Detecting individual palm trees (Arecaceae family) in the Amazon rainforest using high resolution image classification

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Abstract. The identification of plant species individuals in ecological and conservation research is elementary to calculate population and community parameters and indexes. However, the database in these studies is usually limited to small length areas due the difficulty of collecting field data. Remote sensing of high spatial resolution has the potential to identify plant species individual in the forest canopy. In these studies, besides the high resolution images the specialist knowledge is fundamental to quality of the work. There are different high spatial resolution images, which can be acquired from sensors onboard of satellites or airplanes (aerial photographs). This study aims to identify individuals of palm trees using high spatial resolution image from videography, obtained from a flight mission over Amazon, and techniques of digital image processing. Images of different spatial resolution obtained over Madeira-Purus inter-rivers were tested using different techniques the image processing. Region growing segmentation technique and three classification methods were used to test the classification of videography images with two different image contrasts. Considering visual interpretation, the negative contrast in the images enhanced better the palm tree crown than the original real color images. The segmentation and classification methods were efficient to distinguish palm individuals in the 0.60m spatial resolution images. As the resolution improved to 0.20m, palm leaves were identified instead. The use of aerial videography data showed to be a potential alternative for high spatial resolution images in studies of ecology and biodiversity of tropical forests.

Key-words: high spatial resolution, videography, tree crown, palm tree, Amazon.

1. Introduction

The correct identification and localization of the plant species individuals is essential for ecological and conservation studies because they are the basis for several population and community parameters and indexes (Legendre and Legendre, 1998; Magurran, 2003). However, the position and identification of plant individuals are usually restricted to a sample area for data collection on the field. Due to the synoptic overview provided from remote sensing data, this area limitation could be overcome, enabling the observation of larger study areas (Kerr and Ostrovsky, 2003). This is particularly true, considering the availability of high-resolution remote sensing data. Among the examples of remote sensing applications for ecological researches, we can emphasize: the prediction of species distribution (Salm *et al*, 2007; Buermann *et al*, 2008), the identification and understanding of habitat characteristics at different scales of analyses (Affonso, 2004; Salm *et al*, 2007), the study of deforestation process and its consequences (Putz and Redford, 2010), and the spatial variability of species richness and abundance (Coops and Culvenor, 2000; Holmgren and Persson, 2004). Then, as suggested by literature, remote sensing imagery with high spatial resolution combined with field-based data can contribute to improve conservation and biodiversity studies.

Considering the extension and the importance of the Amazon rainforest, the use of remote sensing is even more useful to reach inaccessible areas. Image data from sensor systems of high spatial resolution can provide detailed information about the structure of large areas of rainforest. In this context, the GEOMA project held a flight mission over the Brazilian Amazon to recorded aerial videography aiming to characterize the variety of landscape from forest to urban area (GEOMA/MCT, 2006). This database, containing images of different spatial resolution, and referred to routes throughout the states of Mato Grosso, Pará, Rondônia, Acre and Amazonas, was made available[1] to the general users.

One of the forest measures related to canopy structure that can be assessed by remote sensing is the identification of tree crown. Contrary to the specie identification, which relies on the knowledge of the botanic interpreter, the geographical position and the crown diameter of each tree can be obtained from remote sensing whenever specific methodology is applied (Coops and Culvenor, 2000). The spatial resolution of the image will define the detection limit of the tree crown sizes. Moreover, techniques of digital image processing, as image contrast, segmentation, and classification, can assist the analysis and interpretation of remote sensing data for tree crown detection. Several techniques can be applied to obtain forest structure information from remote sensing data, varying from simple image visual interpretation up to sophisticated algorithms such as Fourier Transformation (Ximenes and Amaral, 2010).

Among the flora diversity of the Amazon forest are the palm trees (family Arecaceae), easily recognized because their characteristic canopy architecture and leaves form. Some palm species occupy the tree habitat, and are emergent in the canopy of the Amazon forest. These features make palm trees individuals likely to be identified and separated by remote sensing data.

This work investigates the use of high-resolution videography images, and techniques of image segmentation and classification to identify palm individual tree crowns over the Amazon rain forest.

2. Methodology

2.1. Study area

The study area is located in central Amazon (Brazil) between the Purus and Madeira Rivers in an upland forest (terra firme) (Figure 1). This area is characterized by great diversity gradient from forest vegetation areas (dense, open and pioneer) up to savannas (RADAMBRASIL, 1978a). The dominant soil type is a red yellow podzolic and the climate is equatorial hot and humid (RADAMBRASIL,1978b).

