INTERPRETATION OF ORBITAL REMOTE SENSOR IMAGES FOR THE ANALYSIS OF AFRICAN OIL PALM PLANTATIONS IN THE BRAZILIAN AMAZON

INTERPRETAÇÃO DE IMAGENS DE SENSORES REMOTOS ORBITAIS PARA A ANÁLISE DE DENDEIZAIS NA AMAZÔNIA BRASILEIRA

Leonardo de Sousa Santos[1]
Christian Nunes da Silva[2]
João Santos Nahum[3]
Cleison Bastos dos Santos[4]
Orleno Marques da Silva Júnior[5]

[1] Universidade Federal do Pará (UFPA). E-mail: leonardodrgeo@gmail.com
[2] Universidade Federal do Pará (UFPA). E-mail: cnsgeo@yahoo.com.br
[3] Universidade Federal do Pará (UFPA). E-mail: prof.joaonahum@gmail.com
[4] Universidade Federal do Pará (UFPA). E-mail: cleisongeo@gmail.com
[5] Instituto de Pesquisa Científica e Tecnológica do Amapá (IEPA). E-mail: orlenomarques@yahoo.com.br

ABSTRACT: The techniques for extracting information from ground targets using remote sensing satellites have been shown to be strategic instruments for collecting reliable data and information on targets on the earth's surface. For this study, data from Landsat 5 and 8 satellites were used, which were interpreted through geographic location, size, pattern, shape, texture, color, tone, shadow, and reflectance values of objects on the earth's surface. The results reveal that the oil palm crop (Elaeis guineensis) has elements that facilitate the recognition of its features among the different targets present in the Microregion of Tomé Açu (MRGTA).

Keywords: Remote Sensing. Land Targets. Commercial Agriculture. African Oil Palm Plantation.

RESUMO: As técnicas de extrações de informações de alvos terrestres, com o uso de sensores remotos orbitais têm-se demonstrado como instrumentos estratégicos para a coleta dados e informações confiáveis de alvos na superfície terrestre. Para este estudo, utilizaram-se dados dos satélites Landsat 5 e 8, que foram interpretados por meio dos elementos de localização geográfica, tamanho, padrão, forma, textura, cor, tonalidade, sombra e valores de reflectância de objetos na superfície terrestre. Com os resultados, revela-se que a cultura do dendê (Elaeis guineenses) apresenta elementos que facilitam o reconhecimento de suas feições dentre os diferentes alvos presentes na Microrregião de Tomé Açu (MRGTA).

Palavras-chave: Sensoriamento Remoto; Alvos Terrestres; Agricultura Comercial; Palma Africana.

INTRODUCTION

With the advancement of collection instruments, the improvements in the techniques of Earth's surface target interpretations, with emphasis on Remote Sensing (RS), as well as the evolution of space programs and their orbital platforms, the Earth began to be revealed more intensely and on large-scale (FORMAGGIO; SANCHES, 2017; PONZONI; SHIMABUKURO; KUPLICH, 2007).

The increase in research, interpretation, quantification and mapping, through the use of RS, with the aim of studying events, phenomena and processes that occur on the surface of the planet Earth, from the registration and analysis of the interactions between the electromagnetic radiation, is linked to the development of photography and space research (NOVO, 1992).

In this context, satellite remote sensing systems for terrestrial observation, due to their high capacity to provide data quickly, repeatably and geographically, have an excellent potential to be associated with agricultural data collection systems (FORMAGGIO; SANCHES, 2017). The advantage lies in the fact that the images collected at the orbital level are available in digital format and can be processed using computers, which are able to highlight, segment and classify phenomena in geographic space, such as commercial agriculture areas (PONZONI et al., 2007).

Another advantage is the set of techniques for extracting information from targets on the planet's surface, through methodologies for the study and definition of shapes, dimensions and positions of objects in space, to deduce their significance, by using measurements obtained from raster images (ZAIDAN, 2008). Studies on this topic seek to understand the characterization and analysis of the elements of interpretation of terrestrial targets, such as: geographic location, size, pattern, color, texture and shadow in satellite images, which are mainly focused on the optical dimension, as well as the spectral behavior of land targets, supporting the preparation of thematic maps (FLORENZANO, 2007; FLORENZANO, 2016; SILVA, PALHETA, CASTRO, 2015).

The effort of interpreting and extracting information from orbital images is adequate and allows the collection of reliable information on several scales, assisting in the monitoring of impacts and the quantifications of biodiversity, landscapes and agricultural areas, as explained by Almeida et al. (2016) and Viçoso (2018). Thus, this work aims to use photoreading and photointerpretation techniques in order to identify the areas of cultivation of African oil palm in Tomé-Açu micro-region (MRGTA), in the Brazilian Amazon, which may serve as a methodology for the segmentation of oil palm crops in remote sensing images at different dates, as a reference for the application in other regions.

1 METHODOLOGY

The methodological approach comprised the use of multispectral remote sensor images, which were submitted to visual improvement by Digital Image Processing techniques (DIP) (FLORENZANO, 2002; FITZ, 2018) and integrated for spatial analysis in a Geographic Information System (GIS), through the OpenGis QGis 2.18® software. Also, at this moment, it was used Landsat images of 223 and 224 orbits and 61 and 62 points, for the years of 1988, 1995, 2004, 2010 and 2018, representing a 30-year temporal analysis. Datum SIRGAS 2000, UTM coordinates and zone 22 South parameters were established for these orbital images, which allowed the proper overlapping of the cartographic databases, in view of the proposed objectives.

