# Forest dynamics in southeastern United States assessed using time series stacks of Landsat observations

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## Abstract

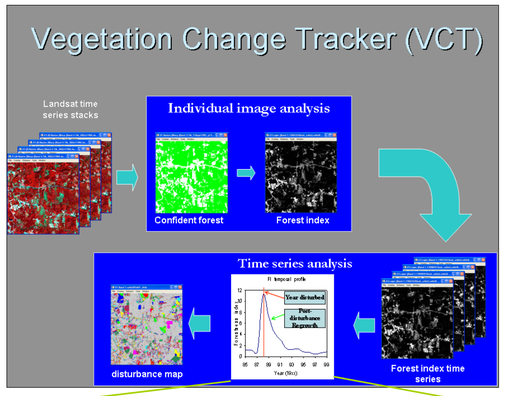
The southeastern U.S. is characterized with active forestry activities and vigorous regrowth. Here we quantitatively assess forest change in this region using Landsat images acquired over the last two decades. The study area encompasses Mississippi, Alabama, Georgia, Florida, South Carolina, North Carolina, and Louisiana, and takes ~50 World Reference System (WRS) tiles to cover. For each WRS tile, we assembled a Landsat time series stack (LTSS) consisting one image every year or every two years. Forest change was mapped using a vegetation change tracker (VCT) algorithm. Mapped changes include logging, storm damage, fire, and other disturbances. Overall accuracy of ~80% was achieved at individual disturbance year level. The results show high spatial and temporal variability of disturbances.

Results from this study will be highly valuable for carbon studies. The wall-to-wall coverage and the spatial and temporal details of the derived forest change products provide an unprecedented opportunity for modelers to reduce uncertainties in quantifying carbon flux arising from forest dynamics for the study area. The spatial details in these change products will satisfy many ecological applications including biodiversity conservation and habitat fragmentation studies, while the annual or biennial temporal resolution and wall-to-wall coverage will facilitate studies at a spectrum of spatial and temporal scales. In addition, the change detection capability developed through this study will allow routine ecosystem monitoring using current satellite observations and historical satellite data archives.

## LTSS and VCT

Landsat time series stack (LTSS):

- One for each WRS tile
- ~50 WRS tiles to cover NC, SC, GA, FL, AL, MS, LA
- Biennial (1 image every two years), 1984-2007 for MS and AL
- Near annual (1 image per year), 1994-2007 for other states
- Temporal characteristics of LTSS driven by data cost imposed at time of study.







## Preliminary Results

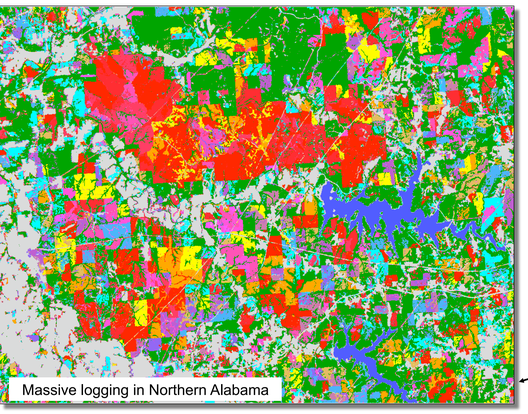
- Forest changes of 7 states in SE U.S. were mapped at annual or biennial steps at Landsat resolution;
- Mapped disturbances include logging and some fire and storm damages;
- Overall accuracy of ~80% was achieved at individual change year level (see table below)
- Derived disturbance rates differ from year to year and from state to state, ranging from ~2% to up to 7% of forest area.

