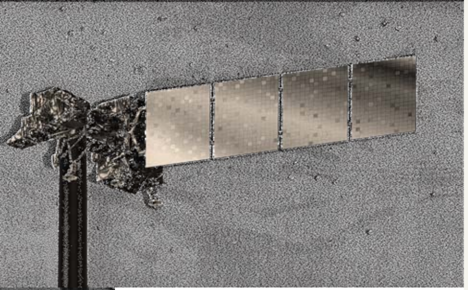


# Relevance of HyspIRI to Carbon and Climate Science

**Susan L. Ustin**

## IPCC Climate Change 2007: Working Group I: The Physical Science Basis

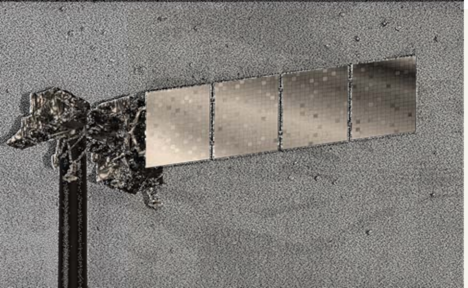
### Chapter 7: Couplings Between Changes in the Climate System and Biogeochemistry

**Executive Summary:**

"Nonlinear interactions between the climate and biogeochemical systems could amplify (positive feedbacks) or attenuate (negative feedbacks) the disturbances produced by human activities."

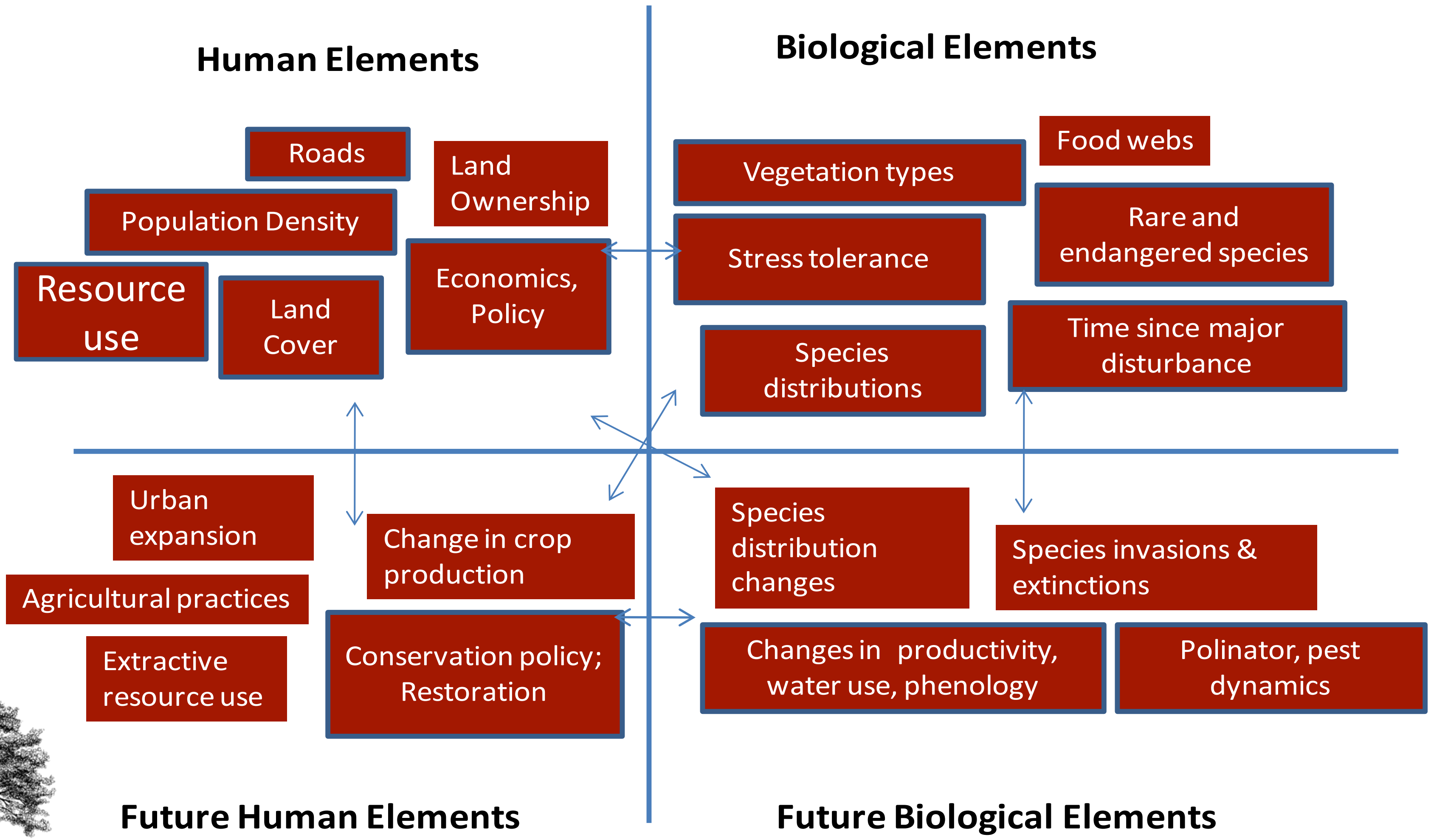
**Decadal Survey Box 1.3 Abundant Challenges: Protecting Ecosystems**

"And yet there are no adequate spatially resolved estimates of the planet's biomass and primary production, and it is not known how they are changing and interacting with climate variability and change." (P.25).



# Predicting Future Ecosystems Under Global Changes in Climate and Land Use

## Nonlinear interactions between climate and complex systems create uncertainty



# IPCC Climate Change 2007: Working Group I: The Physical Science Basis

## Chapter 7: Couplings Between Changes in the Climate System and Biogeochemistry: Executive Summary

### *The Land Surface and Climate*

- Changes in the land surface (vegetation, soils, water) resulting from human activities can affect regional climate through shifts in radiation, cloudiness and surface temperature.
    - ➢Changes in vegetation cover affect surface energy and water balances at the regional scale, from boreal to tropical forests.

    - ➢The impact of land use change on the energy and water balance may be very significant for climate at regional scales over time periods of decades or longer.

***Land Carbon. Understanding land carbon storage is a critical factor in predicting the growth of atmospheric*** $CO_2$ and subsequent global climate change. P. 273 , DS.

