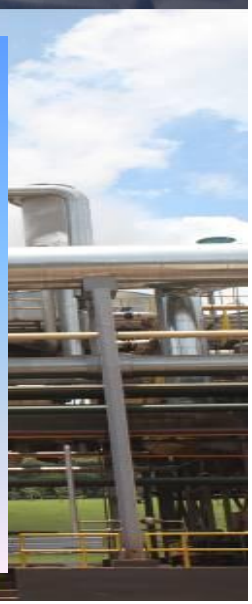
Integrating remote sensing and geospatial analysis to quantify impacts of biofuel expansion



Presented by: Jessica Chalmers and Dr. Cheney Shreve

Co-authored by: Michael Netzer, Jessica Chalmers, Dr. Nancy Harris and Dr. Cheney Shreve

Workshop on Quantifying and Managing Land Use Effects of Bioenergy, Campinas, Brazil

19 September 2011

Project overview

Goal

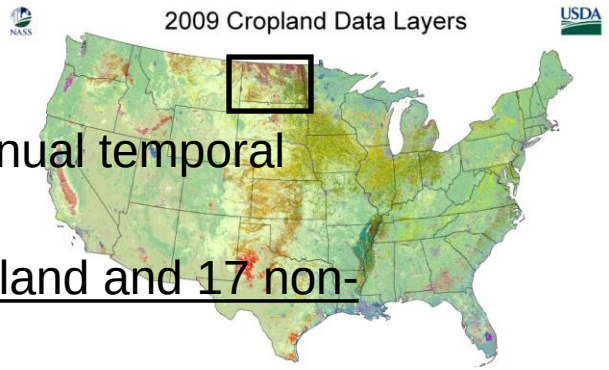
- To support the development of effective sustainability initiatives for biofuels

Objectives

- Develop a monitoring framework for biofuel sustainability which incorporates the site, regional and national scales and includes iLUC

- Evaluate potential improvements in the evidence base for iLUC assessments

Case Study: North Dakota, USA

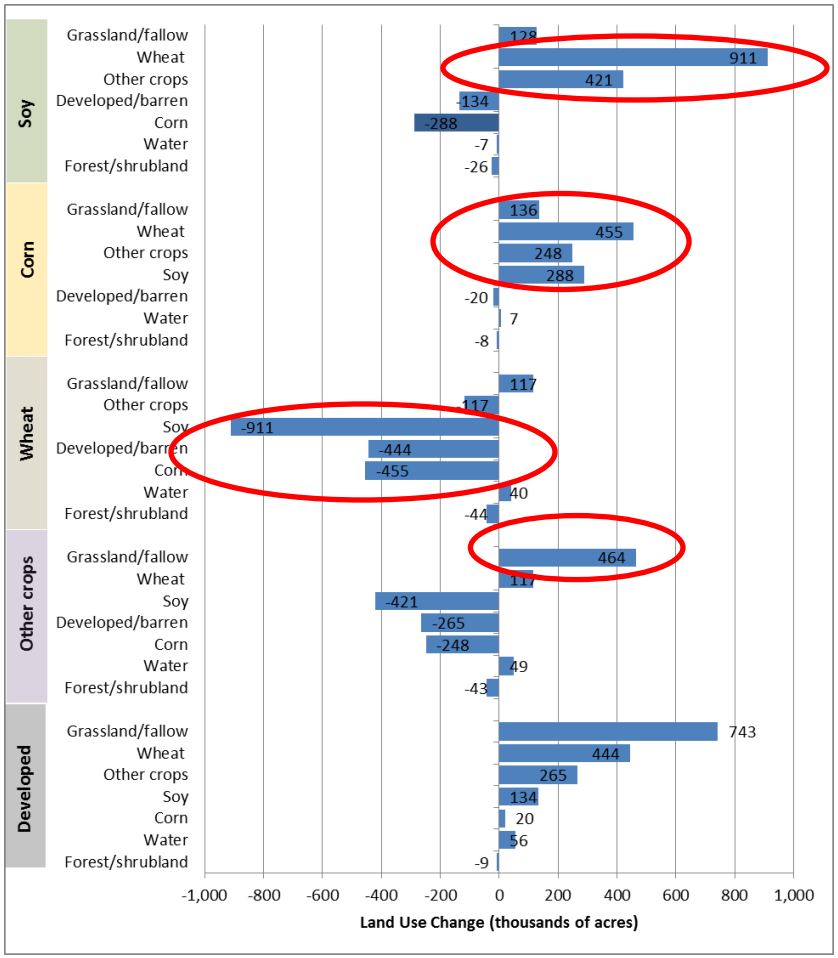


- NASS Cropland Data Layer for ND – 56 m spatial, annual temporal resolution (2010-onward is 30 m)
  - Land cover classification with 46 classes (29 cropland and 17 non-cropland)
  - Utilizes ground truth data from US Farm Service Agency to verify agricultural information

- 2002-2009 analysis selected
  - Prior to 2002 wheat excluded. Some inaccuracies known 2002-2006. *2006-2009 high accuracy statistics*.
  - Reclassified: merge fallow/idle and grassland/pasture; 'other crops' include alfalfa, oats, sugarbeet, potatoes

- Used IDRISI software, utilizing cross-tabulation and Land Change Modeler tools to assess LUC. ArcGIS 10 was used for the analysis of LUC at the county scale and for other general GIS analyses.