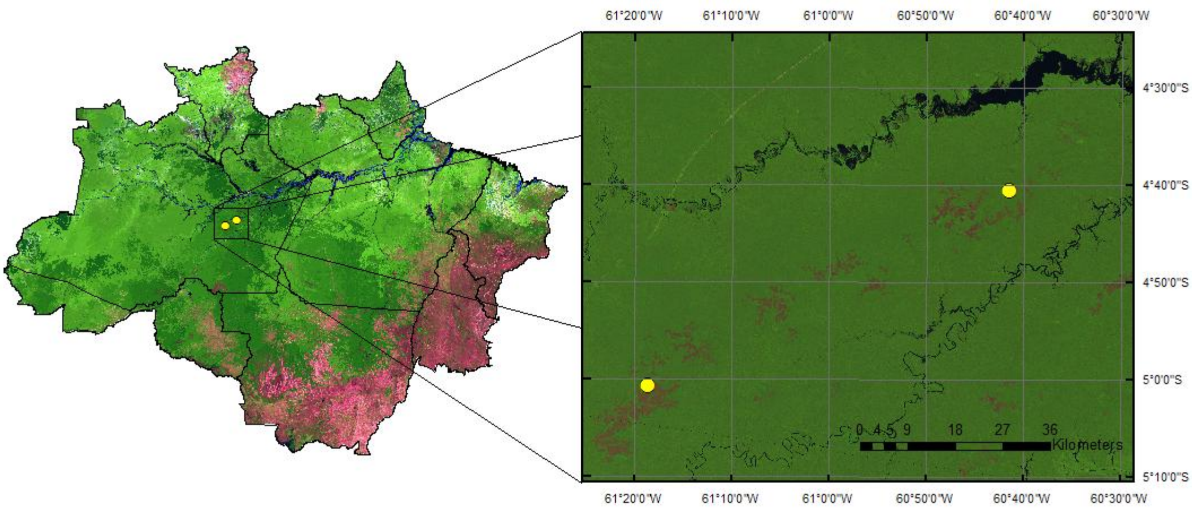

Figure 1. Study area. Points referred to the geographical coordinates of the images center.

2.2. The Arecaceae Family

According Cronquist classification system, the palm trees are plants from family Arecaceae (or Palmae) belonging to class Monocotyledonae, subclass Arecidae and order

[1] http://www.dpi.inpe.br/geoma/videografia/

Arecales (Ribeiro *et al*, 1999). The palm trees are characteristic components of the flora in tropical and subtropical regions due to its peculiar shape and appearance (Henderson *et al*, 1995; Ribeiro *et al*, 1999). The representation of palm in tropical forests can be observed in many forests in Brazil as, for example, the Central Amazon where the palm trees are abundant (Ribeiro *et al*, 1999; Lorenzi *et al*, 2004). Areacaceae family had a great diversity and it is estimated that there are about 1500 species (Henderson *et al*, 1995). In addition to the importance in the rainforest structure and food source for many animals and humans, the palm trees have great economic potential to ornamental plant, medicine and cosmetic industries for human (Henderson *et al*, 1995; Lorenzi *et al*, 2004).

2.3. Images from Aerial Videography

From 2006 Geoma videography mission (GEOMA/MCT, 2006), every flight route had a proper flight altitude and consequently, different spatial resolution images are recorded. A Sony TRV digital video camera coupled with a GPS was used to record the videography, and the georeferenced images were provided in JPG format. Two frames from aerial videography referred route F119 and F120 were selected (Figure 2). Images are compatible to geographic coordinates system, datum SAD 69, and have 640x480 pixels (lines and columns).