# Relevance of HyspIRI to Carbon and Climate Science

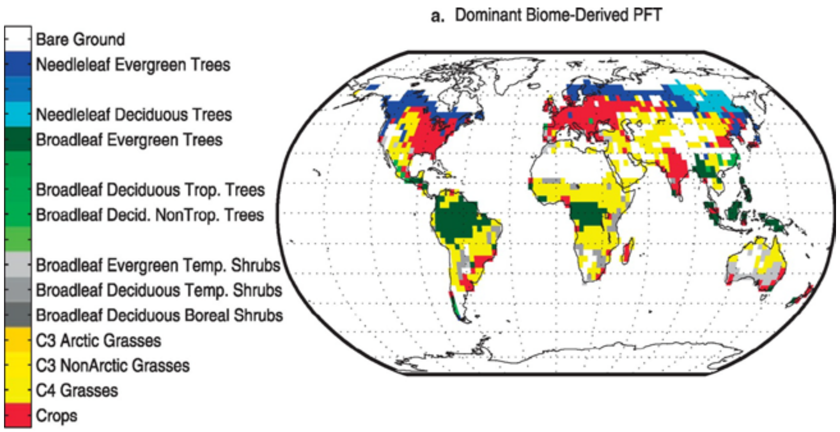
## Monitoring Vegetation Type and Functions

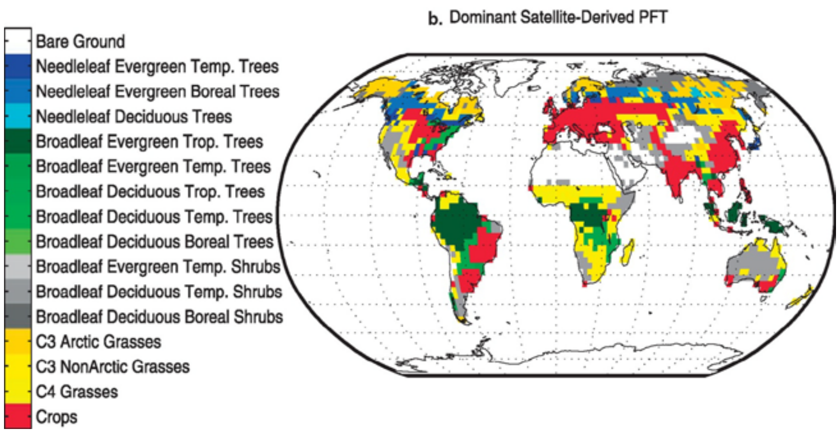
Global Land Cover Maps based on climate potential have biased Distributions

- Coarse Spatial Resolution data do not agree with actual land cover types

Satellite Based plant functional type maps have higher spatial resolution and are derived from actual measurements

- Maps remain too spatially coarse to monitor ecosystem changes
- Limited number of cover types; no subgrid elements



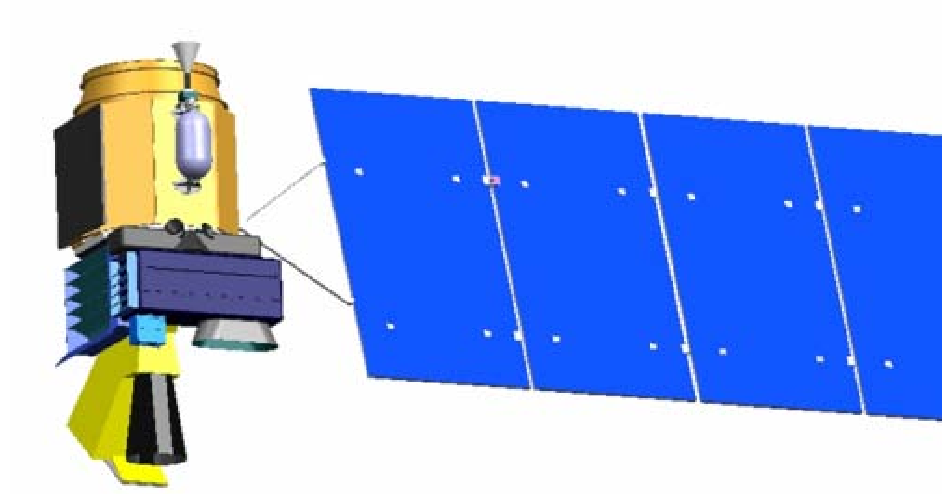




From: Bonan, GB, Levis S, Sitch S, Vertenstein M, Olson KW (2003). Global Change Biology 9: 1543-1556, Figure b from: Ramankutty N. and Foley JA. (1999). Global Biogeochemical Cycles 13: 997-1027.

# Decadal Survey: HyspIRI Recommendation
## by Ecosystem, Climate and Land Use Change Panels

"A hyperspectral sensor (e.g., FLORA) combined with a multispectral thermal sensor (e.g., SAVII) in low Earth orbit (LEO) **is part of an integrated mission concept [**described in Parts I and II] that is relevant to several panels, ***especially the climate variability panel***." p. 368.

HyspIRI Concept



**Visible ShortWave InfraRed (VSWIR) Imaging Spectrometer**
**+**
**Multispectral Thermal InfraRed (TIR) Scanner**

# IPCC Climate Change 2007: Working Group I: The Physical Science Basis

## Chapter 7: Couplings Between Changes in the Climate System and Biogeochemistry: Executive Summary

### The Carbon Cycle and Climate

- Interannual and inter-decadal variability in the growth rate of atmospheric $CO_2$ **is *dominated by the response of the land biosphere to climate variations***.

