SARvi: A Vegetation Index Based on AirSAR Data for South Pacific Volcanic Islands Vegetation Mapping

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Abstract— **With about 120 islands located on 5 million square kilometers in the South East Pacific, French Polynesian islands are sometime difficult to reach and study precisely the vegetation. Remote Sensing is a very promising tool for vegetation mapping of these islands. Searching for a standard vegetation index, we found that the vegetation indexes based on low-resolution sensors (NDVI, RVI, etc…) are not precise enough to map the vegetation because of the small surface of most islands (a few square kilometers). We therefore applied those vegetation indexes formula on medium resolution images (MASTER) and higher resolution images (Quickbird) but the capability of these vegetation indexes to discern various classes of vegetation is limited. Two examples on Moorea (Society Archipelago) and Tubuai (Australes Archipelago) are discussed. We thus propose SARvi: a new empirical and simple vegetation index based on AirSAR Data, using the vegetation polarimetric properties. A study of this index shows its capability to distinguish more details in the vegetation structural properties than the previously studied vegetation indexes.**

Keywords: vegetation index, vegetation mapping, JPL-AirSAR, Classification, NDVI, SARvi.

I. Introduction

In our previous vegetation mapping studies [7] of South Pacific Volcanic Islands using SAR data and Optical data, the ground truth missions appeared to be often difficult due to the remoteness, and isolation of the islands and the aerial photographs or high precision optical images often missing. We therefore needed a practical tool to estimate the vegetation cover.

We tried to apply the standard vegetation index NDVI [4] on MASTER and Quickbird images and we compared the results to the ground truth and SAR data classification of Opunohu Valley and Tubuai Island. The NDVI failed to estimate the simple four classes set previously proposed.

The SAR data is available on most of French Polynesian islands, these data are very helpful in cloudy condition often encountered in the South Pacific islands [2][3].

Thus we propose a new empirical vegetation index for polarimetric SAR data: SARvi. This index exploits the ability of AirSAR data to discriminate different kind of vegetated areas thanks to the polarimetric properties of the vegetation (outlined by a simple SAR Composite (Fig. 1)).

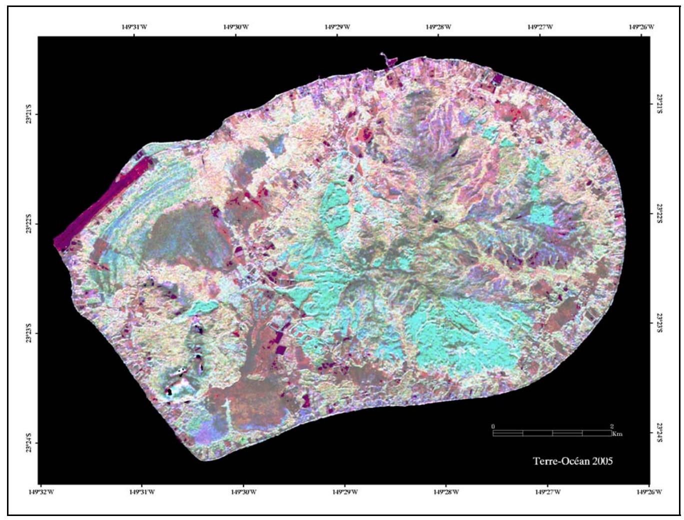

Figure 1. Tubuai SAR Composite (R: C-VV G: L-HV B: L-HH)

II. Materials and Methods

A. Image Data and Study Area

The JPL-NASA PACRIM2 mission [1] (August 2000), provided a complete set of data from both MODIS/ASTER and AirSAR sensors on the main French Polynesian islands and atolls.

- MODIS/ASTER (MASTER) [5] is a multi-spectral imaging scanner with 50 channels distributed in the visible-shortwave infrared, mid infrared and thermal infrared. After geometric correction the pixel size of the Opunohu Valley image (Moorea) is 20 meters.
- JPL-AirSAR: The data set on Moorea island and Tubuai island are made out of two scenes, in XTI1 mode: C-band single-baseline Interferometry in VV polarization (TOPSAR), P-band and L-band Polarimetry (POLSAR). The 40MHz Bandwidth was used, producing a 5 meters pixel size.

