The effects of land use change on terrestrial carbon dynamics in the Black Sea Region (and New England)
Science Goals

• Quantify the effects of land use change on terrestrial carbon budgets in the Black Sea Region
• Significantly minimize the uncertainties associated with the carbon cycle dynamics, particularly associated with land-use change
• Approach is to use remote sensing to measure rates of land use change
• Use rates of land use change in Houghton’s book keeping model to estimate carbon dynamics

• Additionally, apply the same approach to New England
Today: Results from Romania, Turkey and Georgia

• Interesting differences between these countries:
  – Turkey has lowest rates of forest change - urban migration is reducing pressure on rural land use and leading to some abandonment of small parcels of pasture
  – Georgia - limited organized forest harvest - but to some partial harvest (often illegal) from forests in close proximity to roads and settlements
  – Romania has modest forest harvest rates (1990-2000) and little conversion of forest to other uses
Romania

• We knew very little about land cover dynamics in this region

• Significant political/economic changes following the collapse of the USSR
Questions: Carbon and Romanian Forests

• What is happening to Romanian forests?
  – Now 2 kinds of forest ownership:
  – State Forests
  – Private Forest
    • Land returned to families owning forests prior to the communist era, sometimes as “shares” in collective private forests
    • Forest land or “shares” given to towns, schools, ets
• Is Romania a carbon sink or source?
• What are existing carbon stocks?
Carbon Accounting

\[ A = F - S \pm L \]

A = Annual increase in atmospheric CO\(_2\)
F = Release of CO\(_2\) fossil fuel combustion
S = Movement of carbon into oceans
L = Net exchange of C between atmosphere and the land surface (L is large and positive in areas of deforestation, but what about forests in the more developed parts of the world, often with longer land use histories?)
Romania Land Cover Change Map 1990 – 2000

Legend:
- Red: Forest Clearing
- Green: Stable Forest
- Orange: Stable Non-Forest
- White: Clouds
- Black: Clouds Shadow

0 25 50 100 Kilometers
Results

• Forest covers 5.9 millions ha
• In the period 1990 - 2000, 2.4 percent of what was forest in 1990 changed to non forest. (No evidence of land use change from forest to other uses.)
• Average change size 7.9 ha
• Accuracy (829 sites) assessment results used to adjust area estimates
• Most harvesting concentrated in a few areas, mostly on private forests)
Carbon Bookkeeping model

- Originally by Skee (Richard) Houghton et al., Woods Hole Research Center
- Calculates the net flux of carbon as a function of land-use change
- Describes the responses of an ecosystem over time following disturbance events
- Events may include i) forest harvest, ii) conversion to cropland, iii) abandonment, etc.
- Makes extensive use of forest inventory data for growth rates, age distributions of forests and average biomass
- Includes the effects of decomposition of forest products
- Integrates the history of harvest and land use change
- Innovation in this project is integration of remote sensing measurements of forest area and forest change rates
The effect of a forest harvest event

Carbon in vegetation [kg/ha]

Harvest
Sufficient regrowth for a second harvest

Carbon flux [kg]

Release from 1, 10 and 100 y wood product pools

Uptake from regrowth

$t_0$
$t_1$
$t_{10}$
$t_{100}$

Time
The conversion of a forest to cropland/pasture

Carbon in vegetation [kg/ha]

Forest cutting for cropland/pasture

Time

Carbon flux [kg]

Release from the soil

Release from 1, 10 and 100 y wood product pools

Carbon flux [kg]

No regrowth

Time
abandonment of cropland/pasture

Carbon in vegetation [kg/ha]

Carbon flux [kg]

Sequestration of soil carbon following regrowth

Uptake from regrowth of vegetation
Romanian Ecosystems are currently a carbon sink and will remain a sink until about 2070.