Designed-based accuracy assessment of LTSS-VCT derived change map for WRS path 21/row 37

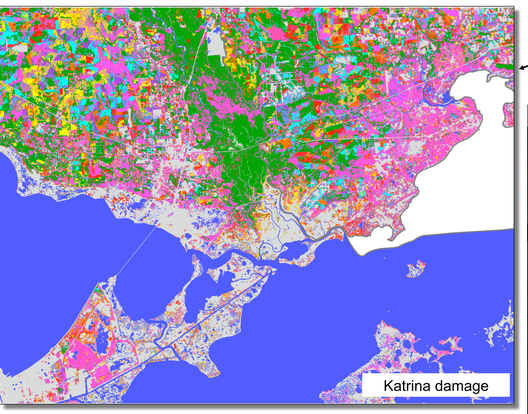
| | Reference | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| VCT | Persist. nonf. | Persist. forest | Pre-1985 | 1987 | 1988 | 1990 | 1921 | 1993 | 1995 | 1997 | 1999 | 2001 | 2003 | 2005 | Row Total | *User's acc.* |
| P. Nonf. | **0.2637** | | 0.0094 | 0.0052 | | 0.0005 | | | | | | | | | 0.2789 | 0.946 |
| P. Forest | | **0.1970** | 0.0086 | 0.0084 | 0.0134 | 0.0144 | 0.0043 | 0.0211 | 0.0153 | 0.0043 | 0.0061 | 0.0091 | 0.0086 | 0.0021 | 0.3126 | 0.630 |
| Pre-1984 | | 0.0014 | **0.0725** | 0.0033 | | | | | | | | | | | 0.0772 | 0.940 |
| 1987 | | | 0.0041 | **0.0465** | 0.0036 | | | | | | | | | | 0.0541 | 0.858 |
| 1988 | 0.0026 | | | 0.0015 | **0.0215** | | | | | | | | | | 0.0256 | 0.839 |
| 1990 | | | | 0.0014 | | **0.0254** | | | | | | | | | 0.0267 | 0.949 |
| 1991 | | | | 0.0030 | | | **0.0170** | | | | | | | | 0.0200 | 0.849 |
| 1993 | | | 0.0019 | | 0.0009 | | 0.0009 | **0.0258** | | | | | | | 0.0296 | 0.872 |
| 1995 | | | | | 0.0014 | | 0.0007 | | **0.0234** | | | | | | 0.0255 | 0.917 |
| 1997 | 0.0017 | | | | 0.0006 | 0.0011 | 0.0017 | | 0.0007 | **0.0246** | | | | | 0.0303 | 0.810 |
| 1999 | | | 0.0009 | | 0.0017 | 0.0026 | 0.0009 | 0.0009 | 0.0009 | | **0.0239** | | | | 0.0316 | 0.757 |
| 2001 | | | 0.0009 | | | 0.0009 | 0.0018 | 0.0018 | | 0.0009 | | **0.0180** | | 0.0009 | 0.0251 | 0.714 |
| 2003 | | | | 0.0014 | 0.0017 | 0.0013 | 0.0011 | 0.0006 | 0.0006 | | | | **0.0158** | 0.0010 | 0.0234 | 0.677 |
| 2005 | | 0.0019 | 0.0017 | 0.0010 | 0.0019 | 0.0019 | | 0.0029 | 0.0010 | 0.0019 | 0.0010 | 0.0010 | | **0.0181** | 0.0340 | 0.532 |
| Column Total | 0.2679 | 0.2003 | 0.1000 | 0.0715 | 0.0467 | 0.0481 | 0.0284 | 0.0530 | 0.0418 | 0.0316 | 0.0309 | 0.0280 | 0.0244 | 0.0221 | 0.9947 | |
| *Producer's acc.* | 0.984 | 0.984 | 0.726 | 0.649 | 0.460 | 0.527 | 0.599 | 0.487 | 0.560 | 0.776 | 0.773 | 0.641 | 0.649 | 0.819 | **Overall** | **0.797** |