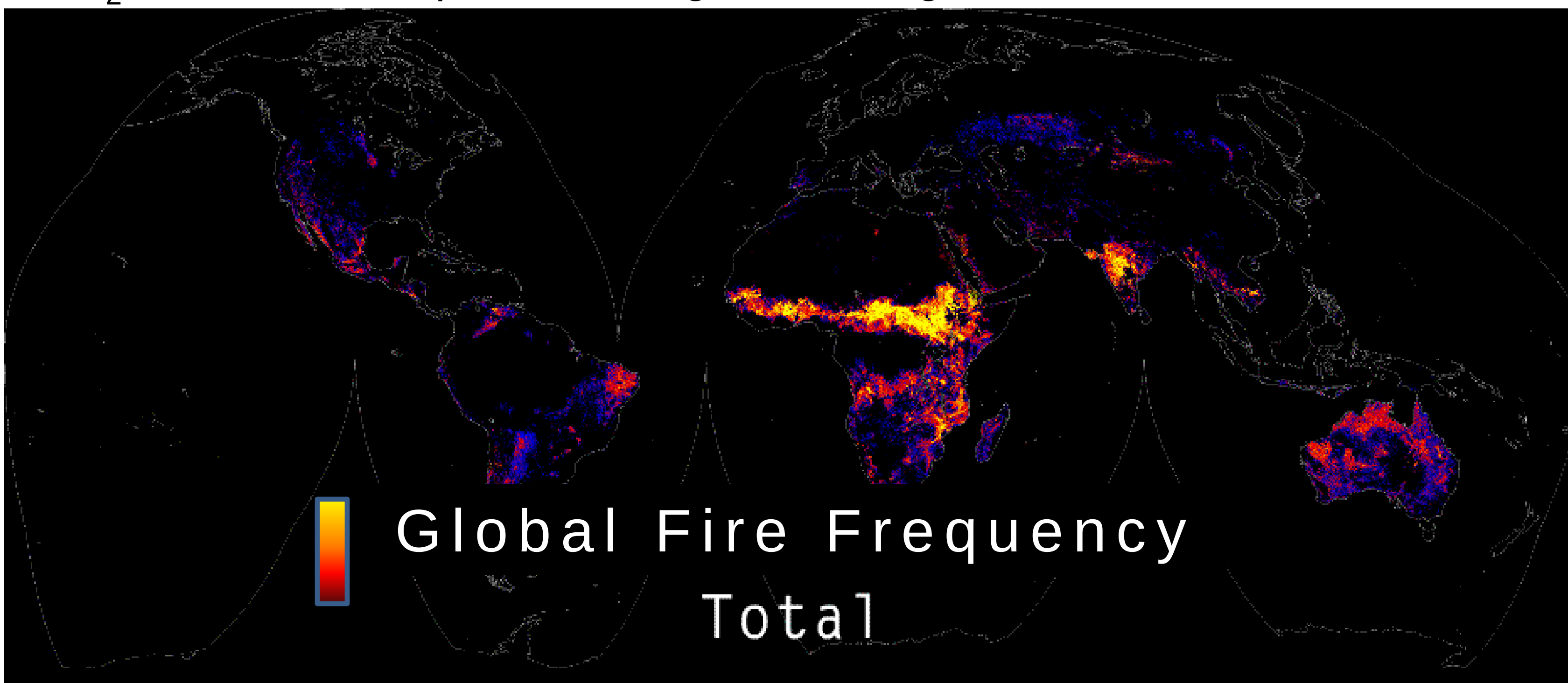
- A combination of techniques gives an estimate of the flux of $CO_2$ to the atmosphere from land use change of 1.6 (0.5 to 2.7) GtC yr$^{-1}$ for the 1990s [ ] and ***continuing uncertainty in the net $CO_2$ emissions due to land use change***.

# IPCC Climate Change 2007: Working Group I: The Physical Science Basis

## Chapter 7: Couplings Between Changes in the Climate System and Biogeochemistry: Executive Summary

## The Carbon Cycle and Climate

- If fire frequency and extent increase with a changing climate, a net increase in $CO_2$ emissions is expected during this fire regime shift.




**Global Burned Area 1981-2000 from NOAA-NASA Pathfinder Data**

Riaño et al. 2007. Global Change Biology

# IPCC Climate Change 2007: Working Group I: The Physical Science Basis

## Chapter 7: Couplings Between Changes in the Climate System and Biogeochemistry: Executive Summary

### 7.3.3 Terrestrial Carbon Cycle Processes and Feedbacks to Climate

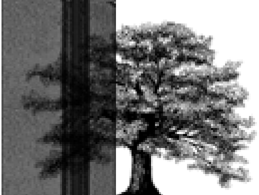
To understand the reasons for $CO_2$ uptake and its likely future course, it is necessary to understand the underlying processes and their dependence on the key drivers of climate, atmospheric composition and human land management.

Drivers that affect the carbon cycle in terrestrial ecosystems can be classified as:

**(1) direct climate effects** (changes in precipitation, temperature and radiation regime);

**(2) atmospheric composition effects** ($CO_2$ fertilization, nutrient deposition, damage by pollution); and

**(3) land use change effects** (deforestation, afforestation, agricultural practices, and their legacies over time).



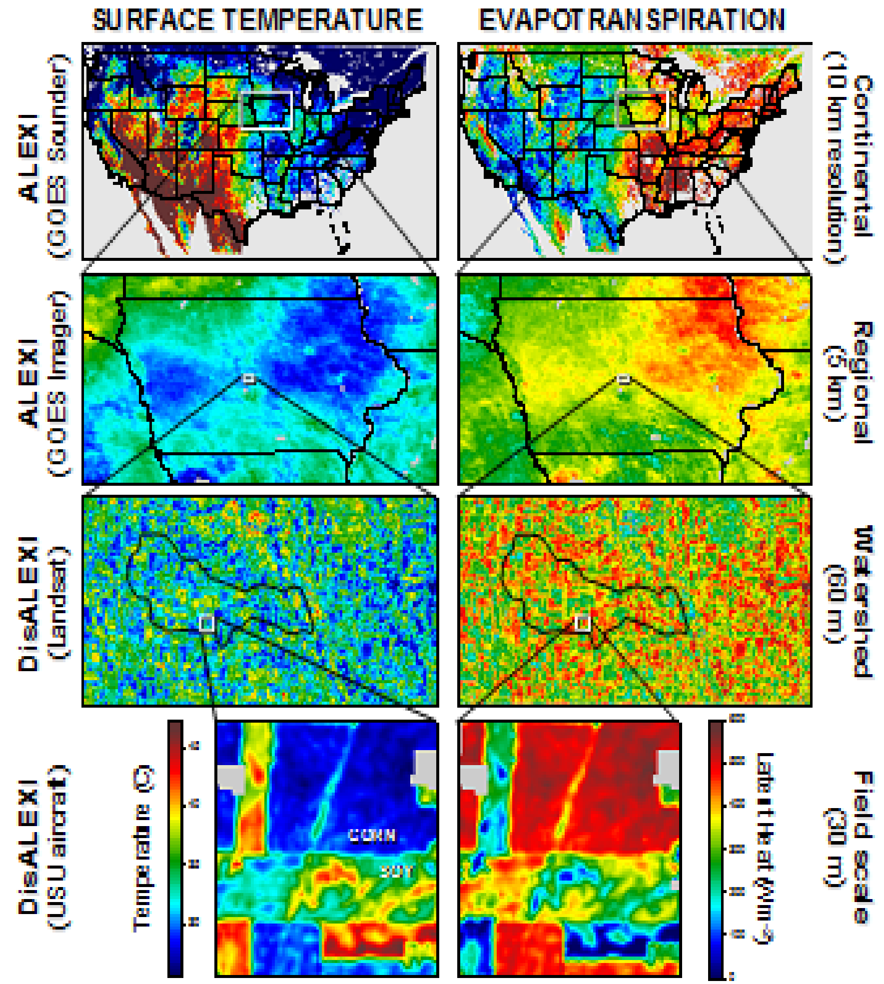
# IPCC Climate Change 2007: Working Group I: The Physical Science Basis

## Chapter 7: Couplings Between Changes in the Climate System and Biogeochemistry: Executive Summary

### 7.1.1 Terrestrial Ecosystems and Climate

The terrestrial biosphere interacts strongly with the climate, providing both positive and negative feedbacks due to biogeophysical and biogeochemical processes.

