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MODELLING THE PASTURELAND PRODUCTIVITY IN AREAS OF SAVANNA IN NORTHERN MINAS GERAIS – BRAZIL

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ABSTRACT

Accurate information on the quality of pastures is essential for the Brazilian economy, as livestock is relevant to the country's Gross Domestic Product (GDP); in addition, well-managed pastures are a necessary step to mitigate the emission of greenhouse gases (GHG). In this work, the productivity of pastures in savanna areas in northern Minas Gerais (Brazil) was analyzed using remote sensing techniques. It was found that dry biomass varied according to climatic seasonality, on the monthly time scale, with the highest values in the rainy season (68.79%) and the lowest in the dry period (31.21%). To observe the importance of well-managed pastures for the studied region, a correlation of environmental parameters that assume the quality of these pasturelans was carried out. We observed a more significant correlation between Gross Primary Production (GPP)), Leaf Area Index/Photosynthetically Active Radiation Absorbed (IAF/RFAA) and altitude with the dry biomass capacity of the Animal Unit (UA / Hectare). We observed that the pastures in the study region do not have enough inputs to meet the needs of the animals, thinking about the intensification logic, mainly when comparing the annual average of AU/ha of this study with the Brazilian median, with a difference of 86.37 %.

Keywords: Dry Matter. Animal Unit. Remote Sensing.

MODELAGEM DA PRODUTIVIDADE DE PASTAGENS EM ÁREAS DE SAVANAS NO NORTE DE MINAS GERAIS – BRASIL

RESUMO

Informações precisas sobre a qualidade das pastagens são essenciais para a economia brasileira, pois a pecuária é relevante para o Produto Interno Bruto (PIB) do país; além disso, pastagens bem manejadas são uma etapa necessária para mitigar a emissão de gases de efeito estufa (GEE). Neste trabalho, a produtividade de pastagens em áreas de savana no norte de Minas Gerais (Brasil) foi analisada por meio de técnicas de

sensoriamento remoto. Verificou-se que a biomassa seca variou de acordo com a sazonalidade climática, na escala de tempo mensal, sendo os maiores valores no período chuvoso (68,79%) e os menores no período seco (31,21%). Para observar a importância de pastagens bem manejadas para a região estudada, foi realizada uma correlação de parâmetros ambientais que pressupõem a qualidade dessas pastagens. Observamos uma correlação mais significativa entre Produção Primária Bruta (GPP), Índice de Área Foliar/ Radiação Fotossinteticamente Ativa Absorvida (IAF/RFAA) e altitude com a capacidade de biomassa seca da Unidade Animal (UA / Hectare). Observamos que as pastagens da região de estudo não possuem insumos suficientes para atender as necessidades dos animais, pensando na lógica de intensificação, principalmente ao comparar a média anual de UA/ha deste estudo com a mediana brasileira, com diferença de 86,37%.

Palavras-Chave: Matéria Seca. Unidade Animal. Sensoriamento Remoto.

INTRODUCTION

Typically, the population growth boosted the demand for food on a large scale, significantly impacting the world's economy and environment. A productive country tends to maintain good human development, especially with rising incomes; however, we understand that the search to meet this demand was responsible for converting natural systems into anthropic mosaics, intensely degrading the environment. A clear example is the savanna biome in Brazil, locally known as Cerrado, which had a large part of its natural ecosystems converted into anthropic systems with intense agricultural production. Although with 45% of remnant vegetation, studies point out pessimistic scenarios for Cerrado up to 2050, when this biome can lose more than 13.5% of its remaining native vegetation cover (METZGER et al., 2019).

Here, we underlined the pastures environment, as they occupy more than 21% of the country and are quite crucial to the Brazilian economy, with livestock being one of the activities that most contribute to the Gross Domestic Product (GDP) of the agribusiness, with 34% (PARENTE; FERREIRA, 2018; VELOSO et al., 2020). Pastures represent the main form of land use in Brazil, being fundamental in the decision making of the country's managers, mainly in the environmental context, as in their territorial extensions they present some degree of degradation. Further, pastures can play an essential role in the environmental context, especially considering their potential to sequester atmospheric carbon, being a carbon stock in the soil. In some cases, not degraded pastures can be more efficient than natural systems, concerning carbon stock (ROSENDO; ROSA, 2012). These pasture areas also contribute to animal protein production, with Brazil leading the world's largest meat producer's rank.

Pastures' quality is a topic of discussion for researchers and academic centers in Brazil, especially to encourage improved management to increase productivity, critical for advancing Brazilian livestock and climate issues (CARVALHO et al., 2010; FROUFE; RACHWAL; SEOANE, 2011). Another issue regarding the quality of pastures is that their improvement can reduce Cerrado's deforestation since more productive rural properties will remove less remnant vegetation cover. Therefore, accurate information on pasture productivity guides managers and stakeholders, mainly inferring about investment applications.