Cropland dynamics 2002-2009 North Dakota

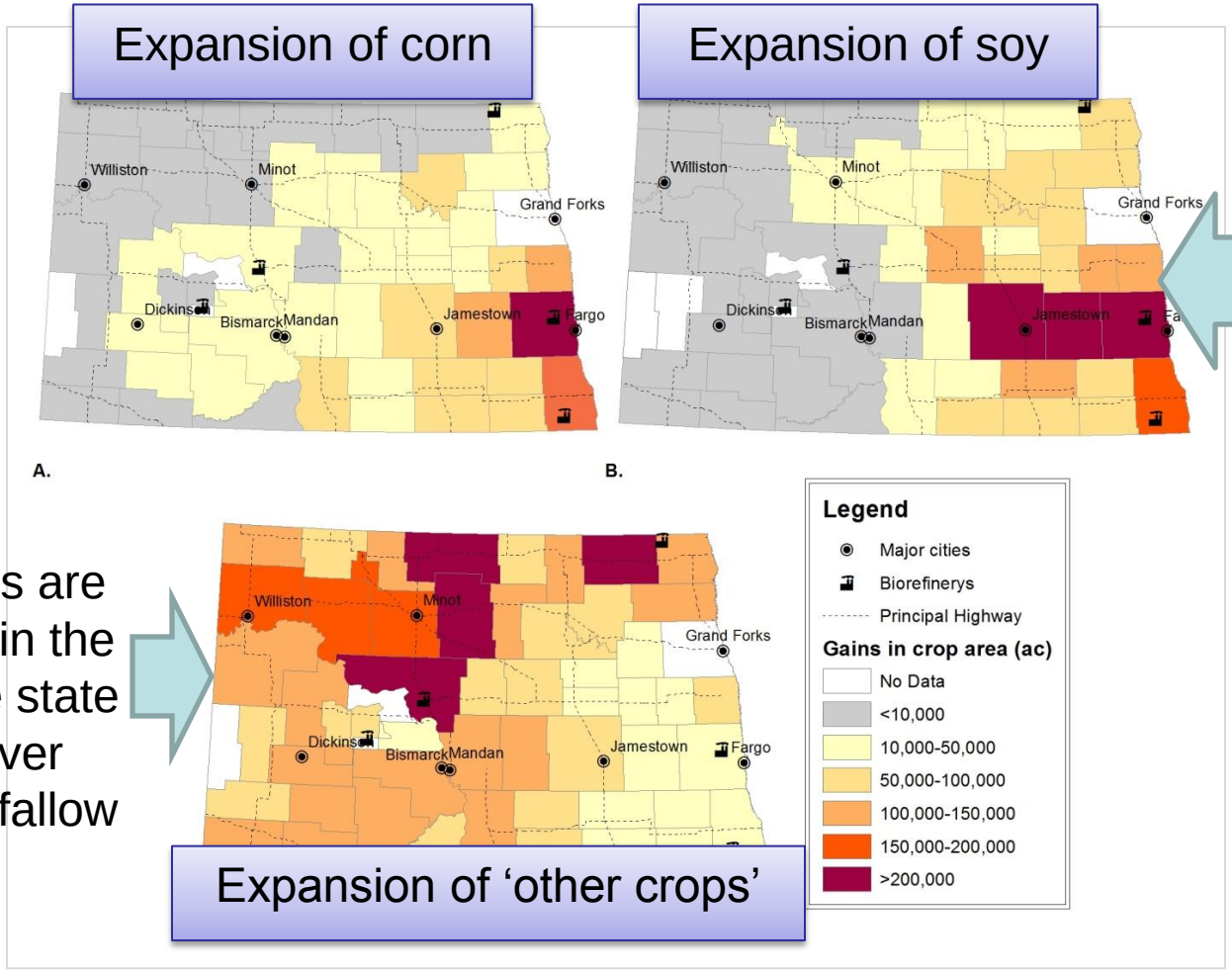


decreasing Increasing

- Expansion of corn, soy and developed land
- Corn and soy replaced wheat and other crops
- Expansion of ‘other crops’ (e.g. barley) into grassland/fallow areas

Corn and soy expanded into previous agriculture regions, not into grasslands/abandoned lands.

GIS allows us to see what is happening in different locations



Corn and soy expanding in the southeast over wheat and other crops

Other crops are expanding in the north of the state largely over grassland/ fallow

Conclusions: Phase I

- Biofuels likely play some part in LUC in North Dakota but there are other driving forces
  - Wet weather in early 2000s
  - New technologies (GM)
  - Farming demographics
  - Expiring CRP land and agricultural policy
  - Oil exploration

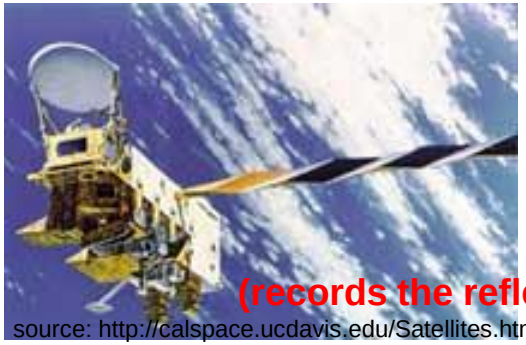
- Annual national monitoring of croplands and non-croplands is possible at the national scale provided detailed products exist (example, NASS cropland data layer)
  - Accuracy at county scale (and coarser) is good for cropland identification.

- Identifying spatial distribution and changes of different crop types plays a key role in understanding LUC (dLUC/iLUC) and the role of biofuels in this change.