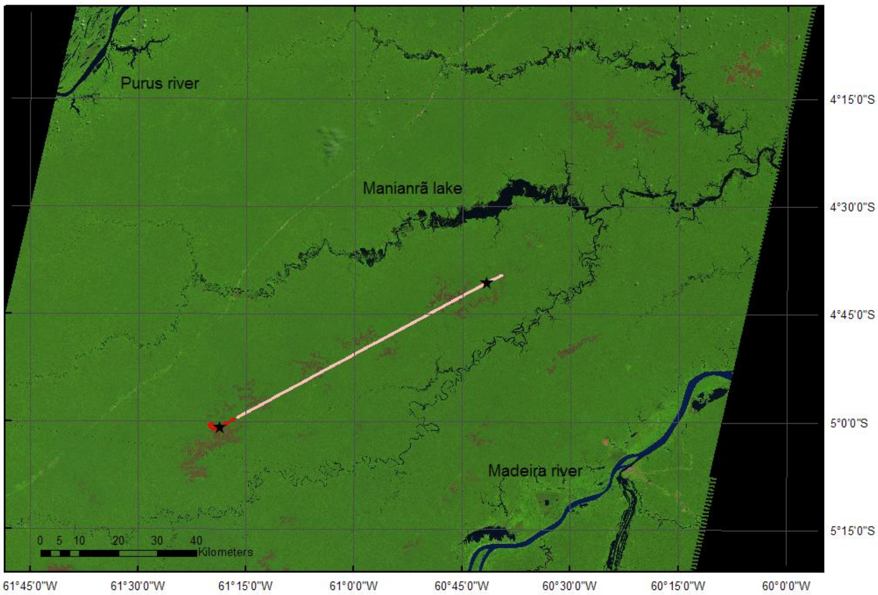

Figure 2. Videography flight route: F119 (pink line) and F120 (red line). Black stars: central points of the frames

Image 119028 (Figure 3a) was captured along flight route F119, with coordinates at central point of the frame of 4°40’35.76”S and 60°41’32.64”W. The flight altitude for this scene was 481,890 m, resulting in a resolution of about 0.60 m, covering 110,592 m^2 in the ground. Image 120089 presents more details (Figure 3b) and it was obtained on flight route F120, with a flight altitude of 143,560 m, leading to image resolution of about 0.20 m, covering 12,288 m^2 on the ground. The coordinates at central point of the frame are 5°0”45.72”S and 61°18’33.84”W.

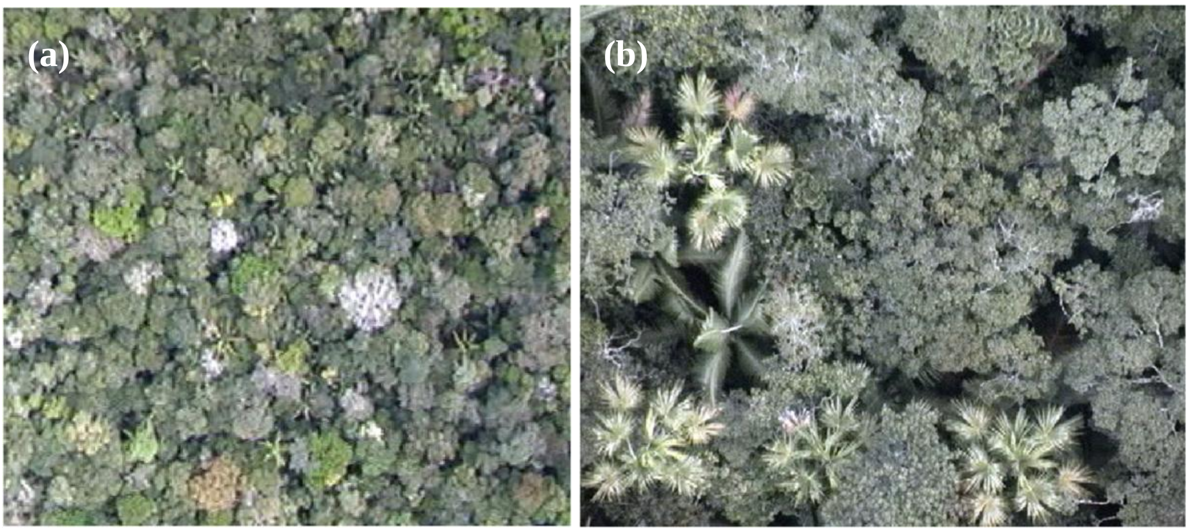

Figure 3. (a) Image 119028 obtained from aerial videography (0.60 m pixel size); (b) Image 120089 obtained from aerial videography (0.20 m pixel size).

2.5. Segmentation and Classification

To analyze the influence of image contrast over crown tree detection, both images were submitted to segmentation process considering the real color composition (positive contrast) and the negative contrast that at first visual analysis showed to better distinguish individual tree crowns. Therefore, four images were submitted to the segmentation procedure based on region growing algorithm (Bins *et al*, 1996), and image classification procedures available at SPRING GIS (Camara *et al*, 1996). Besides providing basic segmentation and classification techniques widely used for researches, SPRING is freeware, what enables the replication of this approach to other areas.