The activities of interpreting orbital images involved the use of both visual interpretation keys method and spectral behavior of different remote sensing products for obtaining the definition of shape, size, pattern, texture, color, hue and spectral response of African oil palm (Elaeis guineenses).

The interpretation of the images was made based on the definition of objects, mapped area, choice of images, cloud coverage shorter period, selection of channels (bands), preliminary interpretation and field checking, as explained by Soares Filho (2000). The field work allowed the reambulation, that is, the in loco verification of the laboratory interpretations of the various natural and/or artificial features of the terrain.

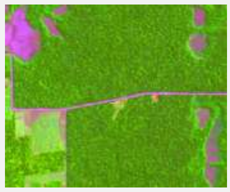
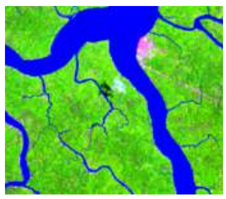
1.1 THE VISUAL INTERPRETATION OF AFRICAN OIL PALM PLANTATIONS IN ORBITAL IMAGES

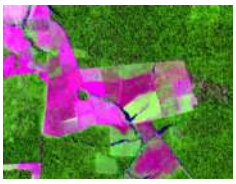
The first element of visual interpretation is related to understanding or familiarization with the interpreted region, called geographic location analysis. In the case of African oil palm cultivations, they were cultivated in the northeastern region of the Pará State, along BR-316, since 1956, in Mosqueiro, Santa Izabel and Castanhal municipalities, on degraded and/or altered areas, due to extensive livestock, represented by the great latifundia (HOMMA, 2016a).

From the 1980s onwards, the preferred regions for African oil palm plantation were in Tomé-Açu micro-region (MRGTA), after the losses of large extensions of African oil palm cultivations by Fatal Yellowing disorder (FY), in Acará, Concórdia do Pará, Moju, Tailândia and Tomé-Açu municipalities, on northeastern Pará, mainly through public and tax incentives (FURLAN JÚNIOR et al., 2006; NAHUM, 2013; HOMMA, 2016b). Thus, through the recognition of the historical context of the study area, it is possible to interpret and identify that the MRGTA represents the focus of African oil palm plantations in the region under analysis.

To continue the African oil palm fields identification process in orbital image, other interpretation elements were considered, such as: shape, size, pattern, texture and color. These elements are shown in Table 1, which describes the most typical interpretation elements for the extraction of information from surface targets via orbital images. With the support of these interpretation elements, it is possible to extract the orbital data and explain the information of the targets on the Earth's surface, such as the African oil palm cultivations in the MRGTA geographical space.

Table 1 – Interpretation elements for Landsat 8 Image, for B6, B5 and B4 RGB compositions

CLASSES		DESCRIPTION	LANDSAT IMAGE
African oil palm area (AOPA)		**Shape**: regular **Size**: **Pattern**: rectangular polygons **Texture**: plain **Color**: dark green with grey **Hue**: high	
Vegetation area (VA)		**Shape**: irregular **Size**: diverse **Pattern**: irregular **Texture**: wrinkled **Color**: light green **Hue**: high	
Water body (WB)	**Rivers**	**Shape**: irregular **Size**: diverse **Pattern**: irregular **Texture**: plain **Color**: blue **Hue**: high	
	Foodplain area	**Shape**: irregular **Size**: diverse **Pattern**: polygonal with watercourses **Texture**: marbled wrinkle **Color**: light green **Hue**: low	

	Lake	**Shape**: irregular **Size**: diverse **Pattern**: polygonal with watercourses **Texture**: plain **Color**: dark blue **Hue**: low	
Exposed soil/Pasture (ESP)	**Anthropic area**	**Shape**: regular **Size**: diverse **Pattern**: polygonal **Texture**: wrinkled with a regular and systematic pattern **Color**: pink **Hue**: medium and high	
	Pasture area	**Shape**: regular and irregular **Size**: diverse **Pattern**: polygonal **Texture**: plain **Color**: magenta **Hue**: low	
	Natural fields	**Shape**: irregular **Size**: diverse **Pattern**: polygonal with watercourses **Texture**: plain **Color**: purple	

Source: made by the authors from Lisboa (2015).

From the data of shape element, it is possible to categorize land surface targets into regular and irregular. In the case of African oil palm areas (AOPA), it is identified that they have a regular aspect, because these crops have a polygonal profile, unlike other categories, such as rivers, lakes and vegetation (forests) that have irregular shapes.

In the Landsat OLI/8 image (at Figure 1), it is possible to see the differences between regular and irregular shapes of Earth's surface targets. River courses and riparian forests are the main irregular targets, while vegetation areas, roads and African oil palm fields present regular forms. African oil palm cultivations, which are considered as an anthropic intervention, usually have regular and rectilinear configurations, due to the flat polygonal physiognomy, with the presence of right angles, easily perceptible to human eyes, as shown in Figures 1A and 1C.