- Better classification of grasslands (low/high biomass or long term fallow vs. rotational, biodiversity) would assist in understanding relative carbon impacts of LUC.

Power source

Collecting Sensor



source: http://calspace.ucdavis.edu/Satellites.html

(records the reflected light from surface)

Sensor output

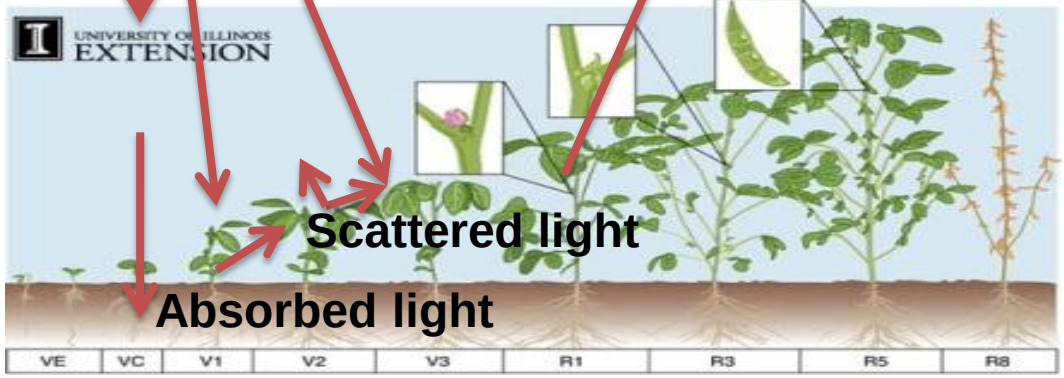
Raw Output: Digital Number (DN)

Apply corrections (atmosphere, terrain, etc)

Processed Output: Surface Reflectance

Transmitted light

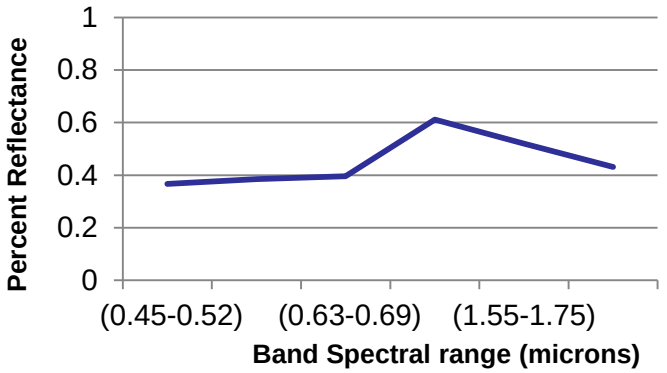
Reflected light



Scattered light

Absorbed light

Example Pixel Spectra (Value)



Next Step:

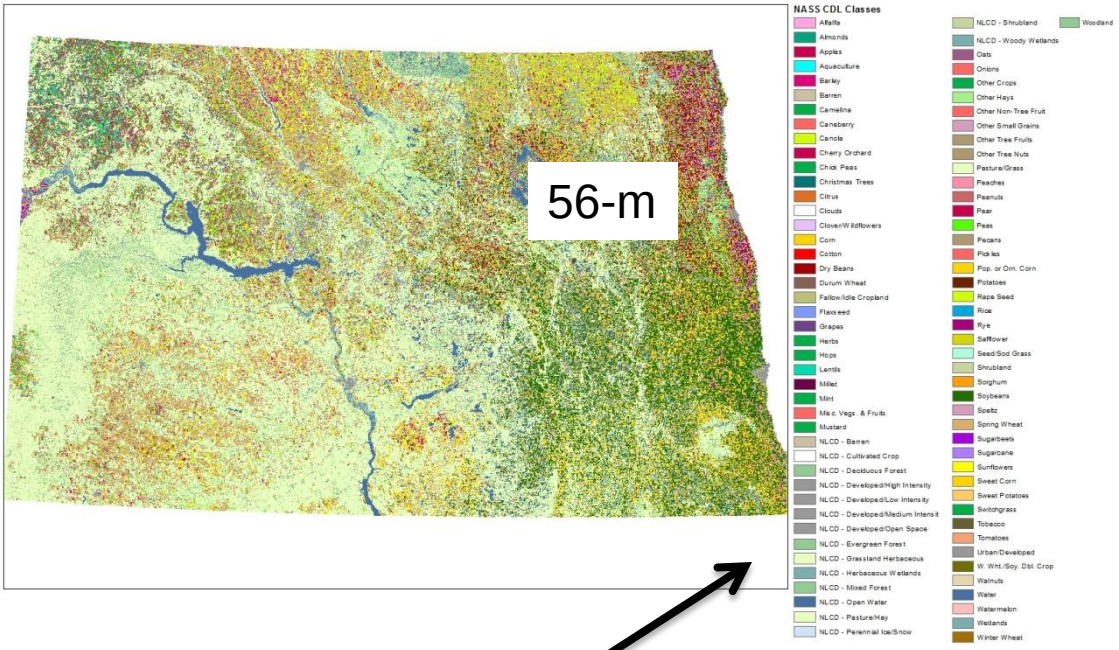
Apply a remote sensing technique to determine what land cover (surface Components) are combined to produce the pixel reflectance.