On the other hand, pastures cover large territorial extensions, and only on-site methodologies can not meet the demands for information in the short term. Thus, an attractive alternative is the use of remote sensing techniques (provided by satellite images), quickly covering vast areas of Brazil, with data made available for free (e.g., CBERS 4A, Landsat 8, Sentinel 2, and Terra/MODIS platforms).

Anjos et al. (2013), characterizing the pastures of the Triângulo Mineiro, have used vegetation indices (EVI2) from MODIS (Moderate Resolution Imaging Spectroradiometer), indicating the potential of remote sensing data in the discrimination of pastures, concerning other types of vegetation in the Cerrado. Garcia, Ferreira e Sano (2013) analyzed the quality of pastures in the Cerrado of Goiás State, using MODIS for providing vegetation indexes to obtain data about net primary productivity; these authors observed the relationship between environmental factors (soils) in the pasture productivity behavior. Moreira et al. (2019), analyzing the pastures' phenological metrics of Brazil's southern, observed that the pastures' physical conditions are controlled by climatic seasonality, especially air temperature variation.

However, the analyzes are growing to understand the Gross Primary Productivity (GPP) in pasture areas, which includes the ability of this land use to fix atmospheric carbon, indicating its state of vigor, through dry matter, because the greater the absorption carbon values of larger pastures are the biomass values (Veloso et al., 2020). Still in this perspective, approaches were developed to point out the capacity of animal support in these pasture environments (Arantes et al., 2018), to understand the disposition of cattle per unit area. Veloso et al., (2020) analyzed the primary productivity using the product MOD17A2 in the state of Goiás, expanding the analysis to understand the animal support capacity and intensification of pastures. Arantes et al., (2018) analyzed the animal support capacity in Brazil, using the product MOD17A2. The authors observed that the national average of the animal support capacity was 3.60 (AU/ha) and the regions with the highest values were North and Southeast. These approaches are essential to the dynamics of pasture productivity.

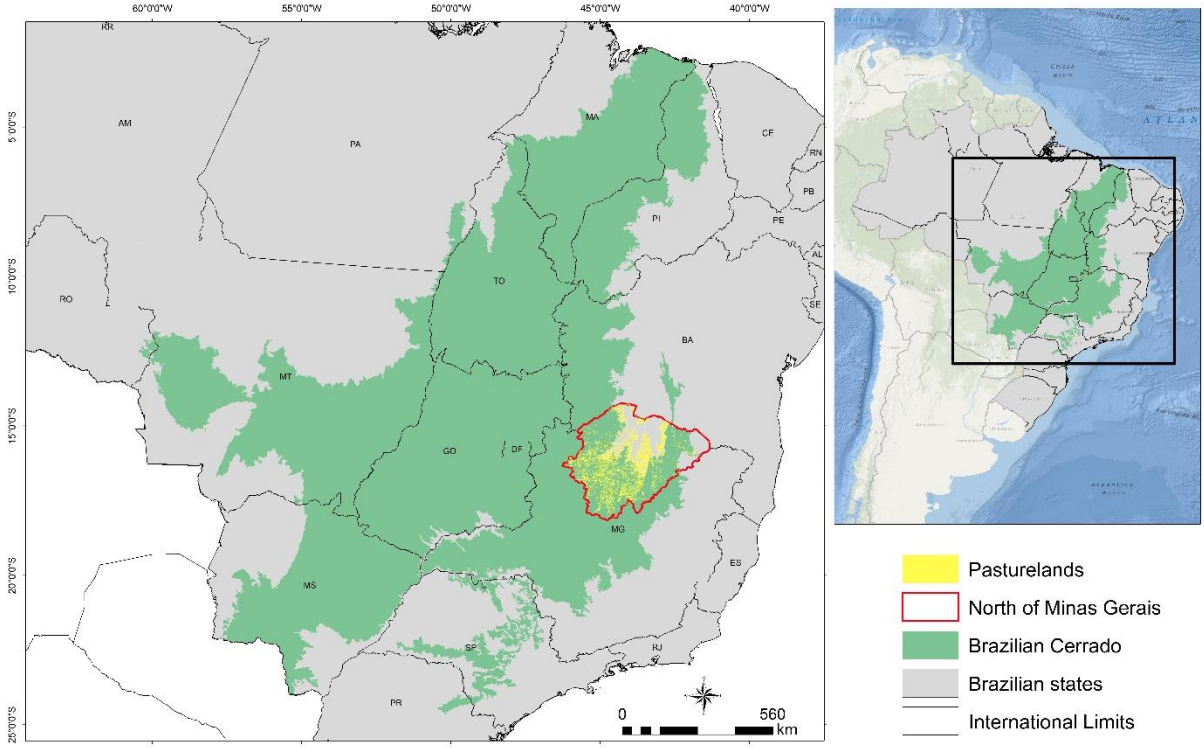
Therefore, the objective of this work was to analyze the pasture productivity in Savannas in the North of Minas Gerais, using remote sensing products, specifically the MODIS sensor (Terra platform), throughout 2019. The choice of the study area was based on importance of pasture due to the economic context of the region and because it represents one of the main land uses in northern Minas Gerais. This study stands out for being the first to address the theme in Cerrado areas of the North region of Minas Gerais, being able to assist managers in the economic and environmental aspects.