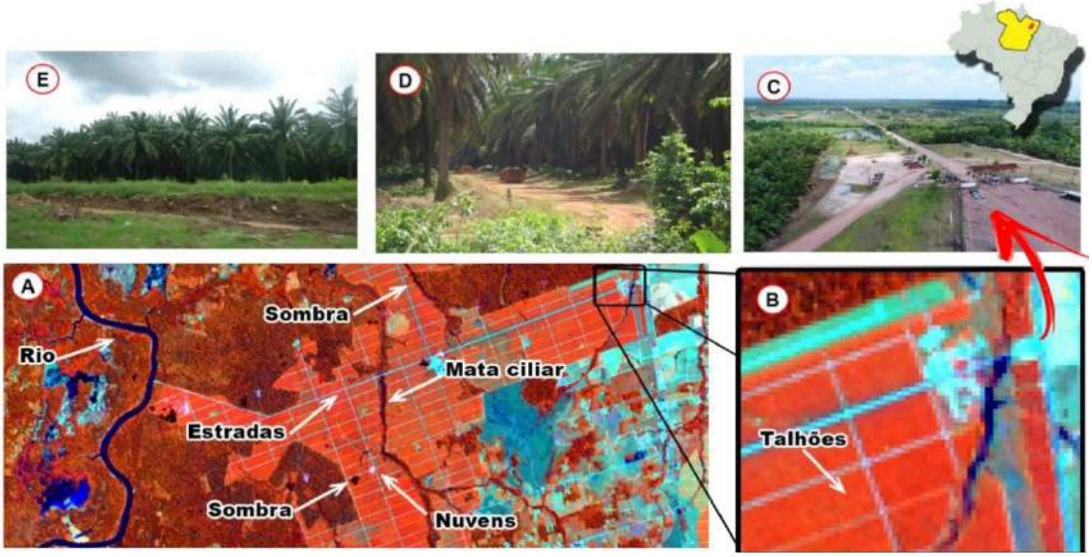
Another important element in the interpretation of the targets of RS orbital images is the size of the objects. It corresponds to the relationship between the dimensions of the regular or irregular shapes of the targets (VENEZIANI; ANJOS, 1982). The size of African oil palm areas is revealed by the extension of the regular polygons on the Landsat images (2018), which correspond to the individualization of this commercial agriculture that was reduced in the orbital image. These cultivations are individualized by their large regular polygons, according to Figure 1B.

The African oil palm crops are individualized by the patterns of the corridors that are formed by the branches and roads of the cultivation region (Figure 1D). That is to say that the spatial distribution of these parallel traces on Earth’s surface, which are imaged by the orbital sensors, are used to individualize the planting polygons (Figures 1B and 1D), since these pathways are built to serve as road axes within this micro-region, in which circulate buses, workers, machinery, as well as all the production.

It is also possible to indicate the African oil palm growing regions by means of the shade, which comes from the relief, the difference of the palm canopies, the vegetation or the clouds. However, this element can also hinder the characterization of these plantations on the Earth’s surface, because, according to Costa (2010); Formaggio and Sanches (2017) dark regions in the orbital images can hide the targets. Formaggio and Sanches (2017) clarify that, depending on the shape (regular or irregular) of the shadow on the image, it may be or may be not to favor differentiations on the terrestrial targets, such as the shading space generated from the limit of African oil palms crops with the forest, as well as the riparian forests, which have their edges highlighted by the shadow element, as shown in Figure 1A.

Regarding the texture element, it is possible to establish and relate aspects of the plain or wrinkled surface of the targets (TEMBA, 2000). Thus, in the oil palm canopies formation, it is observed the predominance of the plain textures that is quite different from the wrinkled appearance of the plant roofs, such as the forest areas, which presents an irregular aspect (Figures 1A and 1B). In this sense, it is possible to see in Figure 1 the differences of plains and wrinkled textures in the identified targets, since forest regions are wrinkled and African oil palm areas have a smooth, plain aspect, in addition to their parallel, square and crosslinked street patterns. The drainage network also presents a plain appearance in orbital images.

Figure 1 – (1A and 1B) A false RGB 564 color composition of a 2017 OLI/Landsat 8 image; (1C, 1D and E) three different targets



Source: made by the author (2018).

Finally, the color element presents itself as a very important aspect in the individualization of the targets, because the color composition, which can be false or true, it can enhance the targets, facilitating their recognition, when allied to shape, size, pattern, shadow and texture elements. The union of all visual interpretation elements of orbital images favors the recognition of the African oil palm plantations.

2 THE ESPECTRAL INTERPRETATION OF AFRICAN OIL PALM CROPS IN ORBITAL IMAGES

A very important instrument for extracting information from remote sensors products is based on the reflectance behavior of each target in different Electromagnetic Spectrum Regions (ESR) that come from the Sun (PONZONI; SHIMABUKURO; KUPLICH (2007); JENSEN, 2009).

In this context, it is emphasized that the orbital platforms capture the information of terrestrial targets, through spectral bands, in which each type of target (each type of material) has a specific behavior of reflectance, absorption and transmittance, within the electromagnetic spectrum, according to their own characteristics, especially when they are exposed to the sun. It makes them to reflect, absorb or let the energy take over their structure, due to their particularities and physical conditions of the sensing time, and this behavior is subsequently converted into Digital Numbers (DN), as explained by Formaggio and Sanches (2017). In this way, tonality, color and spectral response are directly related to the comportment of the solar energy reflectance from Earth's surface, which will be captured by the satellite sensor at the moment of its interaction with the targets (PONZONI, 2007).

