CONTRIBUTION OF TEXTURAL INFORMATION FROM TERRASAR-X IMAGE FOR FOREST MAPPING

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ABSTRACT

This study evaluates the potential of High Resolution Spotlight TerraSAR-X image for forest type discrimination. Emphasis is put on textural analysis accessible with high resolution radar data. Textural attributes are extracted from GLCM matrices, wavelet, and Fourier Transform (i.e. FOTO method). Their contribution for classification is assessed by their performance through the SVM algorithm.

***Index Terms*—** Texture, SAR, TerraSAR-X, Fourier transform, Wavelet Transform, Haralick, SVM, Vegetation

1. INTRODUCTION

Part of the European Union biodiversity strategy is to monitor, in each country, biodiversity on a regular time step basis. In this frame, one of the challenges is to update natural environment maps with an accurate scale (about 1:25000). As an answer, remote sensing appears to be an efficient way for vegetation mapping at large scale : remote sensing data are reproducible, repetitive and inter calibrated, while ground survey data are partial and heterogeneous from a country to another. Presently, most of vegetation maps are made using to photo-interpretation of optical data with high spatial resolution.

Since 2007, radar sensors like Radarsat-2 or Terrasar-X offer high spatial resolution acquisition (about 1m), well suited to the patchwork parcels of European landscape, allowing their use on temperate regions. Beyond giving complementary information to optical data, radar data are insensitive to cloud cover. Such resolution allows to access to textural information which was not possible with previous existing sensors such as ERS, ASAR with almost 25m of spatial resolutions. The launch of Terrasar-X satellite operating in X band (λ=3cm) looks promising for forest observation. This work focuses on evaluating the potential of textural analysis of high spatial resolution Terrasar-X images for forest mapping.

To complete studies that have already shown the interest of textural analysis for forest mapping [1, 2, 3], three textural analysis methods are compared : two methods based on frequency textural analysis : namely wavelet transform and FOTO, the third method is based on the characterization of the of the gray level co-occurrence matrix (denoted GLCM) by retrieving Haralick descriptors from it. The derived attributes of each method are evaluated by analyzing their performance from SVM classification.

2. STUDY SITE AND DATA

The study site is a forest plantation located in Brazil, in Mato Grosso state. Fazenda Sao Nicolau is a forest plantation of native species planted by Office National des Forêts International (ONFI) since 1999 after it was all deforested because of intensive grazing activities. This site was chosen because of its large variety of texture due to different existing tree species and their development stages. This site contains 4 major land use areas (plantation area, service area, riparian area, and dense forest area). Thematical information is available since the beginning of plantation activities due to a regular survey.

The plantation area contains 14 dominant forest species distributed over 135 plots. Because of the high variability inside a mono specie plot (Fig. 1), the classes definition used for this study is based on both thematical and textural information, based on photo interpretation over the intensity image.

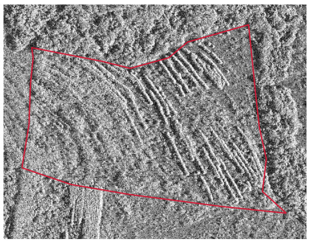
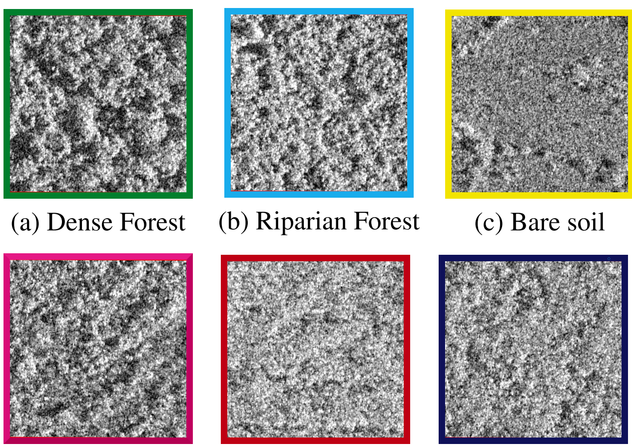


Fig. 1. Example of heterogeneity over a plantation 80% Figueira branca

We focuse on 6 land cover classes presented on Fig. 2 : dense forest, riparian forest, bare and herbaceous soil, heterogeneous plantation with large row spacing, mono-plantation of teck with large row spacing and dense plantation of heterogeneous species. Cover classes shown on Fig. 3.



(a) Dense Forest (b) Riparian Forest (c) Bare soil

(d) Plantation 1 (e) Plantation 2 (f) Plantation 3

Fig. 2. Example of texture over 6 land uses

The Terrasar-X image used for Sao Nicolau Fazenda site is an intensity single polarization HH acquisition (2013/09/28) in experimental mode High Resolution Spotlight 300 MHz. The spatial resolution is 0.6 meter in slant range and 1.1 meter in azimuth. The initial product level is Single Look Slant Range Complex. After being geocoded, the image size is 7.4 x 6.25 km with a square pixel size of 0.8 m.