METHODOLOGY

STUDY AREA

The study area is located in the east of the Cerrado biome, specifically in the north of Minas Gerais state (Figure 1), bordering the Jequitinhonha valley, northwest and central Minas Gerais. The region has 89 municipalities (84 inside the Cerrado limit). Pastures are anthropic systems of significant influence on the northern region's territorial dynamics, covering about 25% of the study area.

Figure 1 - Brazilian Cerrado, pasture distribution, Northern Minas Gerais.



Source - IBGE (2019). Org. The authors, 2020.

The study area has two predominant climates: semi-humid and semi-arid. The northern region of Minas Gerais is a transition area between the semi-arid in the northeast and the humid part in the southeastern Brazil (DA SILVA, 2016). Precipitation for the period studied (2019) recorded an average of 48.97 mm, a total of 538.6 mm, and an average standard deviation of 37.73 mm.

The geology of the region consists mainly of formations of the Espinhaço Supergroup (Paleoproterozoic), Bambuí Group (Neoproterozoic), Urucuia and Areado Groups (Mesozoic), detritus-lateritic coverings, and sedimentary deposits (Cenozoic) (DA SILVA, 2016).

Concerning the Geomorphology, Da Silva (2016) mentions the following geographical accidents (local identification): Chapadas do Rio Jequitinhonha, Chapadas do Rio São Francisco, Depression of the Upper Middle São Francisco, Platforms of the São Francisco/Tocantins rivers, Plateaus of the Jequitinhonha/ Mucuri rivers, Vitória da Conquista / Planalto dos Maracás, São Francisco plaining, Serra do Espinhaço Meridional / Norte.

The phytophysiognomies of the north of Minas are marked by Savanna (grassland, shrublands, and woodland) and Forest Formations, with diversified landscape mosaics with anthropic influences (34% from the north of Minas) (LEITE et al., 2018).

DATA USED

In this work, it was necessary to set up a database, including remote sensing and meteorological products. MODIS sensor images were selected, specifically the products MOD17A2H (GPP – Gross Primary Productivity) and MOD15A2H (IAF/RFAA), both with a spatial resolution of 500 meters and eight days temporal resolution. The products were obtained for 2019. Altimetry data used were obtained using the Shuttle Radar Topography Mission (SRTM), with a spatial resolution of 90 meters. For better refinement of the class of interest (pastures), the limits established in the Atlas of Brazilian Pastures were used. This Atlas was developed by the Image Processing and Geoprocessing Laboratory (LAPIG / UFG), for the year 2018.

At the National Institute of Meteorology (INMET), in Brazil, rainfall data from nine meteorological stations installed in northern Minas Gerais were selected. It should be noted that these rainfall data correspond to 11 months (January to November) of the year 2019. The data for the month of December / 2019 were not available at that time.

PROCESSING AND STATISTICAL ANALYSIS

In this study, dry matter was determined according to the GPP parameter (MOD17). The GPP is obtained based on the efficiency of the use of light (LUE) and the fraction of photosynthetically active radiation absorbed (FRAA) (Equation 1). The LUE and FRAA parameters were obtained when processing the MOD17A2 product.

$$GPP = LUE * FRAA \quad (1)$$

It was possible to obtain dry matter with GPP data. For this, the carbon conversion factor (gC^{-1} / m^{-2} / d^{-1}) to biomass (kg/ha) was applied (NEUMANN-COSEL et al., 2011) (Equation 2):

$$Dry\ Matter = GPP * 2.7 \quad (2)$$

As proposed in Veloso et al. (2020), the animal support capacity (AU/ha) can be obtained through the relationship between dry matter and pasture demand per animal unit (1UA = 450 kg). According to these authors, the average daily consumption is 2.5% of the live animal's weight (450 kg), that is, 11.25 kg. However, the authors recommend that the demand should be doubled, especially considering that part of the fodder is not consumed due to the cattle's trampling, assuming that the daily need is 22.5 kg of dry matter per animal (VELOSO et al., 2020).

The altimetry data were obtained (free of charge) in USGS (United States Geological Survey) and were saved in raster format. After this procedure, the images were mosaic to the north of Minas Gerais, in the ArcMap software.