Measurable components using remote sensing for monitoring land cover change associated with biofuels

Task description	Scientific tools?	Scale: Subnational	Scale: National	Scale: Global	Comments
1. Quantify spatial distribution of land cover classes of interest for **biofuel monitoring** (crops, grasslands, forests, etc.)	✓	✓	✓ * Data for limited countries	✗	Global data does not provide specific crop type or productivity for specific crop types.
2. Track spatial and temporal changes in the land cover classes of interest to **biofuel monitoring**.	✓	✓	✗	✗	Regional, biofuel-specific studies completed, but not national or higher for most countries.
3a. Estimate carbon stocks.	✓	✓	✓ *	✓ *	Coarse scale global net productivity products, but not specific for land cover classes and not a direct measure of yield.
3b. Estimate yield for biofuels and agricultural crops.	✓	✓	✗	✗	

Note: we are not discussing RS and monitoring related to the atmosphere/hydrosphere due to time restrictions in this talk. Capabilities for carbon stock estimation are mentioned, but will not be discussed in detail.

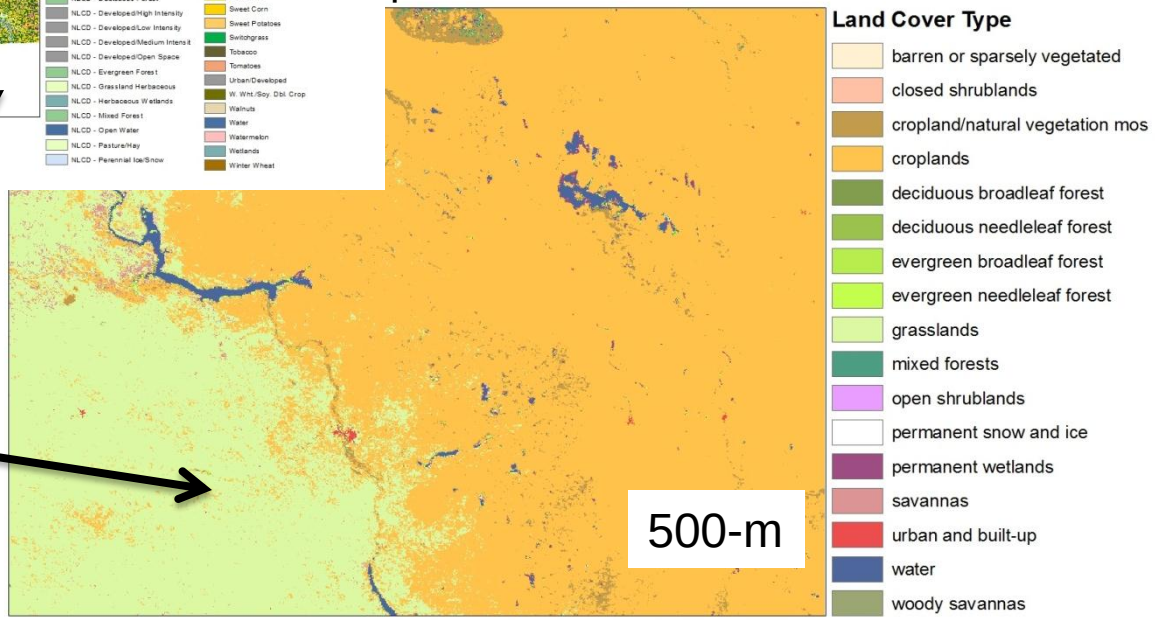
What information do we lose going from high spatial resolution (30-60 m) to coarse spatial resolution (500-m)?



Roughly 30 classes with
Specific crop types: example
Corn, soy, sugar cane

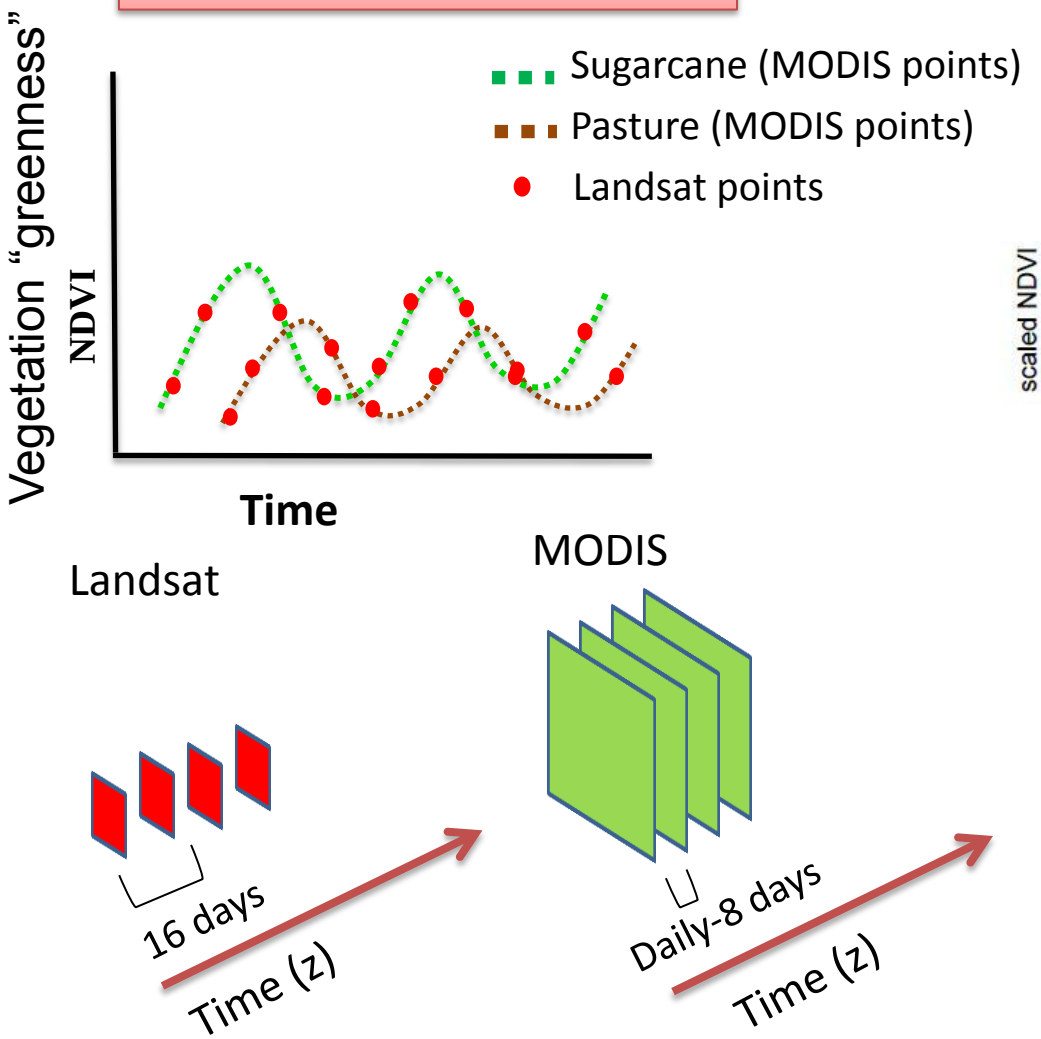
Two crop related classes:
Croplands, crop/vegetation mosaic

