Topics

- Forests, Land Cover, Land Use and Carbon
  - New England
  - Black Sea Region (Romania and Georgia)
- Clouds (briefly)
  - Multitemporal sets of images
  - Cirrus

THE EFFECTS OF LAND USE CHANGE ON THE TERRESTRIAL CARBON BUDGETS OF NEW ENGLAND

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Background

- **New England Forest Change**
- **17th~18th Century- Large areas of forest were converted to agricultural land due to European settlement.**
- **Mid-Late 19th Century – Agricultural abandonment. Regrowth & Urbanization**
- **20th Century – Fully recovered forest. Diversity of forest types**

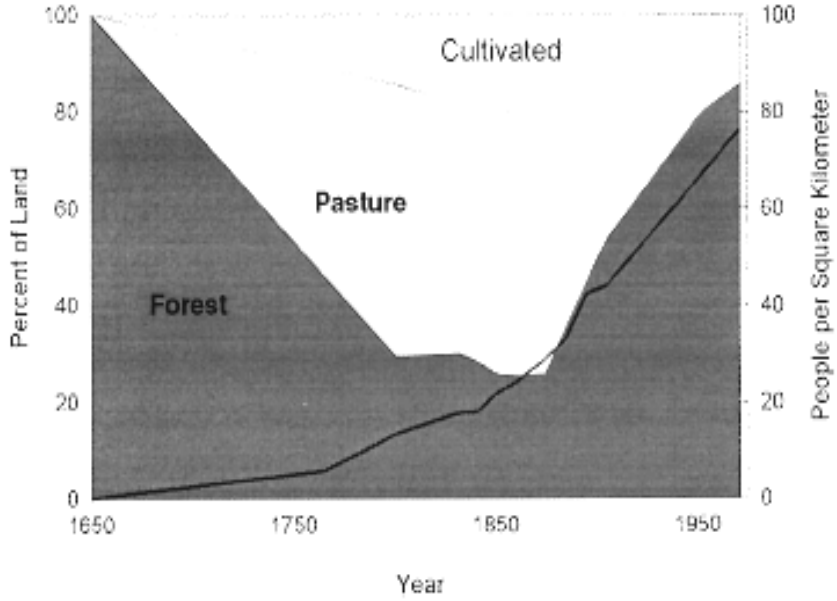
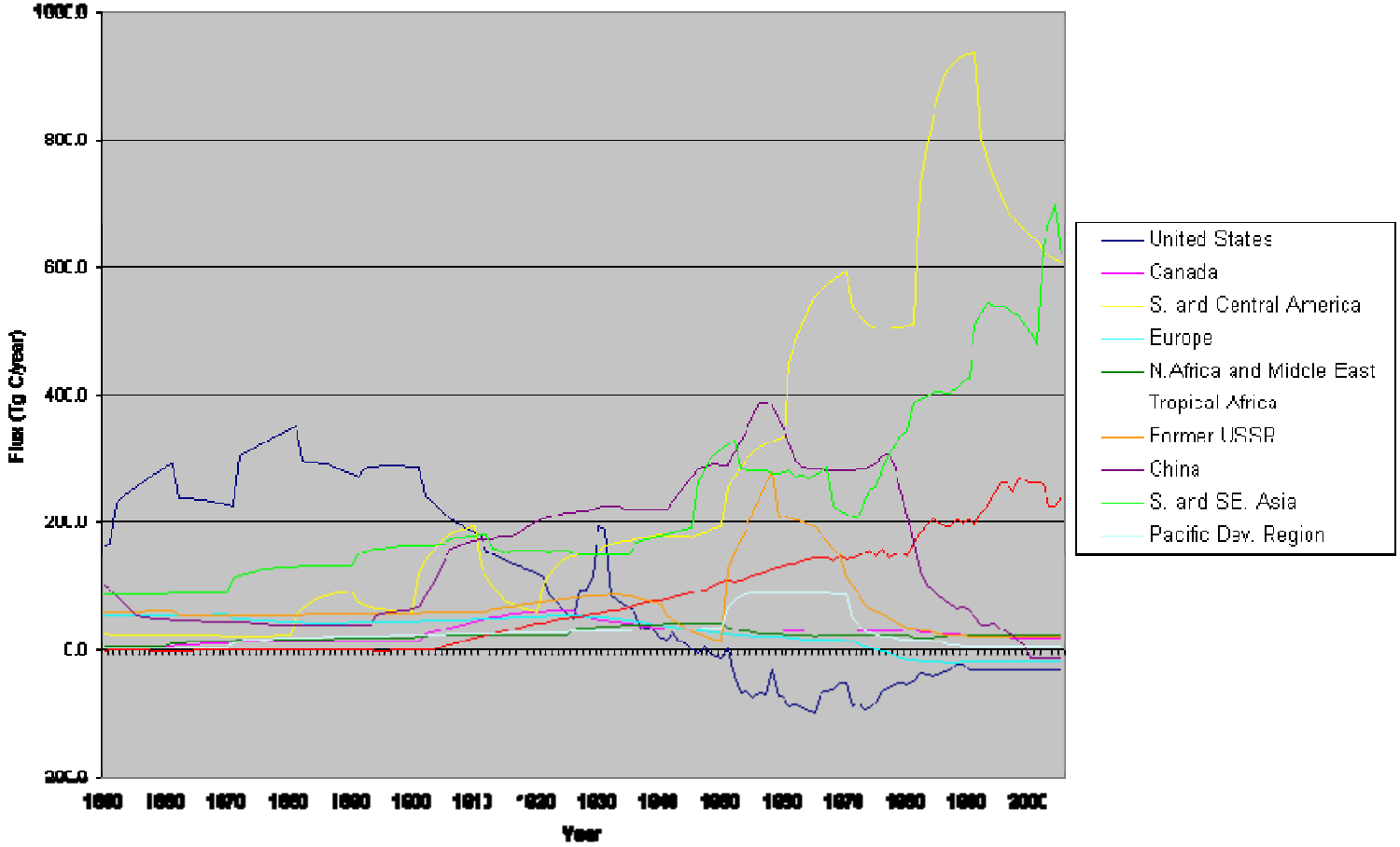


Fig1. Changes in land use and human population (dark solid line) through the historical period in central Massachusetts (Foster et al., 1997).

Fig2. Annual Net Flux of Carbon to the Atmosphere from Land-Use Change : 1850-2005 (Houghton)



http://cdiac.ornl.gov/trends/landuse/houghton/houghton.html

•US became a net sink for carbon after around 1950.

•Northeast US regions became a net sink for carbon after about 1920. (Houghton and Hackler, 2000)

Objectives

1. Remote Sensing of Land Use Change

- Measure rates for recent land use change in parts of New England due to human activities (1990-2005)

2. Carbon Modeling

- How does recent land use change in parts of New England from 1990 to 2005 affect the terrestrial carbon budget?
- Carbon budget projection to 2100

Old growth, Barlette, NH

Study Area

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

The total study area is approximately 82,627km2.

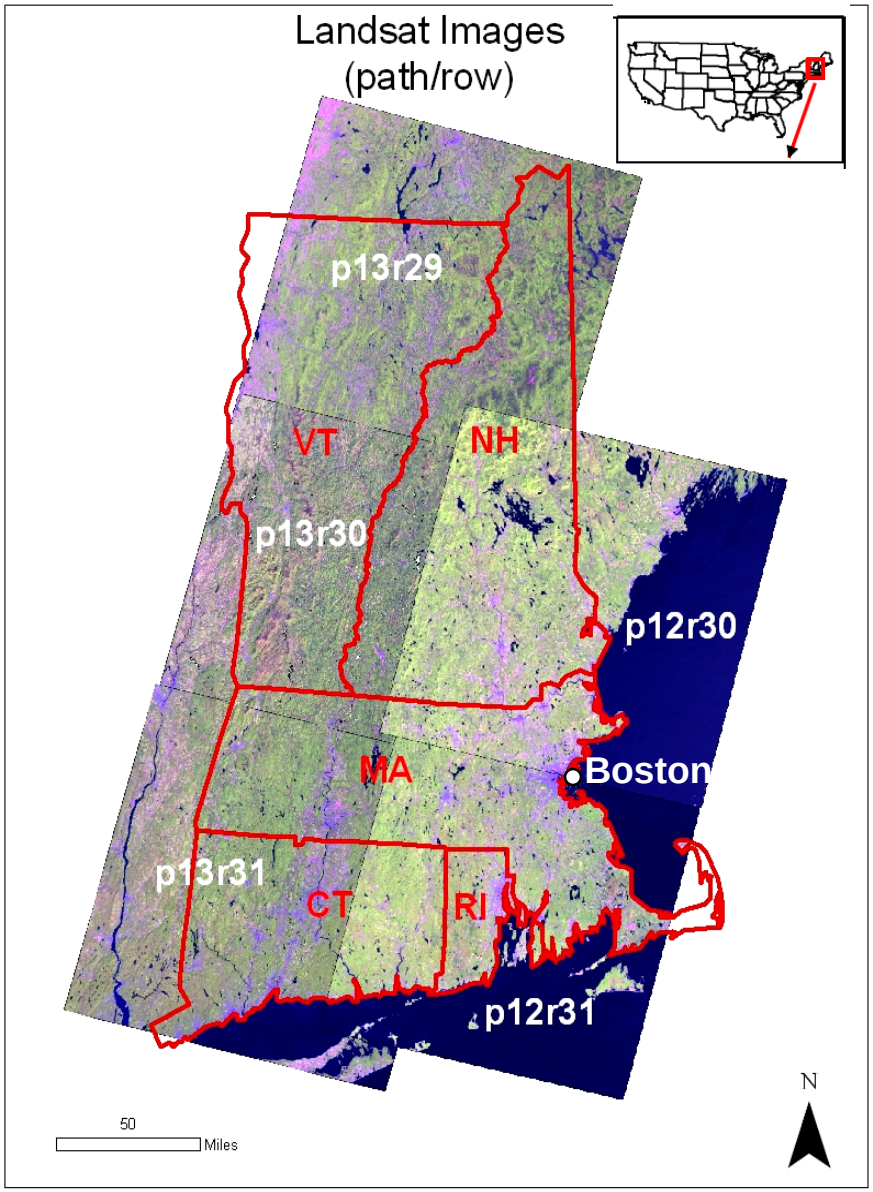


Fig3. Study Area

Landsat Data

Path/ Row (Scene)	Landsat5 TM (GeoCover)	Landsat7 ETM (GeoCover)	Landsat7 ETM (L1G)	Landsat5 TM (L1G)
	TIME 1		TIME 2	
12/30	1990/09/08	2000/09/27	2000/09/27	2004/09/14
12/31	1987/09/16	2000/09/27	2000/09/27	2006/09/20
13/29	1992/06/16	1999/08/31	1999/08/31	2005/09/24
13/30	1989/09/28	2002/09/08	2002/09/08	2005/09/24
13/31	1989/09/28	2002/09/08	2002/09/08	2005/09/08

Table1. Landsat Data for Study Area

- Landsat 5 & ETM+ from Global Land Cover Facility (GLCF) http://glcf.umiacs.umd.edu/index.shtml
- USGS Landsat satellites http://landsat.usgs.gov

Multi-temporal Change Detection

1. Multi-temporal Kauth-Thomas transformation (MKT)

- **based on MKT matrix for TM digital counts data (Collins and Woodcock, 1996)**
- **6 bands B, G, W, ΔB, ΔG, ΔW**