3. METHODS

Three textural analysis methods have been compared : Fourier transform, wavelet transform and Haralick textural attributes.

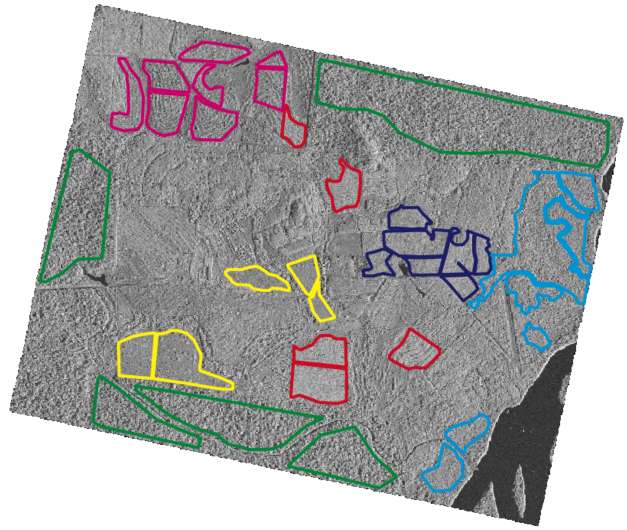


Fig. 3. TerraSAR-X image in mode High Resolution Spotlight 300 MHz (2013/09/28) over 39 km^2 of Forest plantation. The different land cover classes are surrounded with the same color than Fig. 2

3.1. Fourier transform (FOTO)

Studies based on Fourier-based textural ordination (FOTO) analysis on optical images have shown very interesting results in biomass forest mapping [4]. The method consists in deriving the radial spectrum of the 2-D Fourier transform over a sliding window. Then, the radial spectrum is averaged over all directions. Each pixel is consequently represented by a 1-D radial spectrum.

3.2. Wavelet transform

The method based on the wavelet transform uses the continuous wavelet transform. For each selected wavelet, corresponding to a high pass filter, the resulting statistical distribution over a local neighborhood is assumed to follow a generalized Gaussian function. This function is characterized by 3 parameters: α, β and μ which are estimated by maximum likehood [5].

3.3. Haralick

Haralick attributes are extracted from the gray level cocourrence matrix (GLCM) [6]. Studies based on Haralick textural attributes have demonstrated their performances in vegetation mapping [3, 7]. Among the 14 textural attributes introduced by Haralick [6], eight different Haralick parameters have been retained: energy, entropy, correlation, homogeneity, contrast, mean, variance and dissimilarity respectively Ene_i, Ent_i, Cor_i, Hom_i, Con_i, Mea_i, Var_i, Dis_i where i denote the distance.

4. APPLICATION

For each of the 3 three methods, the same 50x50 window size (for the 2-D Fourier Transform, α, β and μ attributes, and GLCM estimations) have been retained. In a first step, this size appeared to be well suited to the scene (with respect to the textural patterns and plots sizes).

- For FOTO method, the size of the resulting 1-D radial spectrum is 35 pixels. A principal component analysis is performed in order to reduce that dimension to 4, as it explains about 80% of the variance. In order to reduce the computational time (3 days) the sliding window is moved with a step of 10 pixels.

- For wavelet transform method, four decompositions have been retained, associated to different wavelet scales. For the ith decomposition ($1 \leq i \leq 4$), the μi, αi, βi, attributes defining the generalized Gaussian distribution are estimated over a 50x50 neighborhood. In order to become independent from orientation, the generalize Gaussian attributes are computed over a co-localized window on horizontal and vertical decomposition. It results a final feature space of 12 dimensions (3 attributes x 4 decompositions). In order to reduce the computation time (6 days), the sliding window is moved with a step of 10 pixels.

- Haralick attributes are derived from GLCM matrices estimated over 3 distances (1, 5 and 10 pixels). For each distance, GLCM matrices are computed over 4 different directions (0°, 45°, 90°, 135°) Then the Haralick attributes are averaged over these 4 directions. It results to a final feature dimension of 24 (8 attributes x 3 distances), the computation time is about 8 days.