- High resolution products (30-60-m) available for only a few countries, computationally expensive
- Current 500-m MODIS land cover and similar products are too general for biofuel monitoring
- 250-m MODIS NDVI has shown potential for biofuel related studies



How do we "get around" these losses?

Idealized time series example



Spatial resolution: **30 m**
Temporal resolution: **~16-days**

Spatial resolution: **(bands (1-2) 250m, (3-7) 500m, (8-36) 1 km)**
Temporal resolution: **daily- 8 days**

Real life time series: West Africa

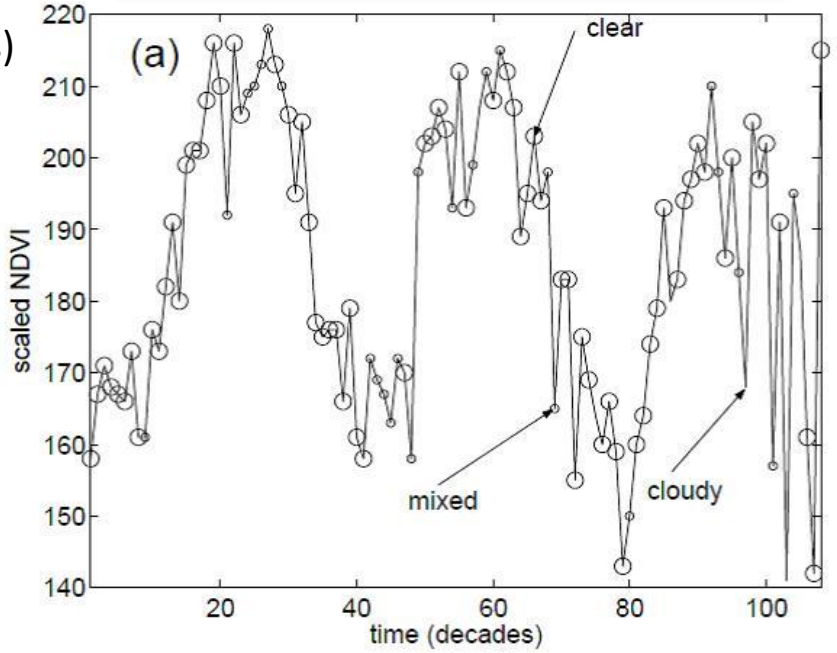


Figure from: Jönsson & Eklundh TIMESAT manual 2006

Phase II: Goals

Exploring methods for using RS at broad scales for cost-effective monitoring

- Quantify biofuels at the ***moderate resolution (250-m) scale using TIMESAT or similar method***
- Utilize geographic regions with wealth of remote sensing analysis data to start with
  - Brazil
  - US (build from Phase I results)
- Utilize well validated, freely available software/techniques when possible
- Report on difficulties/successes