2. Multi-temporal Change Detection

- **Fuzzy Artmap Neural Network**

  5 Classes

  1) Forest to Nonforest

  2) Stable Forest

  3) Stable Nonforest

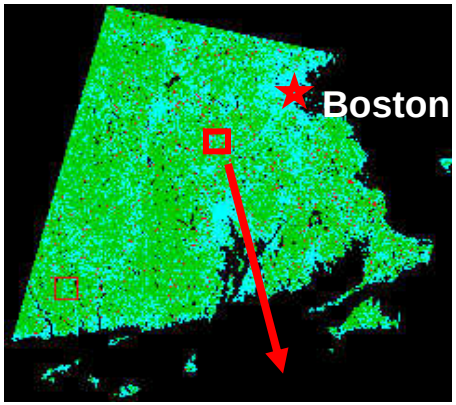
  4) Nonforest to Forest

  5) Clouds and Shadow

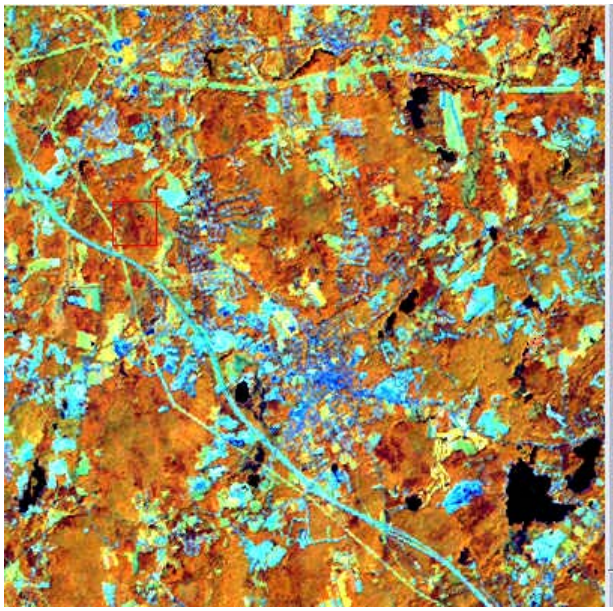
3. Segmentation

- **minimum area of 0.89ha (Landsat 11 pixels).**

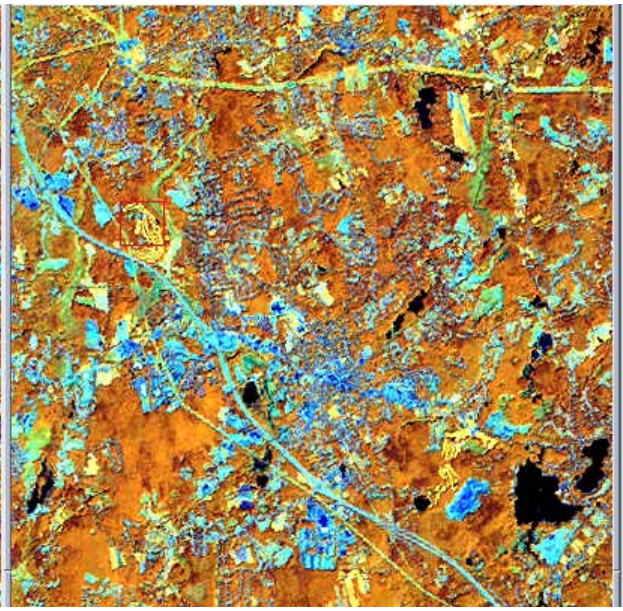
Vermont



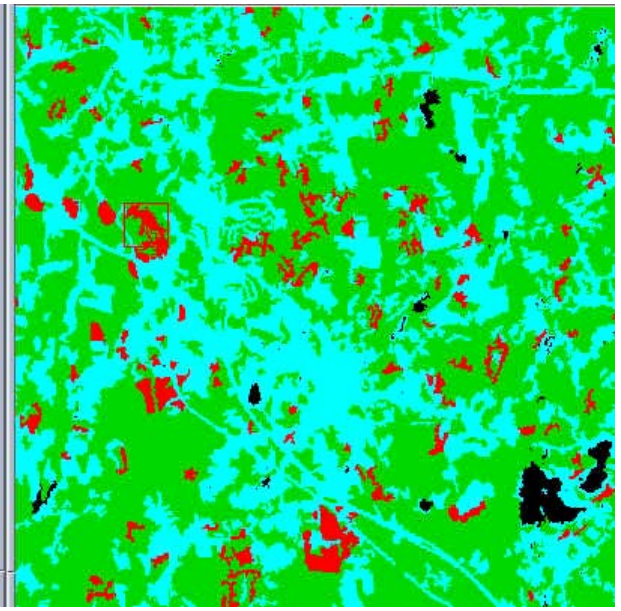
Norfolk County, MA (12,600 ha)



Time1 (1987)



Time2 (2000)

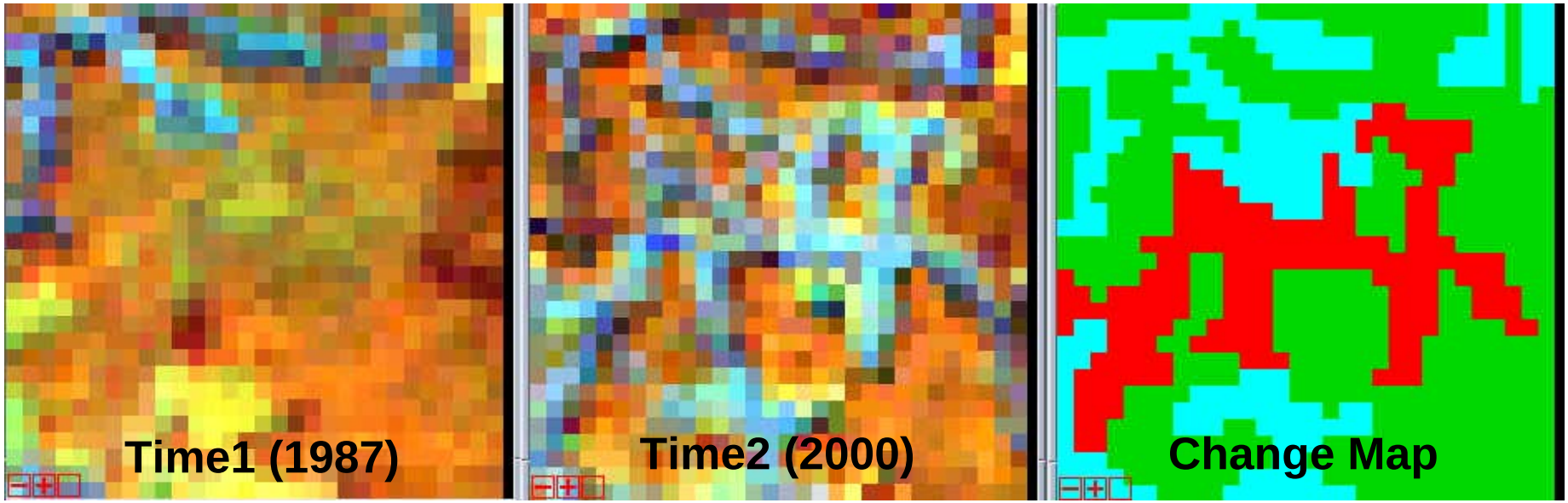


Change Map

453 Pseudo Color Combination

- **Forest to nonforest**
- **Stable forest**
- **Stable nonforest**

Residential Development. Norfolk County, MA (70 ha)



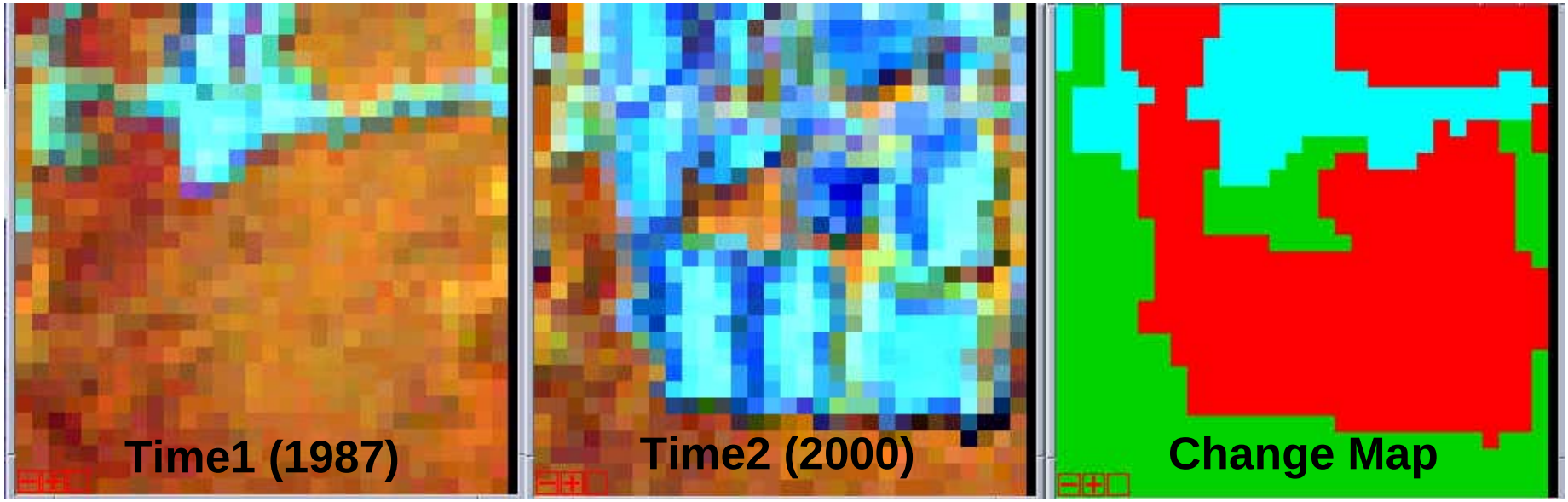
Google Earth (winter)

Forest to nonforest

Stable forest

Stable nonforest

Commercial Buildings. Norfolk County, MA (70 ha)



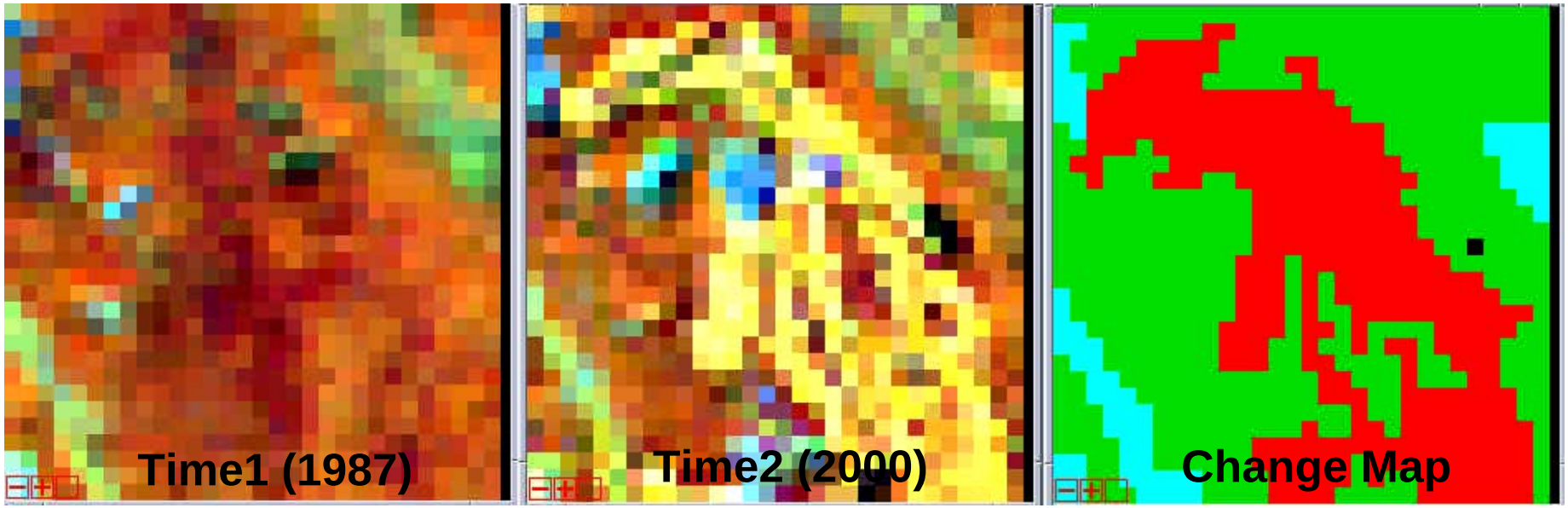
Google Earth

Forest to nonforest

Stable forest

Stable nonforest

Golf Course. Norfolk County, MA (70 ha)



Google Earth

Accuracy	p12r31	Time1	1987-2000		
	1	2	3	Total (polygon)	Total Area (%)
1	97	0	3	100	1.26
2	3	279 (14)	18	300	63.55
3	2	2	96	100	35.19
Total	102	281	117	500	100.00
	producer's accuracy % (omission error)		user's accuracy % (commission error)		overall accuracy %
1	95.10		97.00		94.40
2	99.29		93.00		
3	82.05		96.00		

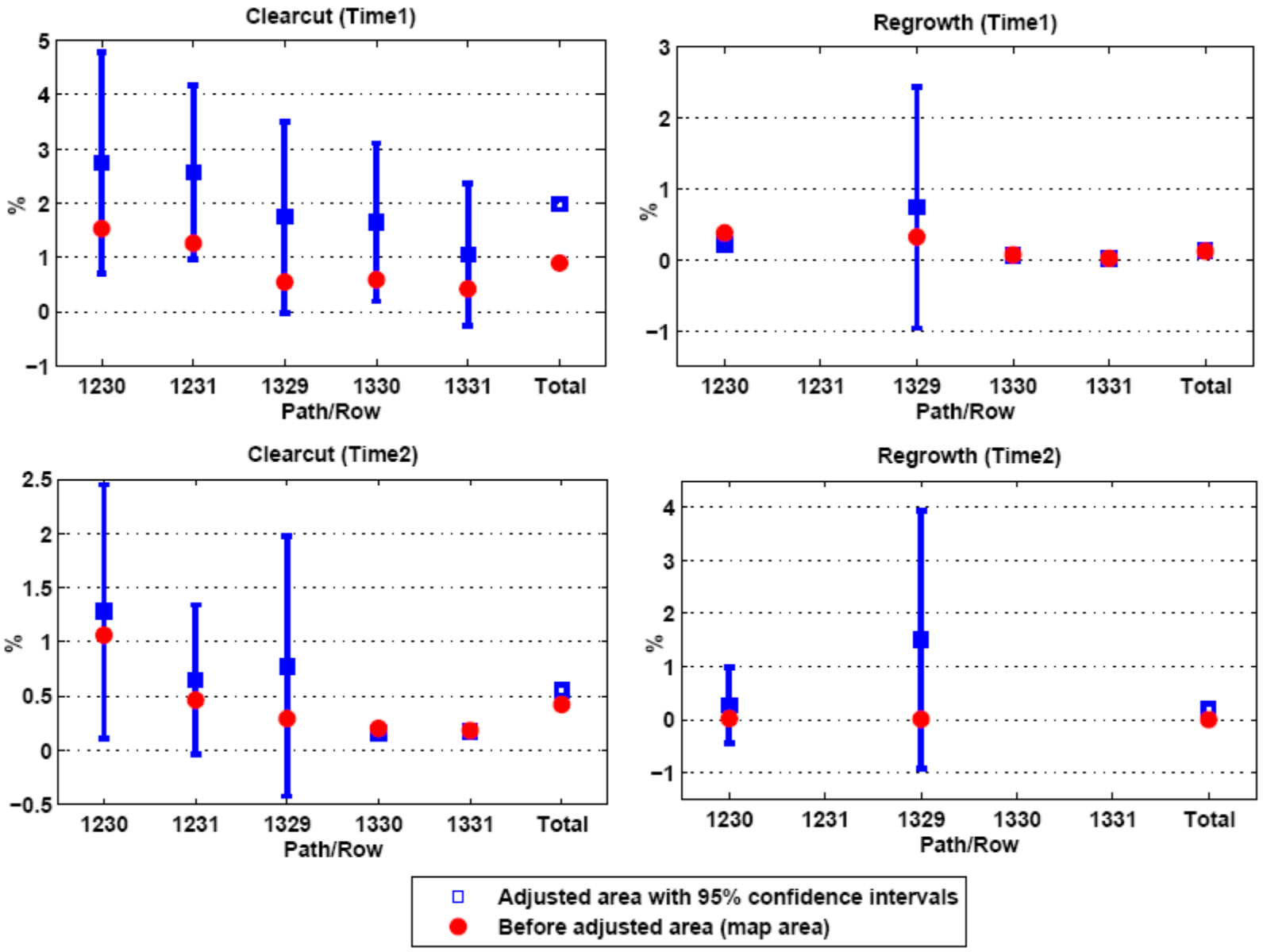
Adjustment	p12r31	Time1	1987-2000		
	1 (%)	2 (%)	3 (%)	Total Area (%)	
1	1.22	0.00	0.04	1.26	
2	0.64	59.10	3.81	63.55	
3	0.70	0.70	33.78	35.19	
Total Area (%)	2.56	59.80	37.63	100.00	
	producer's accuracy % (omission error)		user's accuracy % (commission error)		overall accuracy %
1	47.77		97.00		94.11
2	98.82		93.00		
3	89.77		96.00		