- Quickbird Image of Tubuai (Fig. 2) is 2.4 meters, Blue, Green, Red, and Infra-Red channels.

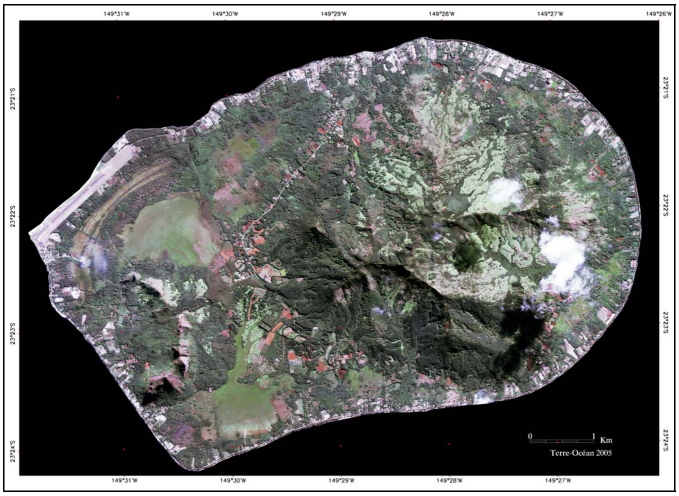

Figure 2. Tubuai Island Quickbird Image

Two study areas have been chosen in French Polynesia (South Pacific):

Moorea island is located in the Society Archipelago (149°5'W, 17°32'S), and its main calderas (Opunohu Valley) has previously been studied [7]. SAR data and MASTER data are available for this area and a SAR-based vegetation classification map is available.

Tubuai island is located in the Australes Archipelago (149°29'W, 23°22'S). It's another typical example of volcanic island with its highly representative diversity of vegetation [6] and land cover (found in other Polynesian high islands), including different types of forests, grass fields, fern lands, agricultural areas, swamps etc… Tubuai SAR (Fig. 1) and Quickbird data (Fig. 2) are available.

B. Image Processing

A geometric correction of the Moorea MASTER Data has been processed (AirSAR Data are already corrected by JPL), to match the AirSAR geometry. A geo-referencement step gives a common ground reference for all images. Quickbird data are already geo-referenced in the WGS84 system.

A mosaic of the AirSAR data has been processed to provide a complete image of Moorea and Tubuai islands. Opunohu Valley has no slope inversion area, but a mosaic is performed on Tubuai data in order to compensate this slope effect. Only the ascendant parts of the image are kept (the given DEM is used), reducing the slope inversion effect.

AirSAR Data masks are based on the radar shadows while the MASTER and Quickbird Data masks include both shadows and cloudy areas. Water areas are also excluded by masking.

The final Opunohu Valley study area is 1024*1024 pixels and the Tubuai study area is 2060*1512 pixels.

C. SAR Data Classifications

A simple class set (see Table I) has previously [7] been defined on a vertical hierarchy of the vegetation. SAR backscattering signal is sensible to the structural properties of the vegetation (volume, crown complexity, …).

TABLE I. VEGETATION CLASS SET

High Forest (HF)
Medium Forest (MF)
Low Vegetation (LV)
No Vegetation (NV)
UnClassified

(Colors and class names suitable for the following classification maps)