Phase II: Exploring biofuel studies at the moderate resolution scale hypotheses

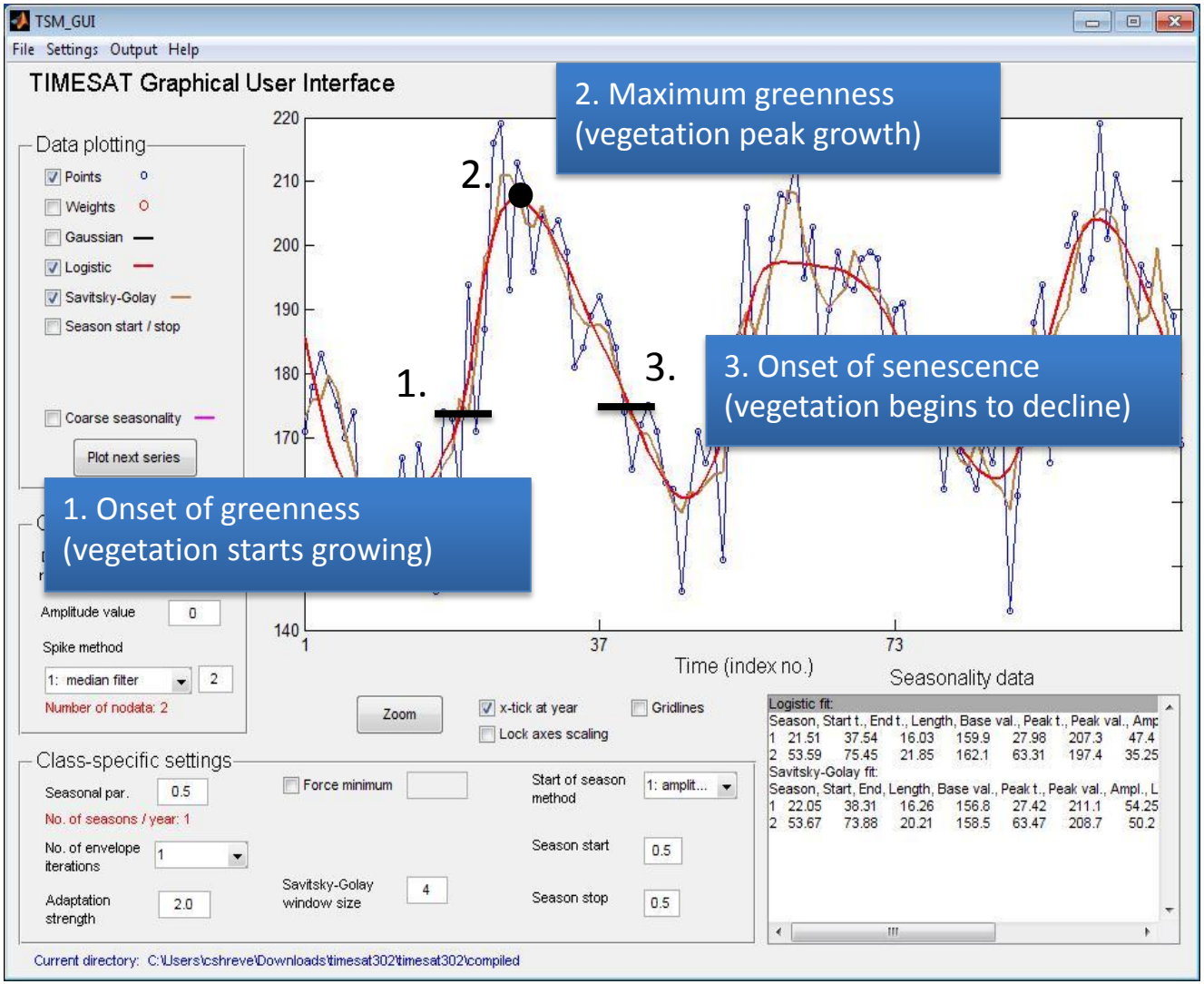
What can be accomplished in moderate resolution studies?

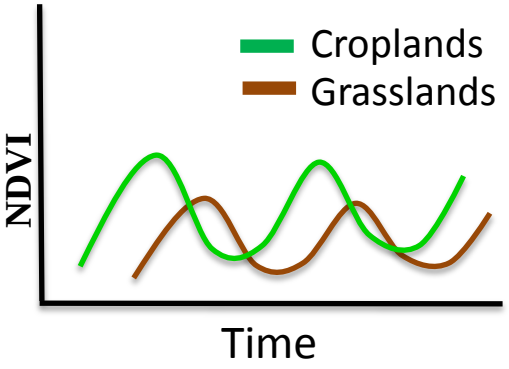
***Hypotheses*:** characteristics of the growing season, which can be extracted using TIMESAT to create maps of these variables, can be utilized to distinguish between biofuel crops, grasslands, and forest. Additionally, these growing season maps will provide information on the "health" of grasslands. Similar, temporally based regional studies have shown 250m MODIS can be used for this purpose (Rudorff et al, 2010; others).

What is TIMESAT?

INPUT

Created by: Per Jönsson & Lars Eklundh (2002) Lund University, Sweden





Using West-Africa example, for actual case-study portions of Brazil, USA, and Indonesia will be used.

- Well validated
- Widely applied
- Free for non-commercial purposes

Using TIMESAT and moderate resolution MODIS imagery to supplement biofuel monitoring. Shreve, Chalmers, and Netzer, *In Preparation.*

What does TIMESAT Produce?