Error Matrix

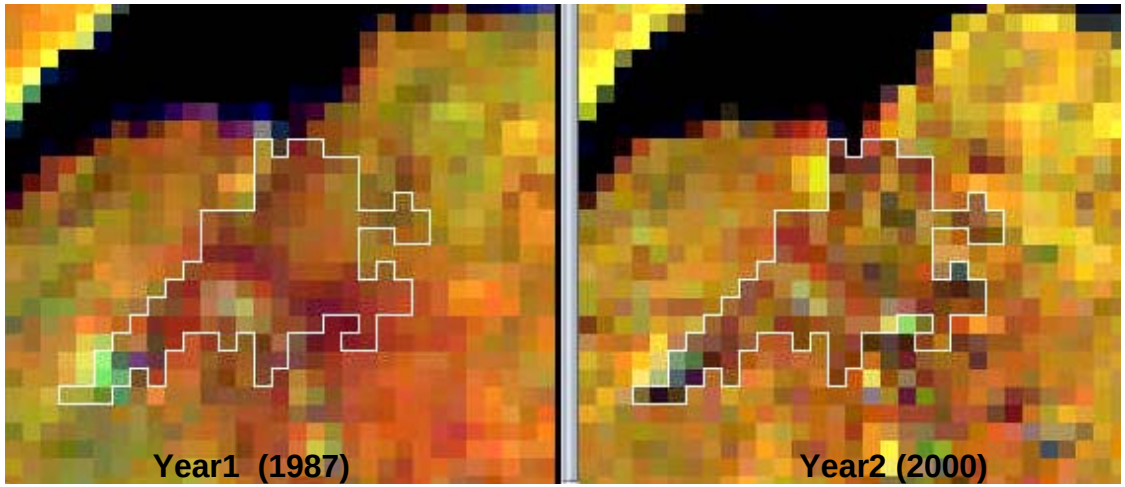
Ground Truth (Reference)

map

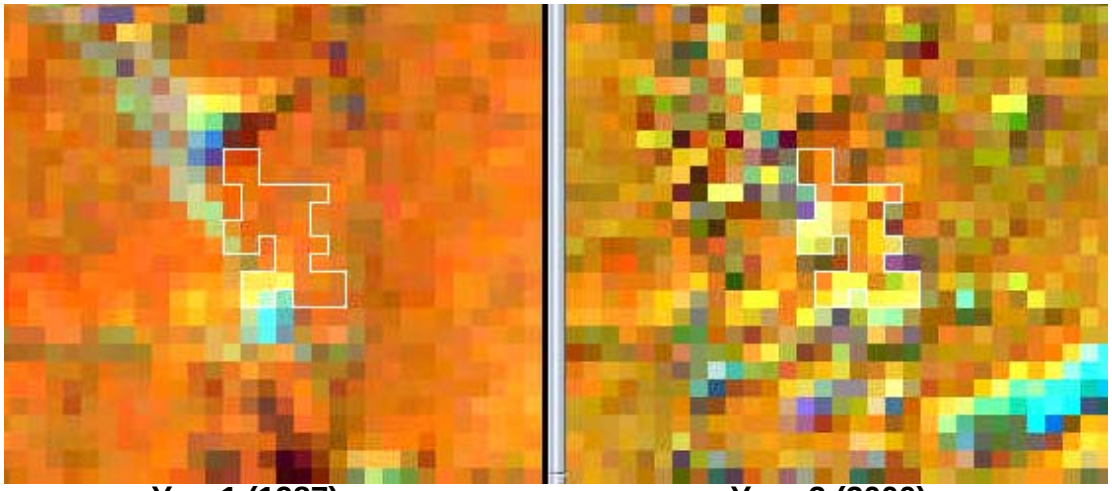
1. Clearcut
2. Stable Forest
3. Regrowth



Comparison with before and after adjusted areas based on accuracy assessment. Adjusted areas have 95% confidence intervals.



Google Earth
(a) Very small clearings for houses, still much forest
(within white polygon boundary -10.5ha)
Examples of missing clearcut polygons

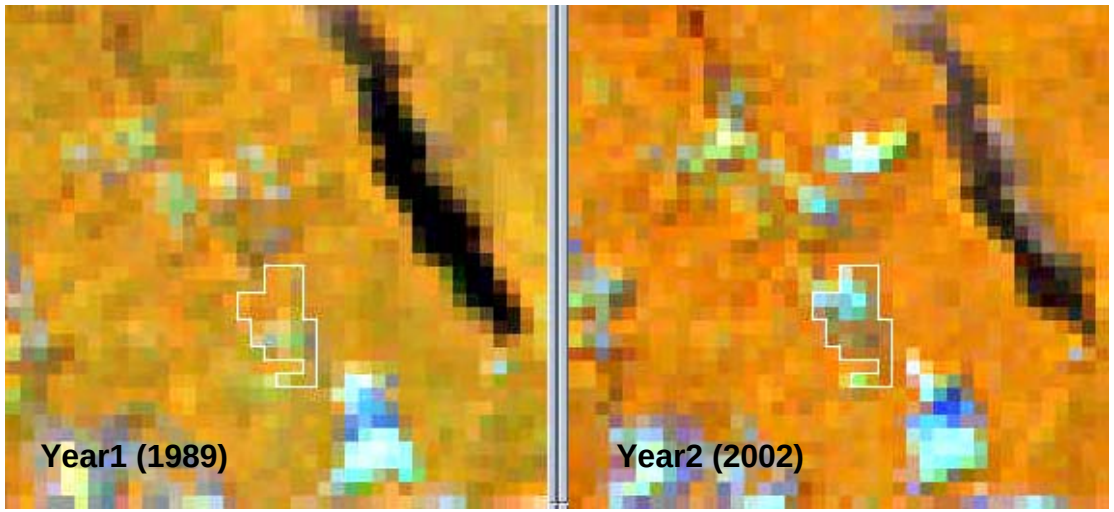


Year1 (1987) **Year 2 (2000)**

Google Earth

(b) New houses (within white polygon boundary -approximately 3 ha)

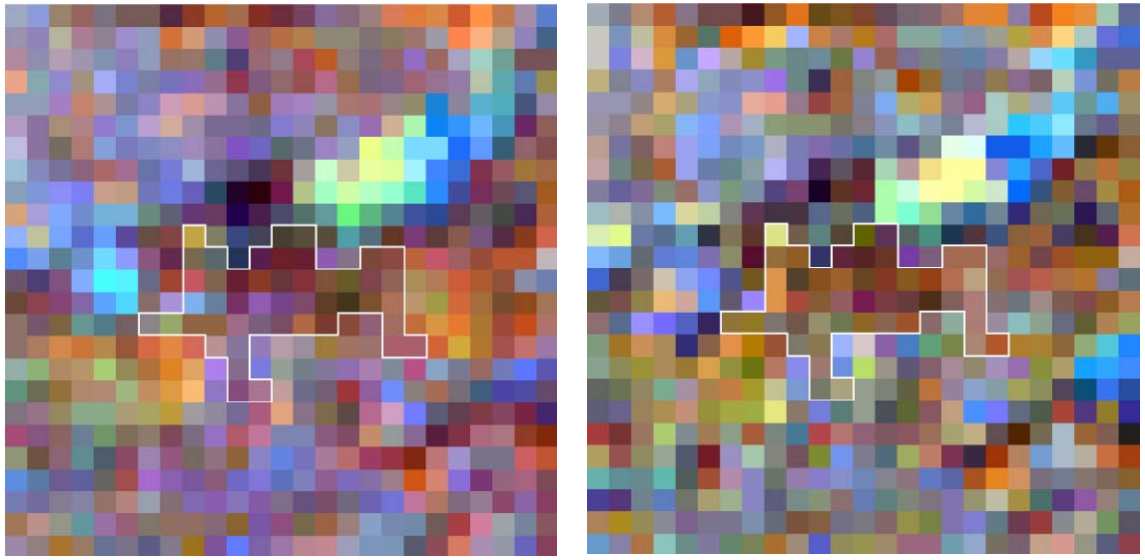
Examples of missed change polygons



Google Earth

(c) New houses with some forest remaining (within white polygon boundary- 2.8ha)

Examples of missed change polygons

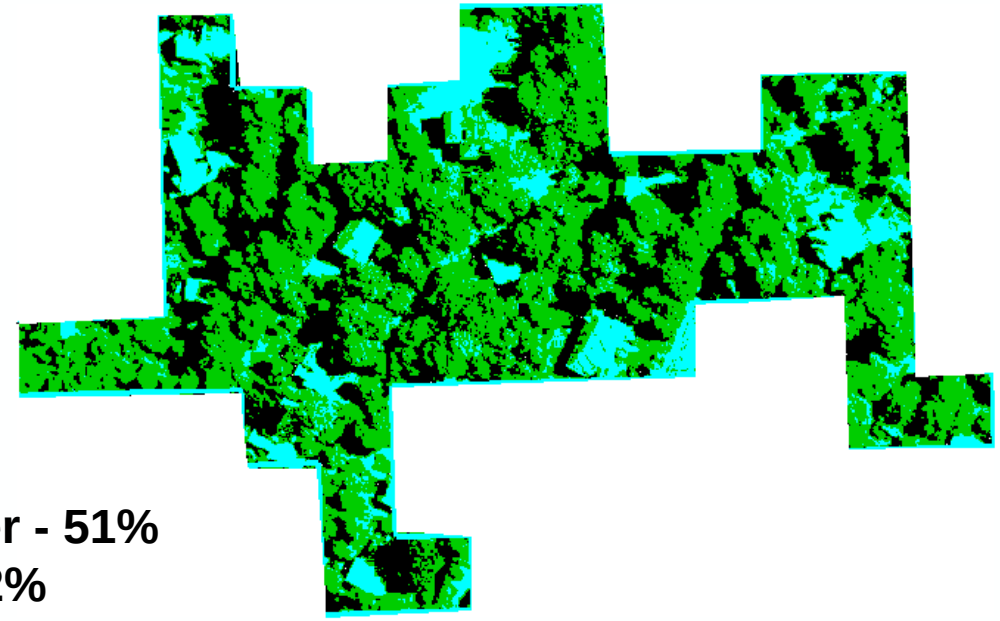


Time1 (1987) **Time2 (2000)**

(Total area: 50ha, 3.8 ha for white polygon area)