The rainfall data were organized into monthly average values for the year 2019, in order to understand the seasonal dynamics of pasture productivity. The rainfall values of the regions without data/stations were interpolated from the values of the nine rainfall stations analyzed. This procedure was performed with the ArcMap software.

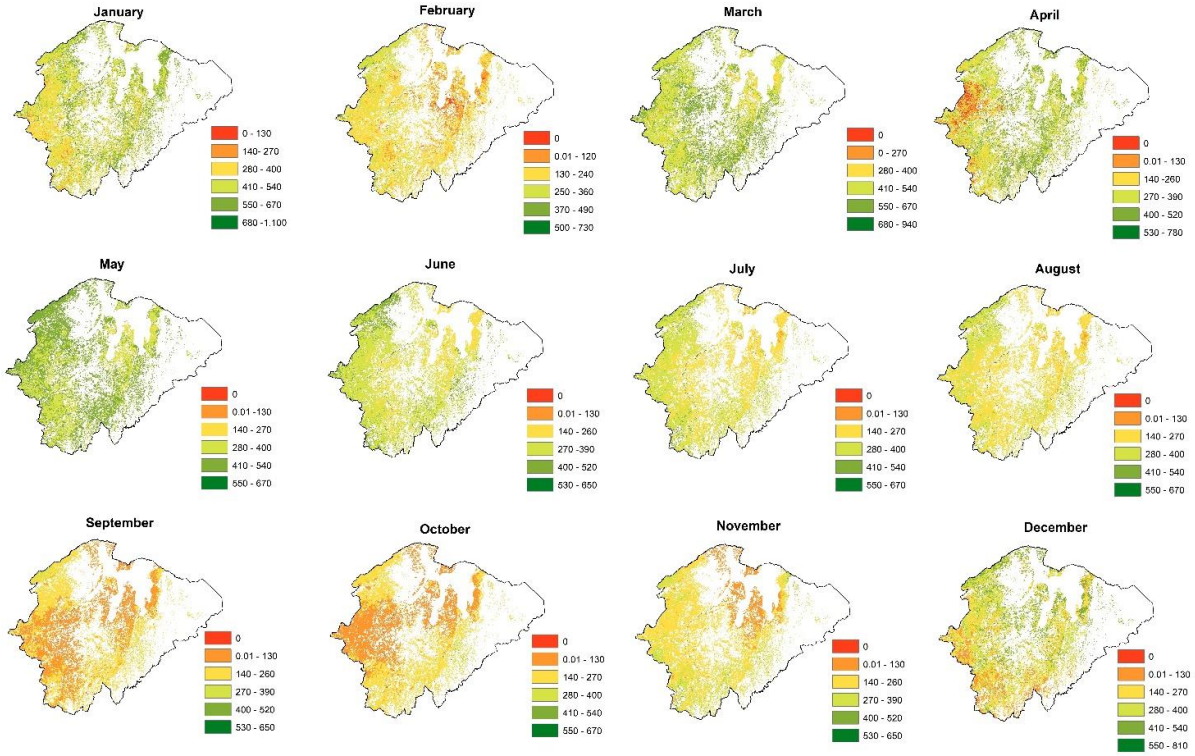
Finally, the mean values of GPP, IAF/RFAA, Dry Matter, Animal Unit and Altitude were extracted, by municipality, using the Zonal Statistics tool on the ArcMap platform. Then, the correlation matrix was calculated with the above parameters. The procedures were performed using the R software.

RESULTS

SPATIAL DISTRIBUTION OF DRY MATTER AND ANIMAL SUPPORT CAPACITY

In the first four-month period (January to April - 2019), differences were noticed in dry matter distribution regarding spatialization and values (Figure 2) in the study area. In January, the highest values were estimated since the minimum values ranged from 0 to 130 Kg/ha (0.11% of the study area), and the maximum is 1,100 kg/ha (3.83% of pastures). There was also a predominance of 540 Kg/ha for this period, representing 44.44% of the study area. In February, variations were observed in the spatial distribution of biomass in the study area. The minimum values represent 14.57% of pastures in this period, being higher than in January. The predominance of this class was, mainly, in the central-north portion. The maximum values represented 0.12% of pastures, with spatial distribution concentrated in the western part.

Figure 2 - Spatial distribution of Dry Matter (Kg/ha) in pastures in Northern Minas Gerais (Brazil), from January to December, 2019.



Source - USGS (2019). Org. The authors, 2020.

It was observed that the maximum values' spatial distribution showed significant variations, with 9.59% of the study area in March, being higher than in February. It was also observed concentration in the western, southern, and central portions of the maximum values for spatialization. There was a predominance of 540 kg/ha, with a concentration in the central-north and northeast regions. In March,

the minimum values represented 12.59% of the spatial distribution, obtaining a decrease of 38.15% about February.

