







Geosciences

Spatio-temporal analysis of urban land use/land cover changes in Cuiabá and Várzea Grande, Mato Grosso, Brazil

Análise espaço-temporal das mudanças no uso/cobertura do solo urbano em Cuiabá e Várzea Grande, Mato Grosso, Brasil

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ABSTRACT

This study addresses the rapid urbanization in the municipalities of Cuiabá and Várzea Grande, located in the state of Mato Grosso, which face environmental challenges due to population growth. Using Remote Sensing and Geographic Information System tools, the research employed data from the Planet constellation and the Random Forest algorithm to map vegetation cover and changes in urban parameters between 2018 and 2023. The results allowed the quantification of four cover classes and highlighted a significant increase in the wooded area in both municipalities during the period, contributing to the shelter of fauna species and thermal comfort of the neighborhood. The accuracy assessment of the results indicates results of excellent quality (Cuiabá-MT) and very good (Várzea Grande-MT). The importance of urban planning in the conservation of wooded areas is highlighted, especially in cities with high average temperatures, where the conversion of native areas affects environmental conditions. It is concluded that there is a permanent need for more efficient urban planning to balance population growth with environmental conservation, thus ensuring local quality of life.

Keywords: Urban afforestation; Random Forest, Remote sensing

RESUMO

Este estudo aborda a rápida urbanização nos municípios de Cuiabá e Várzea Grande, localizados no estado de Mato Grosso, que enfrentam desafios ambientais decorrentes do crescimento populacional. Utilizando ferramentas de Sensoriamento Remoto e Sistema de Informação Geográfica, a pesquisa empregou dados da constelação Planet e o algoritmo Random Forest para mapear a cobertura vegetal e as mudanças no perímetro urbano entre os anos de 2018 e 2023. Os resultados possibilitaram a quantificação de quatro classes de cobertura e destacam um aumento significativo da área arborizada

em ambos os municípios no período, contribuindo para o abrigo de espécies da fauna e conforto térmico da vizinhança. A avaliação de precisão dos mapeamentos indica resultados de qualidade excelente (Cuiabá-MT) e muito boa (Várzea Grande-MT). Ressalta-se a importância do planejamento urbano na conservação das áreas arborizadas, especialmente em cidades com temperaturas médias elevadas, onde a conversão de áreas nativas afeta as condições ambientais. Conclui-se que há uma necessidade permanente de um planejamento urbano mais eficiente para equilibrar o crescimento populacional com a conservação ambiental, assegurando, assim, a qualidade de vida local.

Palavras-chaves: Arborização urbana; Random Forest; Sensoriamento remoto

1 INTRODUCTION

The rapid and uncontrolled expansion of urban areas has precipitated serious environmental challenges, including the imminent threat of water scarcity and exacerbated impacts from extreme weather events, directly impinging upon human well-being (Groth et al., 2015). Throughout the latter half of the 20th century, Brazil has witnessed a swift and progressive escalation in urbanization and its concomitant environmental repercussions. Key elements from the secondary and tertiary sectors of the economy have propelled this phenomenon (Oliveira & Aquino, 2015). As urbanization advances, a conspicuous decline in natural environments ensues, giving rise to myriad urban environmental quandaries, representing one of the foremost challenges confronting contemporary cities (Streglio et al., 2013; Ferraz et al., 2017).

The ramifications of rapid urban growth manifest in substantial disarray within the urban landscape (Pereira; Dias, 2020). Against this backdrop, the preservation of urban green spaces assumes paramount importance, as these areas serve as sanctuaries for preserving fauna and flora species indigenous to their respective biomes. The municipalities of Cuiabá and Várzea Grande, situated in the State of Mato Grosso, Brazil, have undergone pronounced population expansion over recent decades. This demographic surge instigates a cascade of transformations in landscape structure and urban land utilization, leading to the fragmentation of natural habitats and a reduction in vegetation cover (Assis et al., 2018).

Guarda et al. (2019) posited that Cuiabá may potentially become uninhabitable by 2080 due to the projected escalation in the annual percentage of discomfort hours attributable to heat, juxtaposed with a decline in discomfort hours stemming from cold conditions. These phenomena are ascribed to unsustainable land use practices and occupation, compounded by the effects of global warming.

The presence of trees in residential neighborhoods has exhibited a salutary impact on pedestrian thermal comfort, attenuating average radiant temperature (TMRT) and the physiologically equivalent temperature (PET). Tree plantation in communal areas contributes to heightened thermal comfort and local temperature reduction. Thus, comprehending the efficacy of vegetative cooling across diverse urban landscapes is imperative for devising mitigation strategies through tree planting initiatives and urban planning (Sabrin et al., 2021).

Orbital sensors have emerged as efficacious and precise tools for mapping vegetation cover in urban locales. These sensors, affixed to orbital satellites, capture data across the electromagnetic spectrum, facilitating the identification and analysis of vegetated areas. Various orbital sensors, including Landsat, Sentinel, MODIS, and SPOT, have amassed data pertinent to urban vegetation. Leveraging remote sensing techniques alongside satellite image analysis enables the extraction of crucial information pertaining to vegetation cover, encompassing density, height, composition, and distribution (Martins, 2025).

Studies have underscored the utility of Planet satellite data in assessing diverse metrics of urban vegetation cover, encompassing area, density, fragmentation, and connectivity. These metrics are indispensable for discerning the spatial distribution of vegetation and its interplay with factors such as land use, population dynamics, and urban infrastructure. Furthermore, the Planet constellation has facilitated the identification of areas undergoing vegetative degradation, thereby supporting the formulation of restoration and conservation endeavors. With a spatial resolution of three meters, even diminutive green spaces amidst urban edifices and infrastructure are discernible (Britto, 2020).

