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ORIGINAL ARTICLE – Forest Management

Spectral Evaluation of Cocoa: A Methodological Proposal for its Management and Application of the Cabruca Decree

Pedro Jeronimo de Carvalho Neves Cavalcante[1]
Roberto Ferreira Machado Michel[1]
Maurício Santana Moreau[1]
Arlicélio de Queiroz Paiva[1]
Rafael Henrique de Freitas Noronha[2]
Tássio Moreira Silva[3]

[1]Universidade Estadual de Santa Cruz (UESC), Departamento de Ciências Agrárias e Ambientais, Ilhéus, BA, Brasil.
[2]Universidade Federal do Sul da Bahia (UFSB), Centro de Formação em Ciências e Tecnologias Agroflorestais, Ilhéus, BA, Brasil.
[3]Universidade Federal de Minas Gerais (UFMG), Instituto de Geociências, Belo Horizonte, MG, Brasil.

Abstract

The cocoa cabruca is as an agroforestry system with a density of trees equal to or greater than twenty individuals of native species per hectare cultivated in association with native or exotic trees in a discontinuous and random way in the Atlantic Forest biome.It is difficult to separate areas of cabruca cacao from the Dense Ombrophilous Forest by existing satellite imaging techniques.The study was developed in the southern region of Bahia, on two properties in the municipalities of Ilhéus and Uruçuca.The image processing methodology involved the Agisoft Photoscan software, with the multiresolution algorithm, the analysis of digital image data was performed to extract the objects and with the Feature Space Optimization tool, the set of variables that presented the best separation between land use classes.The use of UAVs was effective in classifying the mapped areas, and its use was proposed as an auxiliary tool in the application of the Decree.

Keywords: Agroforestry system, Cabruca cocoa, Atlantic Forest, Remote sensing.

1. INTRODUCTION AND OBJECTIVES

The Atlantic Forest biome is largely composed of the incident Dense Ombrophilous Forest, predominantly on the Brazilian coast. It is characterized by the entanglement of biotic aspects and the abundance of phytophysiognomies mainly due to aspects related to the variation in rainfall, topography, geology and soils.

Among the biomes, the Atlantic Forest is currently considered the most threatened due to its critical condition – around 70% of the population is concentrated at the Brazilian coast and a significant portion of Brazil's biological diversity, with extremely high levels of endemism (Iesb, 2007).

Despite this degradation scenario, the southern region of Bahia has the highest biodiversity indices in the country, with up to 456 tree species recorded in one hectare (Araujo et al., 1998). About 70% of the Atlantic forest where these native trees are concentrated are located on properties managed under the traditional shaded cocoa planting system, known as "cabruca".

As an ombrophilous species, originating from the understory of the Amazon Forest, cocoa (Theobroma cacao) was traditionally cultivated in Agroforestry Systems (SAFs). These SAFs shelter trees that serve as shade for cocoa trees, attenuating fluctuations in air temperature and humidity, and providing important products such as wood, firewood, fruits, resins, in addition to environmental services such as biodiversity conservation, soil protection against erosion and carbon sequestration (Somarriba & Beer, 2010).

In the last two decades, the sustainability of cocoa crops in SAFs has been severely affected in the region by the drastic drop in productivity mainly attributed to the attack on cocoa trees by the witches' broom disease, caused by the fungus Moniliophtora perniciosa, and by the reduction in market prices international (Trevizam & Marques, 2002; Ramos & Martins, 2007).

In this scenario the area of cabruca was reduced, being replaced by more profitable agricultural activities, but less sustainable from a socio-environmental point of view, such as the cultivation of peach palm, coffee and pasture (Piasentin & Saito, 2012).

As of 2010, the debate on forest management of cabrucas and even their conversion to other uses has grown a lot, considering that many of these areas are outside the legal reserve and permanent preservation areas, not having, under the law, difference between the cultivated areas and the forest, its exploitation being limited by law nº 11.428, of December 22, 2006, which governs activities in the Atlantic Forest biome.

This scenario motivated the creation of a specific state decree (Decree No. 15180 of 06/02/2014) with the objective of defining goals for the conservation of native vegetation, protecting permanent preservation areas - special procedure for properties that practice family farming and regularization of the Legal Reserve, upon compensation for easements.

The decree is based on Federal Law Nº. 12,651 of May 25, 2012 which establish general rules on the protection of native vegetation, Permanent Preservation Areas and Legal Reserve areas; forest exploitation, the supply of forest raw material, control of the origin of forest products and the control and prevention of forest fires, the Environmental Regularization Program - PRA and creates the Rural Environmental Registry - CAR; and Federal Law No. 11,428, of December 22, 2006, which provides for the use and protection of native vegetation in the Atlantic Forest Biome.