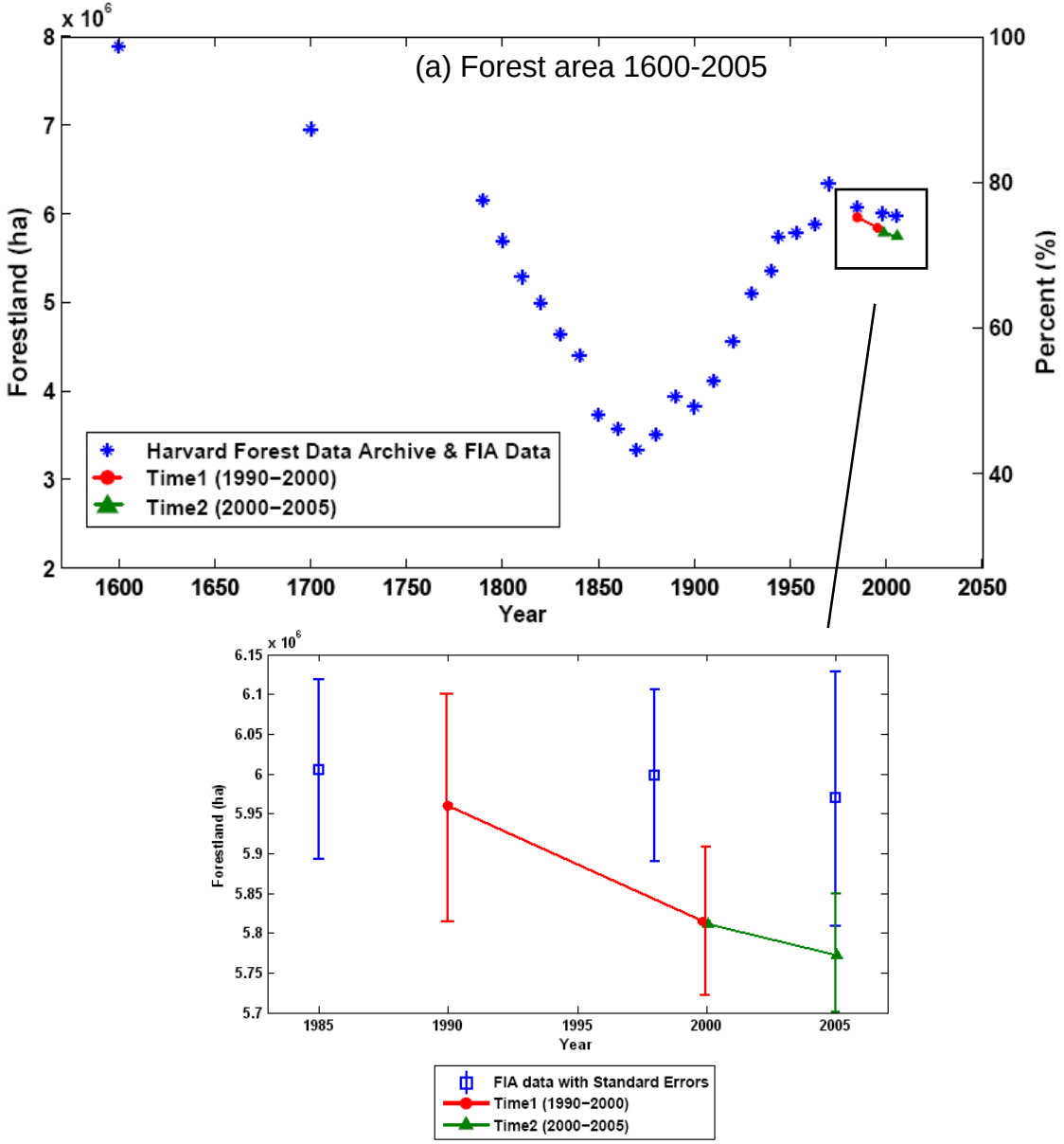
Google Earth- Residential area with lots of trees. It is hard to say whether it belongs in the class *forest* or *residential*.

Suburban Boston- Middlesex County, MA



Green: Forest Cover - 51%
Black: Shadow – 32%
Cyan: Nonforest – 17%

Fig4. Forest Area (comparions with FIA)



(b) Forest Area, 1985-2005

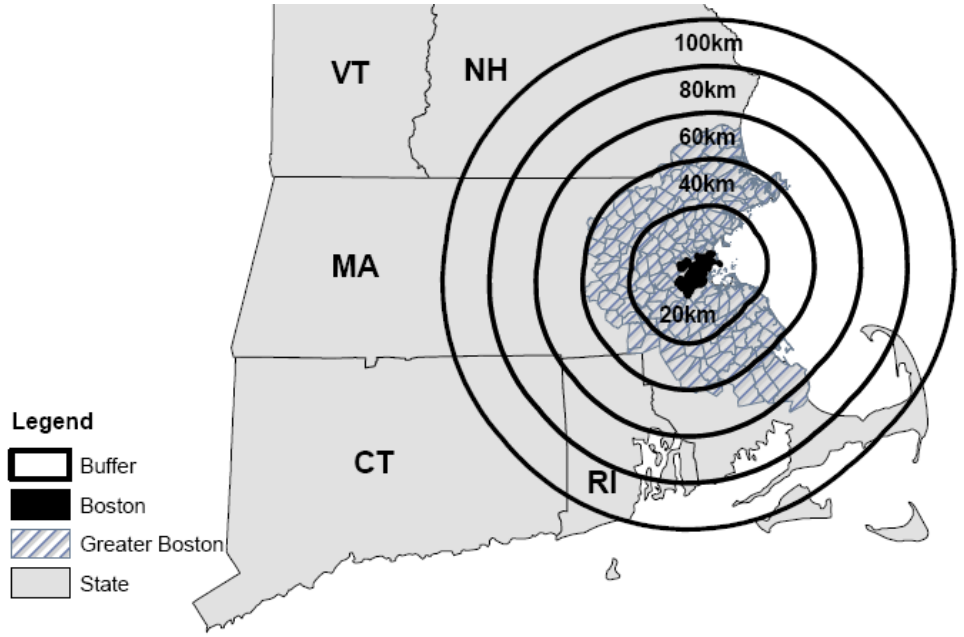
Results: Land Use Change

State	1990-2000			2000-2005		
	clearcut	regrowth	net loss	clearcut	regrowth	net loss
CT	1,236	10	1,225 (0.15)	963	0	963 (0.12)
MA	3,468	61	3,406 (0.28)	1,869	0	1,869 (0.16)
NH	3,335	210	3,125 (0.33)	3,426	691	2,735 (0.31)
RI	395	0	395 (0.24)	269	0	269 (0.17)
VT	2,817	750	2,067 (0.15)	1,242	1,652	-410 (-0.03)
Total Area	**11251**	**1032**	**10219 (0.23)**	**7,769**	**2,343**	**5,427 (0.13)**

Table2. Forest net loss area (ha) per year by state and total area

( ) is annual forest change rate %.

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



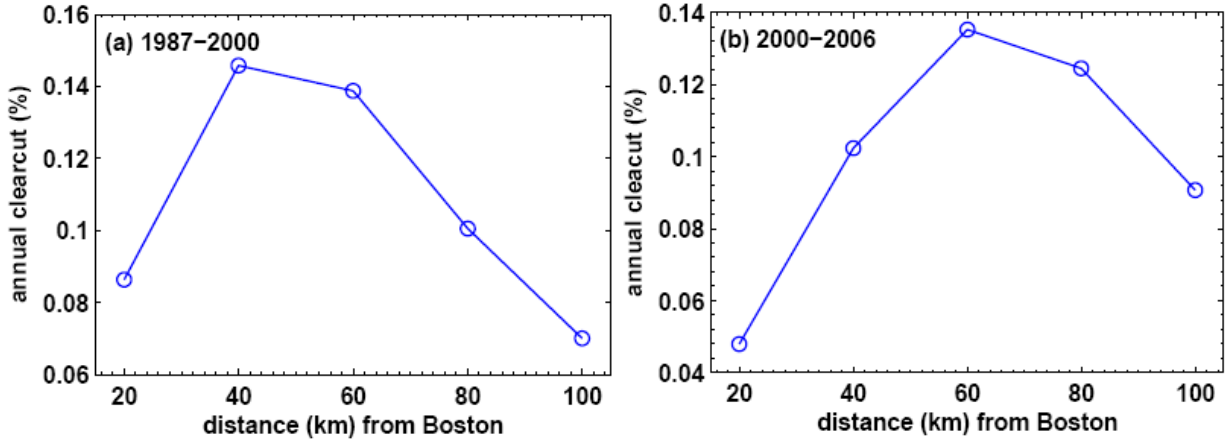
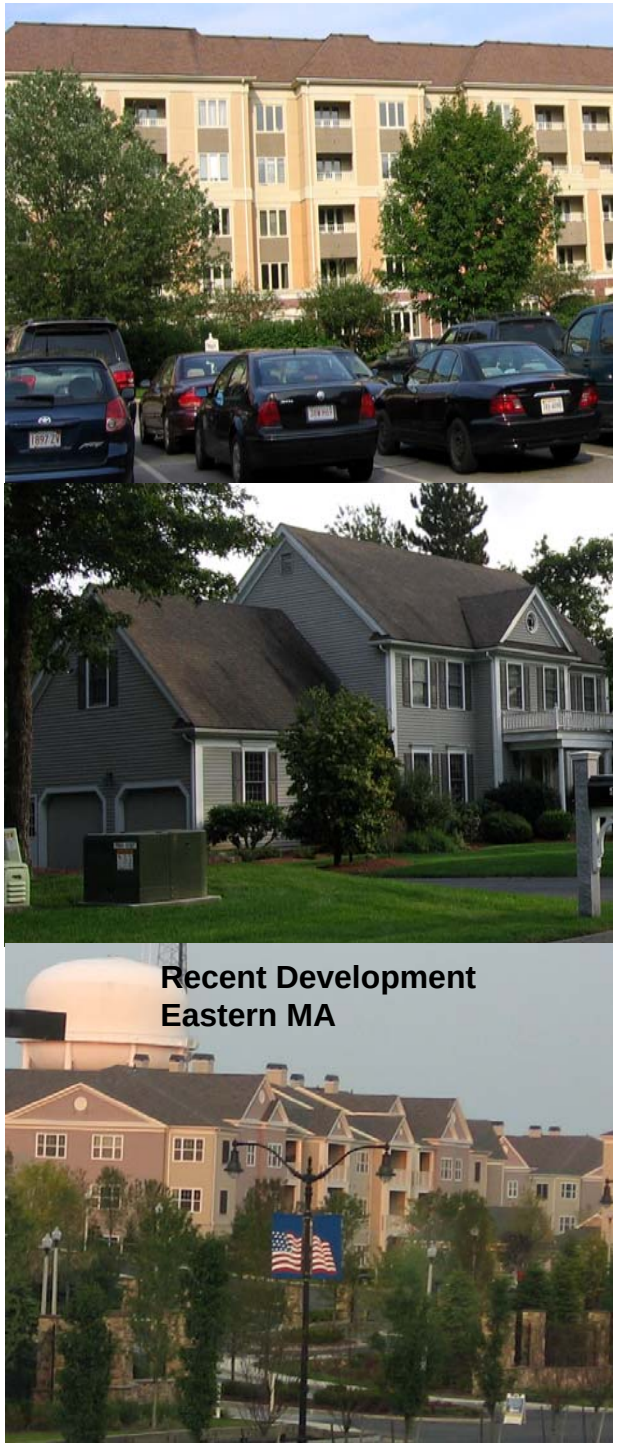
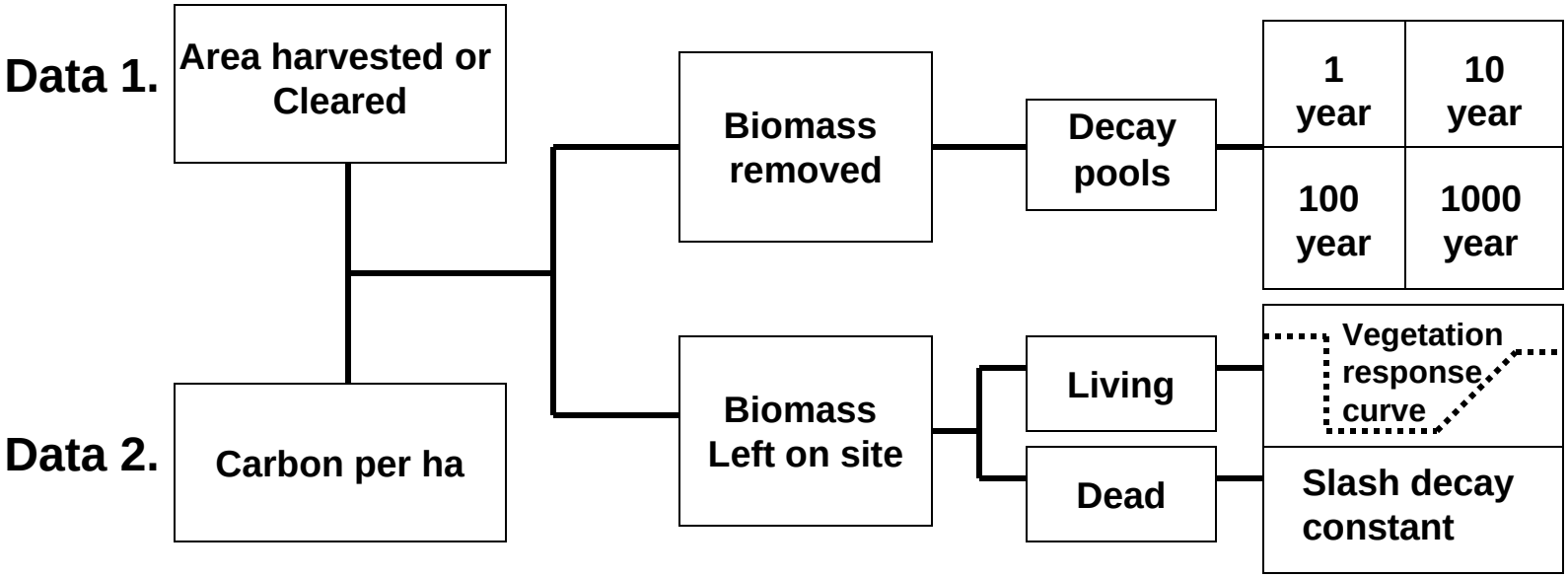


Fig5.