EXAMPLE OUTPUT

Map of the start of the growing season

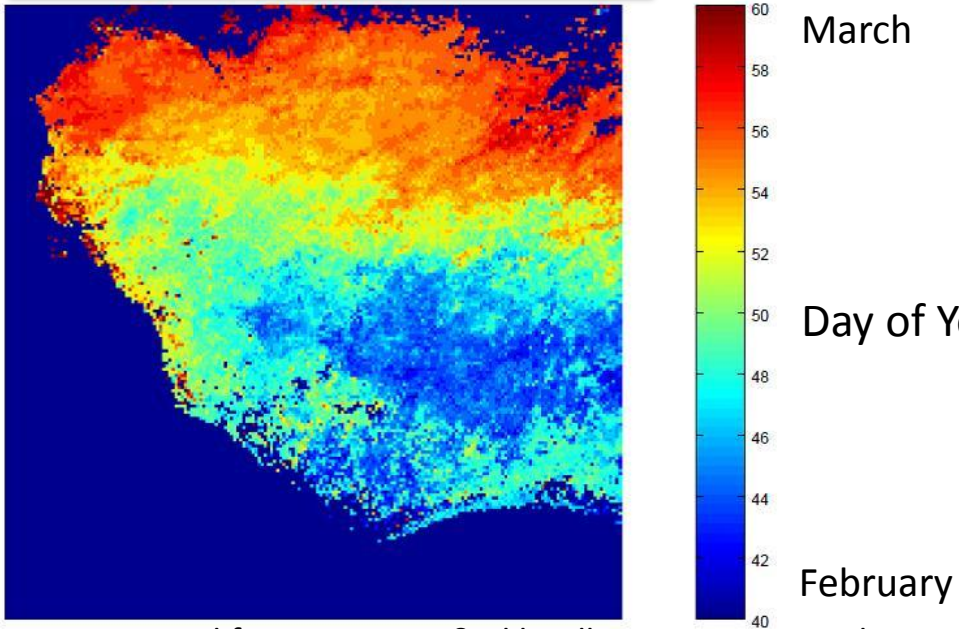


Figure revised from: Jönsson & Eklundh TIMESAT manual 2006

OUTPUT

Spatially explicit maps of:

- Onset of greenness
- Length of the growing season
- Onset of senescence
- Yearly integral under the curve
- Maximum greenness

Using TIMESAT and moderate resolution MODIS imagery to supplement biofuel monitoring. Shreve, Chalmers, and Netzer, *In Preparation.*

COMPARE

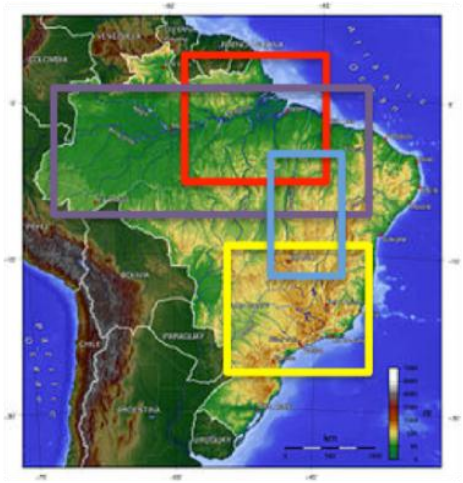
- Compare output TIMESAT maps (onset of greenness, duration of growing season, yearly integral under the curve, etc.) to high resolution studies, available statistics and ancillary data

CONCLUDE

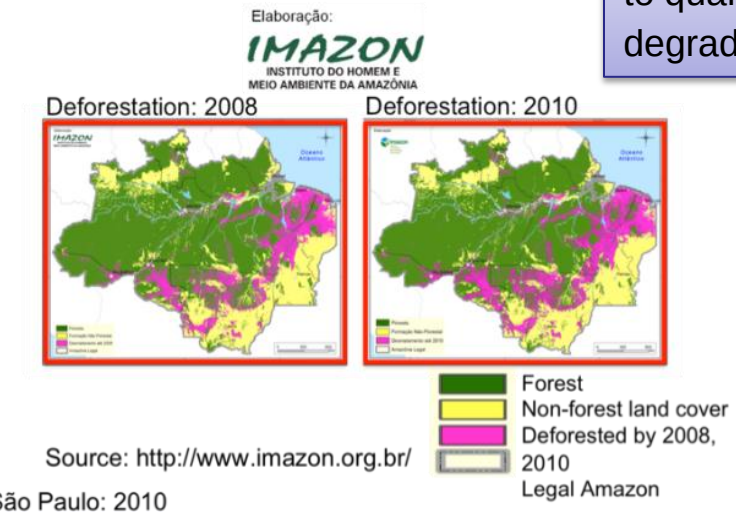
Can growing season characteristics extracted using TIMESAT or a similar method using 250-m MODIS NDVI be used to provide better crop identification than current coarse scale products for biofuel-relevant classes?

Collate and review subnational scale studies

- Usually conducted using 30-m, 16-day RS data

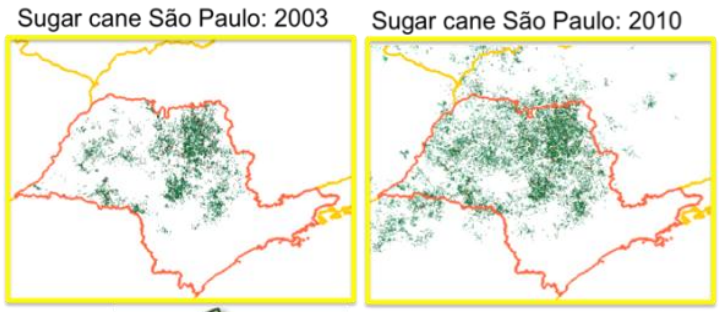


Souza et al (2005, *RSE*) developed/applied RS techniques to quantify deforestation & forest degradation in the Amazon.



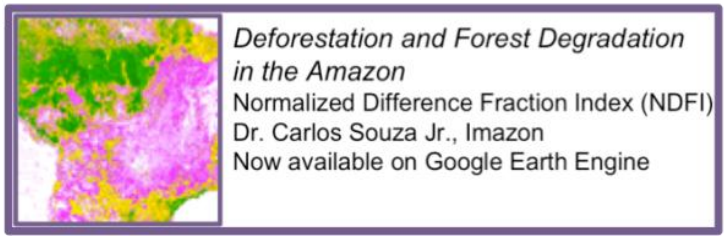
Source: http://www.imazon.org.br/

Numata et al (2007) applied RS to look at grassland degradation In Brazil.