As decree, 15.180/2014 addresses general issues about forest management in the State of Bahia, the State Secretariat for the Environment (Sema) and the Institute for the Environment and Water Resources (Inema) organized the Joint Ordinance Sema/Inema No. 03 of April 16, 2019, which provides for the methodologies for granting the Cabruca Management Authorization – AMC.

In order to assist the application of the cabruca Decree, the document updates the 2015 ordinance on AMC, and judge's broad participation of interested actors. The application of the decree, however, represents a challenge in several aspects. Notably, the separation of different management systems conceptualized as cabruca, the quantification and identification of different native species present in the area.

In relation to use of RPA to support the application of Decree 15.180/2014, there is great difficulty and wide confusion in the mappings that try to differentiate cabruca from dense rainforest, using remote sensing techniques with medium spatial resolution images, since the spectral signature of cabruca incorporates characteristics of the Dense Ombrophilous Forest.

In this sense, high-resolution remote sensing on board small autonomous aircraft brings the possibility of a detailed assessment of the landscape, bringing new information that can support decision-making.

The objective of this work was to evaluate the efficiency of using different UAVs and high-resolution cameras in the zoning of two cocoa producing properties in the cabruca system. The specific objective is access the viability of using UAV and cameras to obtain the separation of different land uses against a variety of sensors available on the market and characterize the spectral response of cocoa cabruca, as well as the possibility of using these tools in the assessment of properties and in the preparation of a proposal to assist the forest management plan regarding the applicability of Decree No. 15180 of (06/02/2014).

2. MATERIALS AND METHODS

2.1. Study Area

The study was carried out in the southern region of Bahia, as shown in Figure 1, where, according to Köppen and Geiger, the climate is tropical, classified as Af. 24.5 ºC average temperature with average annual rainfall of 1946 mm per year, relief varies from soft to strong wavy and the predominant vegetation is the Atlantic Forest (Seasonal Semideciduous Forest), the soil cultivated with cocoa includes the classes Argisol, Gleysol, Cambisol and Oxisol.

The first study area at Farm Chácara das Sucupiras, in Figure 2, is located in the municipality of Ilhéus, in the district of Banco da Vitória, near the coordinates 14º 50' 55"S ;39º 06' 00"W . The property has a strong undulating terrain, in a total area of 20 ha, has been cultivated by the current owner for 20 years, having undergone a change from the predominant use of pasture to the current cabruca cocoa system 10 years ago.

The second property, Farm Santa Tereza, in Figure 3, is in the municipality of Uruçuca, in the district of Serra Grande around the geographic coordinate 14º 26' 46"S 39º 03' 00"W. The property has a total area of 34 ha; the relief is characterized as strong wavy, being cultivated in the organic agriculture system.

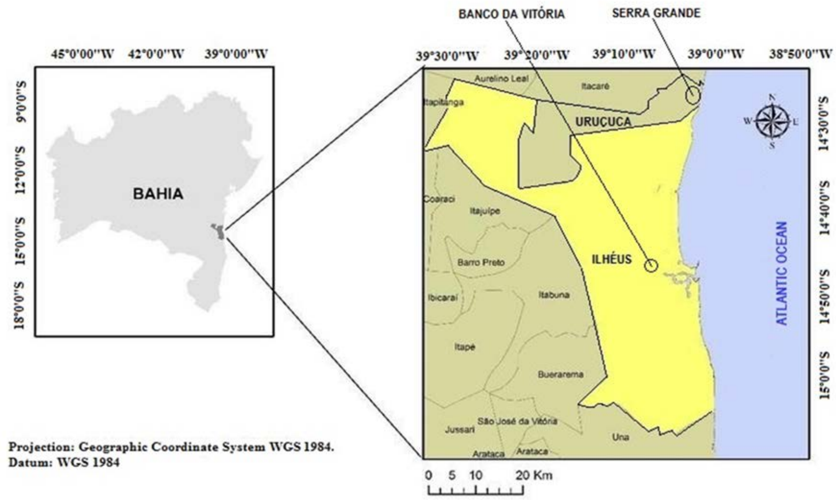

Figure 1. Study area in the Southern Region of Bahia.

