# DYNAMICS OF LAND USE AND LAND COVER CHANGES AND SOCIO-ENVIRONMENTAL IMPLICATIONS IN THE MUNICIPALITY OF SINOP-MT

*Renan de Almeida Silva [1], Carlos Antonio da Silva Junior[2], Patrícia Helena Mirandola Garcia[1], Wendel Buêno Morinigo[3], Daniel Henrique dos Santos[2], Betrielly Zanrosso de Oliveira[2], João Lucas Della-Silva[3], Fernando Sagarosa Rossi[4]*

[1]Universidade Federal de Mato Grosso do Sul (UFMS), Três Lagoas – MS, geo.renanalmeida@gmail.com, patriciaufmsgeografia@gmail.com; [2]Universidade do Estado de Mato Grosso, Sinop – MT, carlosjr@unemat.br, betrielly.zanrosso@unemat.br, daniel.santos1@unemat.br; [3]Universidade Federal de Mato Grosso (UFMT), Sinop, Mato Grosso, Brasil, wendelbmorinigo@hotmail.com, joao.lucas1@unemat.br; [4]Universidade Estadual Paulista (UNESP), PPG-Ciência do Solo, Jaboticabal, São Paulo, Brasil, fernando.rossi@unesp.br.

## ABSTRACT

Land use cover and changes due economic development affects biological dynamics, as biogeochemical cycles and biophysical factors. The objectives of this study were (a) to identify the land use and land cover changes in the municipality of Sinop-MT over the years 1984, 1994, 2004, 2014 and 2022, (b) to quantify the efficiency of carbon sequestration in different classes of land use and land cover, and (c) to investigate the surface temperature in different years of land use and land cover changes. Our analysis suggests that along these years, the study area had an average of 25% change, with the Forest class having the greatest decrease (-47%) and the Anthropic Actions class with the greatest increase (42%). It can be concluded that the geographic space lost Amazon Forest for the insertion of diverse economic activities, which decreased the absorption of $CO_2$ and increased the average surface temperature as a whole.

**Keywords —** $CO_2$Flux, environment, remote sensing.

## 1. INTRODUCTION

In recent decades, the biogeographical limit of Amazon biome in northern Mato Grosso has suffered deep exploitation of natural resources as a result of colonization projects, supported by the federal government's occupation policies since 1970 [1]. In this region, the city of Sinop economically ascended due to significant advances in development of temporary agriculture, the offer of services and, consequently, the expansion of its urban area [1]. The closeness to the federal highway network has contributed massively to this scenario, making Sinop a investment hub for agricultural production and the residential and commercial sector, with a development pace of 10% per year [2].

As indication of this economic development, the steep change in land use and land cover (especially in vegetation cover) impacts the exchange of fluxes of several elements (e.g., carbon dioxide, methane) over atmosphere and earth's surface. Biogeochemical cycles and biophysical factors (albedo, evapotranspiration efficiency, and surface roughness) are affected, and these factors involve ecosystem services regulation and its changes [3].

This kind of study are suitable for remote sensing (RS) and geographic information systems (GIS) techniques application. This combination is increasingly useful in the analysis of the Earth's surface, owing to satellite image processing and in situ-based data collection (quantitative and qualitative) via geoprocessing software, which in turn allows the understanding of recurring phenomena in geographic spaces and assists researchers in making decisions [4].

The changes in land use and land cover analysis enable those biological dynamics understanding, as they impact both regulation of ecosystem services and population residing in this municipality. For this, we used GIS and RS techniques, where environmental changes and their influences can be seen., as well as carbon sequestration, based on spectral indices for carbon flux estimation, existing in the elements present on the earth's surface [5].

Finally, the objectives of this study were (a) to identify the land use and land cover changes in the municipality of Sinop -MT in the years 1984, 1994, 2004, 2014 and 2022, (b) to quantify the carbon sequestration efficiency in different land use and land cover classes, and (c) to investigate the surface temperature in the different years of land use and land cover changes.

## 2. MATERIALS AND METHODS

### 2.1. Study Area

The study area (Figure 1) comprises the municipality of Sinop located in the state of Mato Grosso, between 11°43'48.24" to 12° 1'44.24" and 55°22'10.77" to 55°38'8.40" with an area of 399.086. 99 hectares (ha), estimated population of 146,005 inhabitants [6] and climate classification according to Koppen of 'Am', as it presents an average temperature of 18ºC in the coldest month and a dry season of short duration that is compensated by high precipitation totals [6].

