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Forest Inventory Applications using Optical, IR, and SAR Images

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Abstract

*To evaluate the potentialities of radar for remote sensing of forest areas, investigation on radar images acquired with the JPL L-band synthetic aperture radar during flight campaigns**over France are carried out. There is a need for accurate and up to date forest inventories due to concerns related with sustainable development programs. Forest inventories in the past have been incomplete and are not useful at regional levels. The national forest inventory is scheduled to be updated soon -optical remote sensing techniques and traditional field surveying are envisaged.*

Forest land cover is dynamical due to urban area growth, illegal logging and forest clearing for agricultural purposes in many regions.

This study aims to evaluate the capability of radar to determine the required parameters, which are mainly related to the forest structure. As a first step the total forested area is determined from optical aerial photography images. It also, aims to evaluate combined optical/radar approaches to improve forest inventory at regional scales. As a first step the total forested area is determined from optical aerial photography images. It is clear that the preliminary results from the optical data are being validated on the field. As radar images become available, polarization signatures for forest parameters will be obtained. The radar images acquired the JPL L-band synthetic aperture radar SAR during flight campaigns over France are carried out.

Keywords: *SAR, Forest Inventory, Land Cover, Texture Analysis*

1. Introduction

Sustainable Forest Management (SFM) aims at managing forest land to obtain products and services without undesirable effects on the social and physical environment. There are many intervening aspects but SFM relies first on establishing the extent, location and status of different forest types: permanent forest estates managed for timber or areas that are susceptible to be so redefined and protected areas where logging and extracting activities are to be banned [1]. Radar remote sensing poses many challenges for forest applications in general. Although preliminary results using radar images simulated data have not been very promising for forest inventory, there are important capabilities for detecting structural differences between forest types and burn areas [4]. We are interested in researching the potential benefits of synthetic radar data in our test region, motivated by the acknowledged lack of understanding of the relationship between radar imagery information content and polarization of the radar signal [5] and encouraged by promising new techniques for exploiting this kind of data [6].

2. Materials and Methods

2.1. Study Area

The site under study is a transect of the Foret Landaise, located in the South West of France Figure1. The entire forest covers one million hectares of pins pin-aster mainly generated from artificial sowing. The large area of the forest, along the lack of relief and the presence of only one tree spices make the site suitable for an experimental study of radar imagery. Furthermore, the forest which produces 1/6 of timber volume in France is constituted of private plots, leading to a difficult management. For inventory purposes, the following parameters are needed: density of stocking, age class, stand size, as well as timely information on the cut-off areas

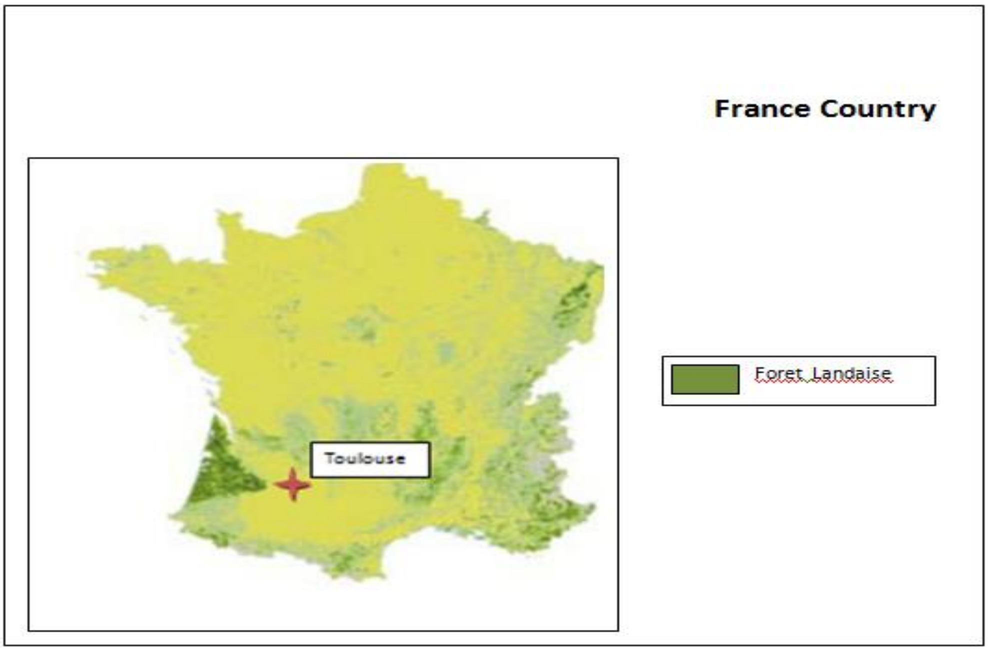

Figure1. *Study area Foret Landaise municipality*

2.2. Radar and Optical Images

The radar images to be used are JPL L- band synthetic aperture radar images in HH, VV and VH polarizations; the optical images are conventional aerial photography images.