The base of the spectral interpretation process of terrestrial targets by remote sensing images is the relationship between the behavior of the imaged object with the visible range of the electromagnetic spectrum available in bands of the orbital sensor, as explained by Moraes (2002). After capturing the solar energy reflectance of the targets, the orbital sensor (usually in the optical spectrum) makes up a grayscale image that corresponds to the ratio between the radiation flux that hits the target and radiation flux that is reflected by it, which composes the optical sensor image (ROSOT, 2001).

The energy (light) captured by the orbital sensor corresponds to variations in shades of gray that compose the ESR image in different bands. Thus, the more reflected energy, the more the target tends to have white color and the reverse will be projected in the dark color, mainly due to the absorption and / or transmission of ESR from terrestrial targets, as explained by Rudorff, Moreira and Alves (2002) and Liu (2006). In this sense, the first element of spectral interpretation of the African oil palm crops in orbital images is given by the values of the spectral response, representing the tone of the targets in the image. In other words, the intensity of electromagnetic energy (ESR) reflected by a target in the different bands of the orbital sensor provides the greater individualization of the targets, considering their spectral signature captured by the satellite imagers, which Meneses and Almeida (2012) define as target's tonality considering the different shades of gray available on the sensor bands.

As an example, it is possible to identify the different gray grades of the African oil palm plots in Figure 2A, through the near infrared tonality element (band 5) of OLI/Landsat 8 sensor. In the green arrow, the light gray shades are projected on the African oil palm groves with more vegetative strength. Still in the tonality targeting process, the rivers (the red arrow in Figure 2A) appear in black color, due to the absorption of solar energy, and the areas with no vegetation, as exposed soil, appear in intermediate gray (blue arrow) because of the low reflectance.

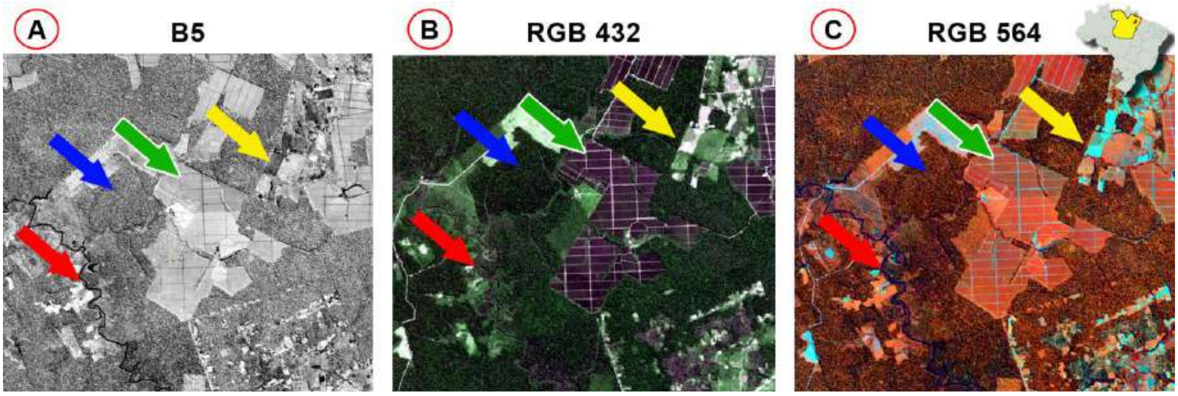
Thus, tonality become a key element for the interpretation of the behavior of agricultural targets, such as the African oil palm, which are seen in different gray shades, according to the electromagnetic spectrum (band) available in the sensor (FORMAGGIO; SANCHES, 2017). However, for a better interpretation of the African palm plantation areas it is necessary the aid of the color.

The color is a form of interpretation of targets by joining different spectral bands in three color channels (Red, Green and Blue) to construct a color image, as shown in Figures 2B and 2C. The difference of Earth's surface targets is most evident when the interpretation is performed based on a color composition, rather than a gray scale image. According to Formaggio and Sanches (2017), in addition to aggregating information from different bands, the advantage of the color image is that the human eye distinguishes more targets in color than in gray levels.

There are two types of color composition for orbital optical sensors images, false-color and true-color. In the first type, three-channel specific bands are established with the colors red, green and blue, forming the images with painted colors, making it possible its interpretation by the human vision, according to Figure 2C. In Figure 2B, the true-color composition gives natural colors to the targets, such as forest areas (blue arrow), African oil palm cultivations (green arrow) and rural properties (yellow arrow). Comparing these two images, the targets in Figure 2C assume unnatural colors, which are important to highlight relevant aspects on each target or material in Landsat scene, nevertheless (LIU; MASON, 2013).

The interpretation of agricultural targets in scenes like these is usually made by the use of false-color composition type, according to Figure 2C (NOVO, 1992; FORMAGGIO; SANCHES, 2017). The choice of this composition is justified by the fact that agricultural targets are easily differentiated in this composition, in which red shades (green arrow) (Figure 2C) enhance the African oil palms better, instead of green tones. In addition to the prominence given to objects, the false-color compositions highlights physiological elements of vegetation, such as the vegetative vigor, as mentioned by Lillesand, Kiefer and Chipman (2014) and Formaggio and Sanches (2017).