In April, values between 270 and 390 kg/ha of dry matter predominated, representing 45.17% of the study area. The maximum values represented 2.88% of the study area, while the minimum values 6.70%. For the second quarter of 2019, a stagnation in the biomass values from June onwards were observed, differing only in June, where the maximum amount is 650 kg/ha, and the minimum amount ranges from 0 to 130 kg/ha.

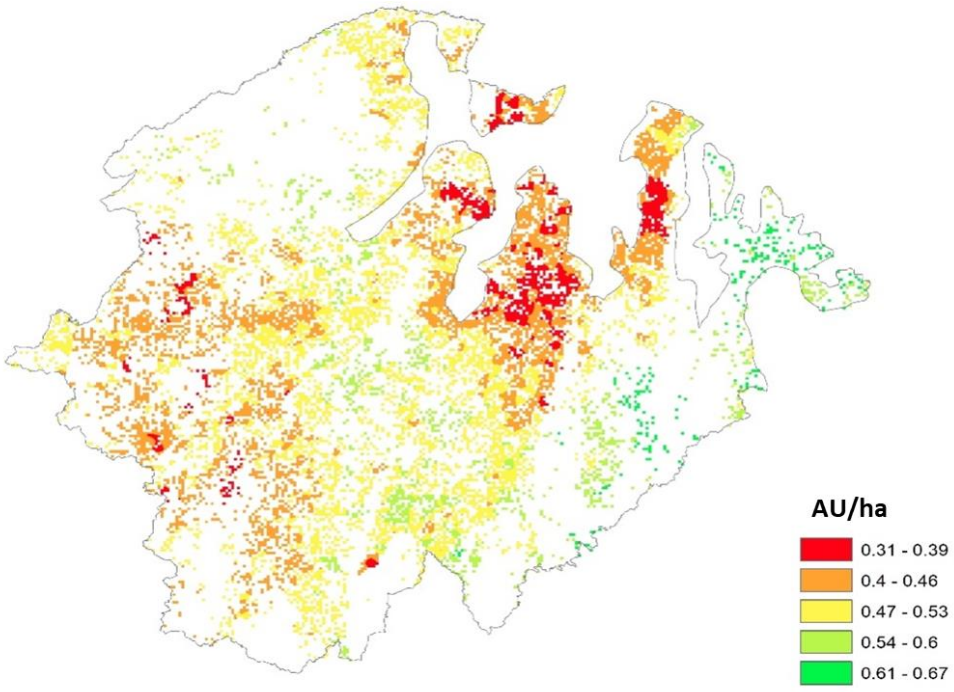
From a spatial point of view, the lowest dry matter values' predominance in the center-north portion stands out. Meanwhile, the highest values are shown in fragments in the east/northeast and northwest. It is also emphasized the intermediate values, predominate in the study area, spatialized in all parallels.

There was homogeneity in the distribution of intermediate values in May, with fragments of maximum values in the southeast portion. For July and August, the same behavior was observed in May and June, with differences in the class with lower values, which are located predominantly in the central-north and northeast regions.

The most extensive dry matter variations were recorded in the last four months, especially in the lowest values. In September and October, a greater concentration of the minimum values was observed in the southwest and south portions, with advances to the extreme north (an area bordering the Caatinga biome). There is a significant decrease in the minimum values in November, decreasing the southwest and south portions, thus maintaining concentration in the central-north part.

As pointed out in the technical and operational procedures, the Animal Unit (AU/ha) comes from dry matter, so it is unnecessary to present the data monthly. Thus, assuming an annual representation (Figure 3), the predominant values were between 0.47 and 0.53 AU / ha, or 41.03% of the study area, with a spatial concentration in the central, south, and southwest portions. The maximum values (0.61 to 0.67) were concentrated in the east part, with 2.34% of the study area's spatialization. The minimum amounts are concentrated in the central-north and northeast regions, with fragments in the east, covering 8.67% of the analyzed area. It highlights that the general average was 0.47 AU/ha, with a standard deviation of 0.059 AU/ha.

Figure 3 - Annual Distribution (2019) of the Animal Unit in the Cerrado of northern Minas Gerais, Brazil.