2.3. Methodology

Selected approaches for exploiting radar data which have been applied elsewhere [9] will be assessed for the geographic region of interest. The aims are to evaluate combined optical/radar information by testing classification technique based on textural indices.

The general methodological steps are:

(1) Derive spectral signatures and classifications data from aerial digital images.

(2) Derive maps showing the extent and type of forested areas.

(3) Correction techniques (geometric & Radiometric) have been applied. Corrected images allow to locate the samples and to compare sample responses extracted from different parts of each image.

About 200 plots of 10 to 30 hectares are inventoried by combining field work and conventional aerial photography interpretation [10]. The following parameters are determined for every located plot:

- Type of surface: forest, crop, water,

- Density of stocking: 10 classes from clear cut to > 2000, stocks by hectare.

- Percent cover: 9 classes from 0 to 90%

Texture analysis is performed on the samples in order to quantify the discriminate capability of texture applied to radar images. In the case of un-calibrated data the effect of the lack absolute value is less in texture than in tonal analysis. Texture indexes are calculated for elementary areas of 8x8 pixels (200m x 200m) related to water, crop, clear cut areas and forest plots over 40 years. The other forest age classes could not be sampled; the plots are almost long and narrow.

2.4. Extraction of Information

Several homogeneous surfaces have been located with the aid of visible and IR aerial imagery [11]. The survey of the terrain allowed identification of homogeneous areas. Many samples were then extracted from the corrected images (table 1) and the related values are studied by HH/HV diagrams.

Table 1. *Corrected density values of different reference samples*

Samples	HH	HV	HH//HV
- Clear cut area from 2 years	47.42	131.50	0.361
- Clear cut area from 3 years	54.92	141.25	0.389
- Pinus maritime reforestation	43.75	120.85	0.362
- Quercus (oakwood) > 10 m	27.47	65.30	0.420
- Quercus (oakwood) > 10 m	29.00	57.45	0.505
- Quercus (oakwood) > 15 m	28.70	70.54	0.407

Several factors influence the quality and the interpretation of radar imagery [5]. They can be classified into two groups:

- Source parameters: including system and geometry, parameters

- Target parameters.

The discrimination of objects by radar imagery is based on the target parameters which are mainly the electrical properties and the surface roughness. The roughness in the case of natural surface depends not only on the type on the type of object but also on the spatial distribution of the objects on the surface. For the vegetated surfaces, density and structure of the vegetation are important factors. The following results can be deduced from an examination of Figure 1 and table 3:

- HH: good classification of water and forest while crop and clear cut areas are mixed.

- HV: good classification of different forest types, built up areas and crops with fairly poor result for water.

The results show good agreement with theoretical hypotheses, as for example:

- Direct polarized signal is better indicator of water than cross polarized signal,

- Cross polarized signal is more sensitive for surface roughness of different forest structures,

A classification test using the minimum distance decision rule is applied on the set of HH and HV sample values related to homogeneous surfaces identified as forest types, clear cut areas, crops, water, and built up areas. Table 2 resumes the well-classed percentage obtained by two tests; the first one considers the whole set of samples, while in the second built-up area class is canceled.

Table 2. *Well-classed percentage computed by classification test from HH & HV sample responses*

% well-classed	Clear-cut area	Forest	Crops	water	Built-up area
5 classes	71.68	80.95	44.19	97.56	28.69
4 classes	80.53	86.77	64.52	95.12	

Table 3 shows the performance matrix resulting from the second test, each term A_{ij} denotes the percentage of samples from class i which are assigned to class j. Classification using HH and HV data gives good classification of water (95%), forest (86%), and clear-cut area (80%), rather fair result for crop (64%).

Table 3. *Performance matrix computed form HH & HV sample responses*

	Clear-cut area	Forest	Crops	water
Clear-cut area	80.53	16.81	2.65	0.0
Forest	8.47	86.77	4.76	0.0
Crops	17.74	0.0	64.52	17.74
water	0.0	0.0	4.88	95.12

The same samples are located on digital images IR & panchromatic aerial images acquired over the area. The following results are obtained from the sample study:

- Visible: good classification of water, crops, forests, while built-up and clear-cut areas are partly mixed.

- IR: confusion between forests, built-up and clear-cut areas.

In this case, the IR images while presenting better support for photo-interpretation involving textural considerations, is not suitable for spectral study of samples. Figures 2 & 3 show the diagrams visible/HH and IR/visible.

