Semantic network applied to IKONOS-2 image for the delineation of *Araucaria angustifolia* (Brazilian pine) crowns in a Mixed Ombrophilous Forest

A.A. Disperati [a,*], J.R. Santos [b], E. Servello [b], F. F. Camargo [b], J. Disperati [c], G. S. Lisboa [c]

[a] Departamento de Engenharia Florestal, Universidade Estadual do Centro-Oeste, Irati, Paraná, 84.500-000, Brazil
[a] disperati@avalon.sul.com.br; [c] juliana012002@yahoo.it, [c] gerson.lisboa@gmail.com
[b] Instituto Nacional de Pesquisas Espaciais, Av. dos Astronautas, 1758, São José dos Campos, SP, 12.227-010, Brazil
{jroberto, fortes}@dsr.inpe.br, elservello@gmail.com

Abstract – This work shows the treatment of IKONOS-2 data for delineation of *Araucaria angustifolia* crowns in the Mixed Ombrophilous Forest. The methodological procedure used classification oriented to object multi-level, through techniques of multiresolution segmentation and cognitive process of semantic net, substantiated by fuzzy rules, considering descriptors in form and texture for classification of the *Araucaria* crowns. Experiment was carried out in the National Forest of Irati (Paraná State, Brazil). In the classification step, some statistical attributes were employed, textures (averages of sub-objects, Haralick measure) and ratio of bands, which allowed the thematic stratification of the following classes: agricultural areas, exposed ground, reforestation of *Pinus* spp, broadleaves crowns and *Araucaria* crowns. The performance of discrimination of *Araucaria* crowns from other species was evaluated by global accuracy (0.655), Tau index and Kappa coefficient, having as reference the positioning of the trees observed in field survey.

Keywords: Mixed Ombrophilous Forest, *Araucaria angustifolia*, semantic network, IKONOS image, object-based analysis,

1. INTRODUCTION

Mixed Ombrophilous Forest (FOM) occurs in several countries of South America, but the largest area is located in the states of Paraná and Santa Catarina in the southern region of Brazil. *Araucaria angustifolia,* called also Brazilian pine, is one of the most important trees that occurs in the FOM; in the mature and old age natural forest the *Araucaria* is the most common and dominant specie in highest canopies. It usually forms the main part of the forest since it has a comparatively well-developed crown. The other tree crowns can reach the upper canopies of the forest, but none of them has a distinguished crown canopy characteristic as *Araucaria* tree. In the past there was a high FOM exploitation and an intense exploitation of *Araucaria* due it is high quality timber. Nowadays the specie and the forest are protected by environmental legislation.

The availability of high resolution spatial images (e.g ≤ 4 m pixels) are more appropriate for forest stand-level parametrization (Wulder et al., 2004) and with (10-100 cm/pixel), it is better to deal directly with the essential structural element of the forest stands: the individual tree crown (Gougeon and Leckie, 2006). Disperati and Oliveira Filho (2005), using 70 mm 1:1,000 normal color aerial photographs, evidenced the inconsistency to delineate the *Araucaria* crowns exclusively through their peripheral shadows. Another method to characterize individual crown of trees is the local maximum filtering (Disperati et al., 2007) but it is not adequate since the *Araucaria* has large crown diameter. Other procedures that the conventional pixel-based image analysis must the considered in order to delineate semi-automatically the *Araucaria* crowns in a forest environment. The present paper use an approach based on image objects than pixels as a first attempt for the task.

2. METHODOLOGICAL PROCEDURE

2.1 Area under study

The study area is located at the central-south of Paraná State (central coordinates W 50º 34' 30" and S 25º 23' 30"), Brazil. The climate, according to Koppen, is Cfb (temperate) with frequent frost during winter and rainfall distributed along the year. Temperature oscillates between a maximum average of 24º C and a minimum average of 11º C, the averages monthly of rainfall and relative humidity are 194 mm and 80%, respectively.