Based on empirical simulation, different thresholds of similarity and area were defined for segmentation of each scene. For both 119028 images, the better thresholds were 20 of similarity, and 50 of area, and for both 120089 images, 20 of similarity and 600 of area thresholds.

For classification procedure, we tested unsupervised methods: K-means for pixel-by-pixel classification approach and Histogram and Isoseg mehods for region classification approach (after segmentation procedure). The K-means algorithm considered tree themes, and 1000 interactions for both scenes. Histogram method used three themes for 119028 images, and four themes for 119028 images. Isoseg method used a threshold of 75% for 119028 images, and 99% for 119028 images

3. Results and Discussion

3.1. Drawing Tree Crowns from Segmentation

Region growing segmentation technique showed to be effective to separate some palm treetops in canopy of the Amazon Rainforest for the all the images, considering different contrasts and resolutions (Figure 4 and 5). Generally, the identification of the tree crowns depended on homogeneous texture, well-defined forms, and color patterns distinct from the background and neighborhood features.

Comparing the images with positive and negative contrasts, the segmentations results were similar. However, by a visual analysis, the images with negative contrasts (Figure 4b and 5b) showed better enhanced the tree crowns of the palm, and some other species, than the positive images (Figure 4a and 5a). In some cases, the segmented images didn't show the perfect limit of tree crowns of palm trees. Limitations concerning to delineating individual tree crowns for the same high spatial resolution image were already cited by other studies

(Ximenes and Amaral, 2010). These restrictions may be related to the dominant presence of one treetop species in the forest canopy, or even due to the phase of the individual development or its phenological stage (Hirschmugl *et al*, 2007).

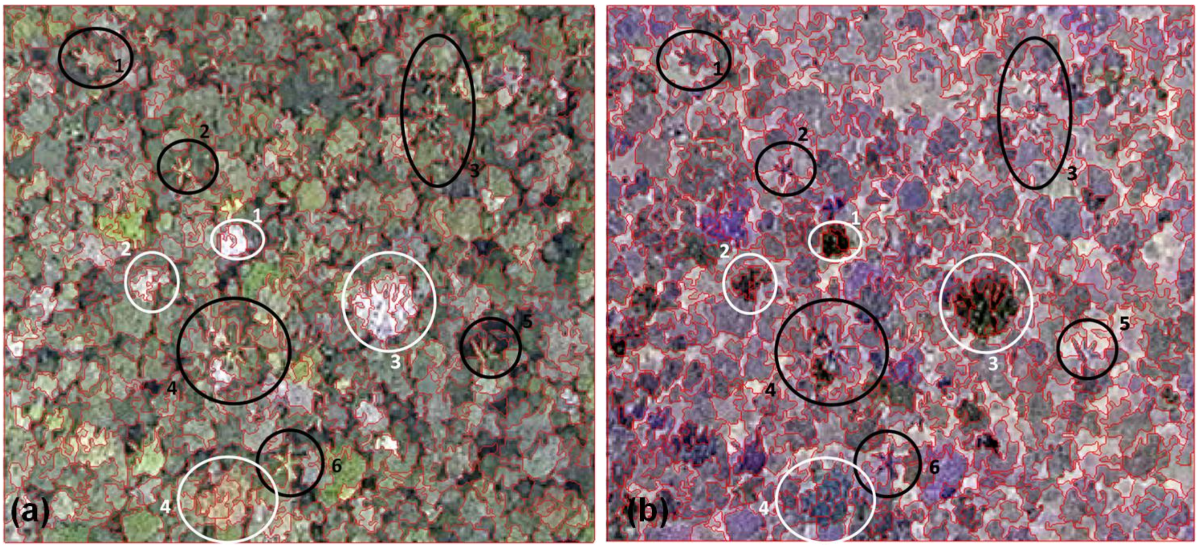

Figure 4. 119028 Image segmentation (red line) with positive (a) and negative (b) contrast. Tree crowns of individual palm (black circle) and other tree species (white circles).