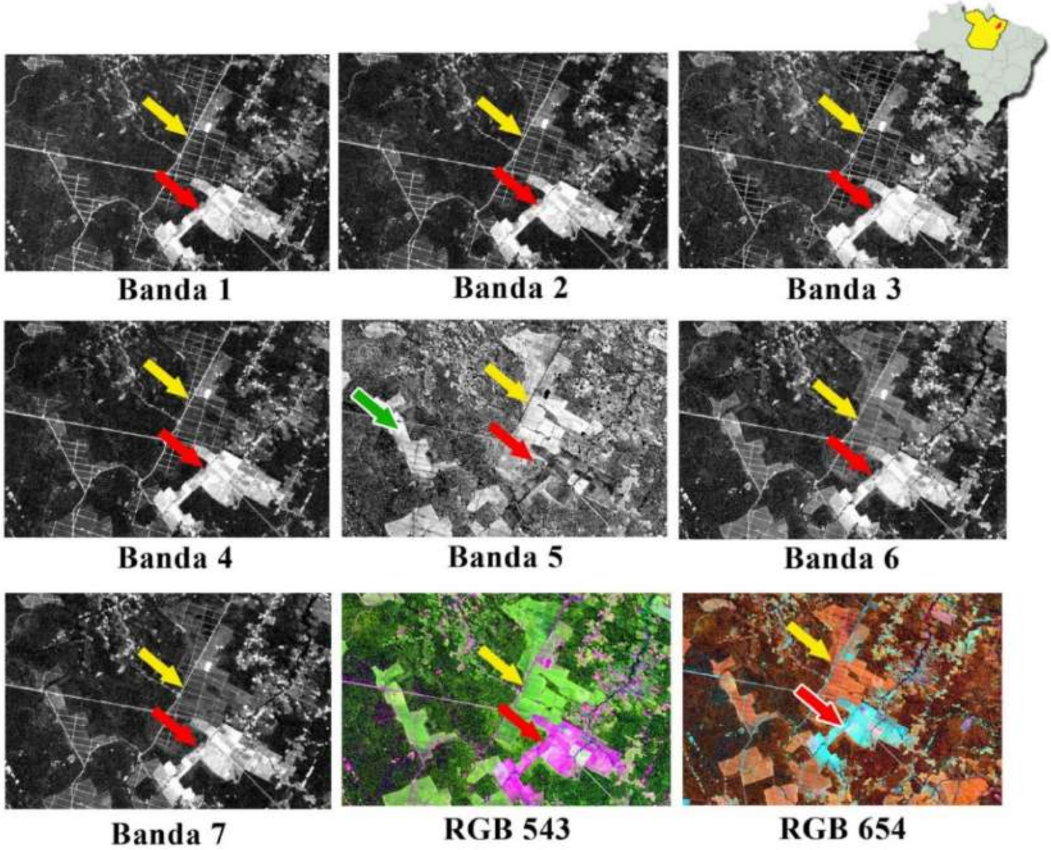
Figure 2 – Comparison of 2018 Landsat 8 images in band 5 (NIR) (2A), RGB 432 (true-color) (2B) and RGB 564 (false-color) (2C) of the same African oil palm cultivation in Tomé-Açu micro-region



Source: made by the author (2018).

Also, according to the authors, spaces with less vegetation generally have lighter pixels, as seen in Figure 3, in which the yellow arrow identifies African palm oil cultivation plots in dark colors, with the exception of band 5. The dark colors come from the chlorophyll and water absorbed by the African oil palm leaves and vegetation in general, as explained by Rudorff, Moreira and Alves (2002) and Shimabukuro and Ponzoni (2017). In the band 5 (near infrared), the green leaves of the African palm crops have high values of reflectance, corresponding to lighter tones, which are also associated to the planting in rows that allow a greater reflectance, high transmittance and low absorption, as explained by Hoffer apud Formaggio and Sanches (2017).

Figure 3 – Cutouts of 2018 Landsat 8 images (223/61) at the bands 1, 2, 3, 4, 5, 6, 7 and RGB 543 and RGB 654 color compositions



Source: made by the authors (2018)

The Figure 3 shows grayscale monochrome cutouts of the bands of OLI/Landsat 8 satellite. It is observed that the clearest places have, at least in theory, little or no vegetation cover (red arrow) while African oil palm cultivation areas are darker, as they have a higher coverage rate, in this case with chlorophyll, which absorbs the ESR, causing the greater brightness in the grayscale.

In the same figure, the RGB 654 composition (false-color) highlights the healthy vegetation in shades of red. This composition gave the best evidences of African oil palm cultivation areas, being commonly used for agricultural studies (FORMAGGIO; SANCHES, 2017). However, the great difficulty in interpreting the spectral behavior of these crops (color variations) was due to age differences or phenological phases of this cultivar, which should appear at different levels of gray in the optical image. That is, the development stage of the plants interferes with the levels of radiation penetration in the canopies and, therefore, in the color composition, like in the red scale, which becomes darker in the images, corresponding to a larger or a higher canopy vegetation, as in the forest that surrounds the African oil palm plantations.