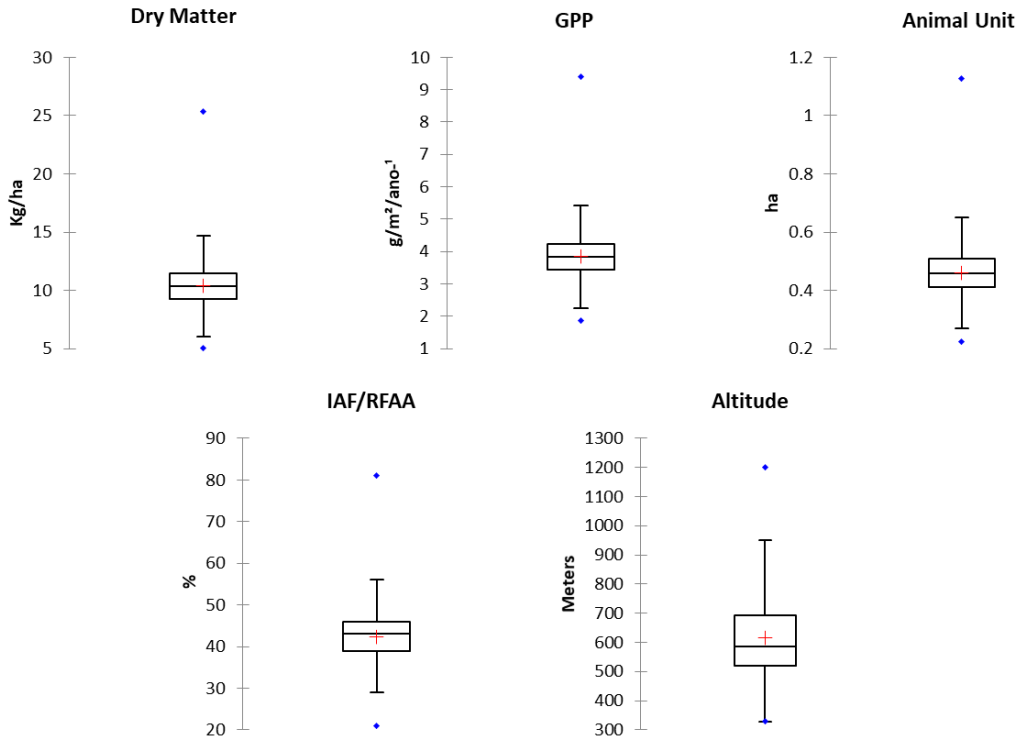


Source - USGS (2019). Org. The authors, 2020.

STATISTICAL DESCRIPTION BY MUNICIPALITY

Even with the explanation of dry matter and animal unit in the context of the Cerrado of North of Minas Gerais, we decided to represent the covariables at the municipal level, being available at the municipal, territorial level. Initially, we describe the statistical distribution of environmental covariates (Figure 4).

Figure 4 - Statistical distribution of environmental covariates.



Source - SRTM (2002) and USGS (2019). Org. The authors, 2020.

We noticed a considerable variation in values for the municipalities for dry matter, with a standard deviation of 39.10 kg/ha. We highlight the municipalities with higher and lower values, being Indaiabira (412.10 kg/ha) and Mato Verde (250.41 kg/ha). The values of AU/ha showed no variance, and a very low standard deviation (0.06). The municipality with the highest animal support capacity was Indaiabira, while Mato Verde was the lowest.

The highest altitude was Montezuma (866.31 meters), and the smallest Matias Cardoso (468 meters). The municipality with the highest gross primary productivity was Indaiabira (5.03 g / C^{-2} / d^{-1}), and the smallest Mato Verde (3.04 g / C^{-2} / d^{-1}). The municipality with the highest IAF/FRAA was Indaiabira (50.82%), and Mato Verde obtained the lowest value (30.14%).