The study area (~450 ha) is located mostly inside of the Irati National Forest, with elevation ranging between 820 and 880 m, and includes ~ 70% of remnants of FOM, which is important to maintain the biodiversity of this biome. Detailed forest inventory in multipurpose study experiment of 25 hectares of this fragment of forest was carried out, considering all trees with diameter at breast height ≥ 10 cm. Among the data collected for each tree there were: botanical identification, circumference at breast height (cbh) and spatial distribution of each individuals. Besides the 25 ha planimetric map showing the location of all trees, the survey indicated an average number of 460 trees/ha, being 42 *Araucaria*/ha (volume of *Araucaria* ~100 m^3/ha according to Disperati, 2002a; Figueiredo Filho et al., 2006). Based on a visual interpretation of the 70 mm aerial photographs and covering two hectares of this study area, Disperati (2002b) discriminated 54 crowns of *Araucaria*, from a total of 1,121 individuals surveyed during field work. This demonstrates a certain concentration of *Araucaria* in some places with a better site index and a higher recovery capacity of the forest.

2.2 Data used

The input data was an IKONOS-2 image acquired on Dec. 29th 2004, with the blue (0,45 - 0,52µm), green (0,52 - 0,60µm), red (0,63 - 0,69µm) and near infra-red bands (0,76 - 0,90µm). These channels were fused to the panchromatic band with a resolution of 1 m. The 25 ha forest inventory database was also used. As ancillary data, in the orientation of the field work and delineation phase of the *Araucaria* crowns, 70 mm aerial photos at scales 1:1.000 and 1:2.000 were used.

* Corresponding author.
** Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq), Fundação Araucária, UNICENTRO and INPE/MCT.

The commercial software Definiens 5.0® was used for classification oriented-object; ArcGIs 9.2® software for the crossing of the plans derived from data IKONOS and the field information in the validation phase of the classification through semantic network.

2.3. Methodological procedure

The software Definiens 5.0® was used by allowing the multiresolution segmentation (in the attainment of objects of the analysis), applicability of hierarchic semantic net and oriented-object modeling (storage and modeling of the knowledge), beyond fuzzy logic (Benz et al., 2004). The multiresolution segmentation uses the method of growth of regions to create homogeneous objects from pixels seeds. It uses the criteria of scale, color, shape, compactness and smoothness. The color is function of the spectral characteristics of the image and the others aspects compose the criterion of shape (Baatz and Schäpe, 2000).

In the present study it was adopted initially a strategy of segmentation (first level) and classification multilevel with intention to separate those polygons belonging to the two main classes: (1) reforestation areas with *Pinus* spp; (2) no reforestation, referring to the polygons of FOM, considered as remaining, beyond some few areas of agricultural activities or fallow areas. Thus, in this first level of segmentation, after intensive experimental process, the following settings were used: scale (240), color (0,3), shape (0,7), compactness (0,7) and smoothness (0,3). In the first segmentation level, it is possible to observe that the criterion "shape" has the highest weight, due to the need to discriminate those objects with regular edges (e. g. reforestation areas).

In the second level it was carried out a more detailed segmentation, with the delineation of referring polygons of the following classes: reforestation of *Pinus* spp; exposed ground; agricultural areas; broadleaves crowns (it would non-*Araucaria*) and *Araucaria* crowns. Also after intensive experimental process, the following settings were used: scale (75), color (0,7), shape (0,3), compactness (0,7) and smoothness (0,3). In this level, the criterion "color" was considered more important for the delineation of the diverse patterns of crowns.

From this multi-level segmentation, a hierarchic and semantic net was used (Figure 1) for the thematic classification, which incorporated rules of interpretation and attributes based on the multi-spectral bands and the objects of the segmentations. Graphs of dispersion and histograms were used in the initial analysis of attributes. Afterwards, the selected attributes were mapped, using trapezoidal functions, for fuzzy sets, and combined by the fuzzy operator "*AND"* (which returns minimally between n sets). It pointed out that the semantic relationship (is-one) and the hierarchic relationship (part-of) were used as restrictions, looking for *a priori*, to minimize the confusion between some objects of the scene, case of the *Pinus* spp with those polygons of occurrence of the *Araucaria*. This is due to the fact that forest targets present a certain proximity in the domain of spectral attributes.

