Applicability of SAR Sentinel-1 data to distinguish drivers of deforestation in the Amazon

XXV IUFRO World Congress
Saturday, October 5, 2019

Andrea Puzzi Nicolau
Africa Flores-Anderson
Dr. Robert Griffin
Kelsey Herndon
SERVIR is a partnership of NASA, USAID, and leading technical organizations. SERVIR develops innovative solutions to improve livelihoods and foster self-reliance in developing countries.
SERVIR-Amazonia focus countries
Additional countries reached
Biome limits of the Amazon
Motivation

- Is it possible to use Sentinel-1 data to distinguish drivers of deforestation?
  - Why is it important to distinguish drivers of deforestation?

- We know where and when deforestation is happening, but in order to have an impact in how to prevent deforestation, we need to know what is causing it.

- Optical systems:
  - Cloud cover
  - Hard to distinguish different land uses with similar land cover (Joshi et al., 2016; Hagensieker et al., 2017)

- The identification of drivers of deforestation is a need for early warning deforestation monitoring systems (International Forum of Early Warning Systems, Lima, July 2018)

- Important towards more sustainable land management and to aid global initiatives such as REDD+ (UNFCCC, 2013)

- The use of SAR data is a priority by GFOI (GFOI, 2013)
Motivation

- Is it possible to use Sentinel-1 data to distinguish drivers of deforestation?
- Why is it important to distinguish drivers of deforestation?

- We know where and when deforestation is happening, but in order to have an impact in how to prevent deforestation, we need to know what is causing it.

- Optical systems:
  - Cloud cover
  - Hard to distinguish different land uses with similar land cover (Joshi et al., 2016; Hagensieker et al., 2017)

- The identification of drivers of deforestation is a need for early warning deforestation monitoring systems (International Forum of Early Warning Systems, Lima, July 2018)

- Important towards more sustainable land management and to aid global initiatives such as REDD+ (UNFCCC, 2013)

- The use of SAR data is a priority by GFOI (GFOI, 2013)
Research Questions and Study Area

Can we use Sentinel-1 data to distinguish land uses/covers?

Can we observe signature trends on Sentinel-1 time series data for different LULC?

Which metrics are the best to distinguish LULC?

Can LULC maps be produced with high accuracy?

Madre de Dios

Total area: ~2,500 km²
Madre de Dios
Capital of Biodiversity (Peruvian Law N° 26311; Myers et al., 2000)
Deforestation rates have been increasing since 2001 (MINAM, 2017)
Presents a mosaic of land uses and covers

Total area: ~2,500 km²
Methodology

- Quarterly Composites
- VV, VH, VV/VH, Radar Forest Degradation Index (RFDI; Sassan, 2019) modified
- Metrics: Mean, Min, Max, Max-Min ratio, Standard Deviation, Coefficient of Variation

$$RFDI = \frac{\gamma^o_{HH} - \gamma^o_{HV}}{\gamma^o_{HH} + \gamma^o_{HV}}$$

$$RFDI \ mod. = \frac{\gamma^o_{VV} - \gamma^o_{HV}}{\gamma^o_{VV} + \gamma^o_{HV}}$$
Sample Collection (CEO)

- Land Use Land Cover Map (2016) from Geobosques (MINAM)
- Sample Design: Stratified Random Sampling (Olofsson et al., 2014)
  - 900 points for all classes
  - 88 random plots (5 ha) with 25 gridded points each
  - Minimum of 25 reference points each class
  - Addition of 4 and 6 extra for Agriculture and Mining classes, respectively (10 plots; 250 points)

<table>
<thead>
<tr>
<th></th>
<th>Forest</th>
<th>Sec Veg</th>
<th>Agriculture</th>
<th>Pasture</th>
<th>Mining</th>
<th>Urban</th>
<th>Water</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plots</td>
<td>62</td>
<td>8</td>
<td>7</td>
<td>8</td>
<td>7</td>
<td>1</td>
<td>5</td>
<td>98</td>
</tr>
<tr>
<td>Pts</td>
<td>1550</td>
<td>200</td>
<td>175</td>
<td>200</td>
<td>175</td>
<td>25</td>
<td>125</td>
<td>2450</td>
</tr>
<tr>
<td>Total Pts</td>
<td>1718</td>
<td>163</td>
<td>75</td>
<td>53</td>
<td>73</td>
<td>25</td>
<td>66</td>
<td>2173</td>
</tr>
</tbody>
</table>

http://collect.earth
Time Series Analysis

Sentinel-1 C-VV backscatter

- Y-axis: $\gamma^o$ (dB)
- X-axis: Time
- Legend: Mining, Pasture, Urban, Secondary Vegetation, Forest, Agriculture, Water
Time Series Analysis