Some of these feedbacks, at least on a regional basis, can be large. Both radiative and non-radiative terms are controlled by details of vegetation.



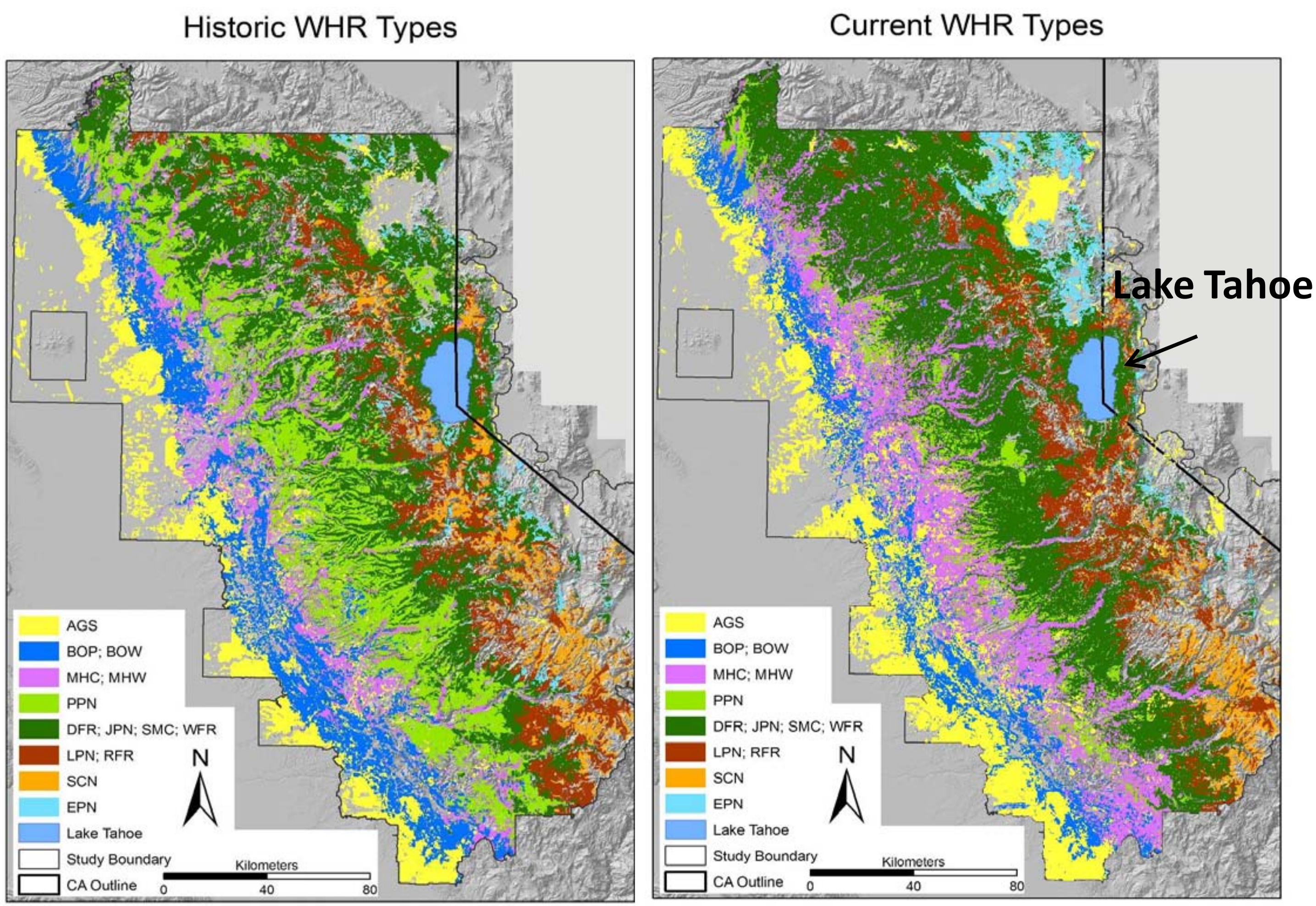
# IPCC Climate Change 2007: Working Group I: The Physical Science Basis

## Chapter 7: Couplings Between Changes in the Climate System and Biogeochemistry: Executive Summary

## 7.1.1 Terrestrial Ecosystems and Climate: Carbon Cycle Drivers

Changing Plant Functional Types in California from 1934 to 1996

Grasslands
Mixed oak-pine savanna
Ponderosa pine forest
Mixed Montane Hardwod & Conifer
Mixed conifer
Lodgepole pine, red fir
Subalpine conifers



# IPCC Climate Change 2007: Working Group I: The Physical Science Basis

## 2.5.8 Effects of Carbon Dioxide Changes on Climate via Plant Physiology: ‘Physiological Forcing’

### Radiative Forcing and Physiological Forcing

As well as exerting an RF on the climate system, increasing concentrations of **atmospheric $CO_2$ can perturb the climate system through direct effects on plant physiolog**y.

A decrease in **moisture flux modifies the surface energy balance**, increasing the ratio of sensible heat flux to latent heat flux and therefore warming the air near the surface (Sellers et al., 1996; Betts et al., 1997; Cox et al., 1999). Betts et al. (2004) proposed the term ‘physiological forcing’ for this mechanism.

**Increased $CO_2$ concentrations** can ‘fertilize’ plants by stimulating photosynthesis, Models suggest this has contributed to increased vegetation cover and leaf area over the 20th century (Cramer et al., 2001).