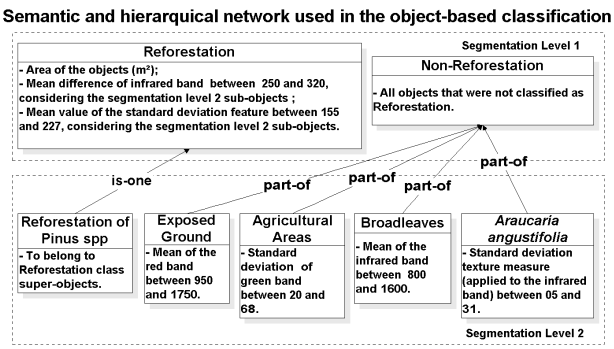

Figure 1. Diagram of semantic and hierarchical network used in the object-based analysis and the some settings used in the segmentation/classification procedures.

Considering that the main objective of the present work is the delineation of *Araucaria* crowns, the accuracy of the thematic mapping was carried through only of classified objects as *Araucaria* and broadleaves crowns. This was made through the analysis of the contingency matrix, which collected the data inventoried in field (species *census*) and the guided classification derived from image IKONOS. This matrix supplied the following statistics: accuracy of the producer and the user, global accuracy, Tau index and index Kappa (Landis and Koch, 1977; Ma and Redmond, 1995). The field database of 238 individuals (*Araucaria* and broadleaves) with cbh $\geq$ 200 cm were selected, assuming that the crowns of such trees stands out in the upper canopies of the forest, categorized as dominant or co-dominant. Nutto and Spathelf (2003) analyzing the effects of competition of *Araucaria* trees found out that there is a narrow relation between crown projection and diameter. The positioning of these 238 points, representing promptly each crown of the tree, on resultant map of segmentation level 2 allowed the quantitative evaluation of the performance of the system. In essence, it was verified if each point was located inside of the perimeter of the crown or the group of crowns, generated for this boarding of classification. This procedure was used with intention to minimize errors caused by non-dominant species that, possibly, had not been recorded by sensor system IKONOS-2.

2.4 Results and Discussion

Figure 2 shows the area studied in image IKONOS and the result of the classification of level 2. In a visual comparison of the information contained in this Figure 2, it is possible to see an accented agreement in the delimitation of the polygons for the reforestation classes of *Pinus* spp, exposed ground, forest and agricultural areas.

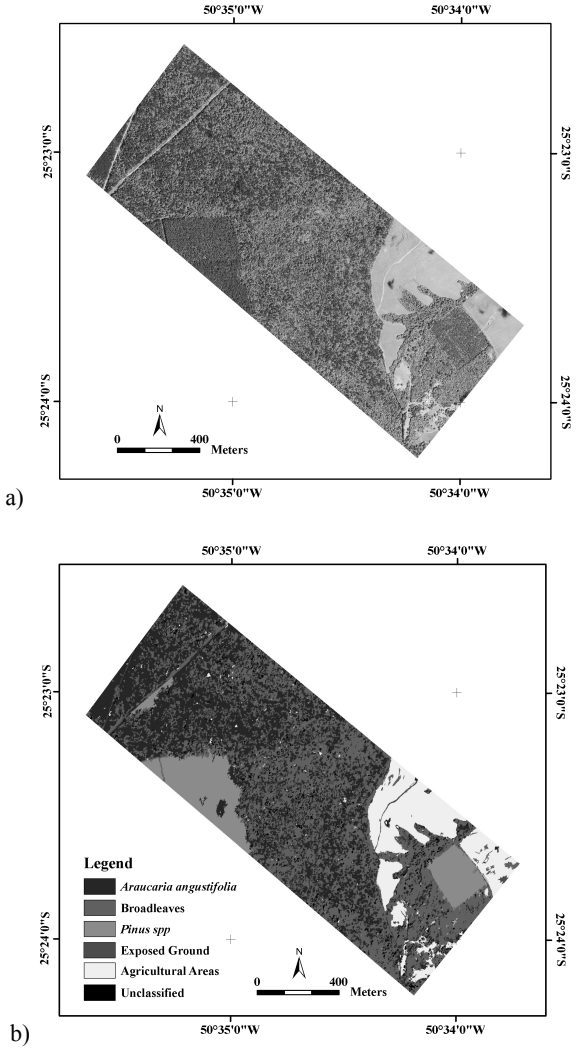

Figure 2. IKONOS-2 color composite of the bands 4R, 3G and 2B (a) and respective classification by semantic network with the land-use and land-cover classes (b)