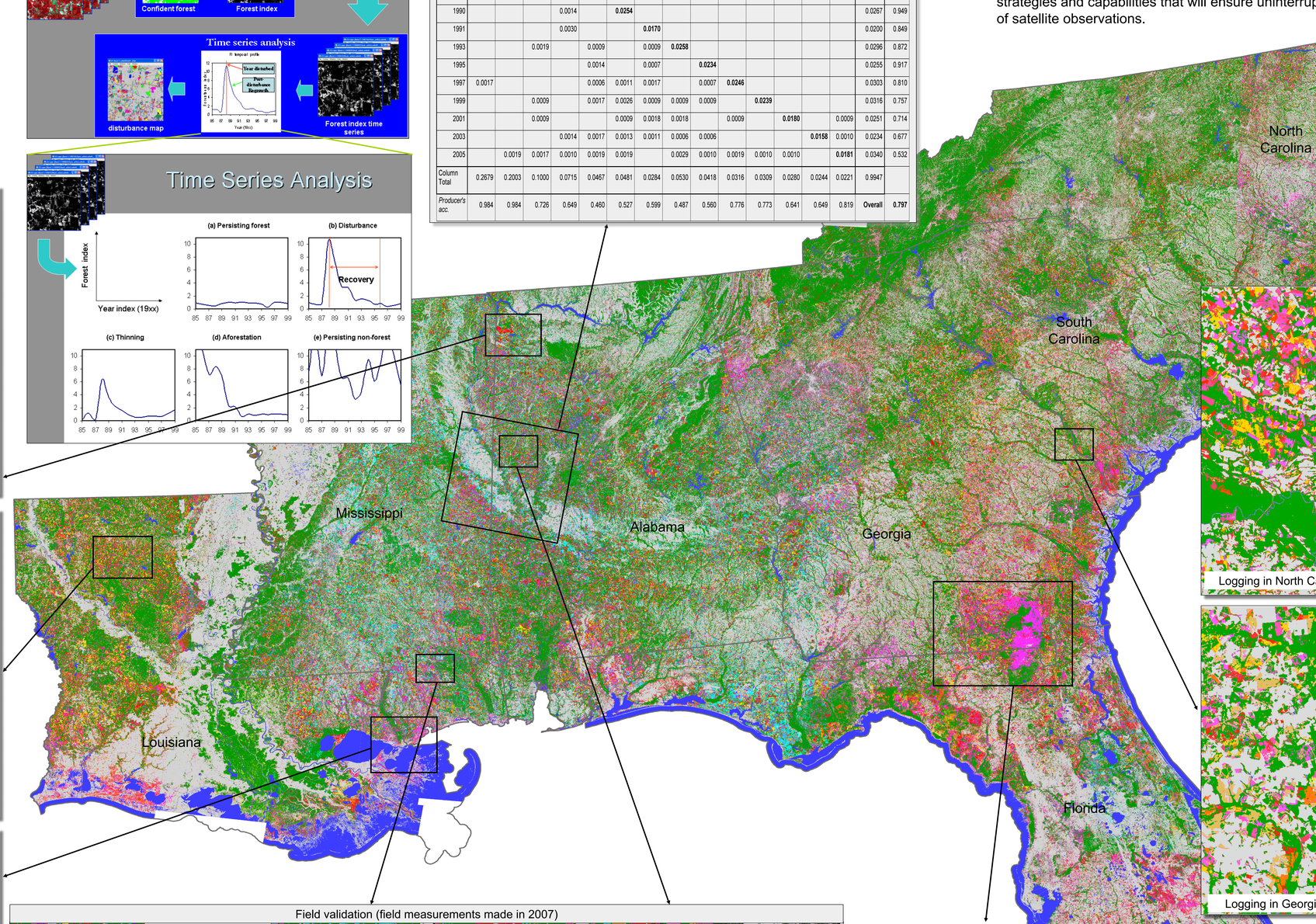
## Implications

- Most disturbances in SE U.S. are followed by regeneration. High disturbance rates and vigorous regrowth can transfer large quantities of carbon between the land and the atmosphere. The fate of disturbed woody biomass is key to understanding of net flux;
- The LTSS-VCT is an efficient approach for reconstructing forest disturbance history dating back up to the 1970s, and for monitoring ongoing dynamics at annual or finer temporal resolutions:
  - Now that the entire US Landsat archive can be accessed with no cost to users, wall-to-wall mapping of annual dynamics for the U.S. has become feasible;
  - Applicability of this approach outside the U.S. will depend on data availability:
    - Landsat archives at international ground receiving stations (IGRS) are not open for no-cost access yet;
  - For continuous monitoring of global ecosystems, it is necessary to develop acquisition strategies and capabilities that will ensure uninterrupted, systematic acquisition of time series of satellite observations.