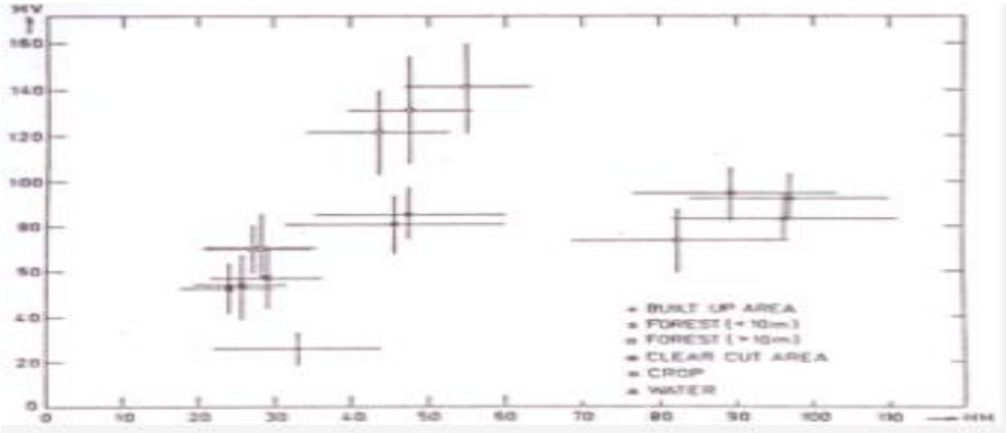

Figure 2. *HH/HV Diagram*

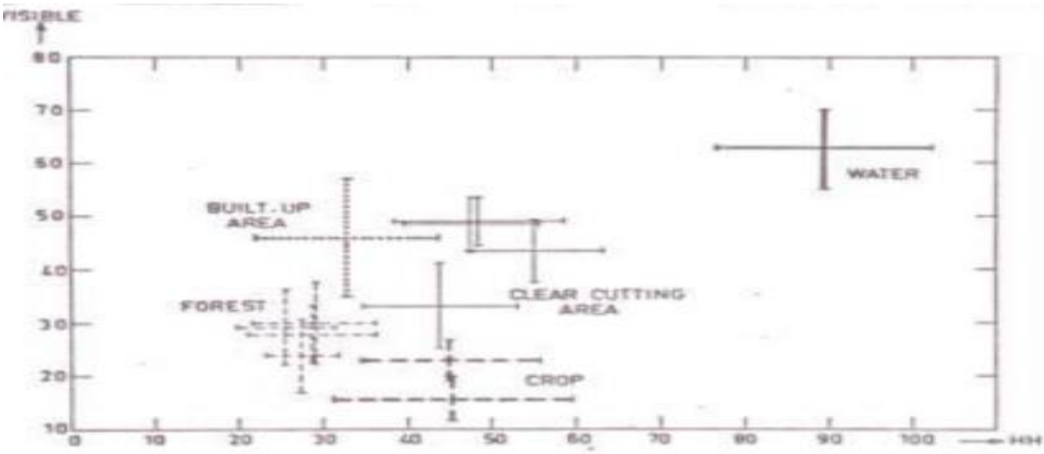

Figure 3. *HH/visible Diagram*

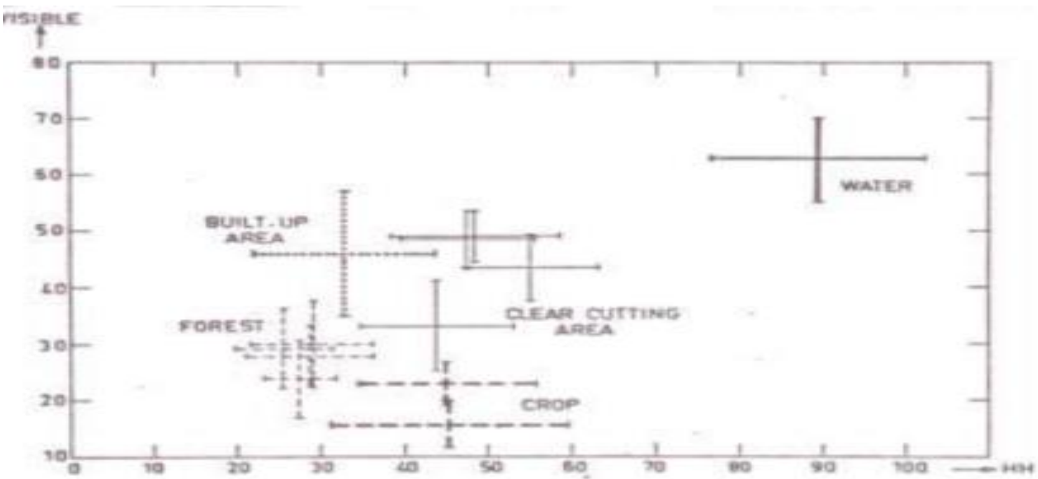

Figure 3. *Visible/ IR Diagram*

3. Conclusion

Texture indices using homogeneity, contrast, correlation entropy criteria are tested. The first index allows separating forest – water and clear cut-areas. The other indexes give only two main classes: forest – water and crop – clear cut areas. Interpretation of the results is presented.

The first results of the study show that radar can have a role in the following applications:

- Discrimination between forest / non forest areas,

- Estimation of age class for such a mono-species forest.

Further work will evaluate the complementarities with optical signatures in determining forest species.

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