In Figure 3 a small section of the study area can be observed showing the specific delineation of the classification of individual crowns of *Araucaria* and broadleaves. Through a series of statistics indicators it can be verified that the performance of semantic network for all the study area was considered "to regulate", with global accuracy of 0,655 and accuracy of the producer around ~0.70. In turn, the Tau indices and kappa (to fair agreement) to present bases values of agreement in the discrimination of the crowns of *Araucaria* and broadleaves. *Araucaria*, when component of the dominant or co-dominant canopies, has an almost circular crown in an umbrella format, of straight trunk, branching off in the top of the tree, with the overlapped branches developing itself horizontally with the bending tips and forming some horizontal floors in the forest. However, the crowns have low density, small alternated needles (5-6 cm length), linear format and disposed generally spiral-like (Carvalho, 1994; Wadsworth, 2000; Côrte et al., 2007). Because of this little dense configuration of the crowns of *Araucaria* in the canopy, the "regular" performance can be justified, therefore some broadleaves species situated soon in the intermediate and dominated canopies can perfectly be contributing in the spectral mixture of the reply of the *Araucaria*, registered in high resolution image IKONOS. Probably this justifies, in part, the low values found for kappa (to fair agreement) and Tau indices. It is important to say that the *Araucaria* in the upper canopies of the natural forest can presents a large crown diameter reaching values of 20 m; the dominant species in FOM have little overlapping of crowns (< 10%) in the upper stratum. In summary, this level of performance was affected by the super estimation of crowns from broadleaves of the foliar structure inside the Araucarias. It indicates a refinement in the establishment of criteria and attributes at the multi-level segmentation and of the parameters from the semantic net.

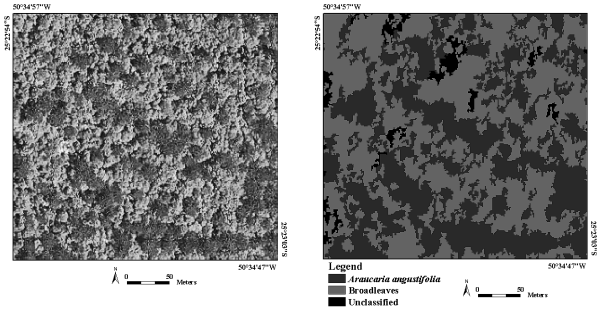

Figure 3. Section of IKONOS-2 color composite of the bands 4R, 3G and 2B (a) and respective classification semantic network showing the *Araucaria* crowns and broadleaves crowns (b).

Table 1. Performance of the object-oriented classification for delineation of *Araucaria*.crowns in IKONOS-2 image.

		Ground Reference		
		Araucaria	Broadleaves	Unclassified
Classification	*Araucaria*	128	24	0
	Broadleaves	49	28	0
	Unclassified	7	2	0

Global Accuracy: 0.655; Tau Index: 0.483;
Kappa Index: 0.204

	Producer´s Accuracy	User´s Accuracy
Araucaria	0.6964	0.842
Broadleaves	0.5199	0.364

3. CONCLUSIONS AND RECOMMENDATIONS

In a general way we conclude that using the segmentation procedure, the settings considered and multi-level strategy used, were adequate to discriminate among the thematic classes under investigation. Referring to the semantic and hierarchical net, there was a possibility to establish context rules to define objects at different segmentation levels, at more general or more detailed

scale (2nd level). We recommend at the strategy for the selection of the attributes new approaches could be explored, such as data mining methods (e. g. fuzzy logic, decision trees), delivering possibly more adequate thresholds of attributes to discriminate among the canopies of *Araucaria* and broadleaf trees.

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