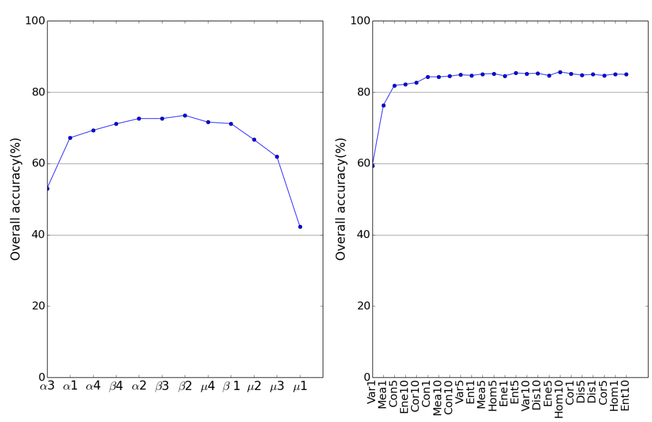
Past studies have shown that the SVM classification method is well suited to vegetation classification using radar data [8]. This algorithm allows taking into account numerous attributes, which can be heterogeneous with respect to their physical dimension. Furthermore it presents better results than Random Forest algorithm (overall accuracy is 5% higher). The kernel used is Radius Basis Function (RBF), because of it's good results compared to linear, polynomial and sigmoid kernels.

To eliminate redundancies, we used an incremental selection of attributes (Greeedy forward [8]) based on the overall accuracy (OA). Each classification is iterated 5 times over 5 different training samples in order to lower the influence of the randomly selected training samples. Finally, for a given method, the significance of the best attributes combination for the classification is analyzed on a plot basis, by performing a majority post-classification process over each plots.

5. RESULTS AND DISCUSSIONS

The FOTO method gives an overall accuracy of 58%. After the post classification, the bare soil, Plantation 1 and Plantation 3 classes have been well classified. Further investigation will be conducted using bigger window sizes, as we expect it could better discriminate dense forest classes.

Results of greedy forward analysis are shown Fig. 4. The wavelets transform method (Fig. 4a) leads to an overall accuracy of 74% obtained with 7 attributes (i.e. he $\alpha3$, $\alpha1$, $\alpha4$, $\beta4$, $\alpha2$, $\beta3$, $\beta2$). It appears that α and β parameters are more relevant than the μ parameters. The large decrease observed for these latter is mainly due to an overfitting effect, but tests made with ($\alpha1$, $\alpha3$, $\mu1$, $\mu2$, $\mu3$) parameters only confirm that μ parameter is not significant. When analyzed on a plot scale basis, the 7 attributes combination above give a performance of 87% (i.e. 21 over 24 plots). In particular, dense forest, riparian forest and bare soil are well classified, while 25% of the plantation 1, 2, and 3 are misclassified.



(a) Wavelet transform method (b) Haralick's method

Fig. 4. Incremental attributes selection

The Haralick attributes allow an OA of 86% that is rapidly reach for 6 attributes, the result is shown on Fig. 5. On the contrary to Wavelet transform, no attributes appear to introduce confusion in classification (i.e. the OA remains constant). On a plot-scale basis, 22 over 24 plots (i.e. 92%) are well classified (white on Fig.5). The 2 misclassification plots are plantation 1 and 2 which are swapped (black on Fig.5).

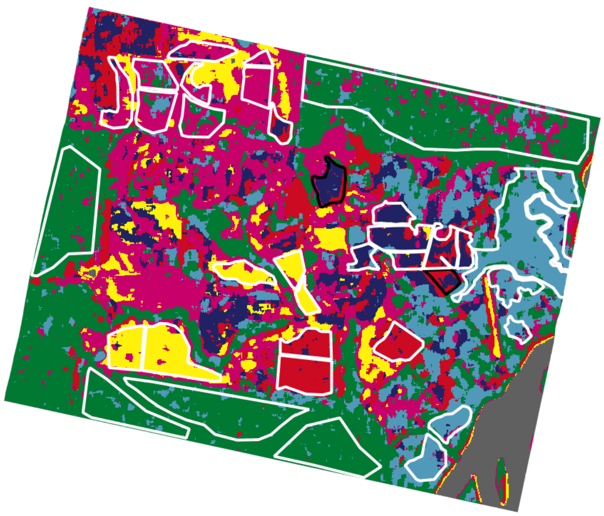


Fig. 5. Post-classification result (Haralick attributes)

6. CONCLUSION

Among the three methods that has been tested to Investigate the contribution of textural analysis over a forest plantation site, the Haralick method shows the highest performance (OA = 86%), in front of the wavelet transform (OA = 74%) and the FOTO method (OA = 58%). It appears that FOTO is able to successfully discriminate the plantation 1 and 3 classes, while these classes are confused with the wavelet transform. The fusion of both methods will be investigated as their results appear complementary. As a first step, the same 50x50 local neighborhood has been used for all the 3 methods. However, this size should be adapted to each of the method. For example, a different window size could be better suited depending of the method. In particular, a larger window could improve the results of the FOTO algorithm. It is worth noticing that the different method are better suited for different types of texture. The latter has also a strong impact on the analysis scale. The results shown here concern a forest plantation site, which is far different from the natural dense forest over which the FOTO algorithm has been developed. Additional studies have to be made over different study sites to draw more general conclusions.

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