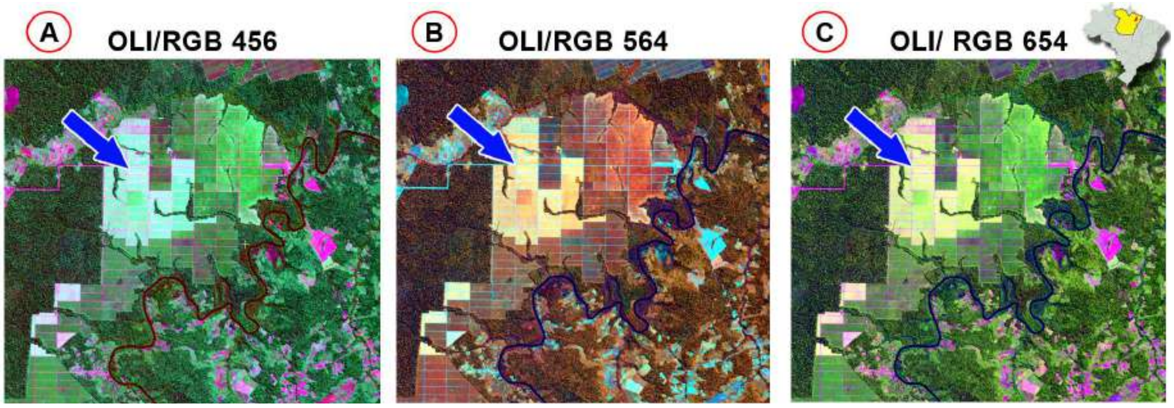
In addition to the African oil palm plots being highlighted differently in the false-color composition (blue arrows on Figure 4), it is possible to identify in a singular way the hydrography, forest, rural spaces, exposed soil, riparian forest and shadows. In the RGB 564 false color composition (Figure 6B), the African oil palm crops assume red color, corresponding to a full vegetative vigor region, as stated by Gitau et al. (2009) and Cordeiro et al. (2009).

The different colors of the rectangular polygons of the African oil palm areas are also associated with the ESR energy levels reflected by the targets in the 11 bands of the OLI/Landsat 8 images, which, according to Nascimento and De Abreu (2012), corresponds, again, to the active photosynthetic vigor of the oil palm cultivations, as well as their ages, heights, cultivation practices, among other factors, such as irrigation, healthy versus infected areas, as stated by Ponzoni and Shimabukuro (2017).

The chemical, physical and biological properties of the soil influence the color differences of the orbital images (CREPANI et al., 2001). Ponzoni et al. (2007) emphasize that the plant cover appearance in remote sensing products are also the result of complex processes involving environmental factors, allowing different color levels, which can enhance or hide the shapes of the targets, in the same way as the biophysical characteristics that compose them.

In Figure 4, it can be seeing the three-color compositions of Agropalma oil palm plantations (two false-color type and one true-color), in which it is possible to observe the East-West orientation of their rectilinear plots, showing the roads and vicinal paths between the polygons, as well as an anomaly that is evidenced by the color compositions, which may be due to water stress, biomass difference, crop productivity, plant vigor and/or phenological stage.

Figure 4 – Three false-color compositions of a 2018 OLI/Landsat 8 image (RGB 456 (4A); RGB 564 (4B) and RGB 654 (4C) from the same African oil palm cultivation area in the Tomé-Açu micro-region



Source: made by the authors (2018).

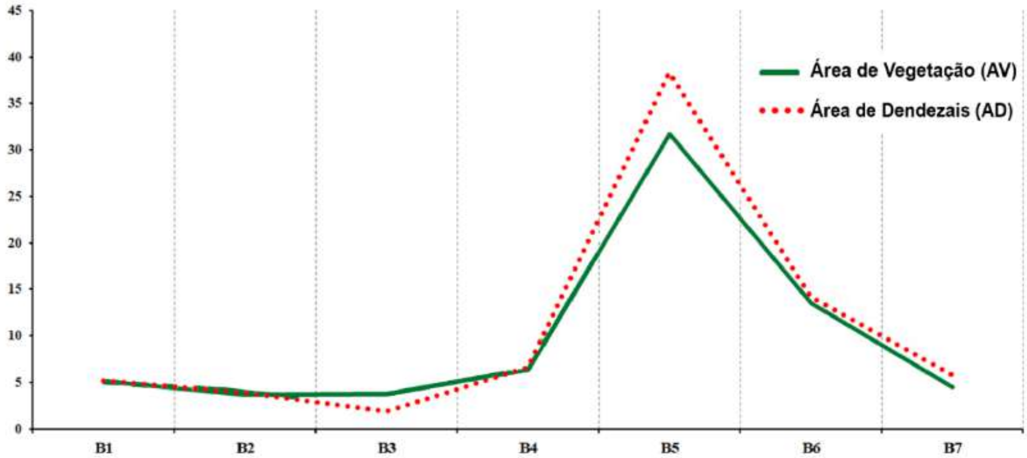
In this way, remote sensing represents a potential technology for the study of agriculture, the valuation of biophysical parameters, through the conversion of gray scales (Digital Numbers – DN) for radiance and later reflectance, by using calibration coefficients (FORMAGGIO; SANCHES, 2017). However, Ponzoni et al. (2007) state that it is necessary to convert the Digital Numbers into surface Bidirectional Reflectance Factors (BRF) or physical values to obtain the spectral characterization of the targets on the Earth's surface.