Source: http://www.dsr.inpe.br/laf/canasat/

Rudorff et al (2010, *Remote Sens.*) quantified the expansion of sugarcane for ethanol in São Paulo State using Landsat data.



Assad (EMBRAPA-CPAC); Klink (UnB); mapping Cerrado

USDA Global Agricultural Monitoring (GLAM) Project

Global Scale Studies:
Typically 250-m, 1-8 day RS data

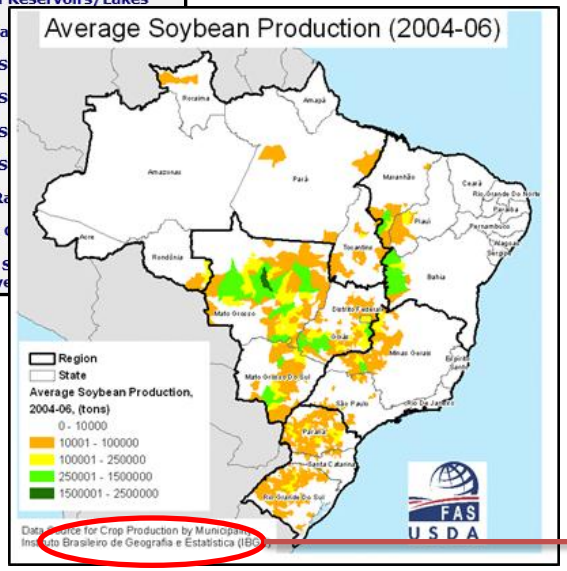
Brazil - Area, Yield and Production

Date Created 09/13/11 14:09:24

Select a Country

	Area Harvested (Million hectares)			Yield (Metric tons per hectare)			Production (Million metric tons)			Change in Production	
										From Last Year	
Commodity	2009/10	2010/11	2011/12	2009/10	2010/11	2011/12	2009/10	2010/11	2011/12	MMT	Percent
Barley	0.077	0.080	0.085	2.610	3.163	3.059	0.201	0.253	0.260	0.01	2.77
Corn	12.925	13.800	14.500	4.340	4.167	4.207	56.100	57.500	61.000	3.50	6.09
Oats	0.134	0.154	0.154	1.888	2.461	2.403	0.253	0.379	0.370	-0.01	-2.37
Oil, Palm	0.000	0.000	0.000	0	0	0	0.240	0.265	0.275	0.01	3.77
Oilseed, Cottonseed	0.836	1.400	1.300	2.427	2.261	2.492	2.029	3.165	3.239	0.07	2.34
Oilseed, Palm Kernel	0.000	0.000	0.000	0	0	0	0.063	0.070	0.072	0.00	2.86
Oilseed, Peanut	0.095	0.100	0.100	2.474	2.500	2.600	0.235	0.250	0.260	0.01	4.00
Oilseed, Soybean	23.500	24.200	25.000	2.936	3.120	2.940	69.000	75.500	73.500	-2.00	-2.65
Oilseed, Sunflowerseed	0.070	0.075	0.078	1.371	1.467	1.474	0.096	0.110	0.115	0.01	4.55
Rice, Milled	2.765	2.820	2.800	0.000	0.000	0.000	0.000	0.000	0.000	0.00	0.00
Rye	0.004	0.002	0.002	1.000	1.500	1.500	0.004	0.003	0.003	0.00	0.00
Sorghum	0.793	0.716	0.700	2.338	2.506	2.429	1.854	1.794	1.700	-0.09	-5.24
Wheat	2.428	2.150	2.100	2.070	2.744	2.381	5.026	5.900	5.000	-0.90	-15.25

	Area Harvested (Million hectares)			Yield (Kilograms per hectare)			Production (Million 480 lb. bales)			Change in Production	
										From Last Year	
Commodity	2009/10	2010/11	2011/12	2009/10	2010/11	2011/12	2009/10	2010/11	2011/12	MBales	Percent
Cotton	0.836	1.400	1.300	1419.000	1322.000	1457.000	5.450	8.500	8.700	0.20	2.35



Current limitations for biofuels

Specificity

- Crop types
- Native ecosystems

In collaboration with:
Instituto Brasileiro de Geografia e Estatística (IBGE)

Figures created using data from: http://www.pecad.fas.usda.gov/cropexplorer/

Concluding Remarks

- Monitoring is the essential feedback loop that enables any sustainability standard/initiative to remain meaningful. RS can be used as a monitoring tool to support decision makers regarding biofuel sustainability impacts and outcomes.

- Capability exists to monitor biofuels at the subnational scale, however technical capacity limits most countries from reporting

- Significant advances have been made facilitating RS time series analysis over large geographic regions and allowing for sharing of results among scientists (GLAM, NEX, SPRING, Google Earth Engine, others), however these do not yet cover all the biofuel-relevant land cover classes.

- In the interim, small scale, time series based studies exploring relationships between subnational scale results and moderate scale results may provide a more realistic estimate of biofuel expansion/extent of native ecosystems

Obrigado

Acknowledgements

- The David and Lucile Packard Foundation
- USDA/NASS
- Virgil Dagman (Farm/ranch management instructor, North Dakota)