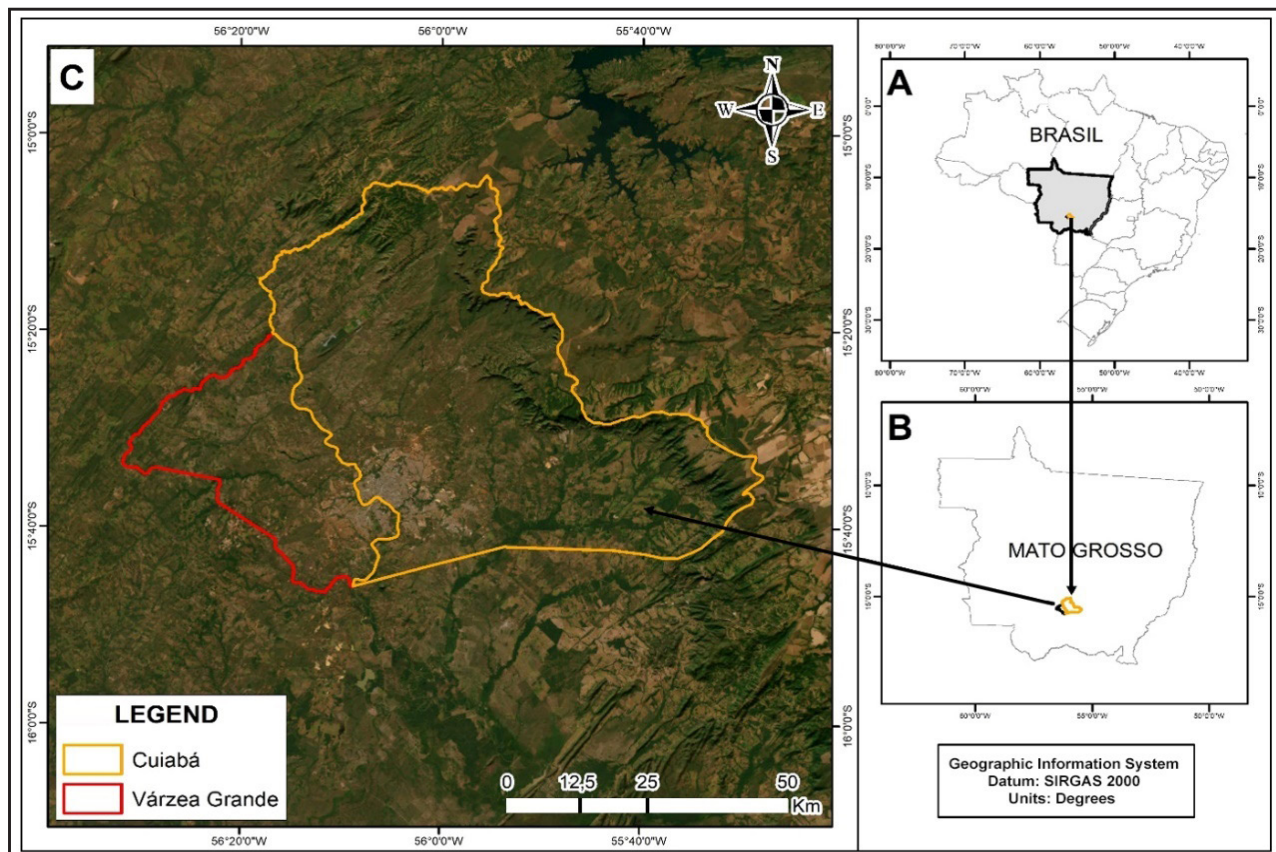
To comprehend urban land occupation and quantify green spaces across both municipalities Cuiabá and Várzea Grande, this study employs mapping geotechnologies, with the objective of delineating landscape alterations in the targeted regions.

2. MATERIAL AND METHODS

2.1 Study area

The municipalities of Cuiabá and Várzea Grande, located in the State of Mato Grosso, lie within the Center-South region of the state, positioned between $15^{\circ}28'29.896''$ S and $56^{\circ}1'9.086''$ W, within zone 21S (Figure 1). The climate of region the "Aw" according to the Koppen's climate classification, characterized predominantly tropical continental, featuring rainy summers and dry winters (Álvares et al., 2013).

Figure 1 – Map of the study area



Source: Authors (2024)

Average temperatures fluctuate between 22°C and 27°C, with peak temperatures reaching up to 40°C during the hottest years. Várzea Grande registers an average temperature of 26.3°C, while the annual precipitation averages around 1,445 mm. Cuiabá, on the other hand, maintains an average annual temperature of 26.1°C, based on climate norms spanning from 1981 to 2010 (INMET, 2021).

The municipalities are situated within the Brazilian Central Plateau, characterized by a topography ranging from flat to undulating. This topographic diversity arises from the region's placement within an area dominated by plateaus and depressions. Vegetation cover typifies the Cerrado Biome, showcasing semi-deciduous forests, "Cerradão," hillside forests, and riparian forests along watercourses (IBGE, 2012). The favorable topography fosters the formation of flooded areas, rivers, streams, and creeks, resulting in a dense drainage network (Pasa et al., 2020).

2.2 Data Acquisition and preprocessing

The data utilized in this study comprise information sourced from the Planet Constellation, encompassing over 150 satellites in orbit that collectively capture approximately 350 million square kilometers of imagery daily from beneath the Earth's surface (Planet, 2023).

The Planet constellation stands out for its frequent imaging, providing comprehensive coverage of the Brazilian territory with minimal cloud interference. Moreover, images are regularly updated on a daily basis, with records available since 2016. The Planet portal granted access to PlanetScope data through a licensing agreement under the Standard Education and Research Program, facilitating data retrieval for registered researchers.

For the year 2018, images were sourced from the Planet's second-generation satellite (PS2.SD), calibrated for Surface Reflectance. Equipped with sensors operating across four spectral bands—blue (464-517 nm), green (547-585 nm), red (650-682 nm), and near-infrared (846-888 nm)—this satellite boasts a spatial

resolution of three meters (Ruiz, 2022). Two scenes were utilized for Cuiabá, and three for Várzea Grande, all acquired on 04/29/2018.

In 2023, images were acquired from the Super Dove satellite, the third-generation satellite of Planet (PSB.SD sensor), also calibrated for Surface Reflectance. Utilizing eight spectral bands—Coastal Blue (431-452 nm), Blue (465-515 nm), Green (513-549 nm), Green II (547-583 nm), Yellow (600-620 nm), Red (650-680 nm), Red-Edge (697-713 nm), and Near Infrared (845-883 nm)—this satellite captured imagery. Similarly, two scenes were utilized for Cuiabá, and three for Várzea Grande, all captured on 04/29/2023.

Vector data delineating the boundaries of the cities of Cuiabá and Várzea Grande were obtained from the IBGE website, while information regarding Cuiabá's administrative regions was sourced from the GIS Cuiabá website. The Universal Transverse Mercator (UTM) projection system, zone 21 South, Datum SIRGAS 2000, was employed.