In order to analyze the African oil palm vegetation behavior on ESR bands, it was necessary to convert the DN into FRB, for the better characterization of the various Earth's Land Use and Land Cover (LCLU). The spectral response analysis of Tomé-Açu micro-region targets was fundamental to distinguish African oil palm, Vegetation and Exposed Soil/Pasture areas, considering some parameters, such as the numerical contribution of DA with regard to the values measured for Vegetation class, whose spectral responses in the band 5 were lower when compared to the other classes (Graphic 1). Thus, Vegetation and Exposed Soil/Pasture classes present similarities between their curves, which can be attributed to the greater amount of green leaves, responsible for the increase in the incidental radiation absorption and the consequent decrease in the radiation reflectance.

This work analyzed only the spectral behavior of homogeneous canopies structures (African oil palm plantation areas). so it was verified that the BRF values in near infrared region (band 5) are higher than in red (band 3), corresponding to the palm trees foliage, which presents a higher ESR reflectance, as explained by Ponzoni et al. (2007). The authors also clarify that the more the ground is exposed to the sun, such as the Exposed Soil/Pasture class, the higher are the ESR reflectance values in the visible region (bands 2, 3 and 4).

Comparing the positioning of the native vegetation (the green curve on Graphic 1) and African oil palm cultivation curves (the red curve), it is observed a certain similarity because these targets have high presence of active photosynthetic biomass, which is different for ESP targets that have higher surface reflectance values in the first four bands, due to the absence of vegetation cover, which will provide higher ESR values to the optical sensor, as Venturieri and Santos (1998) and Ponzoni, Shimabukuro and Kuplich (2102) state.

Graphic 1 – Land surface reflectance values for Vegetation and African oil palm classes, extracted from 223/61 2018 Landsat 8 image specific pixels



Source: made by the authors (2018).

In the study of the spectral behavior of vegetative cycle structures, such as the African oil palm cultivation, it is observed that the higher the canopy, the higher the absorption level, which is represented by the drop of the spectral response curve and the stronger gray tones (the band 3 on Graphic 1).

The absorption is related to the chlorophyll leaf area, which results in the reduction of the spectral response and thus the dimming of the target in the satellite image (FORMAGGIO; SANCHES, 2007), Exposed soil/pasture areas, in which the developed activities have been cause changes in natural vegetation, present an increase in spectral response.

3 INTERPRETATION OF AFRICAN OIL PALM CULTIVATION DYNAMICS IN MRGTA

As already mentioned, by using the appropriate visual interpretation methodology, it is possible to define targets shape, drainage patterns and agricultural crops from the vegetation characteristics, land use types, etc., since the shape, size, pattern and texture features of the targets can describe the geometry, spatial distribution and granulation (average size of the texture element) of the objects, which are directly proportional to the scale and representation of the study (SOARES FILHO, 2000).

In the case of African oil palm plantation areas, which have regular shape, plain granulation and rectangular size and pattern, the interpretation keys method is based on the comparative analysis between different orbital images of the same region. To this end, the African oil palm interpretation study should be guided by the use of different acquisition dates images, associating and ordering their parts by features comparison and/or by grouping similar regions, known as homologous zones (Borges, 1999). Thus, African oil palm crops are considered as Homologous Zones (HZ), since they are constituted by the repetition of texture elements, which have similar properties and the same structure (SOARES FILHO et al., 1993).

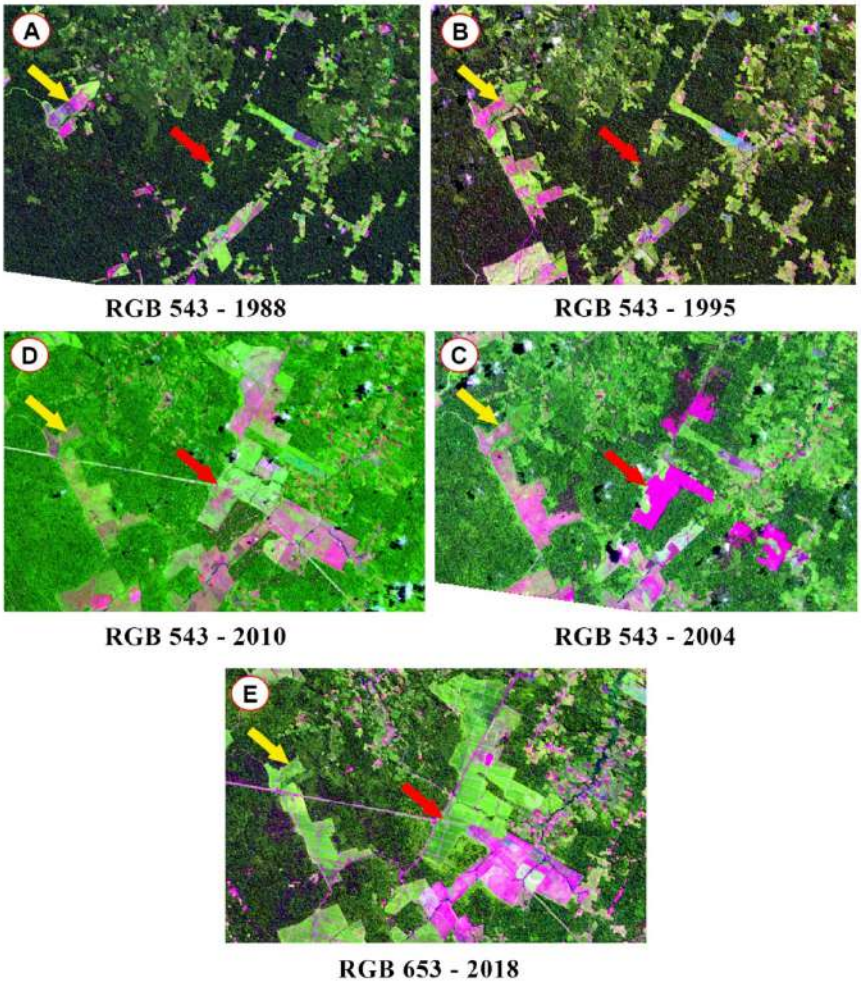
The Figure 5 shows a 30-year Landsat images set, which reveal the occupation and land use dynamics in the area under analysis, especially the African oil palm areas, through successive subtractions and additions of landscape elements (forest, pasture and oil palm). In Tomé-Açu micro-region, the successive subtractions dynamics, mainly from native vegetation (Figures 5A, 5B, 5C and 5D), resulted from the creation of grasslands (agricultural frontier) and, later, the additions and substitutions of the pastures by the African oil palm (biodiesel frontier – Figures 5D and 5E), generally favored by the political, strategic and economic conditions of the time of occurrence, determining the Polamazonic’s organization and economic functionality (PINTO, 1977).