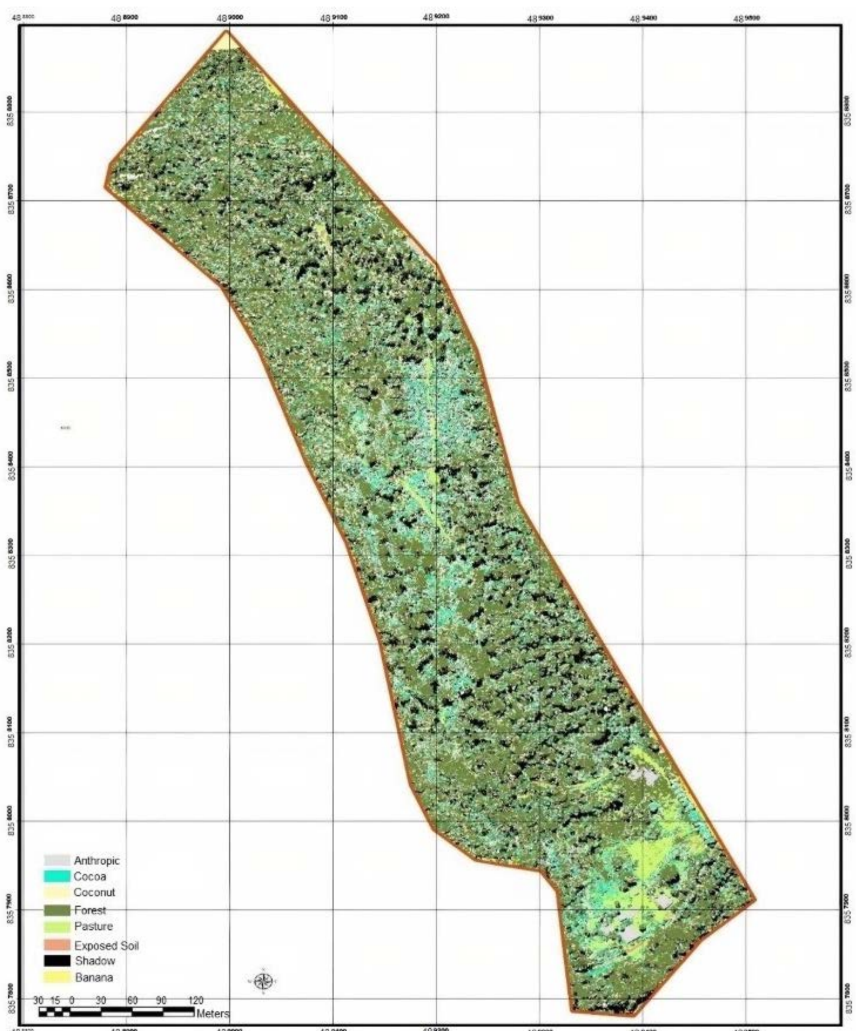

Figure 2. Farm Chácara das Sucupiras.