2.3 Machine Learning Algorithms

Machine learning classification techniques offer the capability to model intricate classes, accommodate various input data types, and make no assumptions about data distribution. Numerous studies have demonstrated the superior accuracy of these methods compared to traditional classifications, particularly for complex and high-dimensional data (Maxwell; Fang Fang, 2018).

Breiman (2001) introduced the Random Forest algorithm, employed in this study, which entails the creation of multiple random decision trees through interactive and random processes, utilizing rules and conditions to define classes. This approach involves generating several random decision trees, subsequently amalgamating them to form a model used for classifying all pixels within a given image.

The ENVI software facilitated supervised classification, with training samples of identified classes within the study area collected through visual image analysis and spectral target behavior. Table 1 enumerates the classes and the number of training samples.

Table 1 – Classes and training samples for training samples collected for each of the studied municipalities

Classes	N° of pixels
Wooded (areas with dense vegetation cover)	35.000
Urbanized (built areas)	35.000
Grasses and Herbaceous (areas with thin vegetation cover)	35.000
Water (areas with water blade or exposed water surface)	35.000

Source: Authors (2024)

2.4 Validation of classification using the Kappa Index

The Kappa Index (K) serves as a measure of agreement, assessing the extent to which observations deviate from those expected by chance. This metric offers an approximation of the validity of interpretations, computed based on an error/confusion matrix. Moreover, the Kappa Index serves as a gauge of agreement between the generated map and the reference data adopted for accuracy assessment (Vale, et al., 2021).

To construct the confusion matrix, images were converted into vector format. For validation purposes, fifty random points were generated for each class and distributed across a Google Earth image mosaic of the study area for 2018 and 2023. After converting the random points into raster format, the data were overlaid onto the classified images. Subsequently, the confusion matrix was generated, and image classification performance was evaluated using the Kappa Index (Landis & Koch, 1977).

Table 2 – Kappa Index Values. Adapted from Landis & Koch (1977)

Kappa index class	Classification performance
< 0.00	None
0.00 - 0.20	Low
0.20 - 0.40	Average
0.40 - 0.60	Good
0.60 - 0.80	Very good
0.80 - 1.00	Excellent

Source: Authors (2024)

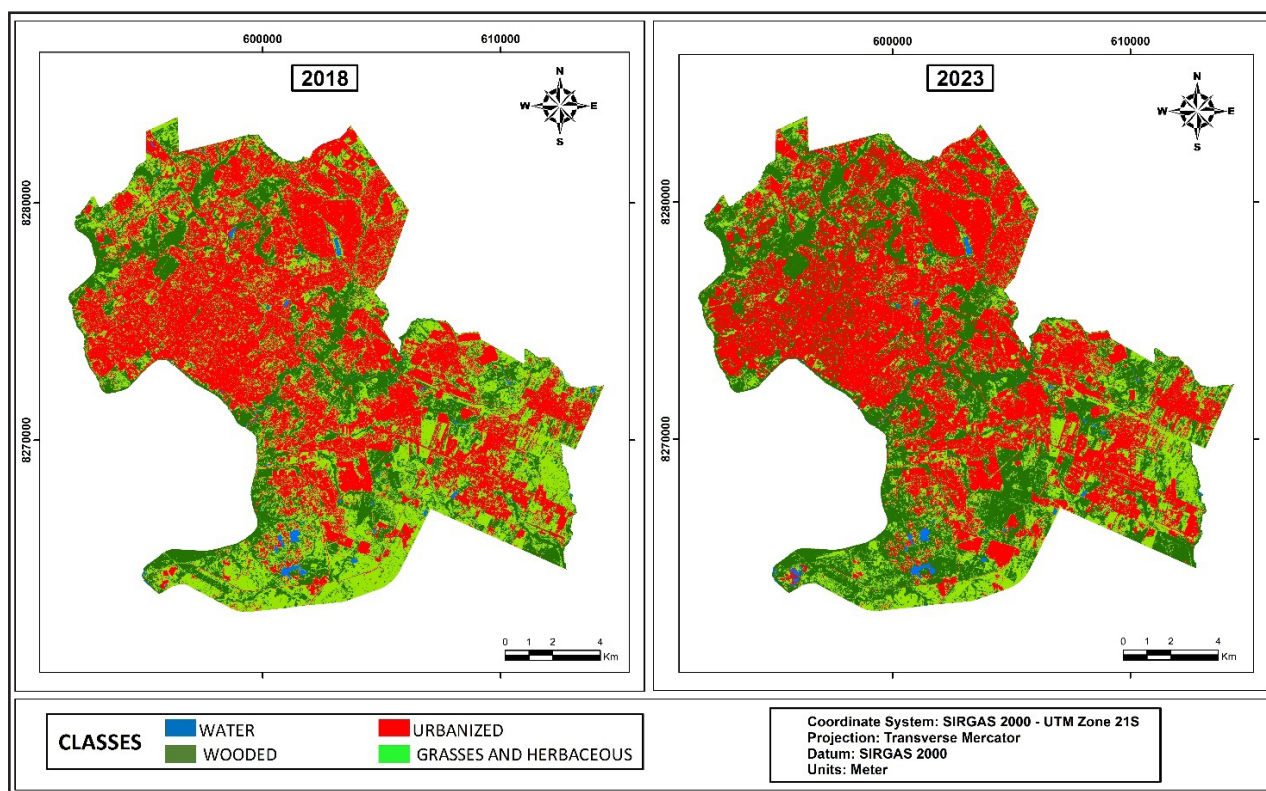
The accuracy assessment of the final maps was conducted for 2018 and 2023 to ascertain data reliability. Subsequently, the reference data and the classified images were compared against the reference values outlined in Table 2.

3. RESULTS AND DISCUSSION

3.1 Cuiabá

The mapping process comprehensively covered the entire urban perimeter of Cuiabá in both 2018 and 2023, delineating four administrative zones for each respective year. The initial map illustrates the trends of the four classes representing the land use and cover of the total urban perimeter, as depicted in Figure 2.

Figure 2 – Classification by the Random Forest algorithm for the municipality of Cuiabá



Source: Authors (2024)

The results obtained from mapping using images from Planet orbital sensors reveal that the capital of Mato Grosso had approximately 32.84% tree vegetation cover (Wooded class) in 2023 (Table 3).