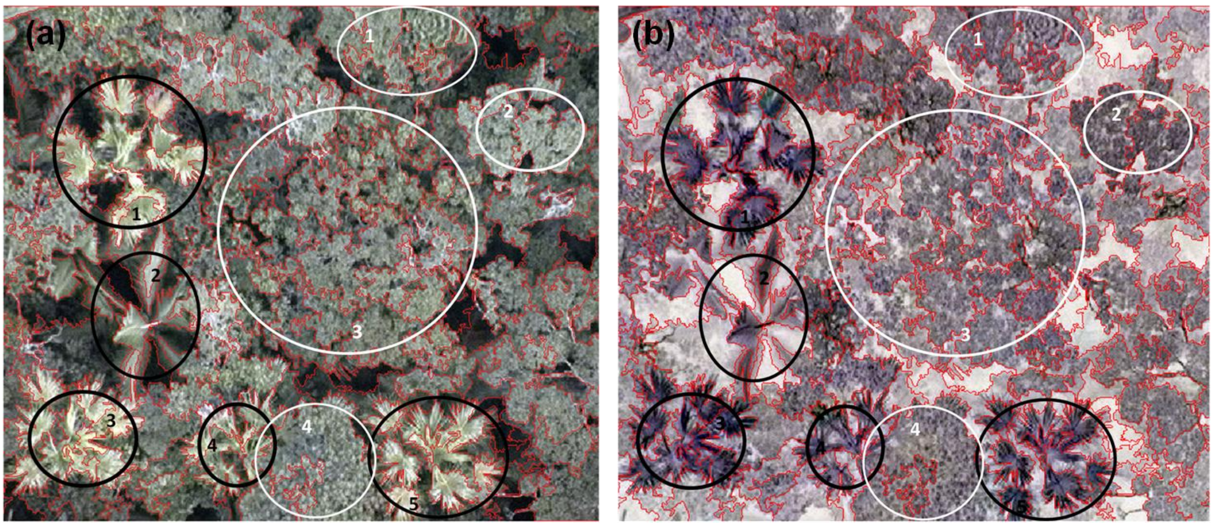

Figure 5. 120089 Image segmentation (red line) with positive (a) and negative (b) contrast. Tree crowns of individual palm tree (black circle) and other tree species (white circles).

For image 119028, the separation of individuals was consistent to the tree crowns shape of palm trees that are star-shaped, and to other tree species with ellipse-shaped crowns. The image 119028 presented better delimitation of the palm tree crowns than the image 120089. Because the more detailed resolution, the segmentation over image 120089 generated polygons that discriminated palm leaves (as cited above) and also split up the tree crowns from others species. These differences can be attributed to the different spatial resolutions of 0.60m and 0.20m in the images, 119028 (Figure 4) and 120089 (Figure 5), respectively.

3.2. Identifying trees by Image Classification

Because both images with positive and negative contrasts presented similar segmentations results, and the negative contrasts better enhanced the palm treetop, only the classification results for negative contrast image is presented.

Comparing the classifications, based a visual analysis, the K-means classification of the negative 119028 image (Figure 6) presented the best result it identified several tree crowns and palm tree. This can be noticed in Figure 6b, where the palm trees and some other trees were grouped at the same class (red).