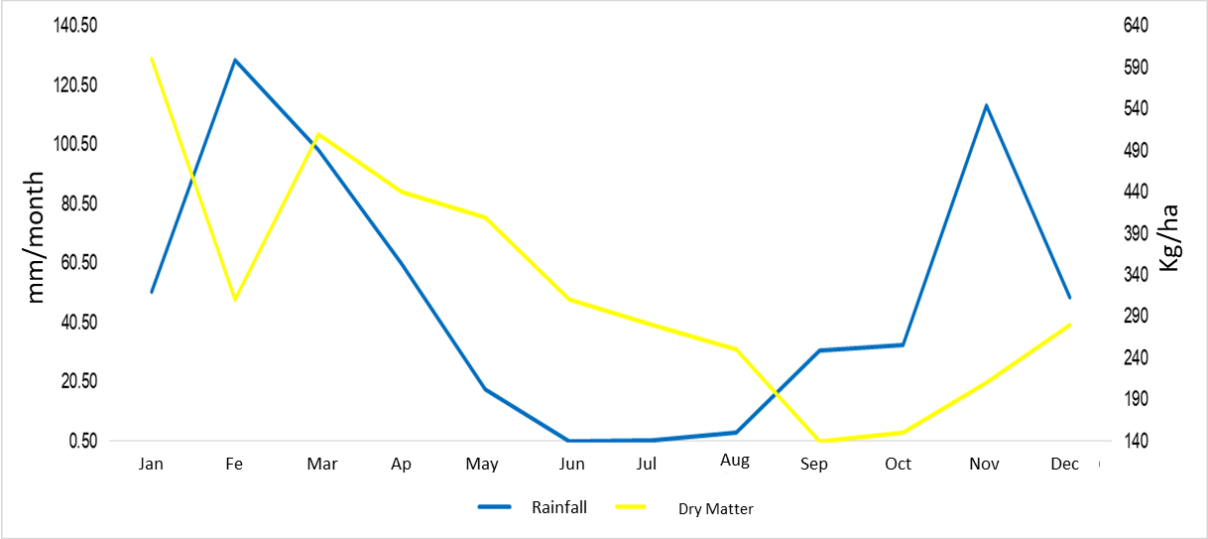
DISCUSSION

INFLUENCE OF CLIMATIC SEASONALITY ON DRY MATTER BEHAVIOR

For the pastures, asymmetrical behavior was observed with rainfall distribution in each month (Figure 5). In the first four-month period (January, February, March, and April) of 2019, we observed a substantial influx of rain in the North of Minas Gerais, followed by a high dry matter production. This

fact was possible due to the greater water availability in the soil, a marked incidence of photosynthetically active radiation, and optimum temperatures for developing the pastures' vegetative vigor (CHURKINA; RUNNING, 1998).

Figure 5 - Relationship between precipitation and dry matter on a monthly scale of the study area.



Source - INMET (2019) and USGS (2019). Org. The authors, 2020.

This curve's unusual behavior was observed in February, when the production of dry matter (Figure 5) declines abruptly, coinciding with the period of most significant rainfall. We emphasize that it is atypical because there is a symmetrical behavior between these variables in the other months. In the following period, with the reduction of rain in May, we observed a drop in dry matter production, a fact also followed by Santos, Ferreira, and Lenzi (2018) in pasture analysis in the Rio Vermelho basin (Goiás), an area with a semi-humid tropical climate, typical of the Cerrado. They observed that the pastures' productivity systematically decreased due to the soil's lack of water availability. De Queiroz Palacio et al. (2019), analyzing the seasonal dynamics of biomass production in the Itagu (Ceará state) microbasin, under the influence of a hot semi-arid climate, showed that there is a reduction in biomass production followed by a decline in rainfall, results explained by the water deficit.

From September, with the resumption of rains, there is a rapid response from pastures to this, especially with an increase in the dry matter curve, indicating an increase in productivity, following this trend until December. It is related to the short roots of pastures, which can quickly access the water in the soil's sandy area. In December, there is a reduction in rainfall; however, this does not interrupt the dry matter production curve, a result explained by the availability of water stored in the soil due to the November rains. The determination coefficients (R^2) were not high, with 0.63 and 0.13 for dry matter and precipitation, respectively, and 0.05 for the relationship between the variables (Figure 5).

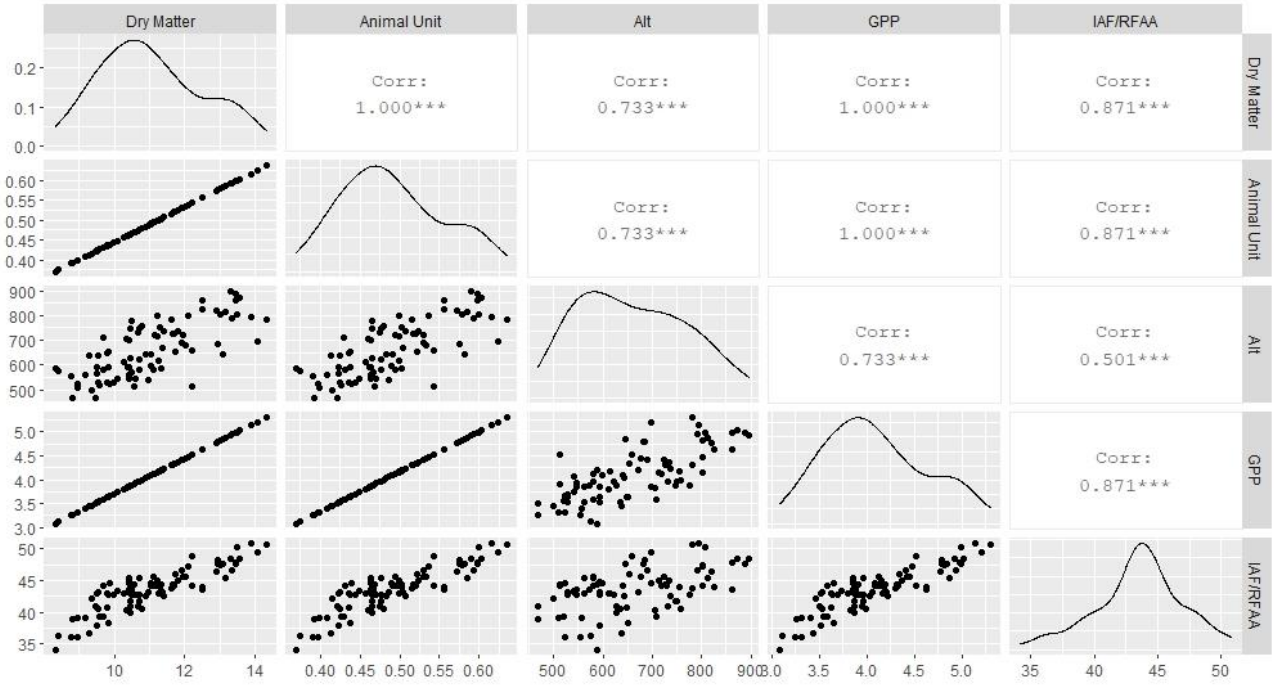
However, this low value does not cancel the relationship between the variables since the model applied is linear regression. I.e., as it can be observed, this variation occurs on slopes and slopes considering climatic seasonality. We have the first four months with high dry matter values and precipitation, the second with a steep slope, and the third with increases again.