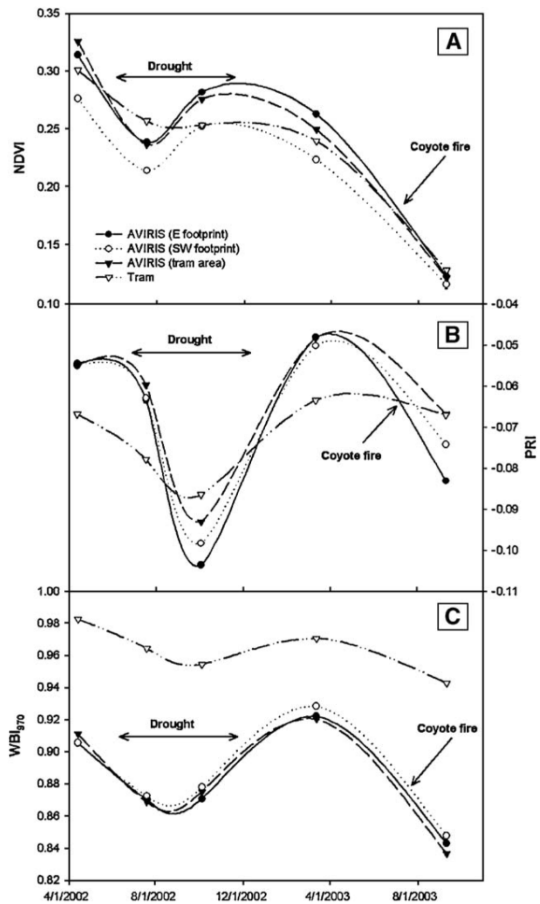
# IPCC Climate Change 2007: Working Group I: The Physical Science Basis

## 2.5.8 Effects of Carbon Dioxide Changes on Climate via Plant Physiology: ‘Physiological Forcing’

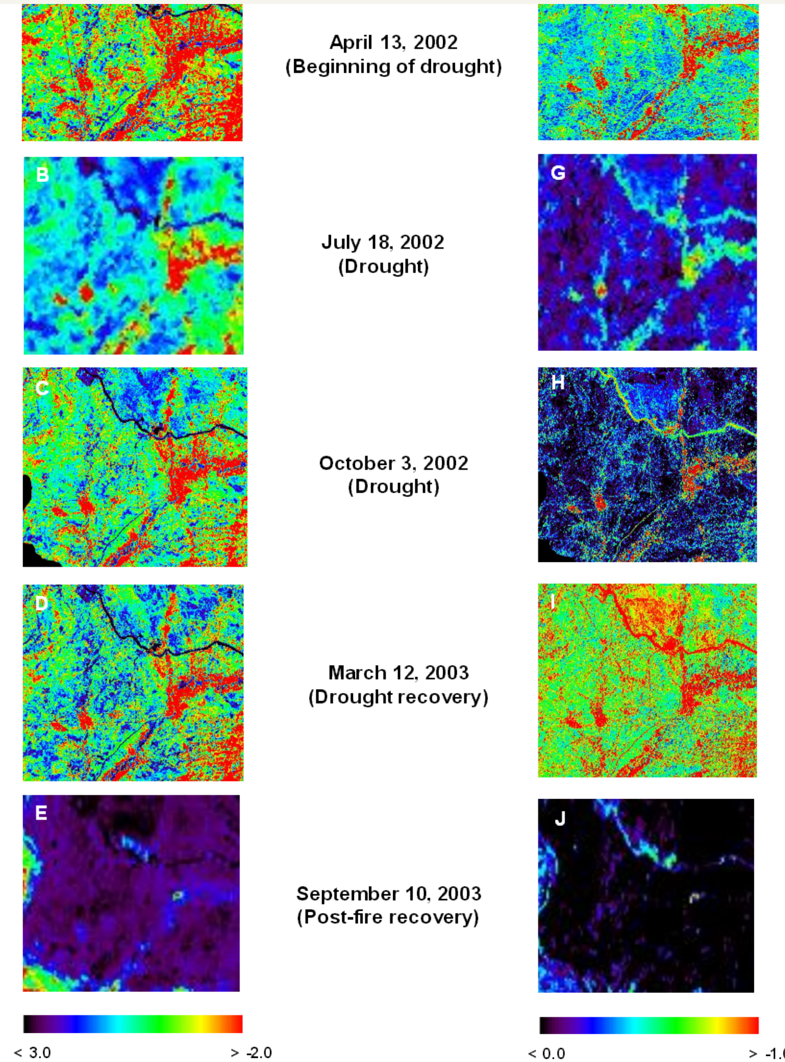
## Radiative Forcing and Physiological Forcing