Table 3 – Quantification of area by class

Classes	2018		2023	
	Area (Km ²)	Area %	Area (km ²)	Area %
Water	1,86	0,73%	1,83	0,72%
Wooded	59,59	23,49%	83,31	32,84%
Urbanized	111,76	44,05%	113,74	44,83%
Grasses and herbaceous	80,48	31,72%	54,80	21,60%
Total	253,68	100%	253,68	100%

Source: Authors (2024)

The presence of vegetation in urban areas offers numerous benefits, including the reduction of rainwater runoff, improvement of microclimatic conditions, enhancement of air quality, mitigation of noise pollution, and sequestration of carbon dioxide. These aspects not only promote environmental sustainability but also significantly contribute to the quality of life in urban areas (Hirye, 2020).

There was an increase in tree vegetation (Wooded class) from 23.49% in 2018 to 32.84% in 2023. Arruda (2023) reported similar findings, recording a tree vegetation area of 26.63% in 2021. The mapping process enabled the quantification of vegetation cover areas within the urban perimeter using Landsat 8 satellite images with a 30-m spatial resolution. Caldas (2014) reported a tree vegetation area of 27.80% in 2010 using a WorldView II image with a resolution of two meters.

Although the findings of the aforementioned study resulted in 26.63% vegetation coverage, this percentage is deemed unsatisfactory considering the uneven distribution of these areas, particularly in terms of access to ecosystem and environmental services. The north and west regions of the city stand out as potential ecological connectors, housing two significant conservation units. Despite being larger and denser, these

areas are isolated by the city's main avenues. Urban vegetation plays a pivotal role in enhancing both human and environmental life quality (Arruda, 2023; Pereira, 2020).

To provide a detailed analysis, this study recorded information on each administrative zone of the city of Cuiabá, as illustrated in Table 4.

Table 4 – Quantification of areas by administrative region

2018			2023		
North Region - Classes	Área (Km ²)	Área %	North Region - Classes	Area (Km ²)	Area%
Water	0,21	0,69%	Water	0,17	0,54%
Wooded	4,74	15,42%	Wooded	7,17	23,32%
Urbanized	19,09	62,06%	Urbanized	19,08	62,03%
Grasses and herbaceous	6,72	21,83%	Grasses and herbaceous	4,34	14,12%
Total	30,76	100%	Total	30,76	100%
South Region - Classes	Área (Km ²)	Área %	South Region - Classes	Area (Km ²)	Area%
Water	1,30	1,02%	Water	1,30	1,02%
Wooded	34,53	27,19%	Wooded	46,38	36,51%
Urbanized	40,19	31,64%	Urbanized	42,98	33,84%
Grasses and herbaceous	51,01	40,15%	Grasses and herbaceous	36,37	28,63%
Total	127,03	100%	Total	127,03	100%
East Region - Classes	Área (Km ²)	Área %	East Region - Classes	Area (Km ²)	Area %
Water	0,20	0,43%	Water	0,21	0,44%
Wooded	7,95	16,74%	Wooded	11,16	23,50%
Urbanized	29,03	61,14%	Urbanized	29,70	62,56%
Grasses and herbaceous	10,30	21,69%	Grasses and herbaceous	6,41	13,49%
Total	47,48	100%	Total	47,48	100%
West Region - Classes	Área (Km ²)	Área %	West Regionb - Classes	Area (Km ²)	Area%
Water	0,15	0,30%	Water	0,16	0,33%
Wooded	12,36	25,53%	Wooded	18,60	38,42%
Urbanized	23,45	48,43%	Urbanized	21,97	45,38%
Grasses and herbaceous	12,46	25,74%	Grasses and herbaceous	7,68	15,87%
Total	48,41	100%	Total	48,41	100%

Source: Authors (2024)

All regions exhibited a significant increase in tree cover between 2018 and 2023, potentially indicating tree planting initiatives, green area restoration projects, or

other endeavors aimed at augmenting tree cover. This increase could be attributed to afforestation efforts, environmental preservation endeavors, or natural growth. The presence of the Mãe Bonifácia City Park, situated in the west region and covering an area of 0.775 km², significantly contributed to the increase in tree cover in that region and provided valuable green space for the local community.

The data revealed a substantial increase of 50.63% in wooded class in the north region of the city, corresponding to an increase of 2.43 km². Notably, this region is home to the Massairo Okamura State Park, a vital conservation unit. Urbanized areas remained relatively stable, with a slight variation from 62.06% in 2018 to 62.03% in 2023, considering the total area. However, there was a noteworthy reduction in the grass and herbaceous class, from 21.83% in 2018 to 14.12% in 2023, corresponding to a decrease of 2.38 km². This analysis underscores the distinct dynamics among different categories of vegetation cover in the region.