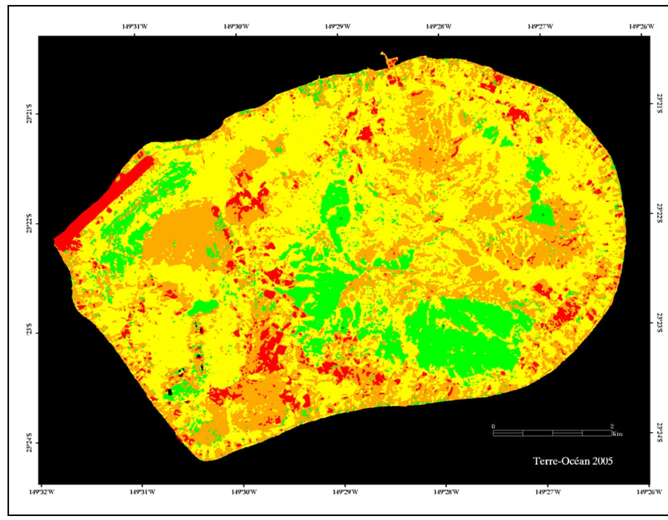

Figure 3. Tubuai SAR vegetation classification

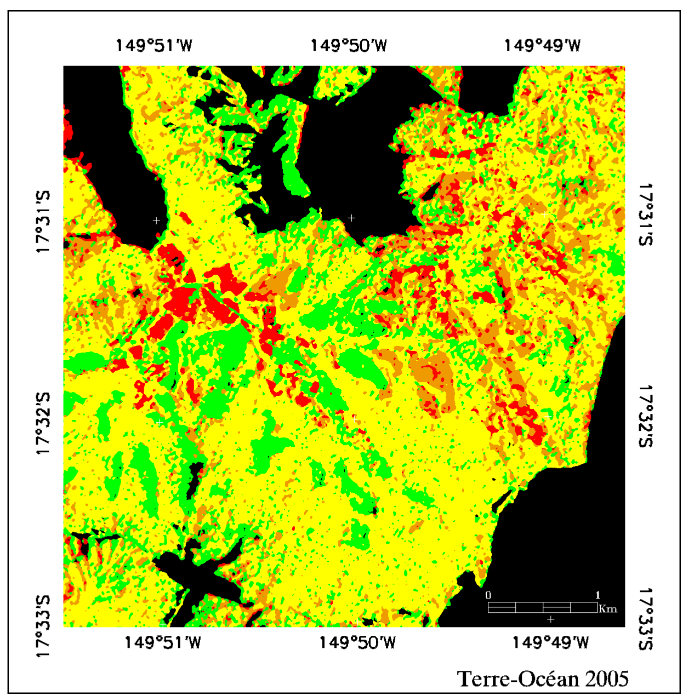

Figure 4. Opunohu SAR vegetation classification

This class set is based on the relative height of the vegetation. "High Forest" class includes essentially *Pinus Caribeae* and *Paraserianthes Falcataria* forests, which culminate above the "Medium Forest", the dominant forest encountered in Polynesian high islands [6]. "Low Vegetation" class includes vegetation up to approximately one-meter height: fern lands, swamps vegetation, and crops. "No Vegetation" class includes the bare fields and low grass fields.

Aerial photographs and terrain missions gives the ground truth. After a classical Speckle reduction step, a Maximum-Likehood classification algorithm is processed. A majority analysis step gives more homogenous maps (Fig. 3 and 4).

III. NDVI VEGETATION INDEX

We roughly applied the standard NDVI (1) vegetation index to the MASTER and Quickbird data and compared the resulting maps (Fig. 5 and 6) to the ground truth.

$$NDVI = 100 \times \left(\frac{IR - R}{IR + R} + 1 \right) \tag{1}$$

NDVI~100 stands for no vegetation
NDVI~200 stands for high probability of vegetation.

The classical NDVI can discriminate the presence of vegetation, but in our case, the NDVI failed in estimating our simple class set. The three vegetated classes (HF, MF, LV) have very similar NDVI values; and results sometime don't match our vertical hierarchy, for example, the High Forest often has a lower NDVI than the Medium Forest (see table II).