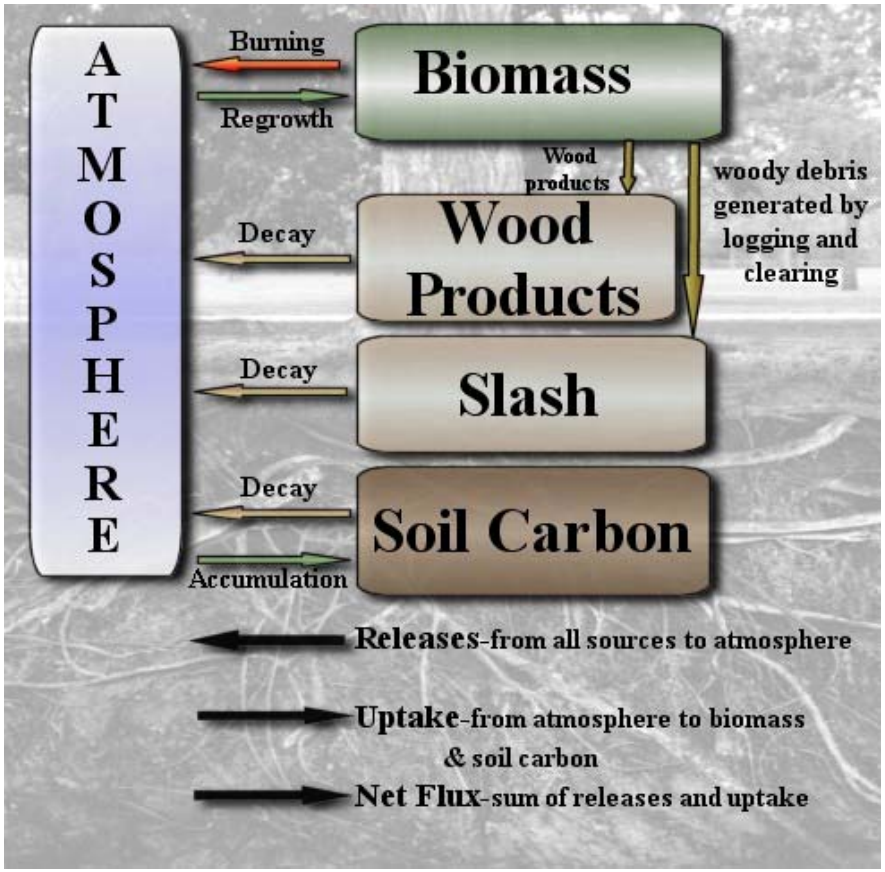
Carbon Modeling

The **bookkeeping** model was used to calculate changes in terrestrial carbon storage following changes in land use.



(Houghton and Hackler,1995; Houghton, 1999).

Bookkeeping Model



Carbon Accounting Model Schematic

http://www.whrc.org/

Book-keeping Model

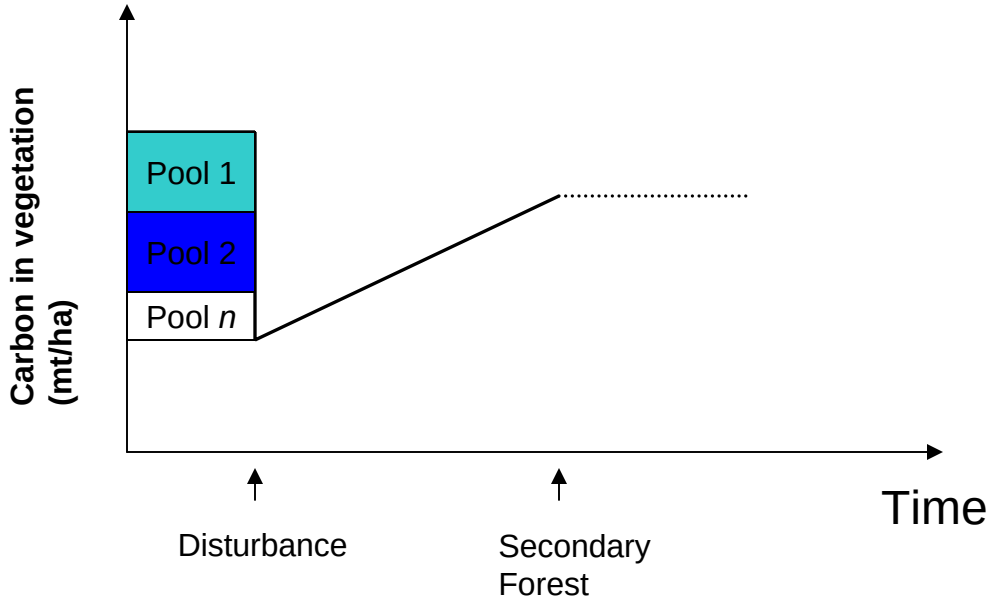
R. Houghton

-Net terrestrial flux

-Full time trajectory of disturbance

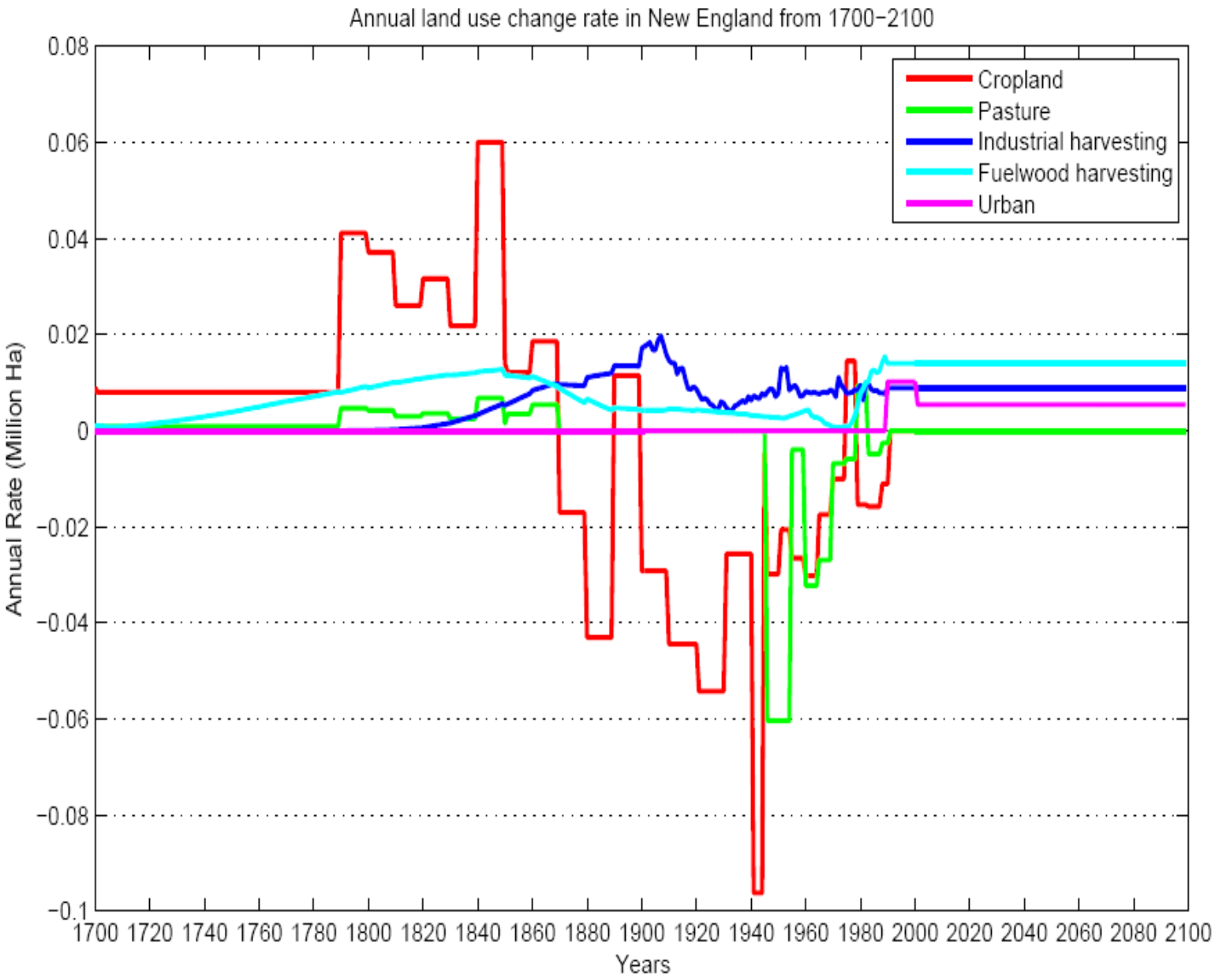
-Inherited carbon fluxes

- Fate of carbon removed



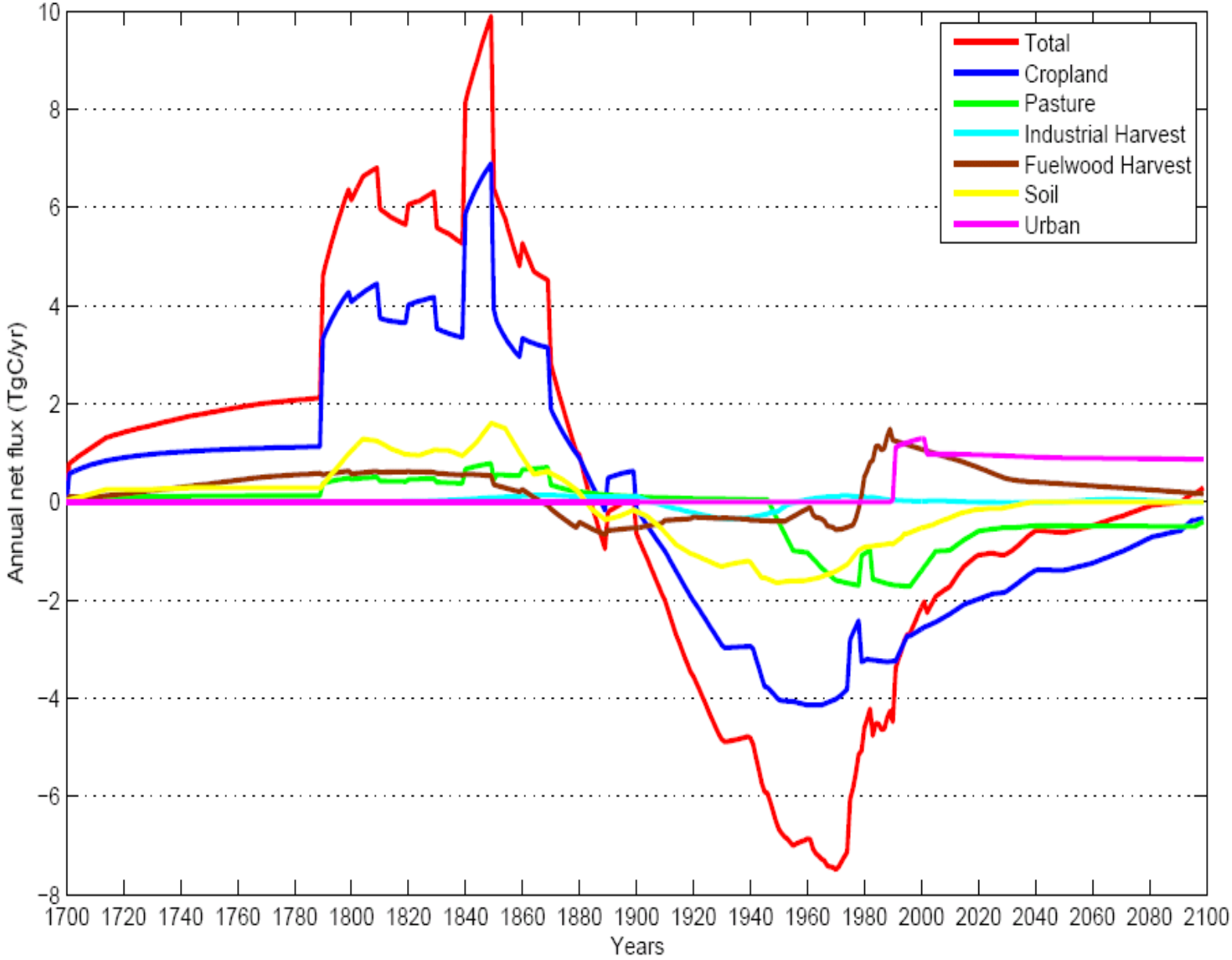
Data for carbon modeling (land use change rates)

- 1700-1945: Historical cropland, pasture, industrial harvesting and fuelwood harvesting rates of the "Northeast" (Houghton and Hackler, 2000)
- 1700-1945: Forestland from Harvard Forest Data Archive for each state of our study area (same relative proportions of cropland to pasture that Houghton and Hackler(2000) used for the entire northeast to calculate the land use change rate for cropland and pasture of New England.)
- 1946-1989: areas of forests, croplands and pasture for each state of our study area, 5 year intervals from agricultural census (USDA)
- 1990-2005: Land use change from remote sensing



