Using time legacy of Earth Observation Data to describe and Monitor Land Surface Dynamics

Neeti
Assistant Professor
TERI University, New Delhi
neeti@teriuniversity.ac.in
GEOSMART INDIA 2016
(March 03, 2016)
Land Surface Dynamics

**Land Use (LU):** Use of land by human for different activities

- **Broad LU**
  - Forestry
  - Cropping
  - Grazing

- **Specific LU**
  - Palm
  - Corn
  - Banana

**Change**
- Forestry → Cropping
- Weak thinning → Strong thinning

**Conversion**
- Forest → Cropland
- Intact Forest → Degraded Forest

**Land Cover (LC):** Physical properties of a land surface

- Forest
- Cropland
- Shrubland
Land Surface Dynamics

- Socio-economic Changes
- Land use change
- Feedbacks and Interactions
- Lands
- Biophysical Changes
- Relationship and Feedback
- People
- Land cover change
- Natural System e.g. resilience
- Human System e.g. Well being

- Causes
- Consequences

Relationship and Feedback

Changes
Stages of Understanding land surface dynamics and monitoring changes

1. Detection: Perceiving the change
2. Quantification: Magnitude of the change
3. Assessment: Significances of the change
4. Attribution: Proximate and distal cause of the change
5. Projection: Future change
6. Policy and Management Planning

- Rigorous and accurate monitoring is crucial
Scales in Monitoring Land Surface Dynamics

![Diagram showing scales in monitoring land surface dynamics]

- **Observer**
  - Field Ecologist
  - High Resolution Remote Sensor
  - Moderate Resolution Remote Sensor

- **Observation Scale**
  - Coarse
  - Fine

- **Spatial Scale**
  - Regional
  - Local

- **Habitat Scale**
  - Landscape
  - Community
  - Species
Remote Sensing for Earth Observation

Advantages
1. Fine temporal resolution
2. Fine spatial resolution
3. Free / low costs

Challenges
1. Data Volume
2. Noise and Clouds
3. Data Gaps
Overview: Monitoring Land Surface Dynamics

Exploiting seasonality in high-temporal resolution EO datasets:
*Case study of Yucatan Peninsula*

Exploiting time series of fine-spatial resolution EO datasets:
*Case study of Washington, Oregon, California*
Overview: Monitoring Land Surface Dynamics

Exploiting seasonality in high-temporal resolution EO datasets:
Case study of the Yucatan Peninsula

Exploiting time series of fine-spatial resolution EO datasets:
Case study of Washington, Oregon, California
Methodological Framework

Monitoring using fine-temporal resolution Earth Observation (EO) Data

Detection, quantification and assessment of changes using Seasonal Trend Analysis (STA)


Quantification

Magnitude of change

Assessment

Significant change

Positive change

Negative change
1. An approach to describe changes in land surface dynamics using seasonality and inter-annual variability in the time series of Earth Observations data

1. Steps:
   1. Decomposing the time series observations for each year into seasonal and annual parameters using Fourier analysis
   2. Analyzing the long term trends in seasonal and annual parameters using a non-parametric statistical approach

---

Seasonality and inter-annual variability: Fourier Analysis

Decomposes complex signals into additive harmonics of sine waves

\[ f(x) = a_0 + \sum_{n=1}^{n=T/2} a_n \sin\left(\frac{2\pi nx}{T} + \phi_n\right) \]

- **Timing of green up**
- **Magnitude of maximum green up** (Variability in productivity)
- **Overall productivity**
Use of Robust non-parametric regression procedure for trend analysis:

1. Theil-Sen’s Procedure for magnitude (slope)

2. Contextual Mann Kendall (CMK) for statistical significance: an extension of Mann Kendall (MK) test

CMK test:

1. Addition of contextual information in MK to make statement about significance in small time series
2. Uses the principle of spatial autocorrelation to characterize geographic phenomena
3. The pixel needs to exhibit a trend which is not radically different from its neighbors
Case Study: Yucatán Peninsula, Mexico
Monitoring Land Surface Dynamics (1982-2007)

Data: GIMMS (Global Inventory Modeling and Mapping Studies) AVHRR data set – normalized difference vegetation index (NDVI) product for a 26 year period (1982 to 2007)

Yucatán Land Cover Transitions from Landsat, 1976-2000

Categorical Losses and Gains

Percent of Study Area

-6 -4 -2 0 2 4 6

1976

2000
Results: CMK Statistical Significance Maps

Amplitude 0
(Overall greenness)

Amplitude 1
(Magnitude of peak annual greenness)

Phase 1
(Timing of peak annual greenness)

- Decline/delay in greenness
- Increase/early in greenness
- Sample points
Results: Seasonal Curves in Significant change locations

