MAPPING INVASIVE PLANT SPECIES IN TROPICAL RAINFOREST USING POLARIMETRIC RADARSAT-2 AND PALSAR DATA

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Study area

- Area: 68 sq km
- one of the last remnants of intact lowland rainforest in Madagascar
- a sanctuary for a vast diversity of flora and fauna
Study area - Tropical Rainforest
Why Invasive Species?

- An indication of eco-system degradation

- Introduced through anthropogenic activities such as illegal logging and urbanization, and climate change

- Animal and plant species diversity in the reserve has become critically endangered through forest degradation and the introduction of invasive species
Invasive Species

- Guava (P. cattleianum)
- Piste Principale
- Wild ginger (A. angustifolium)

Invasive plant species differ in canopy structure than native forest.
Invasive Species

Rubus – a type of invasive raspberry

Longoza

AFRAMOMUM ALBOVIOLACEUM (RIDL.) K.SCHUM

Invasive plant species differ in canopy structure than native forest
Our goal

- to explore the capabilities of Radarsat-2 quad-pol data (C band) and both dual and quad-pol PALSAR in mapping invasive plant species and forest degradation in Betampona Natural Reserve

- assess native forest health and diversity to monitor the effectiveness of in-situ conservation efforts
Hypothesis

- Leaves reflect shorter (e.g., C) but not longer wavelengths (e.g., L)
- Reflections from bare forest floor may introduce some noise in longer wavelengths
- C band (5.6 cm) have a limited ability to penetrate to the forest understory and floor, and therefore, may be more useful in mapping plant species in forest canopies or sub-canopies?

Credit: Rosen, JPL
Hypothesis

Steeper incidence angle is better to map invasives?

A - Steep beam position ( "Small" incidence angle )
B - Shallow beam position ( "Large" incidence angle )
Datasets

- Shallow incidence angles
  - useful for delineation of land use activities, e.g. illegal logging

- Steep (small) incidence angles:
  - may be more useful for vegetation type mapping

<table>
<thead>
<tr>
<th>Sensor</th>
<th>Product</th>
<th>Orbit/ Path</th>
<th>Frame</th>
<th>Acquisition date</th>
<th>Off-nadir angle</th>
<th>Spatial Resolution</th>
<th>Orbit direction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Radarsat-2</td>
<td>FQ10/L1.1</td>
<td>36-71D</td>
<td></td>
<td>05/18/2010</td>
<td>29.32°</td>
<td>8 m</td>
<td>Descending</td>
</tr>
<tr>
<td>PALSAR</td>
<td>PLR/L1.0</td>
<td>474</td>
<td>620</td>
<td>05/18/2008</td>
<td>21.5°</td>
<td>12.5 m</td>
<td>Ascending</td>
</tr>
<tr>
<td>PALSAR</td>
<td>FBD/L1.1</td>
<td>550</td>
<td>6820</td>
<td>07/23/2007</td>
<td>34.3°</td>
<td>12.5 m</td>
<td>Ascending</td>
</tr>
</tbody>
</table>
Methodology: Polarimetric Features

- **Polarimetric Features**
  - Co-pol correlation coefficient
  - Co-Polarization ratio (HH/VV)
  - Polarimetric phase difference (HH-VV) in radians
  - Linear depolarization ratio (in dB)

\[
LDR(dB) = 10 \cdot \log_{10} \left( \frac{\langle S_{HV}S_{HV}^* \rangle}{\langle S_{VV}S_{VV}^* \rangle} \right)
\]

Rodriguez & Martin, 1992
Drinkwater, et al, 1992
Shriever, et al, 2003
Kennedy, et al., 2001
Methodology: target decomposition theorems

- **Pauli Basis**
  \[ k_P = \frac{1}{\sqrt{2}} \begin{vmatrix} S_{hh} + S_{vv} \\ S_{hh} - S_{vv} \end{vmatrix} - 2S_{hv} \]
  - Direct scattering
  - Double bounce
  - Multiple scattering

- **coherency matrix**
  \[ T_{11} = \text{single bounce}, \quad T_{22} = \text{double bounce}, \quad T_{33} = \text{volume scattering} \]

- **Freeman-Durden model based decomposition**
  Freeman and Durden, 1998

- **Cloud-Pottier eigenvalue-eigenvector decomposition**
  Cloude and Pottier, 1997
Methodology: Wishart Classification

WISHART PDF

\[ P([\mathbf{T}] / [\mathbf{T}_m]) = \frac{\mathbf{L}^{T_p} [\mathbf{T}]^{L_p - 1} e^{-\mathbf{L}^{T_p} [\mathbf{T}]} \Gamma(L) \cdots \Gamma(L - p + 1) [\mathbf{T}_m]^{T_p - 1}}{\pi^{L_p} \Gamma(L) \cdots \Gamma(L - p + 1) [\mathbf{T}_m]^{L_p - 1}} \]

UNSUPERVISED POLSAR CLASSIFICATION

H / A / \alpha DECOMPOSITION THEOREM

©ESA
Results: Polarimetric Features - pol-ratio, linear depol ratio

- Radarsat-2
- PALSAR FBD
- Ground truthing

PALSAR FBD campsite gives better results.
PALSAR PLR pol ratio and LDR are noisy!!!
Results: Polarimetric Features – phase differences/coherences

PolInSAR $\rightarrow$ HH-VV Phase Difference (PPD) $\rightarrow$ Coherences
Results: Pauli Decomposition

Radarsat-2  

Ground truthing  

PALSAR PLR

**PALSAR FBD campsite gives better results!!!**
Results: EAA Decomposition/Wishart Classifications

Radarsat-2
Wishart Classification

Ground truthing

PALSAR PLR EAA Classes

EAA classification → Clustering

Embarrassing results???
Results: PALSAR PLR w/ FBD

Greater exposed bare soil (21.9 incidence angle)
Conclusion

- PALSAR polarimetric data are superior for inventorying invasive forest species in rainy forest
- Phase information is crucial, e.g., HH and VV, HH and HV phase differences, and polarimetric coherences should be exploited
- RADARSAT-2 data did not perform well, perhaps a steeper incidence angle may be useful
- PALSAR FBD HH, HV, HH/HV composite is equally impressive as PLR results

Ikonos-2 4m PCA
Hillshade vs. Local Incidence angels

ASTER and Radarsat-2 represent surface elevation while PALSAR and DTEM showing the terrain.
Questions, comments Please!!!

Future work