Interactions bertween water and carbon

Spatial and temporal patterns of carbon and water vapor fluxes,
Sky Oaks, CA



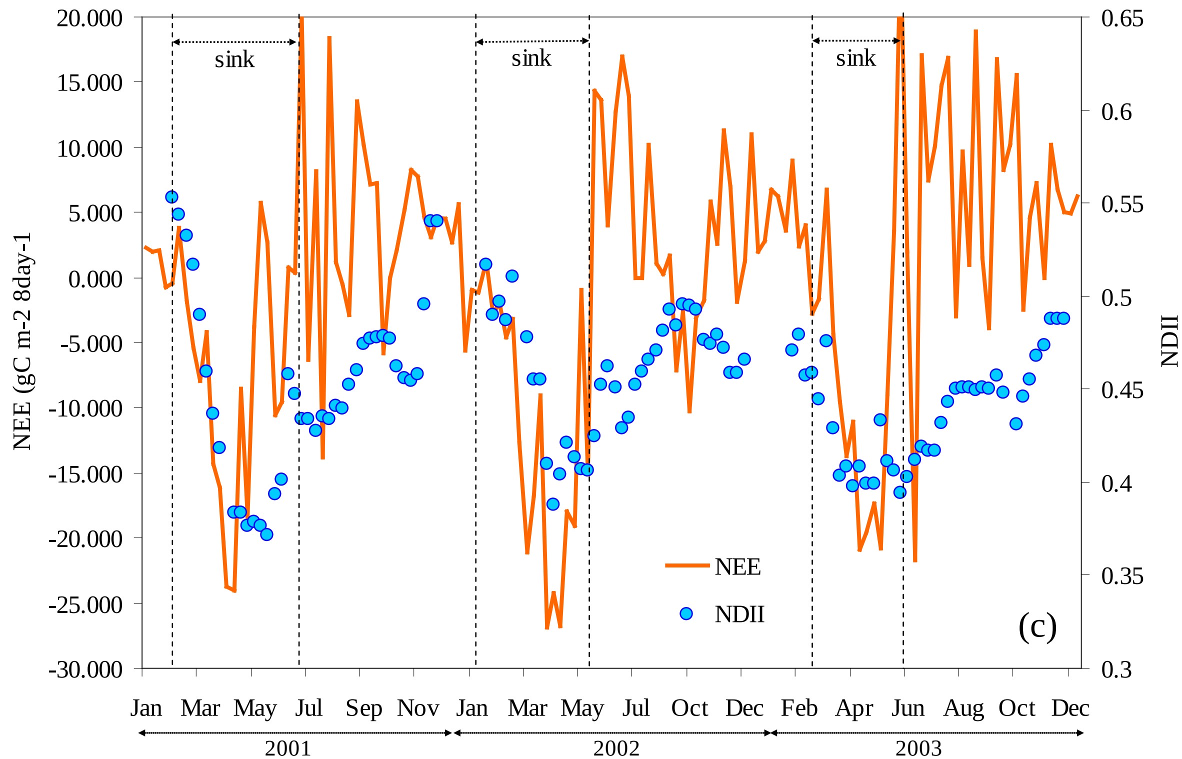

Fuentes et al. 2006



# Role of HyspIRI: detect responses of ecosystems to human land management and climate change and variability (Decadal Survey, P. 114)

**Drought affects the magnitude and timing of water and carbon fluxes**, causing plant water stress and death and possibly wildfires and changes in species composition

- Detect early signs of ecosystem change through altered physiology, including agricultural systems

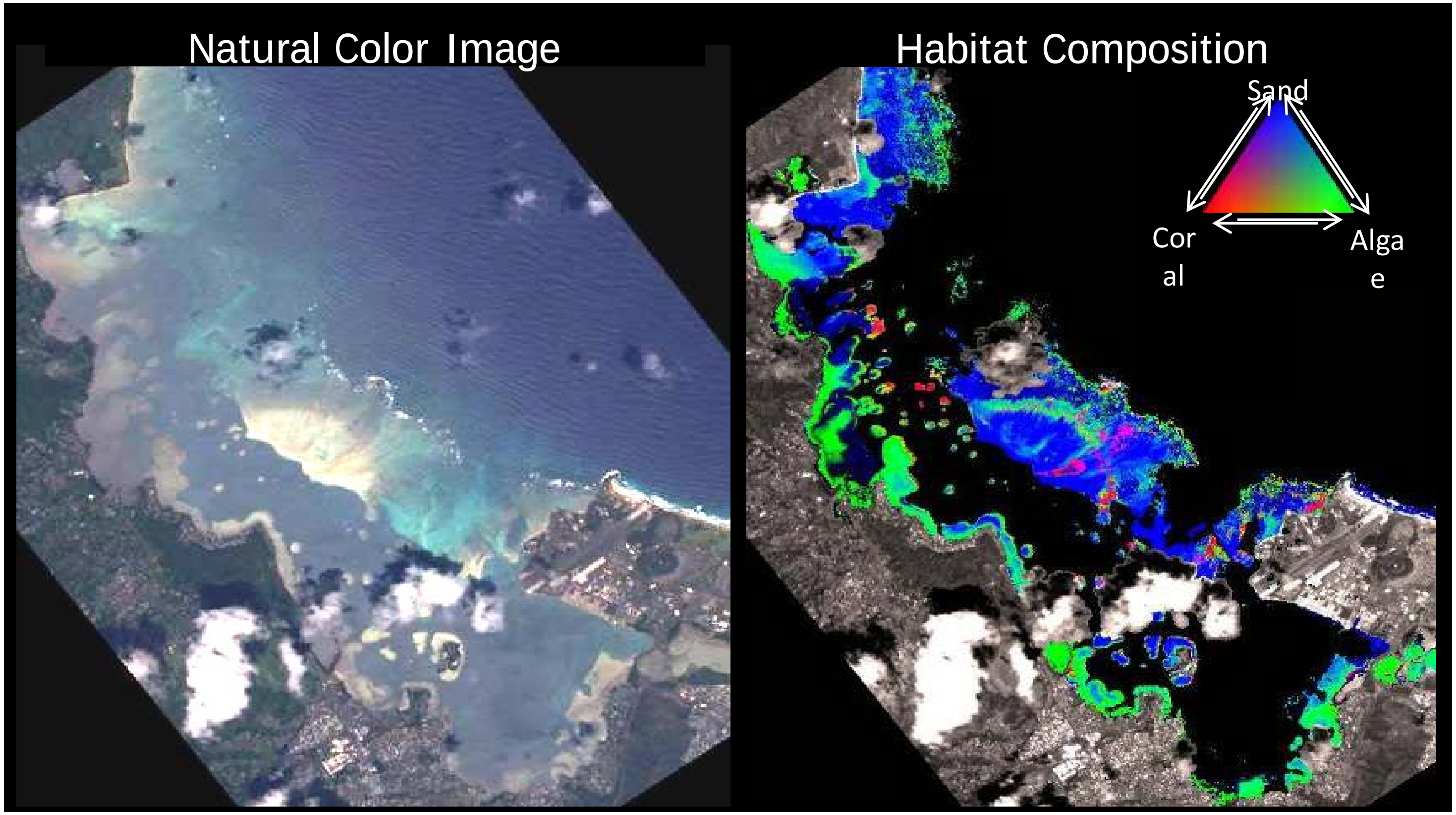



3 Years of NEE and canopy water content (NDII) from an old growth conifer forest

Cheng, Y-B., P.J. Zarco-Tejada, S.L. Ustin, S. Wharton, M. Falk, and K. T. Paw U. International Journal of Applied Remtoe Sensing 2007

# Role of HyspIRI: Detect responses of ecosystems to human land management and climate change and variability (Decadal Survey, P. 114)

Detect changes in the health and extent of coral reefs, a bellwether of climate change.




