biosphere Simulator (IBIS) – United States
Changes in Vegetation (cont.)

- What research has shown

Changes in Vegetation (cont.)

- % change in tree coverage, SRES A1FI, 4 DGVMs, Hadley GCM
- Significant variability across models
- Some areas of general agreement
  - Varying degrees of Amazon forest dieback
  - Boreal forest expansion

Changes in Vegetation (cont.)

- **Key uncertainties**
  - *Potential* vegetation only – most anthropogenic factors ignored; some can be addressed
    - Fires suppression can be accounted for
    - Can screen out urban/agricultural lands
  - Assume no barriers to plant dispersal
  - Pests and pathogens are ignored
  - Significant differences across DGVMs for the same region and climate scenario
Changes in Vegetation (cont.)

- **Affected ecosystem services**
  - Forestry
    - Timber
    - Non-timber forest products
  - Grazing
    - Forage productivity in grasslands, shrublands, savannas, and forests
  - Carbon sequestration and storage
Changes in Vegetation (cont.)

- **Take home**
  - Ecosystems across the globe will be affected, so this is a key impact to consider
  - Can examine multiple scales – countries, regions, the globe
  - Linked to critical ecosystem services
  - Good models, but difficult to know which ones are most reliable
  - Highly dependent on the GCM used
  - Look for areas of agreement, perhaps average DGVM results when possible
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Wildfire Dynamics

How will climate affect wildfire?
- Fires will likely increase in many areas via various mechanisms
  - Direct
    - Higher temperatures = more fires
    - Higher temperatures (and decreased precipitation) = desiccation of vegetation and forest floor (fuel)
  - Indirect
    - Changes in vegetation type (grassland/forest)
    - Changes in productivity (fuel load)
Wildfire Dynamics (cont.)

- **Projecting future wildfire dynamics**
  - Statistical models
    - Examine past fire behavior
    - Identify factors (e.g., via stepwise linear regression) that are key to predicting fire
    - Use equation to predict fires in future (based on key variables)
  - DGVMs
Wildfire dynamics (cont.)

- What research has shown
  - Change wildfire freq. from 2000-2100, A1B
  - More fire: U.S., central South America, southern Africa, western China, Australia
  - Less fire: northern Canada, northern Russia

Wildfire Dynamics (cont.)

- Key uncertainties
  - For both statistical model and DGVM approaches
    - Methods only roughly approximate historical fires
    - Thus, provide similarly rough estimates of future wildfire dynamics
    - Timing/locations of specific fires cannot be predicted
Wildfire Dynamics (cont.)

- Affected ecosystem services
  - Timber/non-timber forest product provisioning
  - Recreation
  - Fire suppression (not an ecosystem service but a real cost)
  - Regulation of air quality – aerosols
    (see Spracklen et al., 2009, *Journal of Geophysical Research*)
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Species Extinctions

- **How will climate affect it?**
  - Climate (temperature/precipitation) is a key driver of species and ecosystem distributions.
  - As climate shifts, areas that support specific species may move (sometimes into areas inhabited by humans).
  - Habitat may disappear (e.g., alpine, cloud-forest dependent species).
  - These dynamics will likely increase the risk of species extinctions.

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Species Extinctions (cont.)

- **Projecting future species extinctions**
  - Most commonly involves application of “climate envelope” models
    - Use current distributions of a species to construct its climatic requirements
    - Under future climate change, then determine where species could live
    - Use species-area relationships to project extinctions
Species Extinctions (cont.)

- **What research has shown**
  
  - Results vary
  
  - 9–52% of species will be “committed” to extinction by 2050 (Thomas et al., 2004)
  
  - 20–30% of plant and animal species at risk of extinction with increase of 2–3°C (IPCC, 2007)
  
  - 0–60% extinctions for different taxa/methodologies (Pereira et al., 2010)

  - Envelope model did no better than “null” models in predicting species occurrence (null = species ranges are randomly placed in region; Beal et al., 2010)
Species Extinctions (cont.)

- **Key uncertainties**
  - Great deal of uncertainty within and across studies and modeling methods
  - Climate envelope models
    - May overestimate extinctions
      - Species may be flexible climatically
      - Biotic interactions may be more important than climate
    - May underestimate extinctions
      - Dispersal may be limited by habitat fragmentation
      - Impacts of climate change may be amplified by land use change
Species Extinctions (cont.)

- **Affected ecosystem services**
  - Another key issue...
  - How do you value global biodiversity?
    - Could query public
      - Some species may matter more to the public, and ecologically, than others
Species Extinctions (cont.)

- **Affected ecosystem services (cont.)**
  - Values could be tied to specific species, or suites of species
    - A given tree may provide highly valued wood
    - Bird watching/wildlife viewing is valuable
  - But values not tied to global extinction risk – linked to species, suites of species, and/or specific locations
Species Extinctions (cont.)

- **Take home**
  - Climate change is a threat to species, and more extinctions are likely to occur
  - Range of estimates available for species extinction risk
  - Robustness of estimates highly contested
  - Link to ecosystem services and values difficult
  - Proceed with caution
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Future research

- Integrating across approaches
  - Across all impacts, variety of methods available that provide different estimates of impact
  - Need to think carefully about how to integrate across studies/tools
    - Meta-analyses?
    - ‘Ensemble means’ of ecosystem impacts with different models?
    - Need to be done with different climate scenarios/GCMs
    - How can this be done practically?
Future research (cont.)

- **Major Gaps**
  - Need to develop large-scale, long term projections for changes in
    - Pest outbreaks
    - Interior wetland change/loss
  
  - Changes in snow pack dynamics
    - Large-scale impacts on freshwater/marine ecosystems
    - Implications for recreational values
Thank you!

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Wildfire Dynamics (cont.)

- What research has shown
  - Fire risk for three different time periods over 21st century
  - Higher fire risk:
    - U.S.
    - Amazon
    - Western China
  - Lower fire risk:
    - Northern Canada
    - Russia
    - Australia (?)