Multi-source imaging of time-serial tree and water cover at continental and global scales

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### Objectives & Timeline

**Tree cover**
- 2010 & 2015 (epochal)
- 2010-2015 over North & South America

**Water cover**
- 2010 & 2015 (epochal)
- 2010-2015 over North & South America

<table>
<thead>
<tr>
<th>Product</th>
<th>Epochal</th>
<th>Annual</th>
<th>Uncertainty layer?</th>
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<tbody>
<tr>
<td>Tree cover (%)</td>
<td></td>
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<tr>
<td>Continental</td>
<td></td>
<td>X</td>
<td>Y</td>
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<tr>
<td>Global</td>
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<td>X</td>
<td>Y</td>
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<tr>
<td>Water Cover (binary)</td>
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<tr>
<td>Continental</td>
<td></td>
<td>X</td>
<td>Y</td>
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<tr>
<td>Global</td>
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<td>X</td>
<td>Y</td>
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<table>
<thead>
<tr>
<th>Year 1</th>
<th>Year 2</th>
<th>Year 3</th>
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<tbody>
<tr>
<td>Q1</td>
<td>Q2</td>
<td>Q3</td>
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<tr>
<td>Acquire data</td>
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<tr>
<td>Landsat</td>
<td>X</td>
<td>X</td>
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<tr>
<td>PALSAR</td>
<td>X</td>
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<td>Sentinel-2</td>
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<td>X</td>
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<td>Small-footprint Lidar</td>
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<td>X</td>
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</tbody>
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| Develop algorithms    |         |        |                     |
| Epochal tree cover    | *       | *      | *                   |
| Epochal water cover   | *       | *      | *                   |
| Annual tree cover     | X       | X      | X                   |
| Annual water cover    | X       | X      | X                   |

| Preliminary validation|         |        |                     |
| Epochal tree cover    | X       | X      |                     |
| Epochal water cover   |         |        |                     |
| Annual tree cover     | X       | X      |                     |
| Annual water cover    |         |        |                     |

| Publication & distribution |         |        |                     |
| Epochal tree cover       | X       | XX     |                     |
| Epochal water cover      |         |        |                     |
| Annual tree cover        |         | X      | X                   |
| Annual water cover       |         |        |                     |
Algorithms

• Fusion of estimates: regression tree
Data

- **Optical**
  - Landsat-5, -7, -8
    - GLS -> entire archive
  - Challenges:
    - Access
    - Misregistration
  - Sentinel-2
    - Original (non-harmonized)
    - HLS
    - MODIS

- **SAR**
  - Sentinel-1
    - Regional test—weak tree-cover signal
  - PALSAR-1
    - 2007-2011
  - UAVSAR

- **Response (tree cover)**
  - LiDAR
    - G-LiHT
  - Hi-Res
    - Quickbird
  - Thematic
    - e.g., MODIS VCF

Covariates
Results & products

• Landsat-based
  • Tree cover
    ✓ Global 2010 & 2015
    ✓ Continental 2010-2015
  • Water cover
    ✓ Global 2010 & 2015
    Continental 2010-2015
Tree Cover in Mongolia (2010)
Tree Cover in Mongolia (2015)
Tree Cover and Loss in Mongolia

Tree Cover (2010)  
Tree Cover (2012)  
Tree Cover Loss (2010-2012)  

Tsagaan-Uur Mongolia
Tree Cover and Loss in Mongolia

Onon-Balj Basin National Park, Mongolia
48.989228N, 111.680703E
King Fire

Dates: Sep 13, 2014 – Oct 9, 2014
Cause: Arson
Location: Pollock Pines, CA, USA
Injuries: 12
Burned area: 97,717 acres
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- Annual composite using images before and after the change
- Fmask water mask commission errors
Calibration & validation

• Boreal taiga/tundra ecotone
  • Reference estimates:
    • High-resolution imagery
      • QuickBird
      • n = 425 across North America & Eurasia
    • LiDAR
      • PALS
      • n = 553,640 across North America

• Removed saturation at >80% canopy cover
• Reduced uncertainty (RMSE) by ~ 50%
• More sensitive to cover of trees defined by > 2 m height

• Additional biomes in process
  • G-LiHT

Optical fusion: Landsat and Sentinel-2

Jun 1, 2016 (L)  Jun 11, 2016 (L)  Jun 15, 2016 (S)

Jun 10, 2016 (S)  Jun 21, 2016 (S)  Jun 24, 2016 (S)
1,974 HLS Landsat and Sentinel-2 images were applied to estimate tree cover over the U.S. east coast.
Toward optical-SAR fusion

TCC estimated from Sentinel-1 (C-band) VV & VH backscatter

• Estimate tree canopy cover
• Fill gaps (e.g., clouds) in optical estimates
• Discriminate natural forests from plantations

• C-band relationships
  • Insufficient tree-cover signal
    • Imprecise estimates
    • Little deviation from regional mean
  • Improves optical estimates, but not sufficient alone
    • Must combine with L-band and/or optical
Toward optical-SAR fusion

- Estimate tree canopy cover
- Fill gaps (e.g., clouds) in optical estimates
- Discriminate natural forests from plantations

- Sentinel C-band backscatter & ratios
- UAVSAR L-band entropy

- Solely C-band models unlikely to discriminate forest types—need to incorporate with optical
- Possible L-band only model
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Pinto et al. in prep.
Algorithms

• Fusion of estimates: regression tree
• Fusion of covariates: spectral library
Fusion of covariates: spectral library

• Objective:
  • Model of cover $\sim$ reflectance
    • Robust across scales
    • Robust across seasons
    • Robust across environments

• Requirement:
  • Harmonize SR across sensors
    • MODIS, Landsat, and Sentinel-2
    • Standardize solar zenith angle

• MODIS NBAR has highest correlation to Landsat-7 ETM+ reflectance

• Correction of MOD09GA SR to coincident solar-zenith angle results in higher correlation to Sentinel-2 estimates of SR

Che, X. & J.O. Sexton, in prep.
Fusion of covariates: spectral library

- **Objective:**
  - Model of cover ~ reflectance
    - Robust across scales
    - Robust across seasons
    - Robust across environments

- **Requirement:**
  - Harmonize SR across sensors
    - MODIS, Landsat, and Sentinel-2
  - Standardize solar zenith angle

- Inverting linear mixture model using high-resolution land cover and low-resolution reflectance provides estimates of pure-type reflectance

Difference (RMSD) between Sentinel-2 estimates of surface reflectance and raw and corrected MODIS SR (MOD09GA) is highest when illumination angles are corrected. Correlation of Sentinel-2 SR to corrected MODIS-based SR is greater than it is to MODIS NBAR.

Conclusions

• Fusion of multi-sensor optical estimates of tree-canopy and surface-water cover straightforward
  • Landsat-based datasets in production

• C-band alone not useful for estimating tree cover
  • Must be combined with optical or other SAR wavelengths

• L-band polarimetry appears useful for estimating tree cover and discriminating natural from plantation forests

• First results of cross-scale models appear promising (stay tuned...)
Questions?

References


Sexton, JO; X-P Song; M Feng; P Noojipady; A Anand; C Huang; D-H Kim; KM Collins; S Channan; C DiMiceli; JR Townshend; *International Journal of Digital Earth* 2013, 6, 427-448.