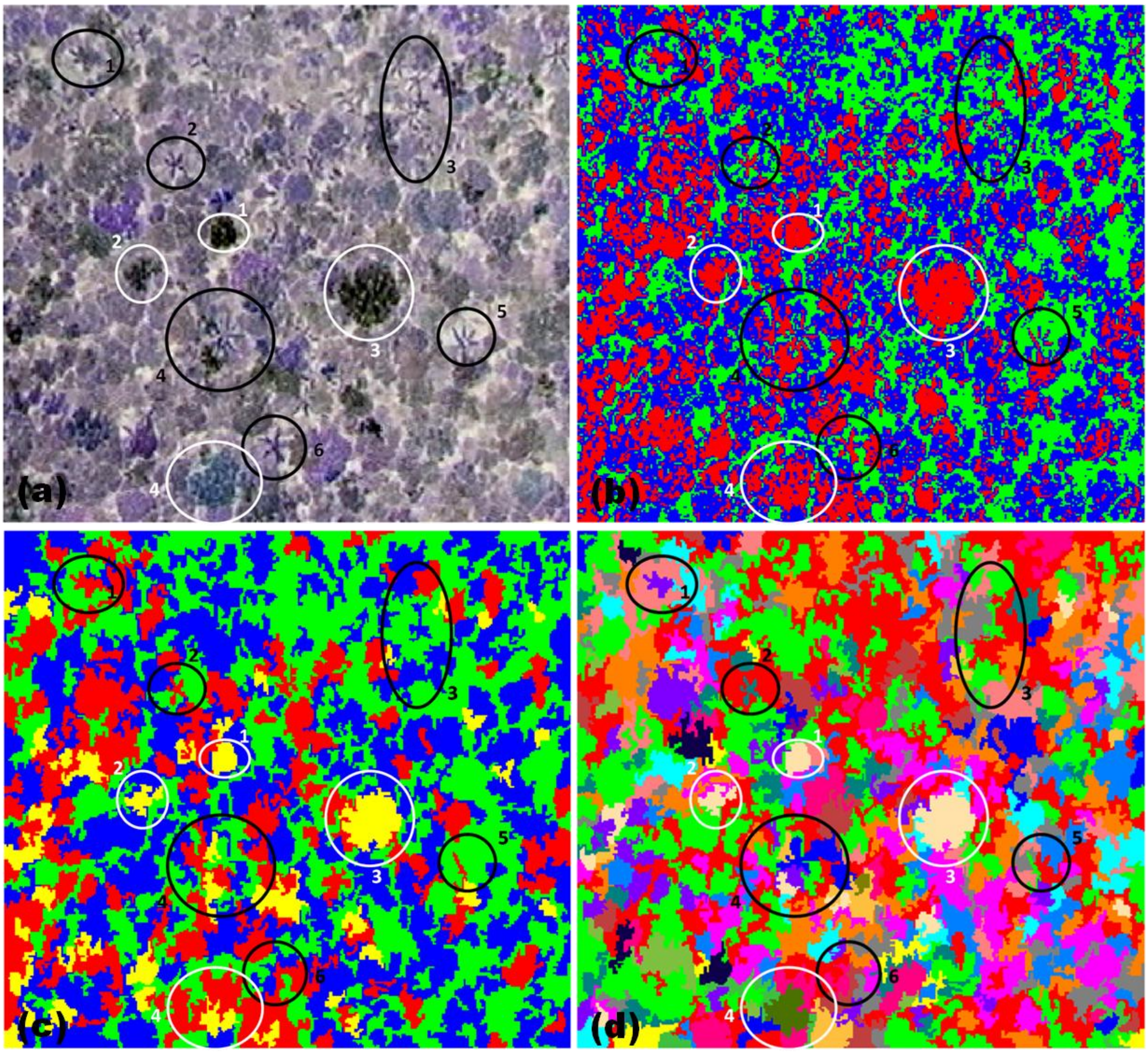

Figure 6. Classification results for negative image 119028(a): K-means (b), Histogram (c) and Isoseg (d). Individual palm trees (black circle) and other tree species (white circles).

For the negative image 120089 (Figure 7a), as segmentation procedure identified leaves instead of tree crowns, the classification procedure did not identify individual trees (Figures 7b, c e d). Similar result concerning to palm tree detection in the forest canopy was described for a region in the state of Pará, Brazil (Affonso, 2003). To identify the position of individual trees in the original image, instead of just identify a single palm tree crown, another procedure is needed to gather palm leaves polygons.