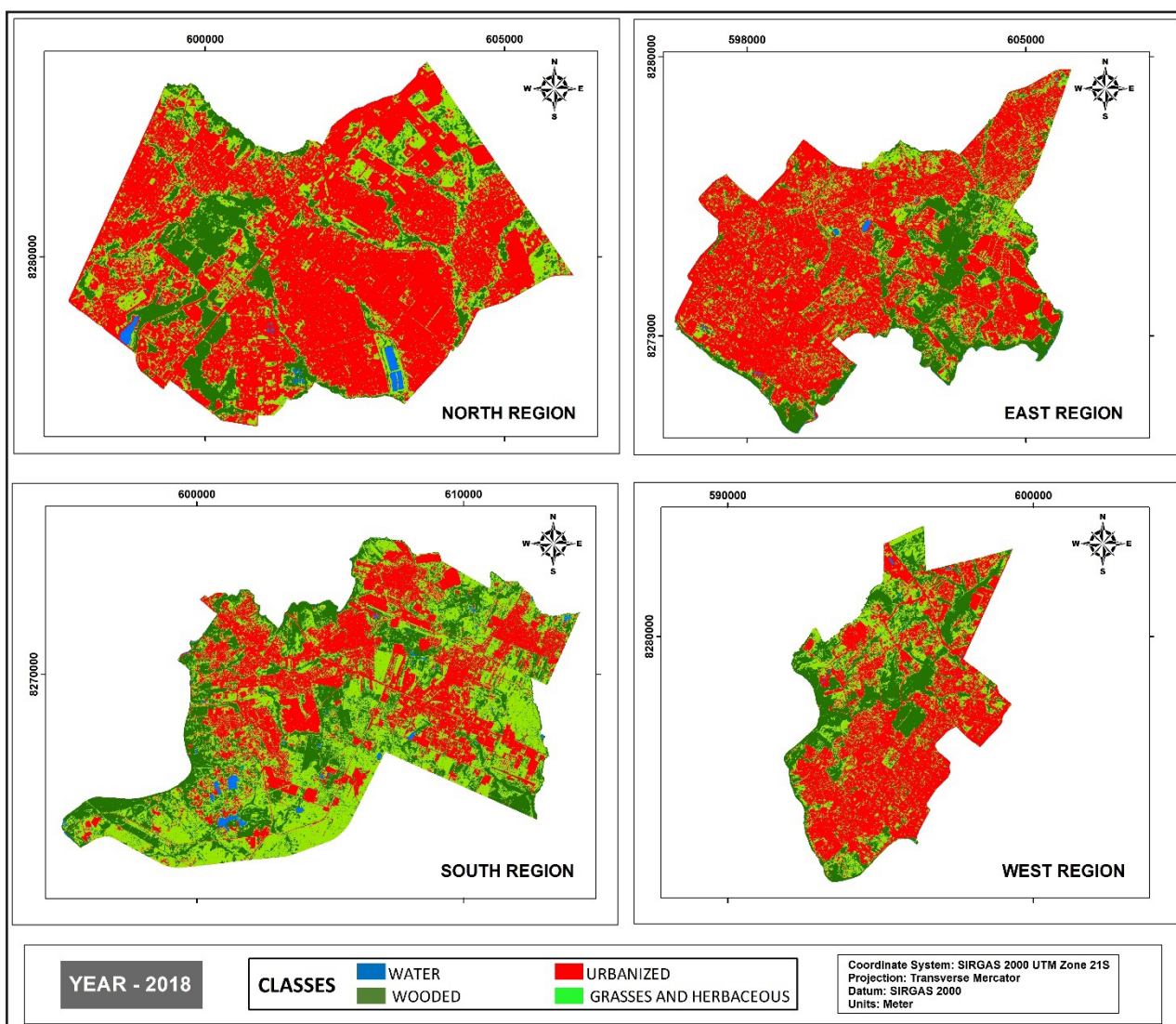
In the south region, grasses and herbaceous covered 40.15% in 2018; however, there was a significant reduction of 14.64 km² in this class, associated with the transition to the wooded category. Simultaneously, the grasses and herbaceous class covered the extremities of the city's south region, encompassing areas of land, farms, and urban subdivisions where vegetation is undergoing regeneration. The city's south region exhibited the lowest percentage of urbanized class: 33.84% in 2023 (Table 4). It is noteworthy that the Zé Bolo Flô State Park is situated within this region.

The eastern region recorded the lowest increase in wooded class, with a growth rate of 40.37%. The high density of buildings in the area may have contributed to this phenomenon. However, this increase is likely associated with the conservation of Permanent Preservation Areas (PPA) of watercourses in the region.

The analysis of the water class resulted in significant stability across all regions, recording close values of 2.44% in 2018 and 2.33% in 2023. In comparison, Arruda (2023) calculated that only 0.18% of the area within the urban perimeter of Cuiabá was occupied by bodies of water.

The land use mappings for each administrative zone in the city of Cuiabá in 2018 and 2023 can be seen in Figures 3 and 4.

Figure 3 – Classification by Random Forest algorithm by administrative zone in the municipality of Cuiabá in 2018

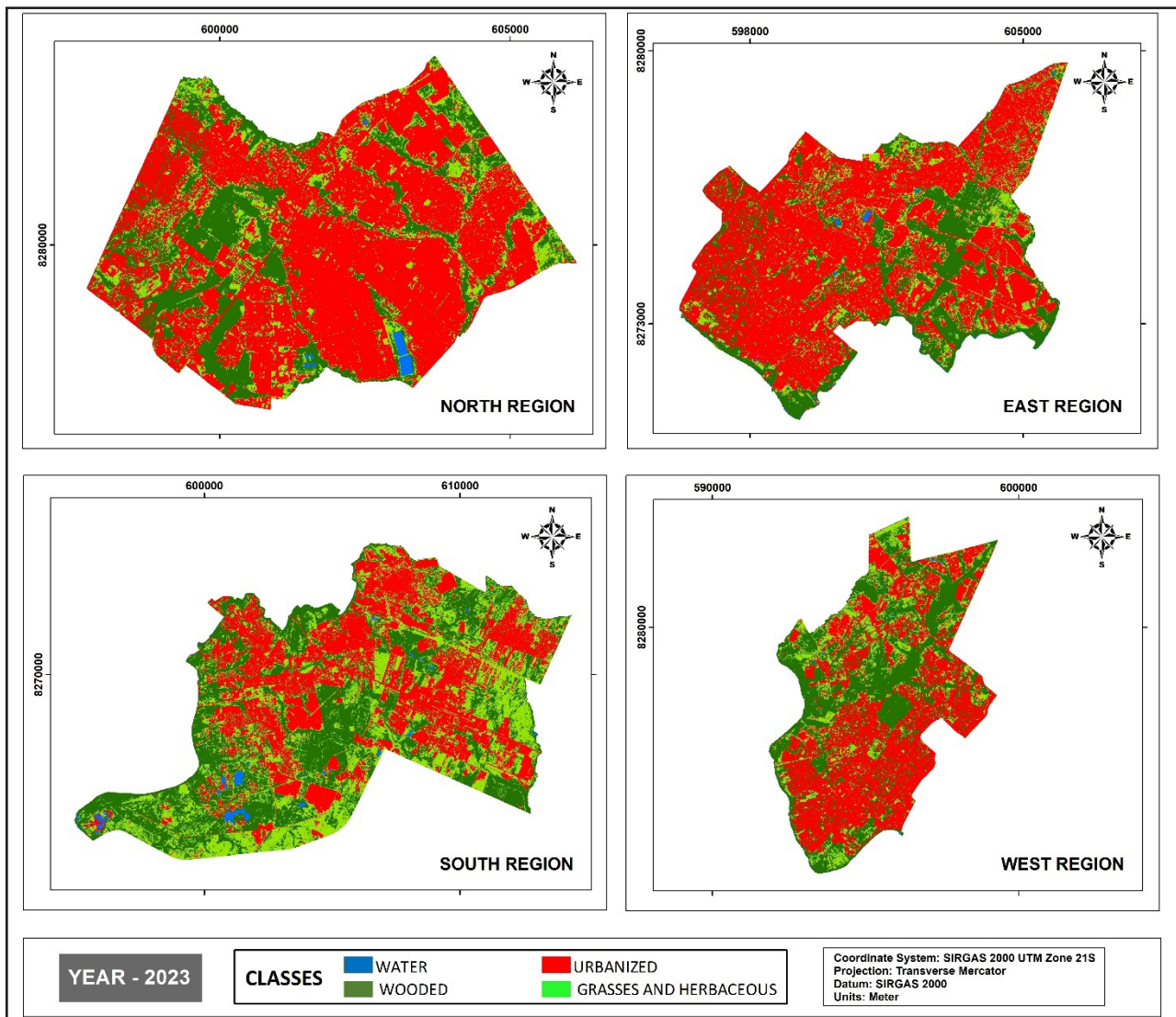


Source: Authors (2024)