J. Goodman and S. Ustin, Int. J. Applied Remote Sensing, 2007

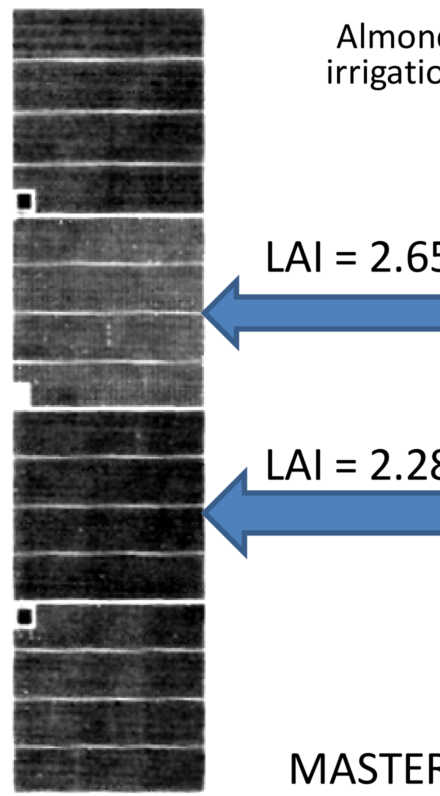
# IPCC Climate Change 2007: Working Group I: The Physical Science Basis

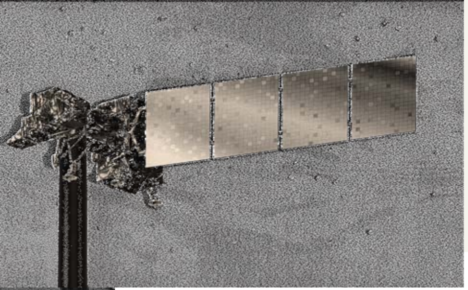
## Chapter 7: Couplings Between Changes in the Climate System and Biogeochemistry: Executive Summary

## Reactive Gases and Climate

•Observed increases in atmospheric methane concentration, compared with pre-industrial estimates, ***are directly linked to human activity, including agriculture, energy production, waste management and biomass burning***.

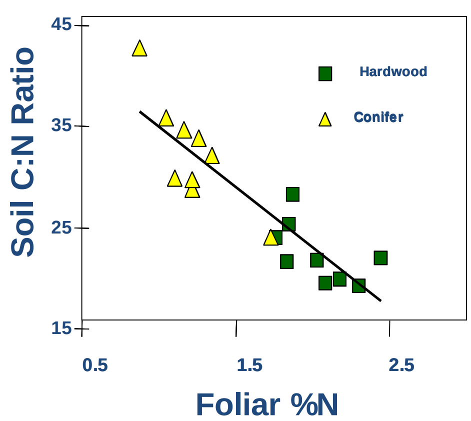
Observed increases in $NO_x$ and nitric oxide emissions, compared with pre-industrial estimates, are very likely ***directly linked to 'acceleration' of the nitrogen cycle driven by human activity, including increased fertilizer use, intensification of agriculture*** and fossil fuel combustion.

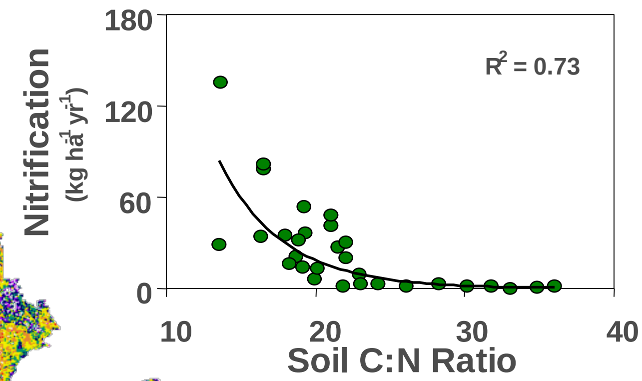


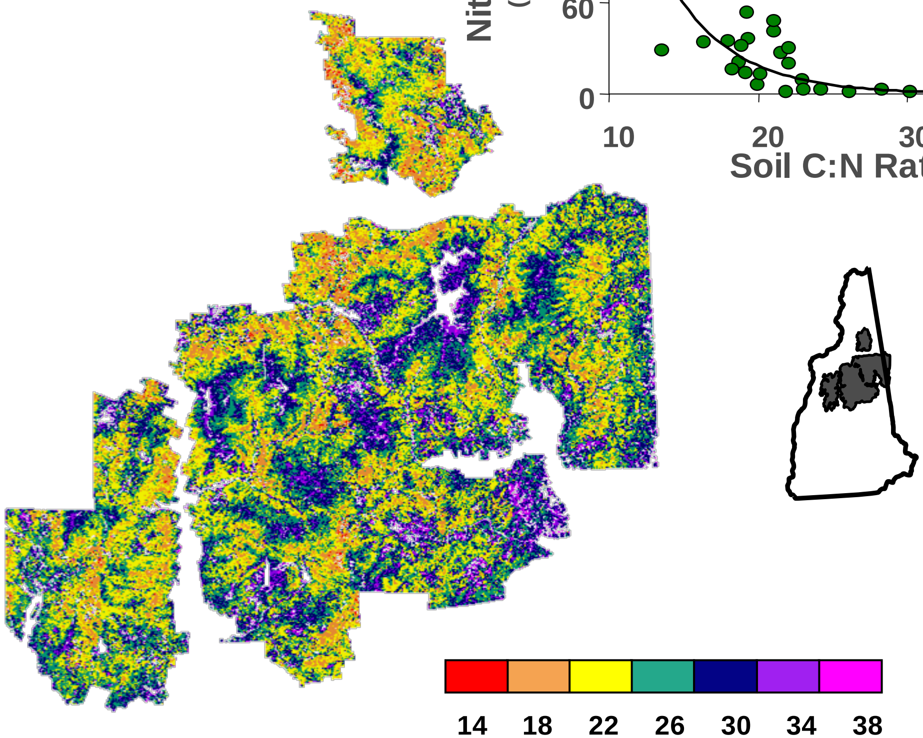


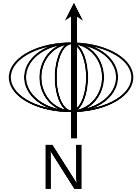
# Decadal Survey: Relevance of HyspIRI to Carbon and Climate Science: Ecosystem Function and Services

HyspIRI is required to detect and diagnose changes in ecosystem function, such as water and nutrient cycling and species composition (Decadal Survey p. 29).