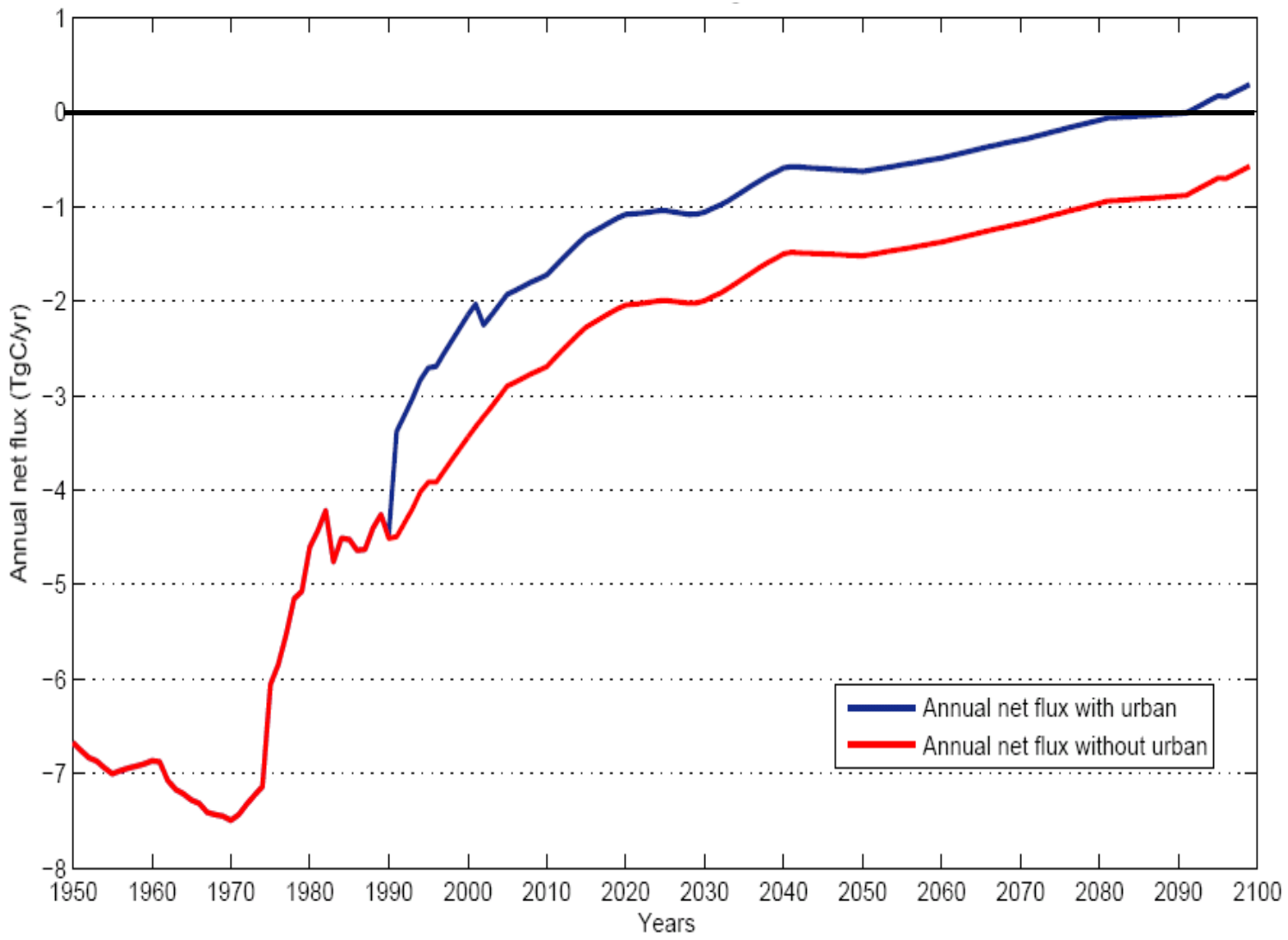
Positive values: clearcutting, Negative values: abandonment

Results of Annual net flux of carbon between the atmosphere and New England region calculated from changes in land use



Positive values: a release of carbon to the atmosphere, Negative values: a carbon sink

Annual net flux with urban and without urban (1950-2100)



Approximately 50% of remaining potential sink is being decreased by urban growth

Conclusion

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 ongoing terrestrial carbon sink in New England.

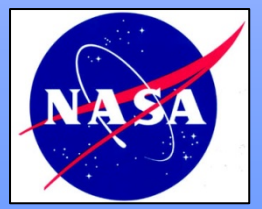
- The area converted from forest to human development for houses and commercial buildings released 17.3 TgC from 1990 to 2005 and approximately 50% of remaining potential sink will be decreased by urban growth to 2100 .

- Currently, New England terrestrial ecosystems are a carbon sink. However, the carbon sink will slowly decrease until around 2090 at which time the trend will reverse and they will become a carbon source.

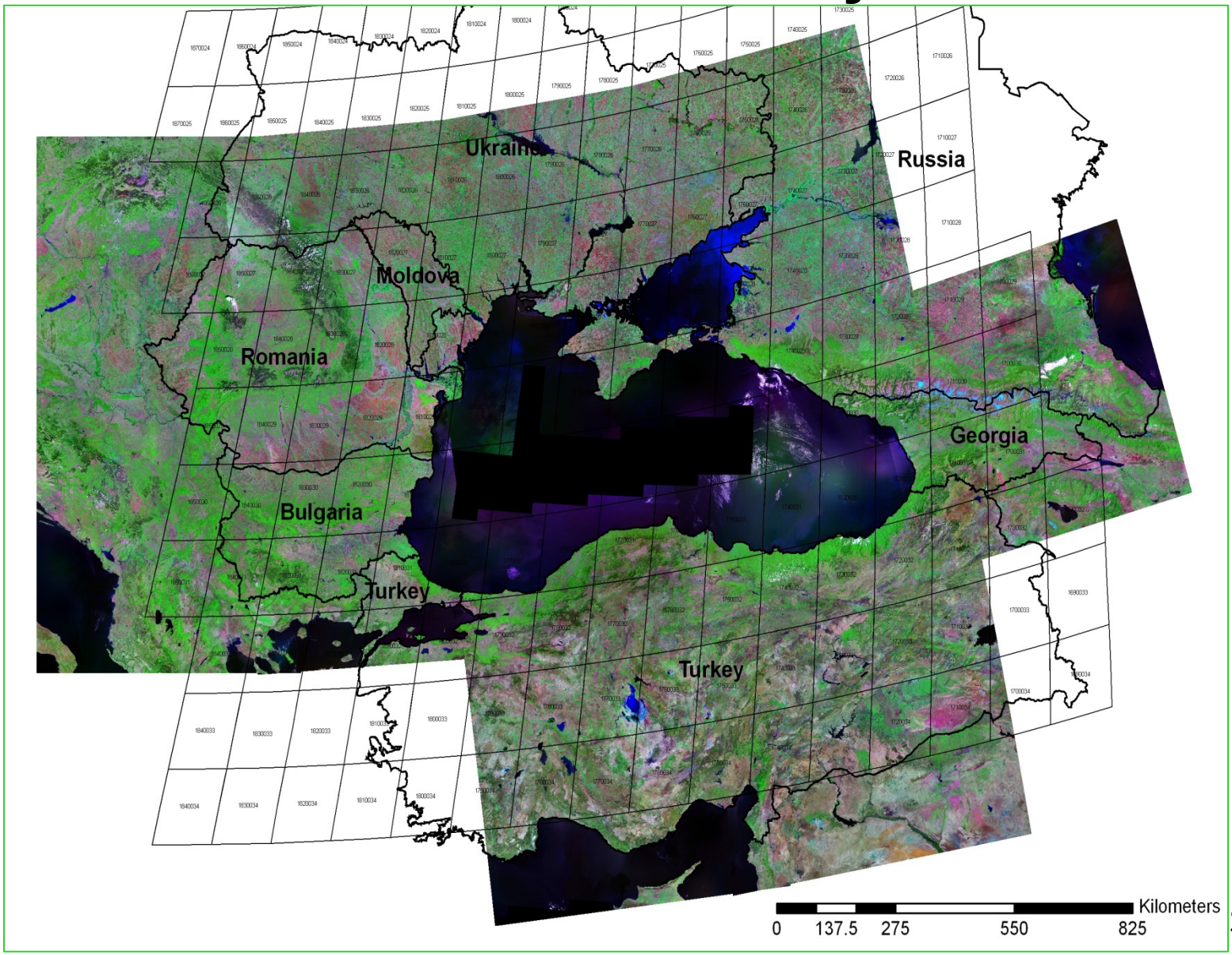
Integrating Monitoring of Forest Harvest with a Carbon Model to Estimate the Effects of Land Use Change on Terrestrial Carbon Budgets in the Black Sea Region

Alessandro Baccini

Curtis E. Woodcock, Richard A. Houghton, Joe Hackler, Mutlu Ozdogan, Vlad Gancz (ICAS), Viorel Blujdea (ICAS)

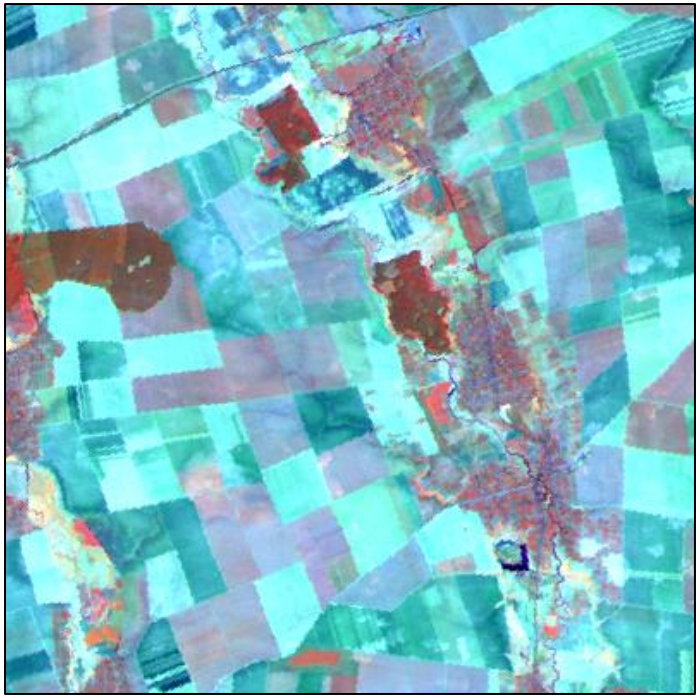


Black Sea Project

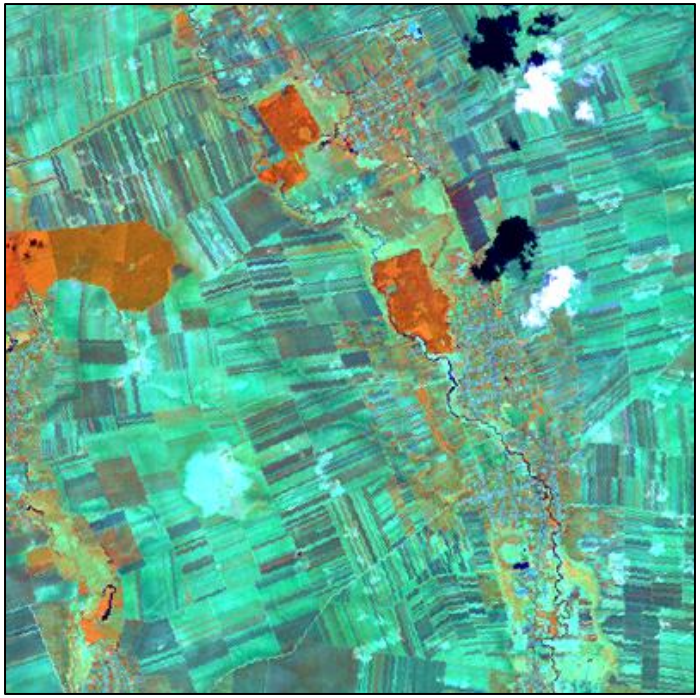


Romania

- We know very little about land cover dynamics in this region
- Significant political changes following the collapse of the USSR



Time 1 1990/08/21

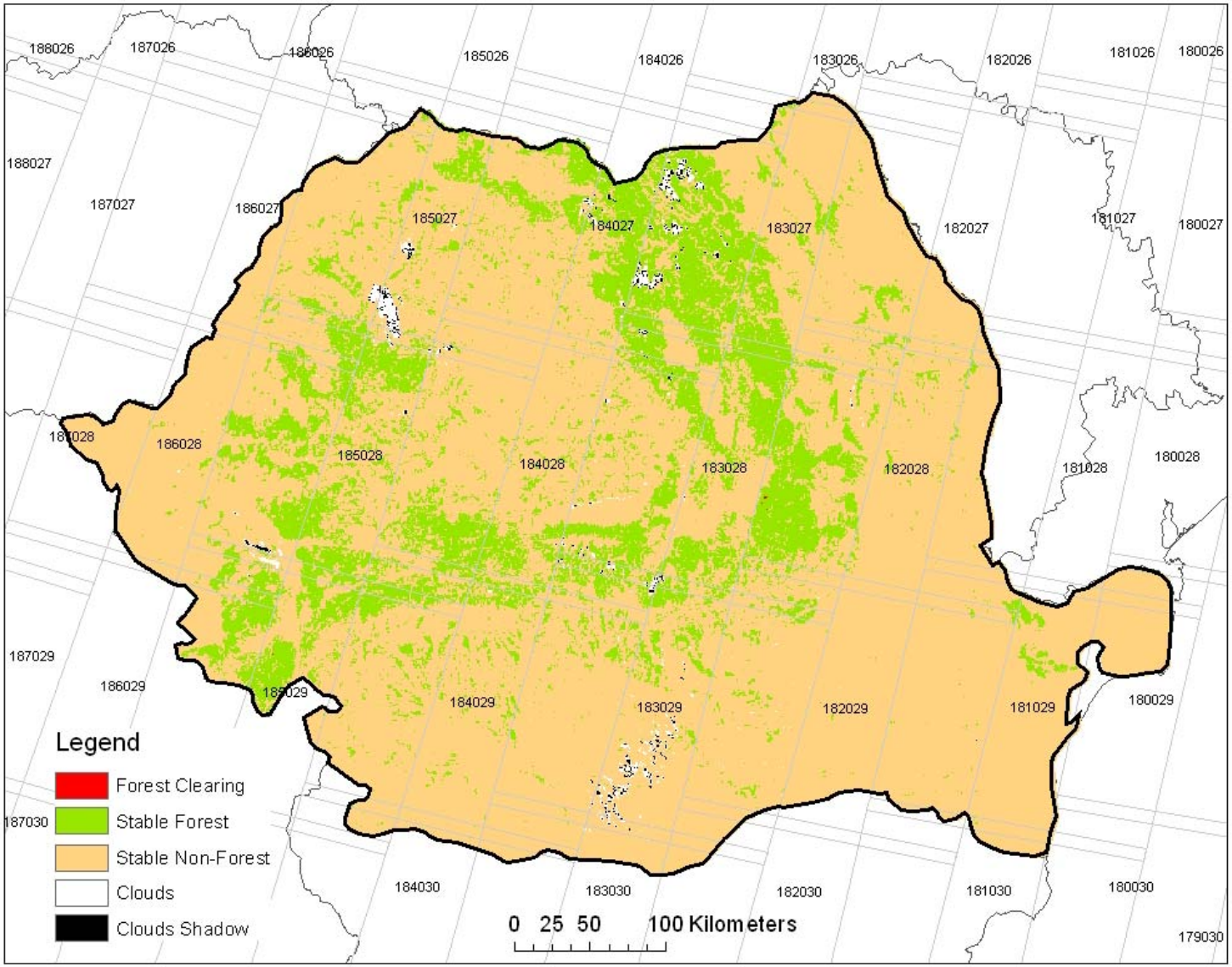


Time 2 2000/06/05

Questions

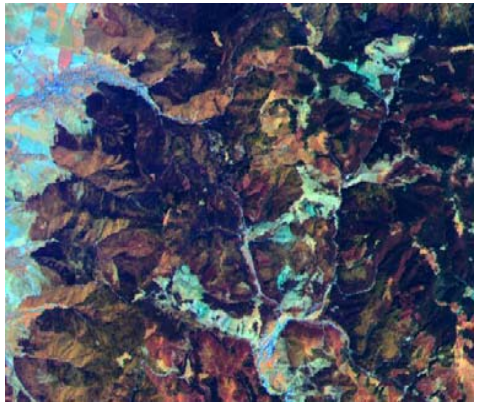
- What is happening to Romanian forests?
- Is Romania a carbon sink or source?
- What are existing arbon stocks?