The comparison of values with data from Arruda (2023), who utilized data from the OLI sensor aboard the Landsat 8 satellite for mapping the municipality of Cuiabá in 2021, resulted in three primary classes of land use and occupation: urbanized areas (73.18%), vegetation area (26.63%), and water (0.18%). The analysis unveiled differences among all classes, with the urbanized areas class showing a disparity of 28.35% (Table 5).

The reduction in the percentage of the urbanized class may be attributed to the inclusion of areas with grasses and herbaceous plants in the urbanized class, as depicted in the comparative map (Figure 5). It's noteworthy that the methodology used by the authors was different and must be carefully considered to justify such disparity, as it may directly affect the classification results. Data from Planet, considering the high resolution used in this study, are deemed more reliable and suitable when compared to data from the Landsat 8 satellite, as utilized by Arruda (2023).

Figure 4 – Classification by Random Forest algorithm by administrative zone in the municipality of Cuiabá in 2023



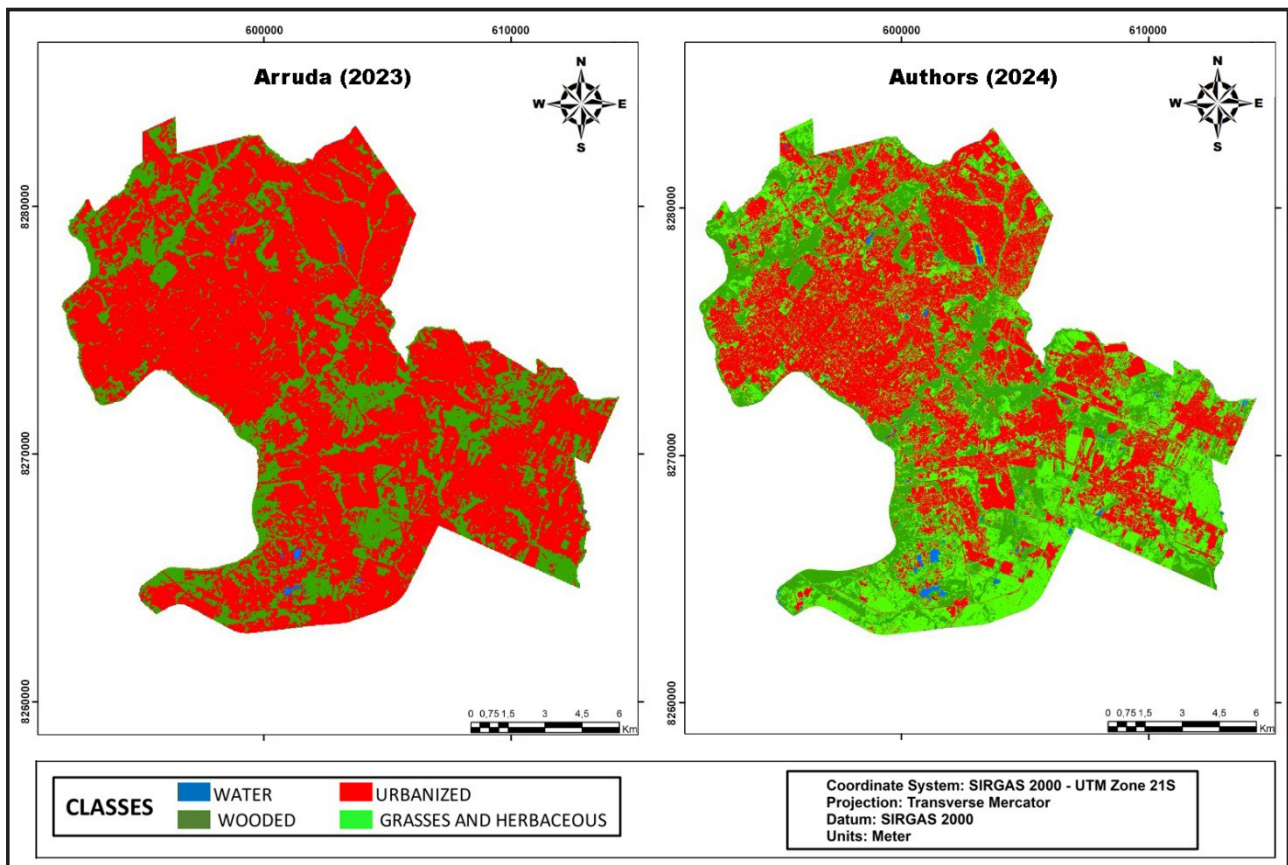
Source: Authors (2024)

Table 5 – Comparison between class percentages between the two different studies

Classes	Arruda (2023)	Authors (2024)	Difference between authors
Water	0,18%	0,72%	0,54%
Wooded	26,63%	32,84%	6,21%
Urbanized	73,19%	44,84%	-28,35%
Grasses and herbaceous		21,60%	21,60%

Source: Authors (2024)

Figure 5 – Comparative map of classification of the municipality of Cuiabá using the Maximum Likelihood algorithm (2023) and the Random Forest algorithm (2024)



Source: Authors (2024)