The magnitude of the current sink is equal to about 10% of the emissions from burning of fossil fuels.
Summary: Romania

• Remote sensing of forest change and a book keeping model allow estimation of national level carbon budgets

• Romania is currently a net carbon sink (approximately 10% of fossil fuel emissions)

• Under the current harvesting rates the annual sink will decline to zero in about 60 years

• Interestingly, doubling the rate of forest harvest would not dramatically change the magnitude or length of the projected carbon sink.
Forest change in Georgia, circa 1990-2000

- Not much forest change - around 2% of the forested area in 1990 has been cut or partially cut (preliminary result)
- Illegal logging apparent in proximity to villages
- 60% of harvest as unrecorded fuelwood (according to FAO)
- Forest change concentrated near roads and villages (much Georgian forest is protected by inaccessibility)
- Less harvesting than in Romania, more than in Turkey
- Higher degree of partial cutting than in Romania and Turkey
Changemap for Georgia, 1990 to 2000

Legend
- Red: Deforestation
- Yellow: Forest regrowth
- Green: Softwood forest
- Light Green: Hardwood forest
- Tan: Non-forest
- Black: Clouds
- Black: Shadows
- Light Blue: Snow
Example of forest change

Next slide
Example of partial cutting (illegal) in Central Georgia
Example of stable forest in Southern Georgia
Conclusions

• Rates of land use change are low in the forests of Turkey, Romania and Georgia for the period 1990-2000
• Remote sensing observations are central to our ability to monitor land cover change
• Romania is a carbon sink currently, and I expect Turkey and Georgia will be, too.
Forest transitions: towards a global understanding of land use change

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Fig. 1. The forest transition.
Forest Transitions: Is the question when, and not if?

Fig. 2. Forest cover at the turning point.
Data for France as an example of historical trends in forest cover in the developed world. Note that following a long decline due to conversion of lands for grazing and agriculture, as development progresses through the 19th and 20th centuries, forest area (and environmental health) increases.
In this graph, each point is a country, and the y axis shows the percent change in forest area. Note that the richest countries are adding forest area.

Returning forests analyzed with the forest identity

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Environmental Kuznets Curve: Idea that human impact on the environment first increases with affluence (or economic development) and then decreases --
Does it apply in the case of forest cover?

Figure 1. Environmental Kuznets curve for sulfur emissions. Source: Panayotou (1993) and Stern, Common, and Rocklin (1996)
THE EFFECTS OF LAND USE CHANGE ON THE TERRESTRIAL CARBON BUDGETS OF NEW ENGLAND

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Concord, MA
Background

- **New England Forest Change**

  - **17th~18th Century** - Large areas of forest were converted to agricultural land following settlement by Europeans.

  - **Mid-Late 19th Century** – Agricultural abandonment. Regrowth & Urbanization

  - **20th Century** – Fully recovered forest. Diversity of forest types

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**Fig 1.** Changes in land use and human population (dark solid line) through the historical period in central Massachusetts (Foster et al., 1997).

**Stone Wall (agricultural land before), MA**
Study Area

- Connecticut
- Massachusetts,
- New Hampshire,
- Rhode island
- Vermont

The total study area is approximately 82,627km².

Fig3. Study Area
Residential Development. Norfolk County, MA (70 ha)


Google Earth (winter)

Forest to nonforest
Stable forest
Stable nonforest
Commercial Buildings. Norfolk County, MA (70 ha)


Google Earth

- Forest to nonforest
- Stable forest
- Stable nonforest

Google Earth
Golf Course. Norfolk County, MA (70 ha)
Trends in Forest Area (comparisons with FIA)

(a) Forest area 1600-2005

(b) Forest Area, 1985-2005
Spatial Analysis - Forest change rate (%/year) for Time1 and Time2
Buffer (20km) from Boston

Fig 5.

Recent Development
Eastern MA
Approximately 50% of remaining potential sink is being decreased by urban growth
Conclusions (New England)

1. The forest area of New England is decreasing due to urban growth.
   • For the period 1990-2000, study area lost 10,219ha (0.23%) forest per year.
   • For the period 2000-2005, study area lost 5,427 ha (0.13%) forest per year.

2. Urban growth is significantly reducing the ongoing terrestrial carbon sink in New England.
   • The area converted from forest to human development for houses and commercial buildings released 17.3 TgC from 1990 to 2005 and approximately 50% of remaining potential sink will be decreased by urban growth to 2100.

Is this new phase of forest loss simply urban growth or a form of postmodern deforestation?