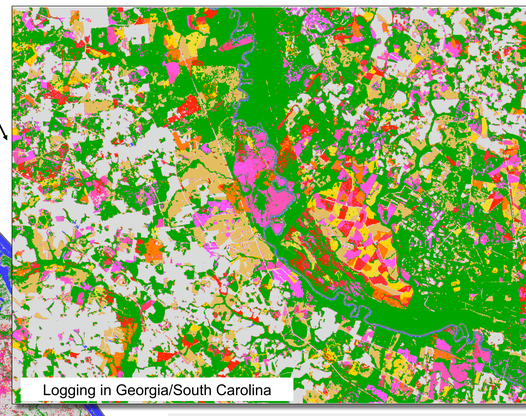

Massive logging in Northern Alabama

Logging in Louisiana

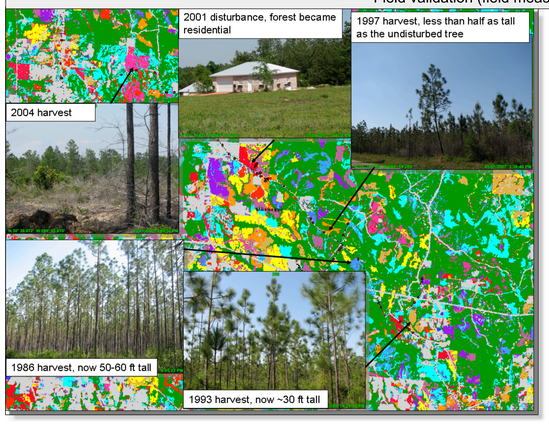

Katrina damage

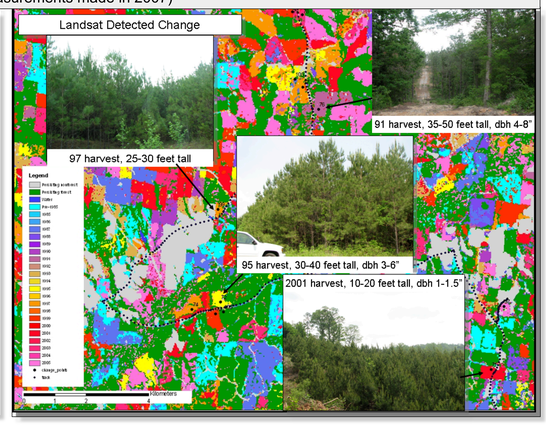


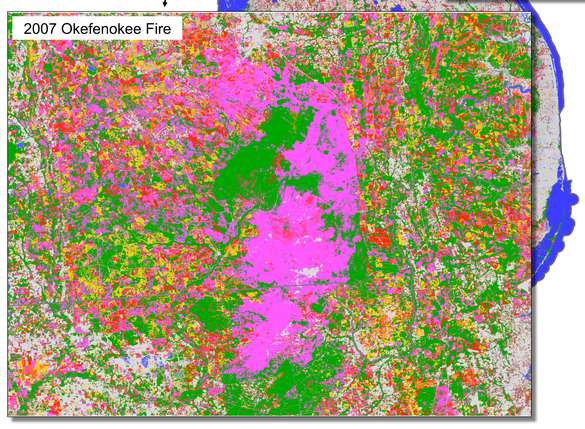
Logging in North Carolina


Logging in Georgia/South Carolina

Field validation (field measurements made in 2007)




**Land cover type and disturbance year**

- Persisting Nonforest
- Persisting Forest
- Water
- Pre-1985
- 1985
- 1986
- 1987
- 1988
- 1989
- 1990
- 1991
- 1992
- 1993
- 1994
- 1995
- 1996
- 1997
- 1998
- 1999
- 2000
- 2001
- 2002
- 2003
- 2004
- 2005
- 2006
- 2007

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