TABLE II. NDVI MAPS STATISTICS

	Opunohu		Tubuai	
	Mean	Stdev	Mean	Stdev
High Forest	150,2	25,3	172,1	4,9
Medium Forest	154,9	23,5	173,9	6,6
Low Vegetation	143,8	7,3	165,3	6
No Vegetation	132,7	33,0	129,9	15,3

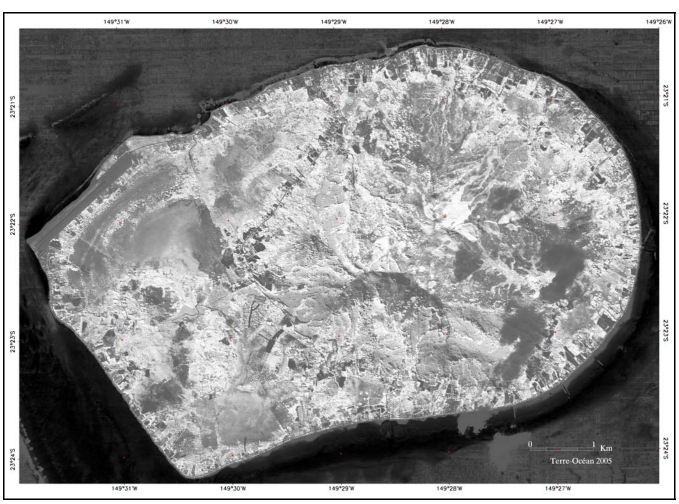

Figure 5. Quickbird NDVI Vegetation Index Map

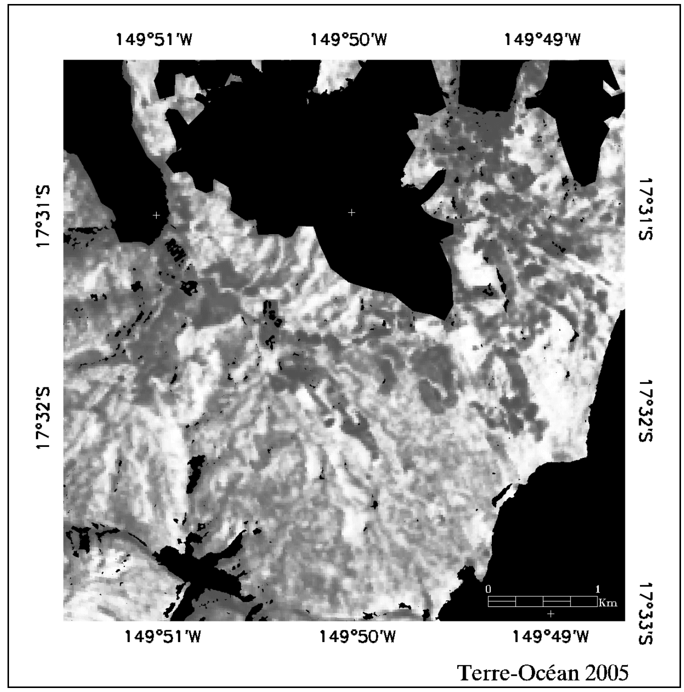

Figure 6. MASTER NDVI Vegetation Index Map

IV. SARVI VEGETATION INDEX

We propose a new empirical Vegetation Index (2) based on AirSAR data, which exploits the polarimetric basic properties of the vegetation: in the non-vegetated areas, the C-VV band has high values and the L-HV band has lower values. On the contrary, on highly vegetated area, the C-VV band has low values and L-HV band has higher values.

$$SARvi = 100 \times \left(\frac{LHV - CVV}{LHV + CVV} + 1 \right) \tag{2}$$

SARvi minimum value occurs for the non-vegetated areas (SARvi ~ 0) and its maximum value represents the highly vegetated areas (SARvi ~ 200).

A. Preprocessing

A normalization of the L-HV band is necessary since this band is powerless compared to the C-VV band. To get a homogenous result, both bands need to have the same power.

Since SARvi applies to SAR data, a Speckle filtering is necessary, Median filter or Lee filter give good results.

B. Results and discussions

The statistics of the SARvi index according to the various ground truth classes (see Table III) show its ability to better discriminate our class set.

In the SARvi maps (Fig. 7 and 8), gray level is indirectly correlated with the vertical hierarchy of the vegetation: black areas stands for no or very low vegetation, while white areas are representative of high level of vegetation (high forests).