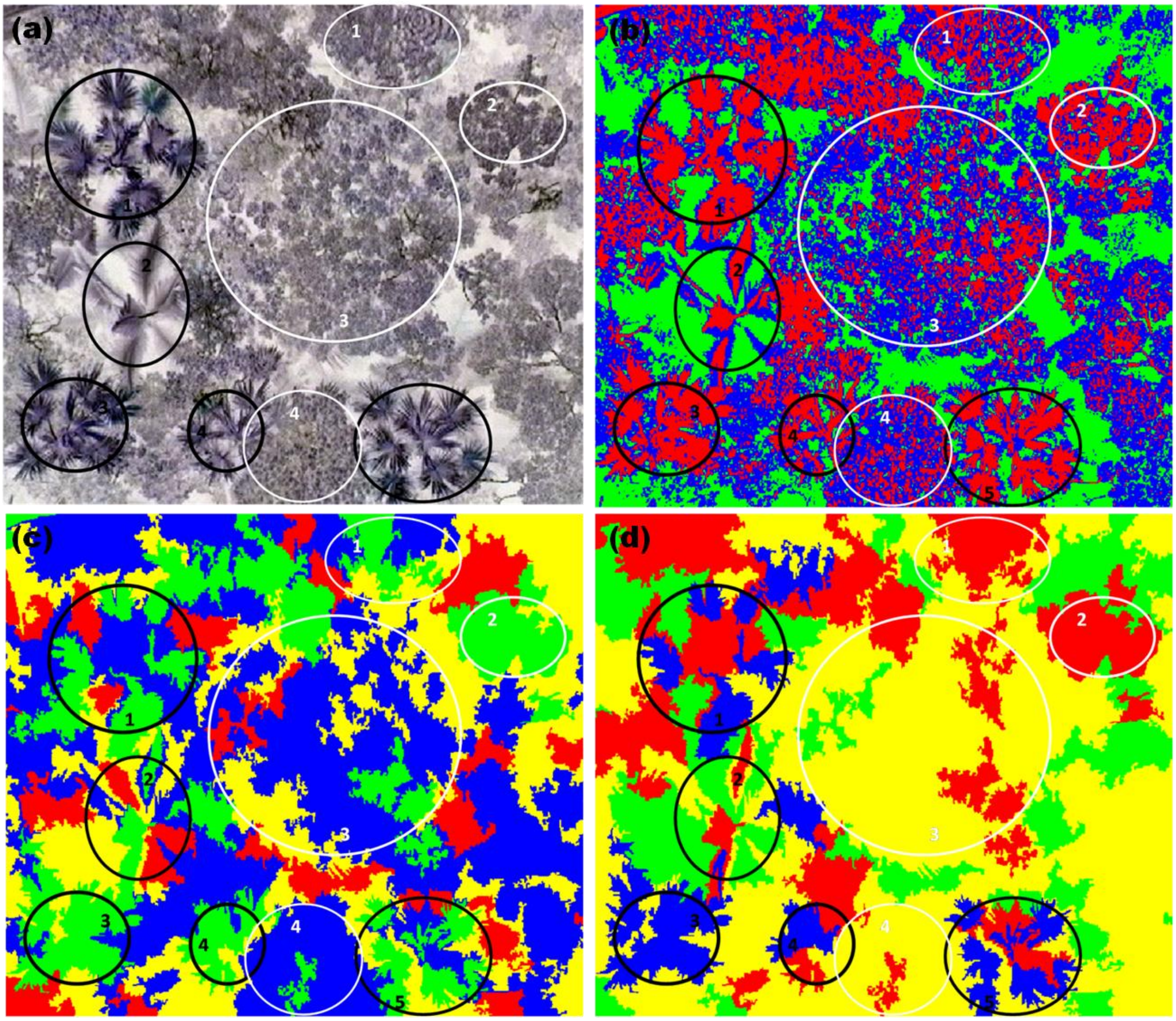

Figure 7. Classification results for negative image 120089(a): K-means (b), Histogram (c) and Isoseg (d). Individual palm trees (black circle) and other tree species (white circles).

4. Conclusion

This paper described as segmentation and classification procedures can identify tree crowns of palm and other species over forest canopy. Different spatial resolution provided complementary information about the tree identification in the forest.

Due to the poor knowledge about the palm species in the Amazon rainforest and their identifications from the high spatial resolution image, the image processing procedure applied showed to be useful as a first analysis. However, to improve the identification of the tree species in the forest canopy is necessary to test other segmentation and classification techniques, using information about texture and crown shape. Moreover, it is essential to search alternatives to aggregate the specialist knowledge about botany and ecology of the Amazon forest.

In conclusion, the use of aerial videography data showed to be a potential alternative for high spatial resolution images in studies of ecology and biodiversity of tropical forests. From the free database available, high-resolution images can be used to identify and locate individual trees in other areas over the Amazon forest, contributing to the knowledge of the dynamics, ecology, diversity and structure of the rainforest.

References

AFFONSO, A. G. **Caracterização de fisionomias vegetais na Amazônia Oriental através de videografia aerotransportada e imagens landsat 7 ETM+. 2003.** 121 p. (INPE-10732-TDI/944). Dissertação (Mestrado em Sensoriamento Remoto) - Instituto Nacional de Pesquisas Espaciais, São José dos Campos. 2003. Disponível em: <http://urlib.net/sid.inpe.br/jeferson/2003/12.03.09.23>. Acesso em: 18 nov. 2010.

BINS, L. S.; FONSECA, L. M. G.; ERTHAL, G. J.; II, F. M. Satellite imagery segmentation: a region growing approach. In: SIMPÓSIO BRASILEIRO DE SENSORIAMENTO REMOTO, 8. (SBSR), 1996, Salvador. **Anais...** São José dos Campos: INPE, 1996. p. 677-680. CD-ROM. ISBN 85-17-00014-5. (INPE-6231-PRE/2321). Disponível em: <http://urlib.net/sid.inpe.br/deise/1999/02.05.09.30>. Acesso em: 18 nov. 2010.