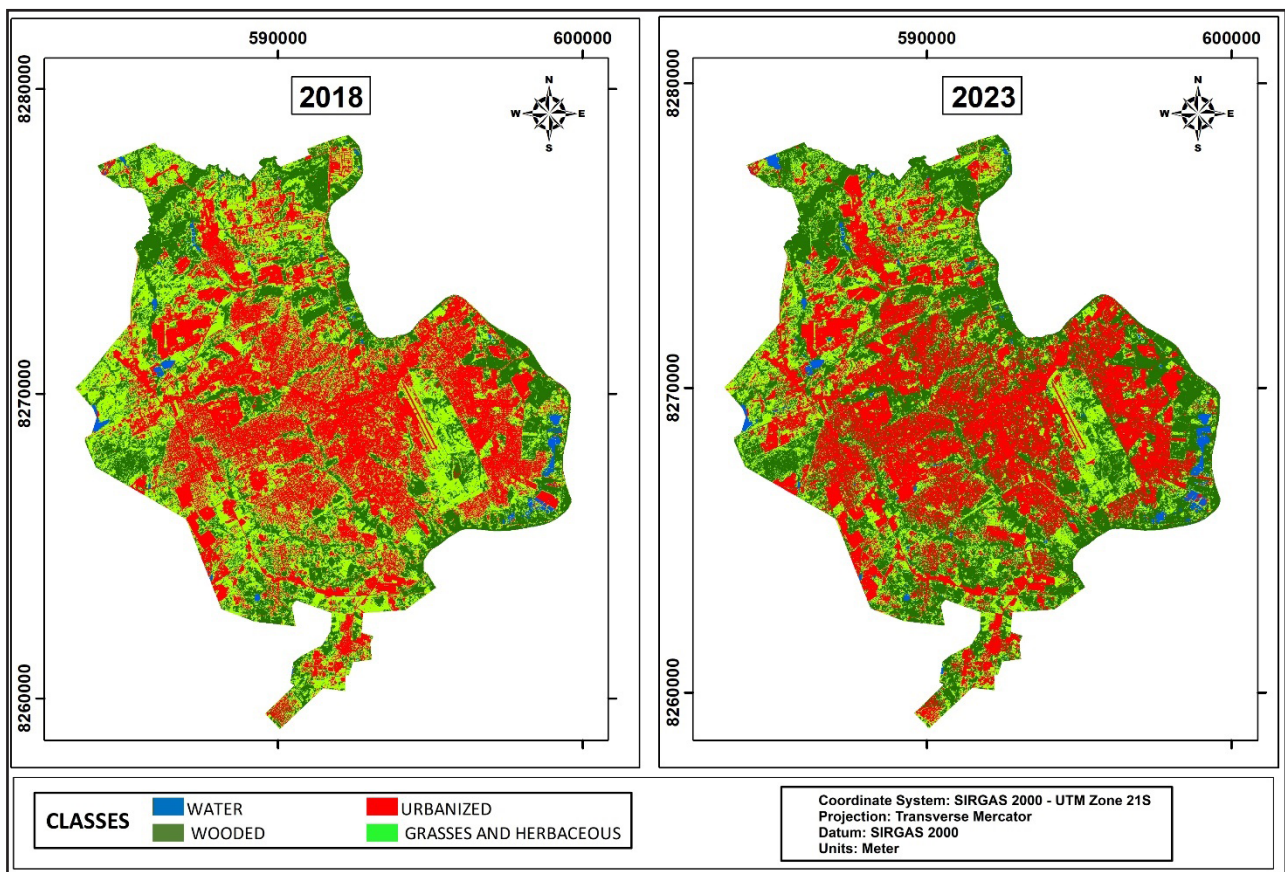
Based on the provided information, the ENVI 5.7 software validated the classification, and samples of the classification were coupled with the images to calculate the Kappa index. The Kappa values obtained for the 2018 and 2023 classifications were 0.8693 and 0.8593, respectively (refer to Supplementary material).

According to Landis & Koch (1977), both values are considered excellent. The global accuracy for 2018 was 89.94%, and for 2023, it was 89.44%.

3.2 Várzea Grande

The municipality of Várzea Grande is not divided into administrative regions; hence, the analyses considered the total perimeter. Figure 6 illustrates the map of the supervised classification of land cover in the municipality of Várzea Grande, highlighting the various categories of land use within its urban perimeter of 162.98 km².

Figure 6 - Classification by the Random Forest algorithm of the municipality of Várzea Grande-MT



Source: Authors (2024)

Classification using the Random Forest algorithm revealed that wooded areas accounted for 26.46% in 2018 and increased to 35.96% in 2023 (Table 6).

Comparing these results with those of Coelho (2016), the percentage of wooded area was reported as 58.05% in 2015.

Table 6 – Comparison between percentages of the defined classes in 2018 and 2023

Classes	2018		2023	
	Area (km ²)	Area %	Area (km ²)	Area %
Water	1,73	1,06%	2,47	1,52%
Wooded	43,13	26,46%	58,61	35,96%
Urbanized	60,19	36,93%	60,23	36,95%
Grasses and herbaceous	57,93	35,54%	41,67	25,57%
Total	162,98	100%	162,98	100%

Source: Authors (2024)

The increase in the wooded class primarily occurred in the peripheral areas of the city, such as land subdivisions and vacant lots, where low vegetation commonly referred to as bush grows. Natural regeneration in these locations resulted in the transition from the grasses and herbaceous class to wooded. Green areas are predominantly concentrated in riparian forests of streams traversing the city, including the Cuiabá River and the Bernardo Berneck Parks, Flor do Ipê Park, and Tanque Fancho Ecological Park. The tree vegetation appears fragmented and dispersed in areas of urban density.

A study conducted by Soria et. al (2024) indicated that over 36 years (1985-2021) Cuiabá's surface temperature has increased by an average of 13°C, as part of the result of the growth of urban infrastructure and loss of vegetation cover, specifically in the peripheral areas. Calejas et al. (2011) and Coelho (2016) reported surface temperature values of 29.96°C and 29.78°C in 2011 and 2015, respectively, in areas classified as vegetated areas in the city of Várzea Grande. This underscores the significance of parks in ensuring cities' thermal comfort. Almeida et al. (2021) found a temperature difference in Mãe Bonifácia Park and urbanized surroundings of 3.94°C, highlighting the significant impact of native vegetation on climate.

The urbanized class did not exhibit significant expansion and remained stable, ranging between 60.19% and 60.23%. Callejas et al. (2011) reported that the urbanized area was 54.23% in 2007. The increase in area from 2007 to 2018 can be attributed to the expansion of the municipality's urban perimeter resulting from Complementary Law no. 3,974/2013, which augmented the municipality's area by 22.16% Coelho (2016).

The central areas of Várzea Grande feature scattered tree fragments, with main avenues paved and median strips lacking large tree species. Consequently, the surface temperature in these areas varies between 32°C and 38°C. Coelho (2016) highlighted that due to the higher population density in the city center, built-up areas, and sparse vegetation, heat islands form.