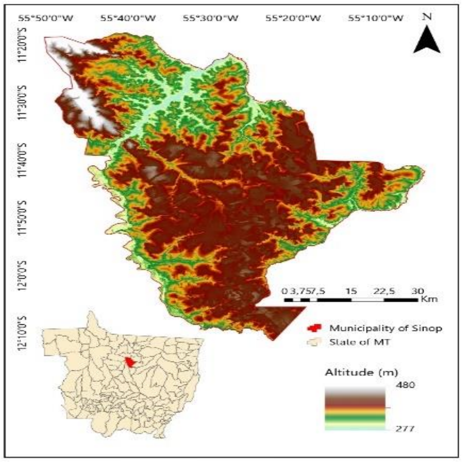


**Figure 1. Location map of the study area, municipality of Sinop, state of Mato Grosso.**

## 2.2. Organization, Satellite Data Quality Control and Radiometric Calibration

Satellite images with the lowest percentages of cloud presence for each year from Landsat 5/TM (1984, 1994, 2004) and Landsat 8/OLI and TIRS (2014 and 2022) (dry season) were used to generate and analyze three distinct products, being land use and land cover (LULC), land surface temperature (LST), and carbon sequestration. The Landsat Collection 2 level-1 data was acquired through the Earth Explorer image catalog, from the United States Geological Survey (USGS) website.

In the perspective of data preprocessing, the digital numbers of the pixels in each band were converted to monochromatic spectral radiance by means of spectral radiance calculation, which means the radiance data were converted to apparent reflectance data [7]. To accomplish these tasks and perform the necessary calculations for radiometric calibration, a map algebra expression was carried out through the raster calculator tool at QGIS Desktop 3.22.8.

## 2.3. Land Use and Cover

For the classification of Landsat 5 and 8 images, the SCP plugin (at QGIS Desktop 3.22.8 software) was used. The procedure started with the collection of 100 samples from each class of interest: Anthropic actions (farming, mining areas and highways); Urban Center (Sinop urban mesh); Water Bodies (Teles Pires River, lakes and ponds) and Forest (Amazon Forest, permanent preservation areas, legal reserve and the like). Then, the Random Forest algorithm was applied to perform supervised classification [8] and, finally, the strength agreement of the results by Kappa coefficient.

## 2.4. Carbon Sequestration

To measure the carbon uptake, the $CO_2$flux index ($CO_2$Flux) was used [9]. $CO_2$Flux relates the photosynthetic rate derived from photochemical processes, described by Photochemical Reflectance Index (PRI) [9] adapted to multispectral data [10], and vigor of photosynthetically active vegetation using the Normalized Difference Vegetation Index (NDVI) [11]. We collected 100 samples from each class in its different years for the purpose of change analysis, and the calculation of the indices were performed using the raster calculator tool available in QGIS Desktop 3.22.8.

## 2.5. Surface Temperature

To arrive at the surface temperature results, band 6 (thermal infrared) of the TM sensor (Landsat 5) and band 10 (thermal infrared) of the TIRS sensor (Landsat 8) were used. First, the raster calculator tool was used for the calculation of conversion parameters from image gray levels to radiance and conversion of data to temperature values in degrees Celsius [12]. Next, using Landsat-8 imagery, the emissivity of the earth's surface was obtained based on NDVI data [13]. In conclusion, 100 samples were collected from each class for each year, aiming at understanding recurring temperature changes.

# 3. RESULTS AND DISCUSSION

Since Sinop emancipation (December 17, 1979, governed by law 4.156/79), the historic process of this municipality presents different economic activities that affected the geographic space, as well as defines the modes and rhythms of land occupation and use [1]. At first, the economic activity developed was logging, a practice that, besides being profitable, it’s the LULC main driver. In a second period, agriculture and cattle ranching led the economic activities, characterized by the expansive character of anthropic action, e.g., agricultural production and cattle raising [1]. The economic development of the municipality from 1984 to 2022 can be observed on orbital data classification (Figure 2, Figure 3).