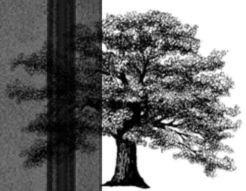



**Predicted Foliar Chemistry (PC) from Spectroscopy Is Used to Estimate Soil Nitrogen Cycling**



# Decadal Survey: HyspIRI

## BOX 7.2 SCIE NCE THEMES AND Key Questions (Page 192)

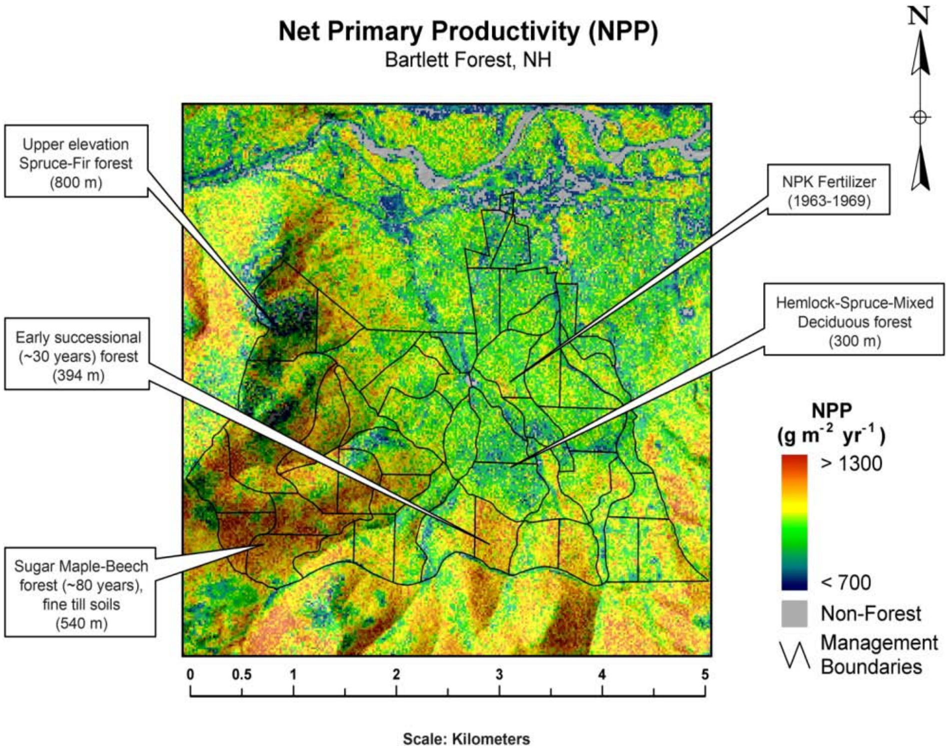
## Disruption of the Carbon, Water, and Nitrogen Cycles

**Key Questions for Identifying Priorities for Satellite Observations for Understanding and Managing Ecosystems**

How does climate change affect the carbon cycle?

How does changing terrestrial water balance affect carbon storage by terrestrial ecosystems?

How do increasing nitrogen deposition and precipitation affect terrestrial and coastal ecosystem structure and function and contribute to climate feedbacks?




Net primary production (NPP) **scales with Nitrogen NOT leaf area index (LAI)** as derived from imaging spectroscopy data over the Bartlett National Forest, New Hampshire. Figure adapted from S.V. Ollinger and M.L. Smith, (2005) *Ecosystems* **8** (2005), pp. 760–778.

# Decadal Survey: HyspIRI

**BOX 7.2 SCIE NCE THEMES AND Key Questions**

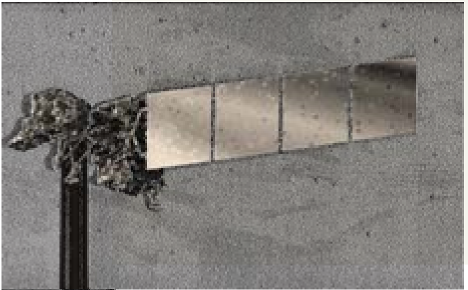
## Changing Land Resource Use **(Page 192)**

**Key Questions for Identifying Priorities for Satellite Observations for Understanding and Managing Ecosystems**

What are the consequences of uses of land and coastal systems, such as urbanization and resource extraction, for ecosystem structure and function?

- How does land use affect the carbon cycle, nutrient fluxes, and biodiversity?
- What are the implications of ecosystem changes for sustained food production, water supplies, and other ecosystem services?
- What are the options for diminishing potential harmful consequences on ecosystem services and enhancing benefits to society?

ASTER June 2002



# Decadal Survey: HyspIRI

## BOX 7.2 SCIE NCE THEMES AND Key Questions (Page 192)

## Changes in Disturbance Cycles

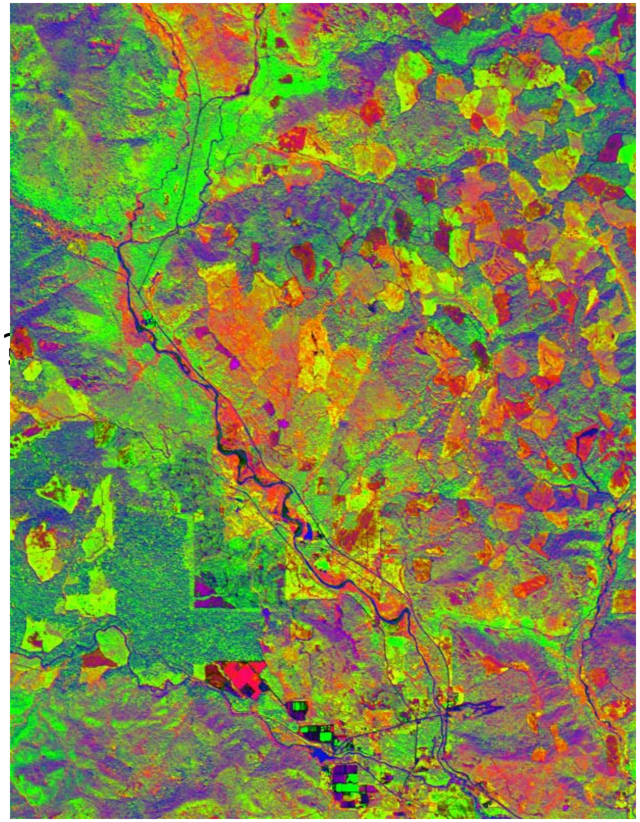
How does climate change affect such disturbances as fire and insect damage?

What are the effects of disturbance on productivity, water resources, and other ecosystem functions and services?

How do climate change, pollution, and disturbance interact with the vulnerability of ecosystems to invasive species?

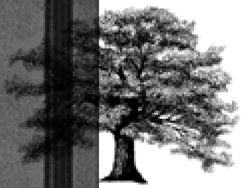
How do changes in human uses of ecosystems affect their vulnerability to disturbance and extreme events?

AVIRIS, MNF image TT Munger Research Site, Gifford Pinchot NF, Washington



Ustin and Trabucco, 2000

Swiss Needle Cast



# Decadal Survey: Relevance of HyspIRI to Carbon and Climate Science

**Decadal Survey Recommendation:**

A hyperspectral sensor combined with a multispectral thermal sensor in low Earth orbit (LEO**) is part of an integrated mission concept** described in DS Parts I and II that is relevant to several panels, ***especially the climate variability panel***. p. 368, DS,