Sentinel-1 C-VH backscatter

Mining
Pasture
Urban
Secondary Vegetation
Forest
Agriculture
Water
Time Series Analysis

Sentinel-1 C-VV/VH backscatter

- Mining
- Pasture
- Urban
- Secondary Vegetation
- Forest
- Agriculture
- Water

Time:
- Jan-Mar 2017
- Apr-Jun 2017
- Jul-Sep 2017
- Oct-Dec 2017
- Jan-Mar 2018
- Apr-Jun 2018
- Jul-Sep 2018
- Oct-Dec 2018
- Jan-Mar 2019
- Apr-Jun 2019
- Jul-Sep 2019

\( \gamma_o \) (dB)
Time Series Analysis

Sentinel-1 RFDIm


- Mining
- Pasture
- Secondary Vegetation
- Forest
- Agriculture
- Water
- Urban
Decision Tree

- Water
  - VH min < 0.1
  - VV min < 0.1
  - VH CV > 0.15
  - VV/VH CV > 0.15
  - VV CV > 0.1
  - VV/VH max > 2.5
  - VV/VH max/min > 1.5
  - VV mean > 0.5
  - VV sd > 0.05
  - VV/VH sd > 0.25

- Urban
  - VH CV > 0.1
  - VV/VH CV > 0.1
  - VH max/min > 1.5
  - VV/VH mean < 0.2
  - VV mean < 0.4
  - VV/VH sd > 0.2

- Mining
  - VV mean < 0.4
  - VV/VH mean < 2.0
  - VH/VH CV > 0.1
  - VH/VH max < 2.2
  - mRFDI min < 0.25
  - mRFDI mean < 0.34

- Pasture
  - VH CV < 0.075
  - VV CV < 0.075

- Forest
  - mRFDI mean > 0.35
  - Slope VV, VH (Apr-Oct)

- Agriculture

- Secondary Vegetation

315 new samples to attest thresholds (High rate of True Positives vs. Low rate of False Positives)
Challenges

- Dual pol → Issues with mapping Urban Areas (HH)
- Airport runway → Misclassification
- Limited to 7 classes
- “Forest Line” on classification

Source: Maxar Technologies
Conclusions and Future Work

- Similar backscatter values when analyzing Forest, Secondary Vegetation, Agriculture, and Pasture
- Some seasonality trends are observed – info for classification – slope
- Limitations: only two polarizations; noise; airport runway, urban areas
- Finish application of decision tree and classification
- Accuracy assessment (Confusion matrix following Oloffson et al., 2014)
- Adapt the algorithm to be applied only on areas that were deforested
- SERVIR-Amazonia: expected that this project can contribute with the Amazon basin conservation


SAR Handbook materials have had a global reach

Top countries by Handbook material accessed:

1. U.S.A. 24,755
2. Germany 18,552
3. Spain 9,443
4. China 9,043
5. India 7,487

Top countries currently covered by SERVIR

<table>
<thead>
<tr>
<th>Country</th>
<th>SERVIR Region</th>
<th>Access</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.Kenya</td>
<td>E&amp;S Africa</td>
<td>6,530</td>
</tr>
<tr>
<td>2.Brazil</td>
<td>Amazonia</td>
<td>5,463</td>
</tr>
<tr>
<td>3.Colombia</td>
<td>Amazonia</td>
<td>4,571</td>
</tr>
<tr>
<td>4.Nepal</td>
<td>HKH</td>
<td>3,845</td>
</tr>
<tr>
<td>5.Vietnam</td>
<td>Mekong</td>
<td>3,214</td>
</tr>
<tr>
<td>6.Ecuador</td>
<td>Amazonia</td>
<td>3,210</td>
</tr>
<tr>
<td>7.Bangladesh</td>
<td>HKH</td>
<td>2,686</td>
</tr>
<tr>
<td>8.Peru</td>
<td>Amazonia</td>
<td>2,426</td>
</tr>
<tr>
<td>9.Pakistan</td>
<td>HKH</td>
<td>2,300</td>
</tr>
<tr>
<td>10.Myanmar</td>
<td>HKH/Mekong</td>
<td>1,526</td>
</tr>
</tbody>
</table>

Between April 10 – July 31, 2019

- The full Handbook has been accessed more than 186,000 times
- Full Handbook and additional materials have been accessed more than 227,000 times
- 162 countries have accessed the SAR Handbook and additional materials
Thank you!

Questions?
Andrea Puzzi Nicolau
Graduate Research Assistant
SERVIR-Amazonia
andrea.puzzinicolau@nasa.gov
andrea.nicolau@uah.edu