The increase in areas classified as water was 0.74%, primarily due to the construction of reservoirs in peripheral areas. Tables 9 and 10 compile the results of confusion matrices referring to the Random Forest. The collected samples for the study area were deemed adequate. The presented results are satisfactory and consistent with the previously assigned classifications. These findings bolster confidence in the validity and accuracy of the utilized model.

The classification accuracy obtained in 2018 yielded a Kappa Index of 0.68, deemed very good, indicating compatibility between the collected samples and the classification. The model evaluation results exhibited a Kappa index of 0.8, suggesting a substantial level of agreement and demonstrating the model's effectiveness in considering classification nuances and possible random coincidences. Moreover, the overall accuracy reached 85.5%, showcasing the model's ability to accurately classify a broad range of samples and providing a comprehensive view of its global performance. These robust results underscore the reliability and accuracy of the model in making classifications.

The performance of urban forests is intricately linked to the effectiveness of urban planning. The utilization and occupation of soil arise from processes initiated by the removal of native vegetation, leading to a new landscape configuration. In this context, ecological dynamics, represented by ecosystem services, are not fully harnessed (Arruda, 2023).

The presence of vegetation in urban areas is deemed an economical and viable solution to mitigate the consequences of rising temperatures. The benefits are pronounced in parks and squares, impacting both macroclimate and microclimate as well as the thermal comfort of the population (Silva; Xavier; Alvarez, 2015; Rodrigues; Pasqualetto; Garção, 2017; Shinzato; Duarte, 2018); Green areas provide favorable conditions in the local ecosystem to offer ecosystem services. Ruppert & Duncan (2017) elucidated that ecosystem services encompass various direct and indirect benefits, monetary and non-monetary, derived from actions in an active, native, or modified ecosystem.

The mapping of vegetation cover and “Urban Forests” within the perimeters of Cuiabá and Várzea Grande, primarily concentrated in parks and squares, contributes to mitigating urban heat islands. This aligns with a study conducted by Lima et al. (2021), which aimed to investigate further the presence of heat islands in the Coxipó region, Cuiabá-MT, Brazil. In that study, the authors collected temperature and relative air humidity data at strategic points using a mobile transect at defined points, aiming to study different urbanization characteristics. The authors followed the classification of Local Climatic Zones for subsequent statistical analysis in the R software. The measurement findings revealed that the most urbanized regions present significantly higher temperature levels than those observed in adjacent rural areas, characterizing the phenomenon known as a heat island. Detailed data analysis identified areas with milder temperatures and higher humidity levels, representing thermo-hygrometric anomalies that benefit the urban microclimate under study.

The conversion of areas with native vegetation into different uses and occupations directly influences local environmental conditions. This process results in a reduction in the amount of energy available for natural processes, as evidenced by the increase in reflected and emitted energy (Borella et al., 2018).

4 CONCLUSION

The employed methodology entailed the utilization of the Random Forest algorithm based on machine learning, demonstrating consistency and reliability in classification. Leveraging sensor data with superior spatial resolution underscores a greater potential for characterizing urban areas, as evidenced by the accuracy of the mappings produced here.

This study elucidates substantial changes in the urban vegetation cover of Cuiabá and Várzea Grande, highlighting a significant increase in vegetation. The algorithm discerned this increase by detecting changes in the spectral characteristics associated with vegetated areas. The direct correlation between the decrease in the field and grass class and the increase in the tree class is evident.

By utilizing images from the Planet satellite, acquired in 2018 with four spectral bands and in 2023 with eight spectral bands, the analysis benefits from the wealth of information captured across different bands of the electromagnetic spectrum. This expansion in the number of spectral bands allows for a more comprehensive and refined view of vegetation characteristics, contributing to a more accurate interpretation of changes in vegetation cover over time.

Data from Planet obtained in 2023, pertaining to sensors integrated into the new SuperDove satellites, facilitate the acquisition of information with superior spectral resolution, leading to a significant enhancement in the qualification and quantification of the mapped classes.

Therefore, the improved identification of the wooded class in 2023 results from the enhanced effectiveness of the vegetation classification algorithm in that year's image. In other words, arboreal vegetation likely existed in 2018, but it was erroneously classified by the algorithm as belonging to the grasses and herbaceous class. The refinement of the algorithm in 2023 likely corrected this interpretation, resulting in a more accurate identification of wooded class.

These analyses contribute to understanding the impacts of disorderly urban growth and provide support for the implementation of environmental preservation measures and sustainable urban planning.

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HOW TO DIAGNOSE URBANIZATION AND ENVIRONMENT IN CITIES – A CASE STUDY OF THE URBAN PERIMETER OF CUIABÁ AND VÁRZEA GRANDE/MT, BRAZIL

Confusion matrix table Cuiabá 2018

Classes	Water	Wooded	Urbanized	Grasses and herbaceous	Total
Water	42	0	0	0	42
Wooded	4	49	0	6	59
Urbanized	0	1	48	4	42
Grasses and herbaceous	4	0	1	40	56
Total	50	50	49	50	199
Aglobal Curacy	179/199		89.9497%		
Kappa index	0.8693				

Confusion matrix table Cuiabá 2023

Classes	Water	Wooded	Urbanized	Grasses and herbaceous	Total
Water	38	0	0	0	38
Wooded	4	49	2	3	58
Urbanized	2	0	46	2	50
Grasses and herbaceous	6	0	2	45	53
Total	50	49	50	50	199
Aglobal Curacy	178/199		89.4472%		
Kappa index	0.8593				

Confusion matrix table Várzea Grande 2018

Classes	Water	Wooded	Urbanized	Grasses and herbaceous	Total
Water	36	0	0	0	36
Wooded	3	36	0	2	41
Urbanized	8	4	43	11	66
Grasses and herbaceous	3	10	7	37	57
Total	50	50	50	50	200
Aglobal Curacy			152/200	76.00%	
Kappa index			0.6800		

Confusion matrix table Várzea Grande 2023

Classes	Water	Wooded	Urbanized	Grasses and herbaceous	Total
Water	37	0	0	0	34
Wooded	9	43	0	3	55
Urbanized	2	1	49	5	57
Grasses and herbaceous	2	6	1	42	51
Total	50	50	50	50	200
Aglobal Curacy			171/200	85.50%	
Kappa index			0.8067		

Source: Authors (2024)

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