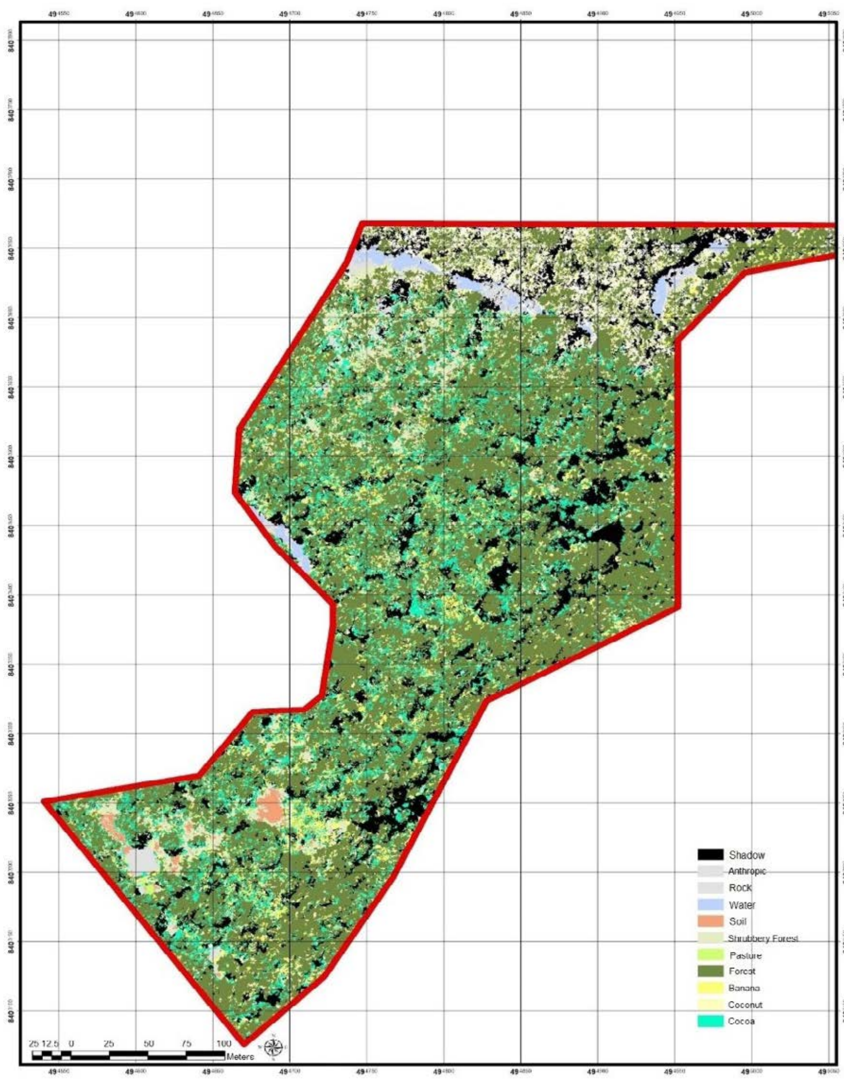

Figure 3. Farm Santa Tereza.

2.2. Materials

The study was conducted using two UAVs from the manufacturer Dà-Jiãng Innovations (DJI), models Phantom4 Pro and MavicPro, to which 3 different camera models from the manufacturer Mapir to were coupled RGN (Red, Green, Near Infrared), NGB (Near Infrared, Green, Blue), OCN (Orange, Cyan Blue).

To carry out the flights, software provided by the company Dà-Jiãng Innovations "DJI" was used and the etrex30 satellite signal receiver was used in field sampling.

For planning and carrying out the flights, the MapPilotBusiness 4.0.8 software and the Agisoft application were used to assemble the mosaic from the georeferenced images. For segmentation and classification of the mosaic, the software ecognition was chosen.

2.3. Methods

The entire proposed methodology for characterizing the spectral response of different land uses, including the form of image capture and processing, was carefully considered as they alter the final result.

In order for the properties to be classified as a cabruca agroforestry system, a forest inventory was carried out in the manner required by the decree (15.180/2014).

2.4. Mapping of agricultural areas

To map the agricultural areas, two complete area surveys were carried out at an altitude of 120 m above the ground, on the dates and with the equipment described in Table 1, allowing the perception of objects up to 5 cm in size.

Aerial surveys were designed in line mode with a high overlap (75%) between adjacent images (side and front) to provide a greater number of views to the same point.

The area surveyed in each individual flight, conditioned by the battery life, is about 25 ha and contains about 250 images. The individual images were processed with Agisoft Photoscan software to create orthorectified image mosaics and digital elevation models (DEM) based on the technique of transforming features by SIFT scale invariant and SfM-Motion Structure.

The generated point clouds were filtered considering minimum quality parameters suggested by the post-processing guide of the American Geological Survey Service (USGS, 2016). The images from the different sensors were georeferenced based on the Drone's RGB image.

The classification involved segmenting the image into objects, sets of "pixels" with similar spectral response. The algorithm used was multiresolution. The disparity achieved between the objects was determined by three parameters. The Scale, which is linked to the final size of objects (linked to the minimum mappable area or final scale of publication), increasing this value decreases the number of objects identified. The Shape, which is linked to the weight of the shape in relation to the spectral response of the object and the third is linked to the degree of similarity between the objects. Segmentation was performed considering the R, G, B bands, parameters 55 were used for the scale, 0.2 for the shape, 0.8 for the spectral response and 0.9 for the uniformity of the object (compactness).

In the ranking process, the ranking algorithm chosen was the nearest neighbor. Forty-five variables were tested for each flight, including the bands used in segmentation (RGB); the mapir camera bands included in this flight (RGN/NGB on flight 1, OCN/NGB on flight 2). For the first flight, the Atmosphere Resistant Index in the Visible Region VARI, Normalized Difference Vegetation Index NDVI, ENDVI, NDVI_Green and NDVI_Blue indexes were generated, on the second flight the VARI, ENDVI, NDVI_Green and NDVI_Blue, and NDVI Ciano indexes were generated.

Table 1. Flight dates, UAVs and cameras used on each farm.

Farm Chácara das Sucupiras							
August 2018				April 2019			
UAV	CAMERAS			UAV	CAMERAS		
Phantom Pro	RGB	RGN	NGB	Mavic Pro	RGB	NGB	OCN
Farm Santa Tereza							
September 2018				**April 2019**			
UAV	**CAMERAS**			**UAV**	**CAMERAS**		
Phantom Pro	RGB	RGN	NGB	Mavic Pro	RGB	NGB	OCN

With the Feature Space Optimization tool, the set of variables that presented the best separation between the classes was defined. Classes that are representative in the landscape of each property were defined and training areas were collected.

For both study areas, the classes shade, water, rock, exposed soil without the occurrence of vegetation, scrub, grassland, forest and cocoa were defined, in addition to the coconut and banana classes as a test for separating other species individually.