1. In Yucatán Peninsula, NDVI change phenomena is mostly human driven
2. Urbanization has led to decrease in greenness in the Yucatán Peninsula
3. Cattle grazing has led to shift in magnitude and timing of peak greenness
Overview: Monitoring Land Surface Dynamics

Exploiting seasonality in high-temporal resolution EO datasets:
*Case study of the Yucatan Peninsula*

Exploiting time series of fine-spatial resolution EO datasets:
*Case study of Washington, Oregon, California*
Monitoring using time series of fine-spatial resolution EO datasets: Legacy of Landsat
Traditional approach

Common training dataset:
1. extending the training dataset for a given year to all the years
2. Issue: Ephemeral differences such as differences in sun illumination angle, atmospheric condition, phenology between the images makes the use of the same training dataset over the time more difficult.

Separate classification model for each year:
1. Post-classification change detection
2. Issues: a) dependent on the accuracy of each of the classification, and b) availability of training data for every map.

Proposed solution

Generating land use / land cover map by incorporating state of class and change over the years through change in signal in the time series of remotely sensed data
Proposed Framework

Preprocessed Landsat time series → Temporal segmentation (Landtrendr)

**Landtrendr**: Landsat-based detection of trends in disturbance and recovery (Kennedy et al. 2010):
- Temporal segmentation approach based on iterative piecewise linear regression
- Extract spectral trajectories for pixels
- Statistically identify and fit segments with consistent trends

National land use/land cover 2001 → Revised land cover map → Random Forest Classification

Recursive Land use/ classification → definition of land cover

Topographic variables

Multi-temporal Accuracy Assessment

Yearly land cover maps
Study Area
Loss of evergreen forest to herbaceous/shrub in California
Change in area for different land use/land cover classes over the years (1991-2012)
Change in area for different land use/land cover classes over the years (1991-2012)

Availability of time series of fine spatio-temporal resolution Earth Observation dataset along with cutting-edge geospatial techniques provide great avenue to understand land surface dynamics and further help in finding solutions to problems related to climate change
Thank You

Neeti
neeti@teriuniversity.ac.in

Collaborators:

Dr. R. Eastman, Clark University, MA, USA
Dr. J. Rogan, Clark University, MA, USA
Dr. R. Kennedy, Oregon State University, OR, USA
Dr. M. Millones, University of Texas, USA
Dr. Z. Chirstman, Rowan University, NJ, USA
# Original and Revised Base maps (2001)

<table>
<thead>
<tr>
<th>Original NLCD Class</th>
<th>Revised land cover Class</th>
</tr>
</thead>
<tbody>
<tr>
<td>Open water</td>
<td>Open water</td>
</tr>
<tr>
<td>Perennial ice/snow</td>
<td>Perennial ice/snow</td>
</tr>
<tr>
<td>Developed open space</td>
<td>Not used</td>
</tr>
<tr>
<td>Developed low intensity</td>
<td>Not used</td>
</tr>
<tr>
<td>Developed Medium Intensity</td>
<td>Developed medium-high Intensity</td>
</tr>
<tr>
<td>Developed High intensity</td>
<td>Developed medium-high Intensity</td>
</tr>
<tr>
<td>Barren</td>
<td>Barren</td>
</tr>
<tr>
<td>Deciduous forest</td>
<td>Deciduous-mixed forest</td>
</tr>
<tr>
<td>Evergreen forest</td>
<td>Evergreen forest</td>
</tr>
<tr>
<td>Mixed forest</td>
<td>Deciduous-mixed forest</td>
</tr>
<tr>
<td>Shrub/Scrub</td>
<td>Herbaceous-shrub</td>
</tr>
<tr>
<td>Grassland/Herbaceous</td>
<td>Herbaceous-shrub</td>
</tr>
<tr>
<td>Pasture/Hay</td>
<td>Not used</td>
</tr>
<tr>
<td>Cultivated Crops</td>
<td>Not used</td>
</tr>
<tr>
<td>Woody wetlands</td>
<td>Not used</td>
</tr>
<tr>
<td>Emergent Herbaceous</td>
<td>Not used</td>
</tr>
</tbody>
</table>
Measuring long-term trends in Harmonics

Use of Robust non-parametric regression procedure for trend analysis:

1. Theil-Sen’s Procedure for magnitude (slope)

2. Contextual Mann Kendall (CMK) for statistical significance: an extension of Mann Kendall (MK) test

Theil Sen’s slope

- Median Slope

MK and CMK test

- C = 5
- D = 1
- S = 5 -1 = 4 > 0
- Monotonically increasing
CMK Test

CMK test:

1. Addition of contextual information in MK to make statement about significance in small time series

2. Uses the principle of spatial autocorrelation to characterize geographic phenomena

3. The pixel needs to exhibit a trend which is not radically different from its neighbors