TABLE III. SARVI MAPS STATISTICS

	Opunohu		Tubuai	
	Mean	Stdev	Mean	Stdev
High Forest	139,8	24,4	158,8	10,2
Medium Forest	100,2	15,0	101	14
Low Vegetation	58,8	12,8	69,4	24,4
No Vegetation	40,8	18,0	9,4	6,2

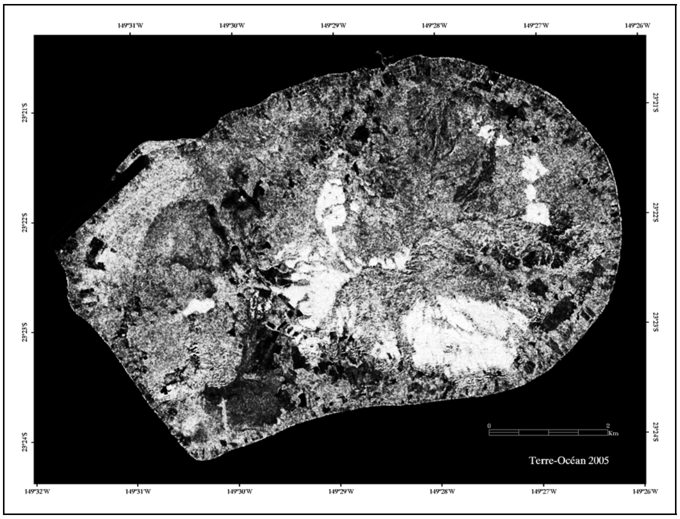

Figure 7. Tubuai SARvi Vegetation Index Map

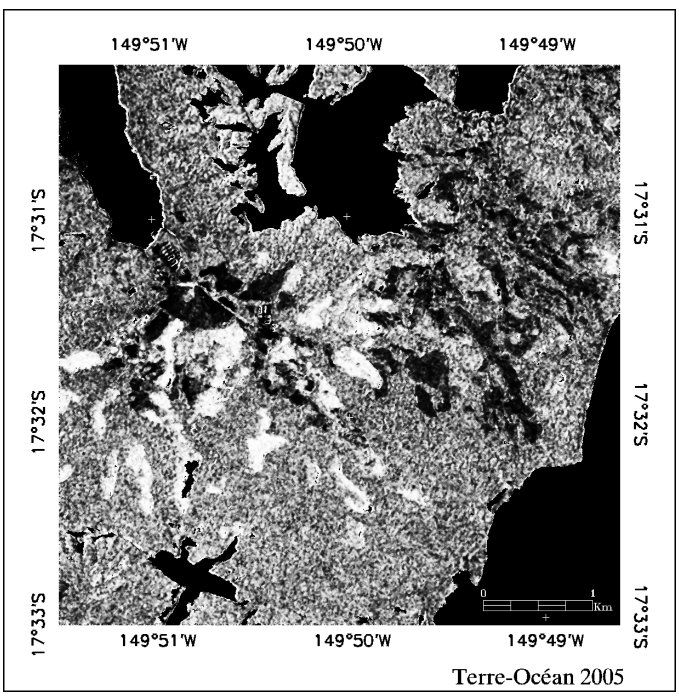

Figure 8. Opunohu SARvi Vegetation Index Map

Thus the SARvi Index can be used as a simple tool for estimating the vegetation maps with no needs for ground truth mission (or high precision images). A segmentation of the SARvi image can be a good approximation of a real SAR classification. The boundaries between the different classes can be obtained by narrowing the class statistics with further studies.

V. CONCLUSIONS

NDVI vegetation index failed in estimating our simple class set of vegetation, moreover the optical images used to process this index are sensible to the weather conditions (sun, clouds) particularly in French Polynesian islands. A new empirical vegetation index: SARvi usable on AirSAR Data is proposed to help the vegetation studies of remote islands in French Polynesia. SARvi proved to have a better separability of our vegetation classes. The SARvi index is more correlated to the vertical hierarchy of the vegetation and can be used for a first blind vegetation study, without real ground truth mission.

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