The red arrow in Figure 5 points out both subtraction and addition dynamics of vegetation over decades, mainly by the addition of easy commercialization perennial crops, such as eucalyptus and African oil palm (Figure 5E), that is, the red arrow shows the dynamics of the landscape events in the region, like scars (landscape marks), such as the timber extraction, which triggered exploitation/degradation processes caused by fire/tillage/charcoal/pasture land use sequence, brought by the advance of the agricultural frontier in this region in the 1970s and 1980s (Figures 5A, 5B and 5C) (BECKER, 1997; 2009).

Also, the red arrow in Figure 5E points out the mark of the African oil palm culture in the landscape, which can be described and inventoried, as explained by Becker (1997). Figures 5D and 5E depicts some of the brands that invested in the Amazon, which according to Pinto (1977), represent the government's preference in the agribusiness sectors, reinforcing the economic dynamics thought for this space, in order to try to sustain its development, such as the National Biodiesel Production and Use Program (Programa Nacional de Produção e Uso de Biodiesel) (2004) and the African Palm Oil Sustainable Production Program (Programa de Produção Sustentável de Óleo de Palma) (2010) (FURLAN JÚNIOR et al., 2006).

Thus, all the arrows of Figure 5 reveal deforestation marks, due to the large agricultural projects that were implanted in the region (red arrows for eucalyptus and yellow arrows for African oil palm). In those images, the yellow arrows also show the unproductive regions that were abandoned after an economic cycle. However, with the attention of the State, these lands became available to be bought or leased for biodiesel production, as occurred in Tailândia municipality, in which the first palm oil monoculture occupations took place, through Amazon Refining Company (Companhia Refinadora da Amazônia – CRAI) and Reforestation of the Amazon Co. (Reflorestadora da Amazônia S.A. – REASA), replacing the forest that was later occupied by pasture areas and/or abandoned fields, as observed by Homma and Vieira (2012).

Figure 5 – MRGTA's African oil palm cultivations occupation dynamics over 30 years



Source: made by the authors (2018)

Thus, by the comprehension of the orbital images of African oil palm crops, it is possible to analyze the occupation dynamics of the MRGTA, since the first one conceives the marks in the landscape and the second, their fragments (matrix) (VERDUM; PUNTEL, 2010). As Verdum et al. (2012) explain, the scenario change is perceived by the description of the quantifiable targets, while the matrices participate the actions and relations of society with space and nature and its fragments, considering the continuous modifications on the spaces in periods and/or intervals that lead to a renewal of the panorama and its functioning.

CONSIDERATIONS

The interpretation study of African oil palm plantation areas by the use of remote sensors images required training and familiarization with terrestrial targets, in order to enable the meaning attribution process to every single imaged object. Thus, the geographical location elements, such as shape, size, texture, pattern, shade, tonality, color, as well as the spectral response aspects, made possible the production of interpretation keys for the agricultural plots of the African oil palm whose areas were four times larger than the 30-meter spatial resolution of the analyzed images.

From the phases of visual interpretation and African oil palm spaces spectral behavior recognition through orbital sensor images, it was possible to obtain many contributions and applications on the landscape dynamics, resulting from the growth of this cultivar, in addition to the mapping of cultivation areas, identification of the development stage or planting time, estimation of biomass and productivity, plotting of water stress and disturbances, visualization of planting patterns and production system, expansion of monitoring activities, among others.

Remote sensing in MRGTA’s African oil palm culture enabled the visual interpretation and recognition of the spectral behavior of this cultivar in the analyzed images, improving the information access for the comprehension of the surface features of that area and facilitating their automatic classification and later segmentation and extraction of African oil palm spatial class, considering the large dimensions of the this territory in the landscape of the area under analysis.

The study of both remote sensor images interpretation techniques and land use occupation dynamics of the African oil palm fields broadened the understanding of these landscape units and enabled the elucidation of land use transformations in Tomé-Açu micro-region. However, it is suggested an analysis of the public plans and policies that made possible the rapid expansion of large palm oil-harvesting companies and small-scale farmers, who now work as employees of these companies in the planting of new African oil palm plantations, representing a differentiated view of the spatial dimension of this agribusiness activity.

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