3. RESULTS AND DISCUSSION

3.1. Acquisition of images and creation of the aero photogrammetric mosaic

In the process of acquiring the images, flights were carried out close to midday. The performance of UAV cameras in image acquisition was superior to that of Mapir cameras, probably due to their longer focal length and consequently less distortion.

The images were efficiently aligned despite the great similarity between the canopies; subsequently there was the elimination of points with poor alignment quality, with the sparse point clouds showing an error of less than 1 pixel, with a final spatial resolution of 5.5 cm.

3.2. Segmentation and classification

The first flight was carried out in 2018, at Farm Chácara das Sucupiras, using the Phantom 4 Pro Drone, equipped with Mapir (RGN) Red, Green and Near Infrared cameras, and (NGB) Near Infrared, Green and Blue.

Later, in 2019, two more flights were carried out on the same property using the Mapir (OCN) Orange, Cyan and Near Infrared cameras, and (NGB) Near Infrared, Green and Blue cameras.

At Santa Tereza Farm, in 2018, the Phantom 4 Pro Drone equipped with Mapir (RGN) and (NGB) cameras was used. On flights performed in 2019, the UAV, Mapir (NGB) and (OCN) cameras were used.

In the segmentation of flights at Chácara das Sucupiras, parameters 55 were used for scale, 0.2 for shape and 0.9 for the degree of similarity between the pixels, generating around 25.000 objects (Cocoa Cups). These were selected according to the number of objects generated. Eleven classes were defined based on the targets that make up the image, including structures, anthropogenic, water, rock, shade, exposed soil without the occurrence of vegetation, forest, pasture, scrub, banana, coconut and cocoa in vegetated areas.

On flights carried out in August 2018, the 22 variables provided for the optimization of the analysis space were the RGB bands of the aircraft cameras, the RGN and NGB bands of the Mapir cameras, the vegetation indices (ENDVI, NDVI, NDVI_Blue, NDVI_Green, as well as the standard deviation of all 9 bands.

The classification presented a minimum distance of 1.11 between classes considering 20 variables out of the 22 provided as shown in Figure 4.

In Figure 5, contemplating that the closer to zero the result, the smaller the difference between the classes, the individual plant species, coconut, banana and cocoa, showed considerable separation in relation to forest (1.12; 1.55; 1.13).

On the second flight, carried out in April 2019, the sensors used involved the Mavic Pro as an aircraft and Mapir's OCN and NGB cameras. The minimum separation between classes was 0.89, with 18 variables used in the separation. The greatest similarity found was between the exposed soil and scrub classes, with the Forest showing a separation of 1.11 in relation to the cocoa class. The 18 variables used involved red, green, blue and near infrared as pure bands, the vegetation indices ENDVI, NDVIO, NDVIC, NDVIG and NDVIB and the standard deviation of all 9 variables.

In the sampling carried out in 2018, from 213.126 m2, the property had 18.459 m2 of cocoa crown area; in 2019, this was 24.465 m2.

The property showed predominant use of forest (44 to 50%) followed by coconut (8 to 13%), cocoa (8 to 12%) and banana (6 to 13%). There were differences in the contribution of all classes, with emphasis on the forest class (6% larger area in the second image), coconut (5% larger area in the second image) and banana (7% smaller area in the second image).

Adding the forest area (44 to 50%), with the cabruca cocoa area (8 to 12%), which also conserves the Atlantic Forest, the APP areas, and the Legal Reserve area (20%), the property preserves around 75% to more than 80% of Atlantic Forest. In this sense, it was observed that the farmer had a preservation area larger than the parameters required even in the Amazon, where legal preservation (legal reserve) is 80%.

In the flights carried out in September 2018 at the Santa Tereza farm, the 23 variables provided for the optimization of the analysis space were the RGB bands of the aircraft camera, the RGN and NGB bands of the Mapir cameras, the vegetation indices (VARI, ENDVI, NDVI, NDVI_Blue, NDVI_Green as well as the standard deviation of all 9 bands.

The classification obtained a minimum distance between the classes of 1.22 considering 23 variables as shown in Figure 6.

In Figure 7, using the 23 variables, the representative classes of the individual plant species, coconut, banana and cocoa, presented a separation of (1.22; 1.41; 1.27), respectively. The result proved to be effective in separating the classes and quantifying the area of participation of each crop, forest and anthropized areas with exposed soil.

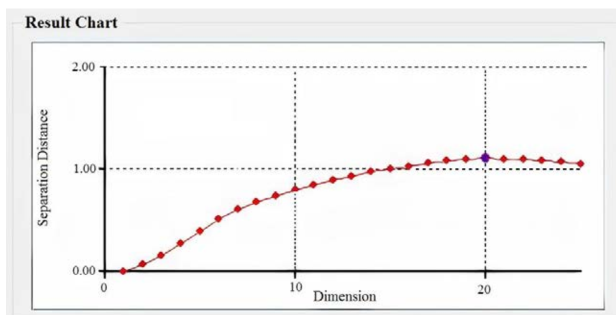

Figure 4. Separation between classes according to the number of variables used.