BUERMANN, W.; SAATCHI, S.; SMITH, T.B.; ZUTT, B.R.; CHAVES, J.A.; MILÁ, B. and GRAHAM, C.H.. Predicting species distributions across the Amazonian and Andean regions using remote sensing data. **J. Biogeogr.**, v.35, p.1160-1176, 2008.

CAMARA, G.; SOUZA, R. C. M.; FREITAS, U. M. and GARRIDO, J. P.. SPRING: Integrating Remote Sensing and GIS with Object-Oriented Data Modelling. **Computers and Graphics**, vol. 15, p. 13-22, 1996.

COOPS, N.C. and CULVENOR, D.. Utilizing local variance of simulated high-spatial resolution imagery to predict spatial pattern of forest stands. **Remote Sensing of Environment**, vol. 71, n. 3, p. 248-260, 2000.

GEOMA/MCT. Sobrevoo para coleta de dados na Amazônia. 2006. Disponível em: <http://www.dpi.inpe.br/geoma/videografia/index.php>. Acesso em: 25 de out de 2010.

HENDERSON, A.; GALEANO. G. and BERNAL, R. **Field Guide to the Palms of the Americas**. New Jersey: Princeton University Press, 1995. 352p.

HIRSCHMUGL, M.; OFNER, M.; RAGGAM, J. and SCHARDT, M.. Single tree detection in very high resolution remote sensing data. **Remote Sensing of Environment**, v.110, p. 533-544, 2007.

HOLMGREN, J. and PERSSON, A.. Identifying species of individual trees using airborne laser scanner. **Remote Sensing of Environment**, v.90, 415-423, 2004.

KERR, J.T. and OSTROVSKY, M.. Review from space to species: ecological applications for remote sensing. **Trends in Ecology and Evolution**, vol. 18, n. 6, p.299-305, Jun. 2003.

LEGENDRE, P. and LEGENDRE, L.. **Numerical ecology.** New York: Elsevier, 1998. 853p.

LORENZI, H.; SOUZA, H.M.; COSTA, J.T.M.; CERQUEIRA, L.S.C. and FERREIRA, E.. Palmeiras Brasileiras e Exóticas Cultivadas. Nova Odessa, SP: Instituto Plantarum de Estudos da Flora, 2004. 432p.

MAGURRAN, A.E. **Measuring Biological Diversity.** John Wiley, 2003.899p.

PUTZ, F.E. and REDFORD, K.H.. The Importance of Defining Forest: Tropical Forest Degradation, Deforestation, Long-term Phase Shifts, and Further Transitions. **Biotropica**, v.42, n.1, p.10-20, 2010.

RADAMBRASIL. Levantamento dos Recursos Naturais. Folha SB-20 – Purus, Vol. 17, DNPM/Projeto RADAMBRASIL, Rio de Janeiro, Rio de Janeiro. 1978a

RADAMBRASIL. Mineral, D.N.P. Folha SB.20 Purus: geologia, geomorfologia, pedologia, vegetação e uso potencial da terra. DNPM/Projeto RADAMBRASIL, Rio de Janeiro, Rio de Janeiro. 1978b

RIBEIRO, J.E.L.S.; HOPKINS, M.J.G.; VICENTINI, A.; SOTHERS, C.A.; COSTA, M.A.S.; BRITO, J.M.; SOUZA, M.A.; MARTINS, L.H.; LOHMANN, L.G.; ASSUNÇÃO, P.A.C.L.; PEREIRA, E.C.; SILVA, C.F.; MESQUITA, M.R. and PROCÓPIO, L.C.. **Flora da Reserva Ducke: Guia de identificação das plantas vasculares de uma floresta de terra-firme na Amazônia Central.** Manaus: INPA, 1999, 816p.

SALM, R.; SALLES, N.V.; ALONSO, W.; SCHUCK-PAIM, C.. Cross-scale determinants of palm species distribution. **Acta Amazonica**, vol. 37, n. 1, p.17-26, 2007.

XIMENES, A. C.; AMARAL, S. Predição de parâmetros estruturais de florestas tropicais a partir de técnicas de Transformada de Fourier e delineação manual de copas aplicadas em imagens de alta resolução espacial. **Caminhos de Geografia**, v. 11, n. 33, p. 202-207, 2010. Disponível em: <http://www.ig.ufu.br/revista/caminhos.html>. Acesso em: 10 nov. 2010.