In general, we observed that pastures show higher productivity in the fourth months of the rainy season, corresponding to 67.87% of production in 2019, 70.45% higher than that produced in the period of lesser rainfall (dry season).

INTERCORRELATION BETWEEN ENVIRONMENTAL ASPECTS IN PASTURES

After we related the dry matter seasonal dynamics and their variables behavior, we considered the environmental aspects as hypsometry, gross primary productivity, and the ratio between leaf area index and absorbed photosynthetically active radiation, through a correlation matrix (Pearson's coefficient) (Figure 6).

Figure 6 - Correlation matrix between environmental variables.



Source - SRTM (2002) and USGS (2019). Org. The authors, 2020.

The r values varied between 0.73 and 1, showing that the environmental variables have moderate positive to perfect positive correlations with dry biomass. The relationship between LAI and RFAA (r = 0.87) for pastures represents a high interception of radiation in the range of 0.4 and 0.7 μm, which is systematically inferred in the GPP, because the more significant the availability in this interval, the greater the production of carbohydrates (organic matter) in the photosynthesis process (ROSA; SANO, 2013). Carbohydrates are converted into biomass (distributed in the vegetation's physical structure), thus having a linear relationship between these variables.

Regarding the altitude (r = 0.73), we understand that it is due to the distribution of areas with higher altimetry in the eastern portion of the Cerrado to the north of Minas Gerais, where the Serra do Espinhaço is located (SAADI, 1995). In these environments, there is a tendency for free movement of the wind (following the logic of the logarithmic profile) (MALACARNE; RIBEIRO, 2018), increasing its speed, which leads to the removal of humid air from the atmosphere adjacent to the surface, favoring high atmospheric demand, expanding the evapotranspiration rate (SILVA et al., 2020).

This component (evapotranspiration) is essential for the productivity of vegetation structures, as the flow of absorbed carbon occurs in stomata where there is water loss; that is, the higher the rate of water loss, the greater the absorption/flow of carbon (SANTOS et al., 2019), which will be converted into organic matter and redistributed into biomass. These aspects systematically infer the distribution of AU/ha in the Cerrado of North Minas Gerais. If there is a greater production of dry matter, they will concentrate more on animals. Arantes et al. (2018) studied the intensification of pasture activities in

Brazil and pointed out the most significant potential for intensification and distribution levels of western Minas Gerais, confirming our findings.

Considering the annual dry matter average (320 Kg/ha), as well as the animal support capacity (0.49 AU/ha) in northern Minas Gerais, it is worth noting, regarding the quality of pastures, that this average AU/ha is 86.37% below the Brazilian average. It is understood that the agro-pastoral systems in the study area need adequate management, seeking improvement. As a result, animal support capacity will increase, considering economic aspects and the environmental context, as well-managed pastures are potential carbon stocks and the provision of climate services.

FINAL CONSIDERATIONS

The present study showed the potential of remote sensing techniques applied in the analysis of pasture productivity at the Savanna limit in the North of Minas Gerais (Brazil). Productivity was characterized by dry matter and Animal Unit, estimated with low spatial resolution orbital data (MODIS sensor).

The dry matter presented seasonal variation for pastures, with the direct influence of the pluviometric indexes. Most of the dry matter production occurred in the two-quarters of the rainy seasons in the study area. We observed that dry matter and AU/ha were directly influenced by GPP, altitude, and IAF/RFAA.

In general, the capacity for animal support in pastures in the north of Minas Gerais is lower than the average in Brazil, which indicates that the production of dry matter is insufficient to supply the needs of the animals and possible intensifications. Qualified information and investments through management in improving pastures tend to promote the municipalities' economic progress in the analyzed area and mitigate the emission of greenhouse gases, aiming at more sustainable livestock.

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