Class/Class	Shadow	Exposed Soil	Anthropic	Coconut	Cocoa	Forest	Pasture	Banana
Dimension: 20								
Shadow	0.000000	19.563850	17.961264	6.560409	8.220716	6.112555	7.740255	9.027214
Exposed Soil	19.563850	0.000000	4.766711	9.222383	9.547003	10.725148	4.621127	8.997486
Anthropic	17.961264	4.766711	0.000000	7.900827	8.474779	6.813752	6.074470	9.346679
Coconut	6.560409	9.222383	7.900827	0.000000	1.190896	1.122241	1.878765	1.317259
Cocoa	8.220716	9.547003	8.474779	1.190896	0.000000	1.135167	1.525625	1.113550
Forest	6.112555	10.725148	6.813752	1.122241	1.135167	0.000000	2.052499	1.557438
Pasture	7.740255	4.621127	6.074470	1.878765	1.525625	2.052499	0.000000	1.902188
Banana	9.027214	8.997486	9.346679	1.317259	1.113550	1.557438	1.902188	0.000000

Figure 5. Separation between the different classes evaluated.

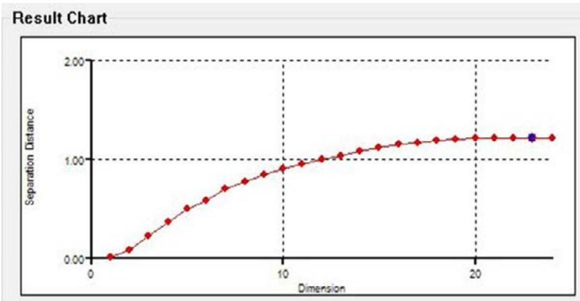

Figure 6. Separation between classes according to the number of variables used.

On the second flight, carried out in April 2019, the sensors used involved the Mavic Pro as an aircraft and Mapir's OCN and NGB cameras. The minimum separation between classes was 1.27, with 23 variables used in the separation.

In 2019, the variables used in the classification involved red, green, blue and near infrared as pure bands, the standard deviation of all 9 variables and the vegetation indices ENDVI, NDVIO, NDVIC, NDVIG and NDVIB. The greatest similarity found was 1.22 between Coconut and Forest classes, with Forest showing a separation of 1.27 in relation to Cocoa class.

Considering the two surveys, the property has a predominant forest cover (43 to 51%) with greater relevance to coconut (8 to 28%), cocoa (6 to 14%) and banana (2 to 5) crops. %).

Adding the forest area (43 to 51%) with the cabruca cocoa area (6 to 14%) which also conserves the Atlantic Forest, the APP areas and the Legal Reserve area (20%), with an area of 75% to more than 85% of Atlantic Forest is preserved in the property.

Class/Class	Shadow	Water	Rock	Anthropic	Coconut	Cocoa	Shrubbery Forest	Forest	Banana	Exposed Soil	Pasture
Dimension: 23											
Shadow	0.000000	12.917029	13.701641	11.301062	9.695921	8.999747	12.760143	7.613862	9.952427	17.613546	18.944133
Water	12.917029	0.000000	3.077512	4.882719	15.197871	15.125446	10.132543	14.768566	19.170911	9.432105	20.680877
Rock	13.701641	3.077512	0.000000	2.553605	8.342670	8.470397	4.668328	9.133408	11.695432	5.768846	14.378977
Anthropic	11.301062	4.882719	2.553605	0.000000	6.516597	6.124445	3.464374	7.037453	6.431481	4.641528	9.195975
Coconut	9.695921	15.197871	8.342670	6.516597	0.000000	1.822260	2.656932	1.223662	1.999992	5.420785	6.180311
Cocoa	8.999747	15.125446	8.470397	6.124445	1.822260	0.000000	3.584132	1.278752	1.790607	7.327963	7.867502
Shrubbery Forest	12.760143	10.132543	4.668328	3.464374	2.656932	3.584132	0.000000	2.730307	2.933961	1.339900	3.821586
Forest	7.613862	14.768566	9.133408	7.037453	1.223662	1.278752	2.730307	0.000000	1.419038	5.807065	5.766336
Banana	9.952427	19.170911	11.695432	6.431481	1.999992	1.790607	2.933961	1.419038	0.000000	6.549622	6.228004
Exposed Soil	17.613546	9.432105	5.768846	4.641528	5.420785	7.327963	1.339900	5.807065	6.549622	0.000000	4.280701
Pasture	18.944133	20.680877	14.378977	9.195975	6.180311	7.867502	3.821586	5.766336	6.228004	4.280701	0.000000

Figure 7. Separation between the evaluated classes.