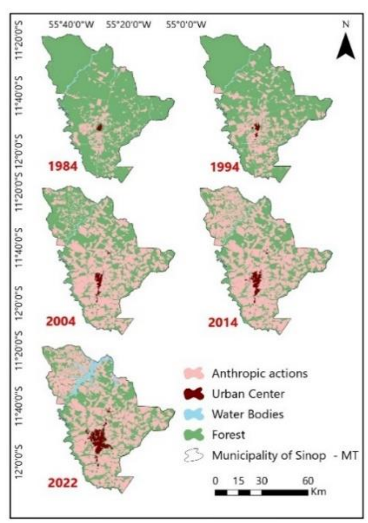

**Figure 2: Map of land use and land cover in the municipality of Sinop - MT, in the years 1984, 1994, 2004, 2014 and 2022.**

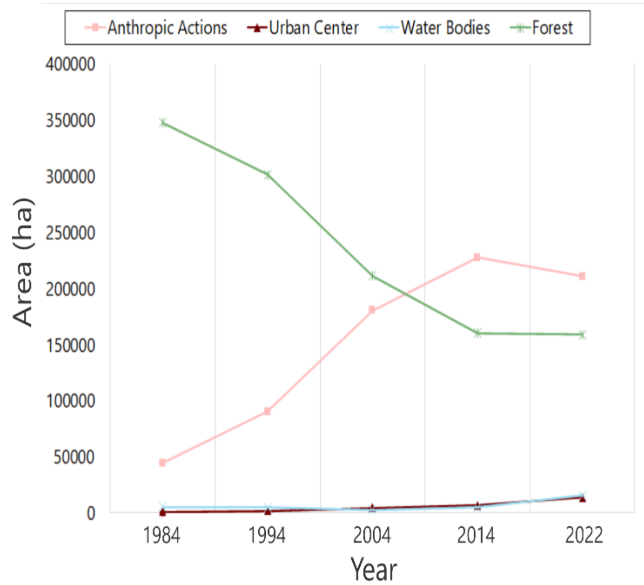


**Figure 3: Graph of land use and land cover in the municipality of Sinop - MT, in the years 1984, 1994, 2004, 2014 and 2022.**

The dataset collected (Figures 2 and 3) suggest that over the years of analysis, Sinop had an average change of 25%, with the Forest class (mainly marked by the Amazonian rainforest) with the greatest decrease (47% deficit, resulting in a loss of 188,593.41 ha), while the Anthropic actions class (characterized mainly by economic activities) showed the greatest increase (42% increase, resulting in a gain in area of 165,920.59 hectares).

The Urban Center and Water Bodies classes also presented a significant advance. The urban mesh (Urban Center) had an increase of 3,12% (enlargement of 12,446.49 ha) as a result of the evolution of the services and industrialization, which increased job vacancy, implying on immigration of new workers and the real estate sector heating [2]. The Water Bodies class increased 2.56% (10,225.99 ha) in defluence of the creation of the lake of the hydroelectric power plant with Sinop reservoir (UHE Sinop), with flooding in January 2019 and completion in April of the same year. The land use and land cover changes over the time series initially occurs close to the lead-off urban area of Sinop, and firstly progressed to the south, then east, thirdly to west, and finally towards north (Figure 2).

In order to parameterize the behavior of the land surface temperature for each land use and land cover class, the boxplot analysis was applied (Figure 4). It is noteworthy that the concentration of values just above the median, being the classes Anthropic Actions and Urban Center with the highest temperature variations, followed by the Forest and Water Bodies classes.

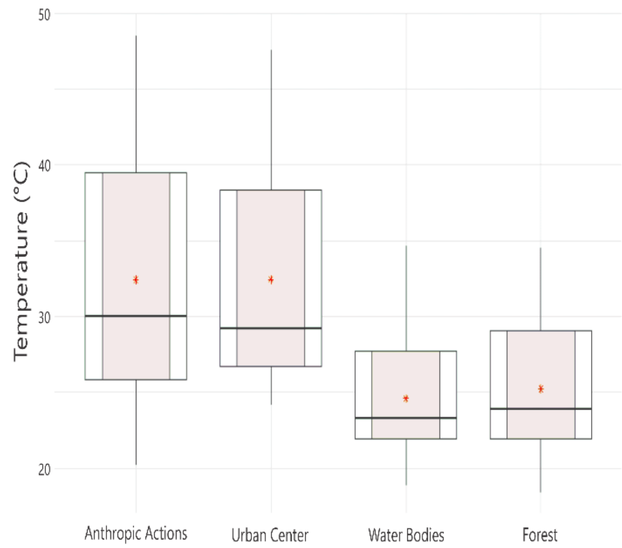


**Figure 4: Graph of surface temperature in the city of Sinop - MT, between the years 1984, 1994, 2004, 2014 and 2022.**

For Anthropic Actions class, values from 21ºC to 48ºC were estimated over the coverage period, with an increase of 13.1º in average temperature (from 26ºC in 1984 to 39.1º in 2022). Areas with higher surface temperature in this layer were found mainly in places where the soil was being prepared for planting, mining areas, and pastures. It is noteworthy that this class was the most responsible for deforestation in the study area and increased its areas by 42%. The Urban Center class suffered an average temperature increase of 11º Celsius. The urban network, which in 1984 had an area of 1,217.54 ha and an average temperature of 26.5º, had 13,664.03 ha of area, with an average temperature of 37.5º C in 2022. The main reasons for this increase in temperature are related to construction of new buildings (mainly in the city center and the new housing developments), the vegetation suppression, and the expansion of the urban road network.