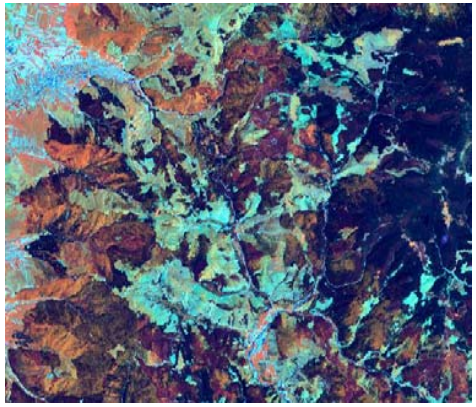
Romania Land Cover Change Map 1990 – 2000

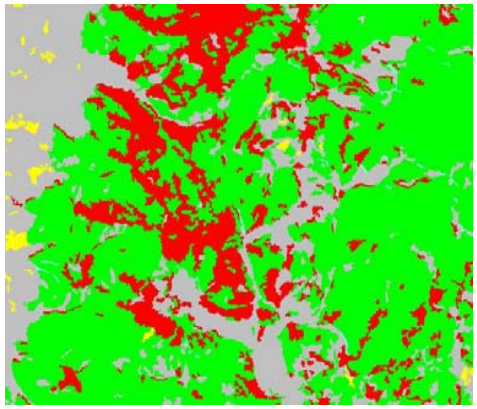


Results

- Forested land 5.9 millions ha
- In the period 1990 - 2000, 2.4 percent of what was forest in 1990 changed to non forest.
- Average change size 7.9 ha
- Accuracy (829 sites) northern region 89 %

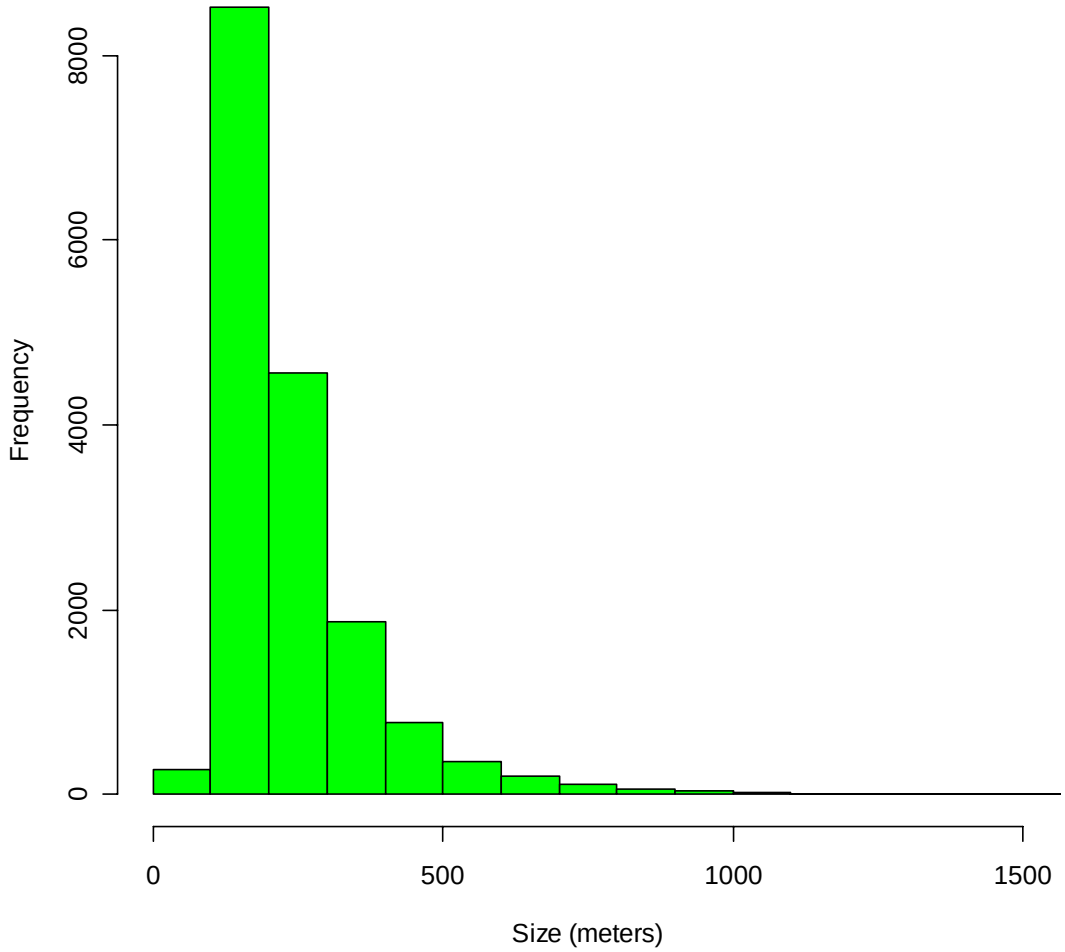






Deforestation
Stable Forest
Stable non Forest
Forest re-growth

Average Linear Size of Changes



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

Terrestrial Carbon

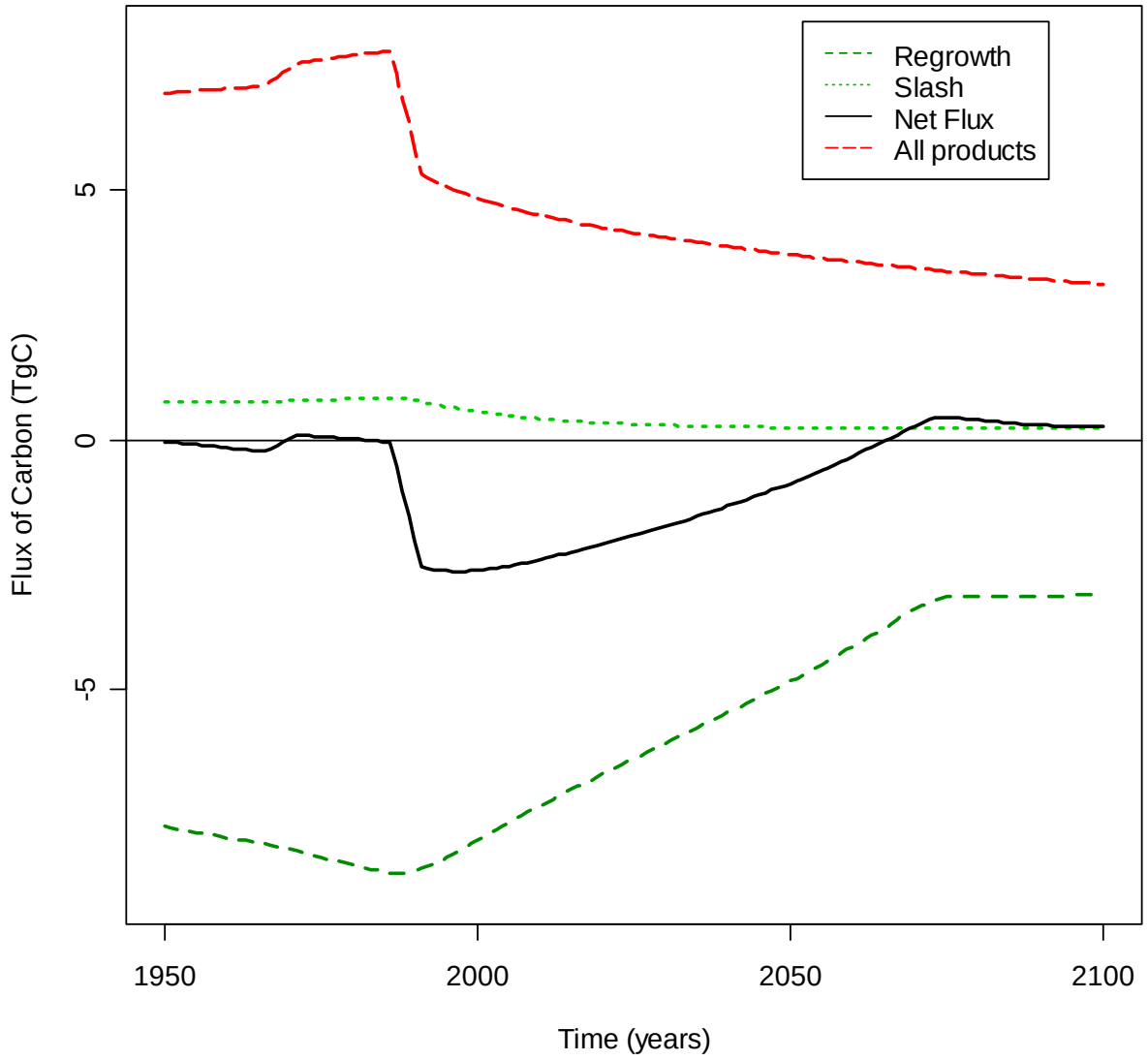
- 1990 – 2000 period
  - Forest area, forest change, growth rate, average biomass

    Ac (Atmospheric carbon) = **Ca** (Carbon absorbed) – **Cr** (Carbon released)
    Ca = Forest area * growth rate * time
    Cr = Forest change * average carbon

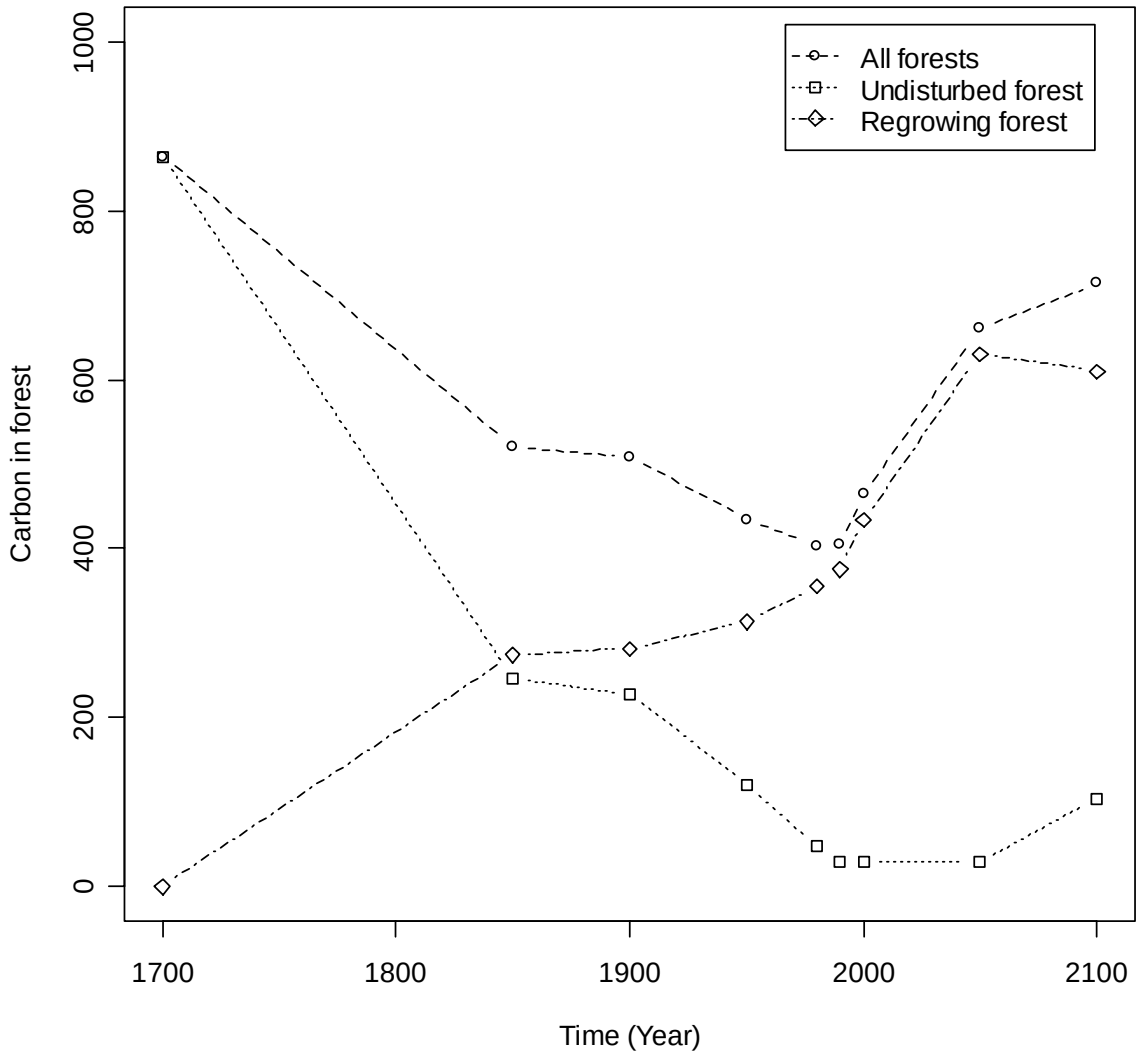
    Romania Results
    Ca = 5,995,217 ha * 3 * 10 / 2 = 89.9 millions (Tonnes)
    Cr = 147,290.3 * 135.2 / 2 = 9.9 millions (Tonnes)
    Ac = – 89.9 + 9.9 = -79.9 millions (Tonnes) of carbon absorbed