3.3. Spectral characterization of targets

The spectral response reported in this work has its limitations; it represents the emittance at the time of imaging and depends on the incident solar radiation. An attempt was made to calibrate the images, but it was not successful, resulting in very low reflectance values, thus we considered all flights separate and compare their performance.

Few studies have been carried out with the aim of evaluating the spectral response of cocoa trees cultivated in the cabruca system, given the difficulty in separating the areas of Agroforestry Systems such as cabruca from the dense ombrophilous forest belonging to the Atlantic Forest biome, using existing satellite image classification techniques (Valadares, 2014).

In this context, the spectral characterization of cacao was focused on the emittance of the moment, with the aim of differentiating and separating cabruca cocoa cultivation from other land and forest uses.

The property Chácara das Sucupiras, in Table 2, presented similar readings in the two samples, considering the RGB camera the target behavior was as expected, greater emittance in green followed by red and blue, showing the preferential absorption of radiation by the photosystem in these bands.

Sampling in the infrared, green and blue bands showed lower intensity in 2019, especially in blue and infrared. Despite the two samples and considering different cameras (RGN and OCN) there was similarity between the sampled bands, the emittance values in general were low with higher values in infrared followed by red or orange and green or cyan, the standard deviation - S.D. was higher considering the Unmanned Aerial Vehicles - UAV sensor.

Santa Tereza farm, in Table 3, was sampled in a very similar period, with a difference of 20 days in 2018 and only 1 day in 2019. The emittance was very close in 2018, showing greater contrast in 2019, the response of the objects was consistent with the type of target with lower emittance in blue and red. There was a contrast considering the infrared band for the two Mapir cameras, greater in 2018. The emittance in green and cyan recorded by the coupled cameras was limited, as well as in Chácara das Sucupiras.

Table 2. Emittance values at Farm Chácara das Sucupiras for the different cameras in 2018 and 2019.

Farm Chácara das Sucupiras							
CAMERAS		2018			2019		
		Average	Median	S.D.	Average	Median	S.D.
UAV	Red	117.20	115.00	40.30	159.40	161.20	36.10
	Green	153.20	153.30	41.50	177.90	180.80	33.60
	Blue	92.90	89.90	34.50	125.60	127.20	31.70
Mapir NGB	NIR	154.60	157.00	15.20	77.10	70.40	34.10
	Green	19.10	18.40	5.70	7.10	3.80	7.00
	Blue	103.80	106.40	14.40	39.50	30.20	22.30
Mapir RGN	Red	62.50	64.10	17.20	X	X	X
	Green	54.60	54.70	17.10	X	X	X
	NIR	92.90	96.50	17.90	X	X	X
Mapir OCN	Orange	X	X	X	64.50	66.00	23.30
	Cyan	X	X	X	34.70	34.70	12.20
	NIR	X	X	X	88.90	93.20	25.20

Table 3. Emittance values at Farm Santa Tereza for the different cameras in 2018 and 2019.

Farm Santa Tereza							
CAMERAS		2018			2019		
		Average	Median	S.D.	Average	Median	S.D.
UAV	Red	117.23	115.00	40.34	135.86	138.83	46.22
	Green	153.25	153.33	41.57	152.59	156.53	45.04
	Blue	92.94	89.99	34.56	100.18	101.12	40.47
Mapir NGB	NIR	154.64	157.00	15.25	119.55	125.06	27.67
	Green	19.12	18.84	5.78	16.40	18.21	9.82
	Blue	103.86	106.41	14.41	70.05	75.54	26.65
Mapir RGN	Red	62.55	64.10	17.21	X	X	X
	Green	54.69	54.77	17.10	X	X	X
	NIR	92.90	96.56	17.98	X	X	X
Mapir OCN	Orange	X	X	X	80.03	85.06	24.63
	Cyan	X	X	X	45.21	45.43	15.82
	NIR	X	X	X	104.01	108.34	24.62

3.4. Applicability of Decree 15.180/14

There is a great difficulty in applying the PTMC on the properties, mainly in the matter the forest inventory, on average it took between 15 and 25 minutes to carry out the census of a tree in the cabruca, not counting the displacement time between one species and another.

The results of the costs of implementing the decree on average in 1 hectare are:

Forest inventory - field survey

(Considering the displacement and preparation of the survey between one tree and another) + 5min x 100 trees = 500min = 8.3 hours TOTAL 33.3 + 8.3 = 41.6 HOURS

Number of inventoried trees = 100

Average time (min.) per inventoried tree + Travel time = 25 min

Total time in hours = 41.6 hours

Considering the technical hour according to the CREA table - technical hour 197.60 BRL o Cost = 8.220.16 BRL

CEFIR – State Forestry Registry of Rural Properties – Santa Teresa Property 34 ha.