Finally, the Water Bodies and Forest classes were the classes with the least change in mean temperature over the period studied. There was a 5°C difference for Water Bodies (average of 22.6°C in 1984 as opposed to 27.6°C in 2022) and 6.6°C of alterity in the Forest layer (Average of 22.4°C in 1984 as opposed to 29°C in 2022). Regarding the carbon sequestration data, the areas classified as Water Bodies had the greatest changes in values, followed by Anthropic Actions, Urban Center, and Forestry (Figure 5).

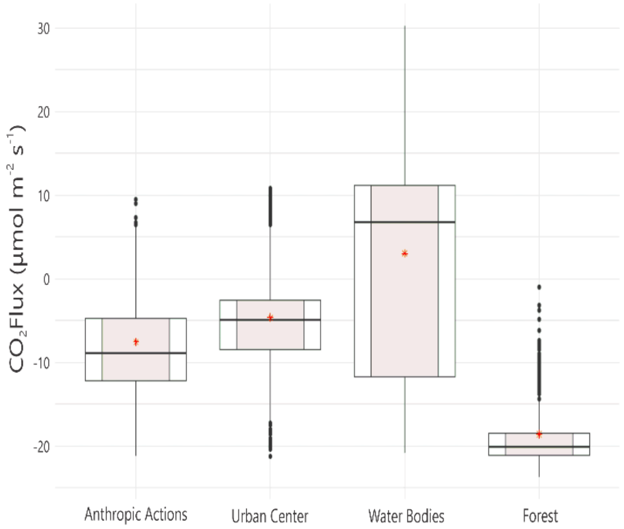

**Figure 5: Graph of $Co_2$flux in the city of Sinop - MT, between the years 1984, 1994, 2004, 2014 and 2022.**

In the course of the years analyzed, Anthropic Actions areas increased in the estimated values of carbon dioxide emissions. In 1984, the data pointed to an average absorption, reaching values of -14.37 μmol m$^{-2}$ s$^{-1}$ against average values of 4.49 μmol m$^{-2}$ s$^{-1}$ in 2022. This condition was already expected since there was a drastic exchange of forest (the main sink of carbon dioxide) for elements that are not significant in the absorption of $CO_2$ such as soil areas in preparation for planting and pastures. The same scenario occurs within the areas of the Urban Center class which was characterized by the advance of the urban network in Amazon and agricultural areas, resulting in an average of -11.35 μmol m$^{-2}$ s$^{-1}$ in 1984 and 6.02 μmol m$^{-2}$ s$^{-1}$ in 2022.

The Water Bodies class presented the greatest variation in average carbon dioxide emission values. In 1984, the layer depicted an average uptake of -5.17 μmol m$^{-2}$ s$^{-1}$ as opposed to an average of 18.82 μmol m$^{-2}$ s$^{-1}$ in 2022. These variations in values may be related to the construction of the Sinop power plant reservoir in 2019, that flooded large areas of Amazonian forests, as increased gas emissions such as $CO_2$ and $CH_4$ due to plant die-offs.

Finally, we have the Forest class that was the only layer that remained with carbon dioxide absorption values between the years analyzed. However, this category also suffered from increased average emission values during this period, since in 1984 the data claimed average values of -20.18 m$^{-2}$ s$^{-1}$ versus -11.21 m$^{-2}$ s$^{-1}$ in 2022.

## 4. CONCLUSION

The method used proved to be effective and important in the analysis of land use and land cover changes and their influences on the ecosystem service of regulation (carbon sequestration), as well as the temperature of the land surface within the municipality of Sinop - MT. Thus, it can be concluded that the geographic space analyzed had a significant loss of Amazon forest (main sink of carbon dioxide, regulator of temperature, biogeochemical cycles and biophysical factors) for the insertion of various economic activities, which directly affected the decrease in $CO_2$ absorption (main contributor to the greenhouse effect); average increase in surface temperature as a whole and growth of areas with higher surface temperature, which generates a thermal discomfort for citizens of this municipality.

## 5. REFERENCES

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