- Full terrestrial carbon accounting
  - Land use history
  - Changes in carbon pools

Romania Net Carbon Flux



Forest Carbon Stocks



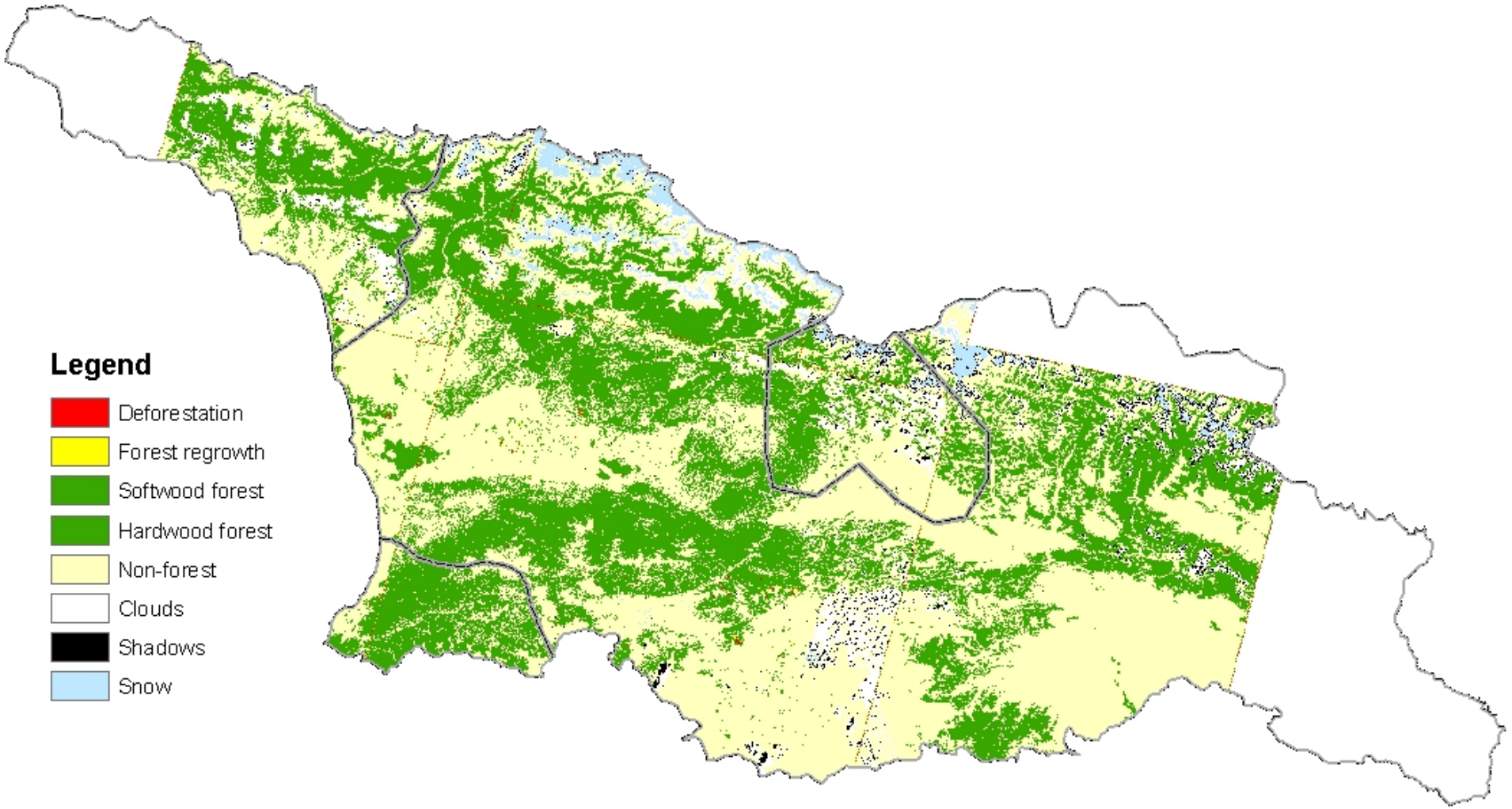
Summary: Romania

- Remote sensing of forest change and a bookkeeping model allow estimation of national level carbon budgets
- Romania is a net carbon sink (approximately 10% of fossil fuel emissions)
- Under the current harvesting rates the annual sink will decline to zero in about 90 years

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 (prel. res.)
- Illegal logging in proximity to villages
- 60% of harvest as unrecorded fuelwood (according to FAO)
- 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



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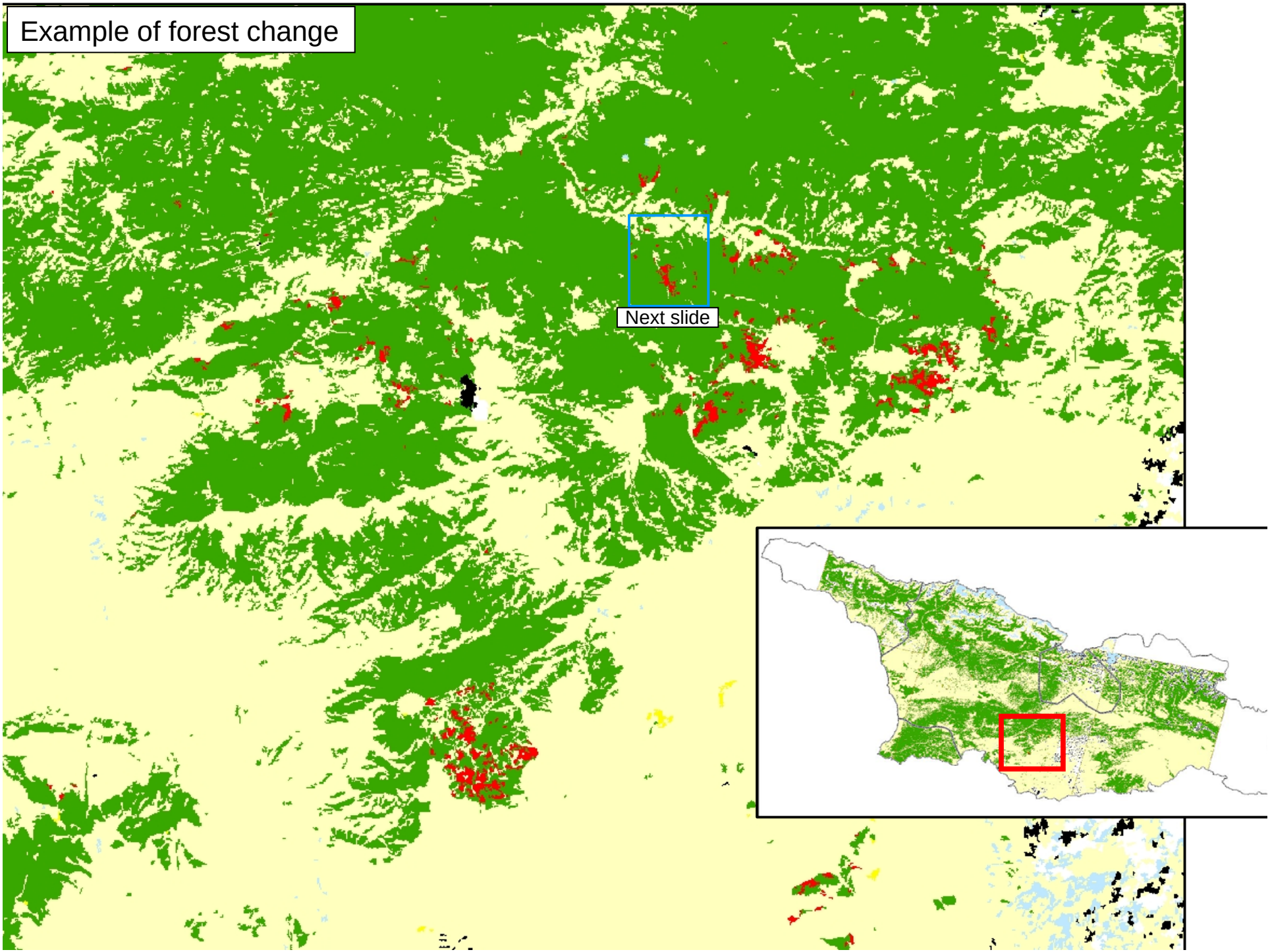
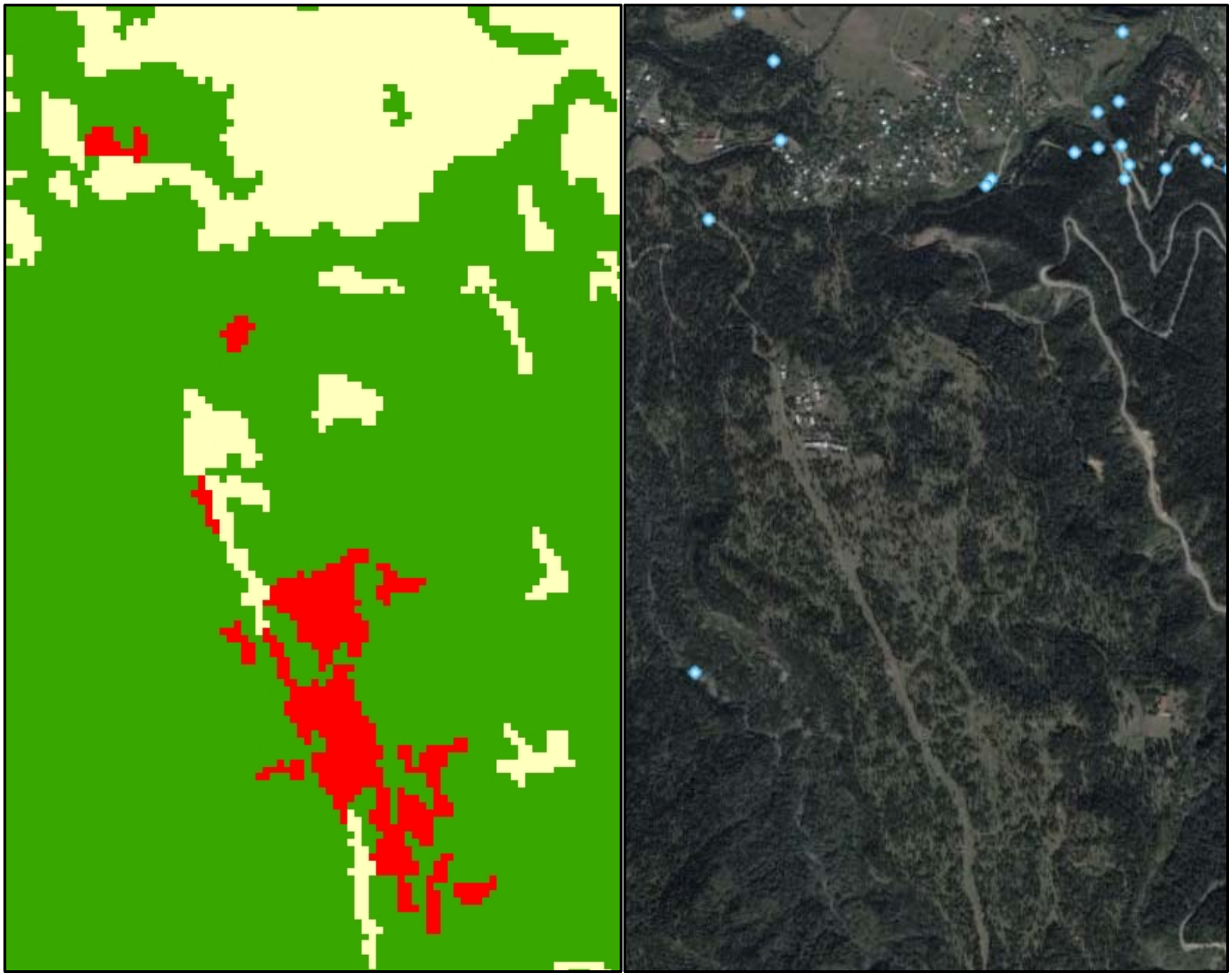

Example of forest change
Next slide

Example of partial cutting (illegal) in Central Georgia



Example of stable forest in Southern Georgia