Field: for field survey costs, professionals have used the formula √ area x 200 and for data entry in the SEIA System √ area x 100.

√ 34 x 200 = R$ 1.095.00

√ 34 x 100 = 583.00 BRL

3 DISPLACEMENTS: ITABUNA X SERRA GRANDE = 70Km = 140km

TOTAL = 420km

50 LITER FUEL = LITER R$ 4.50 = R$ 225.00

3 DAYS OF FOOD: ENGINEER AND ASSISTANT = 150.00 BRL

TOTAL CEFIR = 2.053.00 BRL

Considering the values of the costs for carrying out the surveys carried out in the field, we have:

CEFIR = 2.053.00 BRL

FOREST INVENTORY (1ha) = R$ 8.220.16

FOOD = 150.00 BRL

DISPLACEMENTS = R$ 225.00

TOTAL = 10.648.16 BRL

According to the Association of Cocoa Processing Industries (AIPC) the average price of cocoa weight (15 kg) in 2019 was R$ 153.00 and the Bahian farmer had an average production of 300 kg/ha in 2019, the net value is R$ 3.060.00 per hectare in the year.

Even if there were no costs to produce 300 kg/ha of cocoa and if the farmer uses the profit only to cover expenses with the preparation and application of the PTMC, the farmer would take at least 2.5 to 4 years to cover the costs of implementing the decree in 1 hectare.

4. CONCLUSIONS

1. The use of UAVs with different cameras was effective in separating and classifying the land use areas, quantifying the participation of each class in the total area of the property. The tool helps the farmer to make the decision on where, when and how to carry out the forest inventory, serving as a basis for the application of Decree 15.180/14 and for the AMC.

2. The spectral response reported in this work has its limitations and represents the emittance at the time of imaging depending on incident solar radiation. In the year of 2018, on average, cocoa presented higher emittance values for the RGB camera in the green region. However, for the other cameras, Mapir NGB and RGN, the green values were very low suggesting that the flight schedule might not be the most suitable for the evaluation.

3. The differences obtained in the emittance responses of the two years require further research work on the culture so that there is greater knowledge about the spectral responses over time, because despite the flights having been performed at the same time, the variations of luminosity influenced, generating different results regarding the contribution of the response patterns of the targets.

4. High-resolution remote sensing is a very useful tool to validate the conservationist role of cocoa production in the cabruca system and promote discussion about decree 15180/14 proposing a systemic view of the property as a whole.

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CORRESPONDENCE TO

Pedro Jeronimo de Carvalho Neves Cavalcante

Rodovia Jorge Amado, Km 16, Salobrinho, 45662-900, Ilhéus, BA, Brasil

e-mail: pj_agro@hotmail.com

AUTHORS' CONTRIBUTIONS

Pedro Jeronimo de Carvalho Neves Cavalcante: conceptualization (equal), data curation (equal), formal analysis (equal), investigation (equal), methodology (equal), project administration (equal), resources (equal), software (equal), supervision (equal), validation (equal), visualization (equal), writing – original draft (equal), writing – review & editing (equal).

Roberto Ferreira Machado Michel: conceptualization (equal), data curation (equal), formal analysis (equal), investigation (equal), methodology (equal), project administration (equal), resources (equal), software (equal), supervision (equal), validation (equal), visualization (equal), writing – original draft (equal), writing – review & editing (equal).

Maurício Santana Moreau: conceptualization (equal), data curation (equal), formal analysis (lead), investigation (equal), methodology (equal), project administration (equal), resources (equal), software (equal), supervision (lead), validation (equal), visualization (lead), writing – original draft (equal), writing – review & editing (equal).

Arlicélio de Queiroz Paiva: conceptualization (equal), data curation (equal), formal analysis (equal), investigation (equal), methodology (equal), project administration (equal), resources (lead), software (lead), supervision (equal), validation (equal), visualization (equal), writing – original draft (equal), writing – review & editing (equal).

Rafael Henrique de Freitas Noronha: conceptualization (equal), data curation (equal), formal analysis (equal), investigation (equal), methodology (equal), project administration (equal), resources (lead), software (lead), supervision (equal), validation (equal), visualization (equal), writing – original draft (equal), writing – review & editing (equal).

Tássio Moreira Silva: conceptualization (equal), data curation (equal), formal analysis (equal), investigation (equal), methodology (equal), project administration (equal), resources (lead), software (lead), supervision (equal), validation (equal), visualization (equal), writing – original draft (equal), writing – review & editing (equal).

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