Geographic reconstruction of a Central-West Brazilian landscape devastated during the first half of the 20th century: Mato Grosso de Goiás

Reconstituição geográfica de uma paisagem devastada durante a primeira metade do século XX na região Centro-Oeste do Brasil: o Mato Grosso de Goiás

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ABSTRACT

In the history of humanity, there are various accounts of ecosystems that were devastated to the detriment of scientific knowledge. In Brazil, the Atlantic Forest and Cerrado biomes are emblematic of this phenomenon. Specifically, within the latter, an environment consisting predominantly of savanna, a large tropical forest enclave existed, known as Mato Grosso de Goiás. This ecosystem was almost devastated by the Brazilian land expansion policies during the first half of the 20th century. The objective of this study is to estimate the extent of the original area of the Mato Grosso de Goiás ecosystem through integration of historical and cartographic data using geoprocessing techniques. The original area was estimated around 26,391 km². These data can aid in the planning of conservation policies for the Cerrado biome. In addition, the used methodology can be adapted to similar studies, especially in the field of environmental science.

Keywords: Landscape Modelling; Tropical forests; Brazilian Savanna; Mato Grosso de Goiás

RESUMO

Diversos relatos de ecossistemas devastados à revelia do conhecimento científico são registrados na história da humanidade. No Brasil, o caso dos biomas Mata Atlântica e Cerrado são emblemáticos desse fenômeno. Especificamente no bioma Cerrado, um ambiente predominantemente savânico, havia um grande enclave de floresta tropical conhecido como Mato Grosso de Goiás. Esse ecossistema foi quase integralmente devastado pelas ações das políticas de interiorização do País, empreendidas pelo governo federal na primeira metade do século XX. Assim, este artigo se propõe, a partir de técnicas de integração de dados cartográficos históricos e atuais, utilizando-se de técnicas de geoprocessamento, a estimar qual a área original desse ecossistema. Os resultados permitiram estimar que a área original era de 26.391km². Esses dados podem servir para auxiliar o planejamento de políticas públicas conservacionistas para o bioma Cerrado. Além disso, a metodologia utilizada pode ser adaptada a outros estudos semelhantes, sobretudo no campo das ciências ambientais.

Palavras-chave: Modelagem da Paisagem, Floresta tropical, Savana brasileira, Mato Grosso de Goiás.

1 INTRODUCTION

Among the various arguments that support the defence and protection of biodiversity is the utilitarian perspective: when natural environments are destroyed before being appropriately studied, many possibly useful species of plants and animals are lost, to the detriment of science.

One example of a large alteration of Neotropical vegetation is in the Cerrado biome in Central Brazil, where between 40 and 50% of the soil was transformed for agricultural use over the last 50 years. This biome covers 2 million km2, representing 23% of the Brazilian territory, and is considered one of the 34 global hotspots for the conservation of biodiversity (MITTERMEIER et al., 2004). Another example of destruction of Brazilian biodiversity with national dimensions is the Atlantic Forest biome, which originally included more than 7,000 km in the Brazilian coast and has been reduced to approximately 7% of its former area (DRUMMOND, 1991; DEAN, 1996; CABRAL, 2014).

In the Brazilian state of Goiás, destruction of the landscape known historically as *Mato Grosso de Goiás* (MGG) is another example of this loss of biodiversity and consequent loss of information of this ecosystem unknown to science (DELLA GIUSTINA and FRANCO, 2014).

The term *Mato Grosso de Goiás* was historically used during the colonial period (1722-1889) by laymen and scientists to denote a forest enclave in the middle of the savanna, currently known as the Cerrado biome (MMA, 2006; EVANS and DUTRA E SILVA, 2017). However, because of the records of naturalist travellers such as Saint-Hilaire (1779-1853) and Pohl (1782-1834), who have been in Goiás at the beginning of the 19th century, this expression came to refer to a landscape unit (SAINT-HILAIRE, 1975; POHL, 1976).

The first record referring to MGG in official documents was a request to the King [D. José] by Bento Colaço de Morais, dated February 28, 1769, requesting confirmation of the land title for a site identified as "*Edge of Mato Grosso, old village road that begins, on the Northern band, with D. Margarida da Silva, captainship of Goiás*".[1]

The deforestation of the MGG region resulted from several territorial occupations and land use policies in Goiás during the first half of the 20th century, in association with the historic deforestation of the Brazilian tropical forest for agricultural use (JAMES, 1953; DEAN, 1995, BARBALHO et al., 2015; LEAL et al., 2015). In the MGG region, deforestation was accompanied by the expansion of coffee production into the western region of São Paulo during the initial decades of the 20th century and the search for forested areas for expansion of agricultural activities. This phenomenon was connected to what Preston James (1953) calls the search for "first-class forests": forested areas whose soil fertility was connected to vegetation and deciduous leaf fall (DUTRA E SILVA et al., 2015a; DUTRA E SILVA et al., 2015b; DUTRA E SILVA, 2017).

According to Dutra e Silva (2017), MGG was already being considered for possible agricultural expansion towards the end of the 1930s, motivated by the policy of Westward Expansion (*Marcha para o Oeste*). Simultaneously, the search for forested areas for agricultural expansion was related not only to the colonization process of national agricultural colonies but also to the choice of the new federal capital (DUTRA E SILVA, 2017).

Studies of the historical geography and environmental history of the MGG reveal that the criteria for the choice and construction of Brasília, the new Brazilian capital, favoured areas with considerable forest density that could serve as an agricultural reserve for the population that would migrate into the region. Among the tropical forest areas, the largest area (approximately 20,000 km2) with appropriately fertile soil was the MGG, which in 1947—at the time of the expedition for the selection of the new federal capital—was experiencing intense migration (JAMES and FAISSOL, 1960; DUTRA E SILVA et. al, 2015; DUTRA E SILVA, 2017). According to Preston James (1953), by the beginning of the 1950s, more than 70% of the MGG territory had been deforested for agricultural use in the region.

In light of this, the objective of the present study was to estimate the original geographical extent of this devastated landscape through integrated analysis of geological and geomorphological factors, the configuration of the remaining native vegetation, and historical records of the MGG region. The proposed delimitation is expected to be useful as the geographical basis for conservation policies and for other scientific studies.

2 MATERIALS AND METHODS

2.1 PHYSIOGRAPHIC ASPECTS OF THE STUDY AREA

The MGG is located in the west central region of Brazil, between 14º40’ and 17º20’ South latitude and 48º40’ and 50º45’ West longitude (Figure 1). The geology of the region is associated with the Brasília Fold Belt (ALMEIDA, 1967), an orogen formed by the convergence of the Amazônia and São Francisco cratons and the Paranapanema Block at the end of the Neoproterozoic era, approximately 630 million years ago (BRITO NEVES and CORDANI, 1991; FUCK et al., 2005; PIMENTEL et al., 2011).

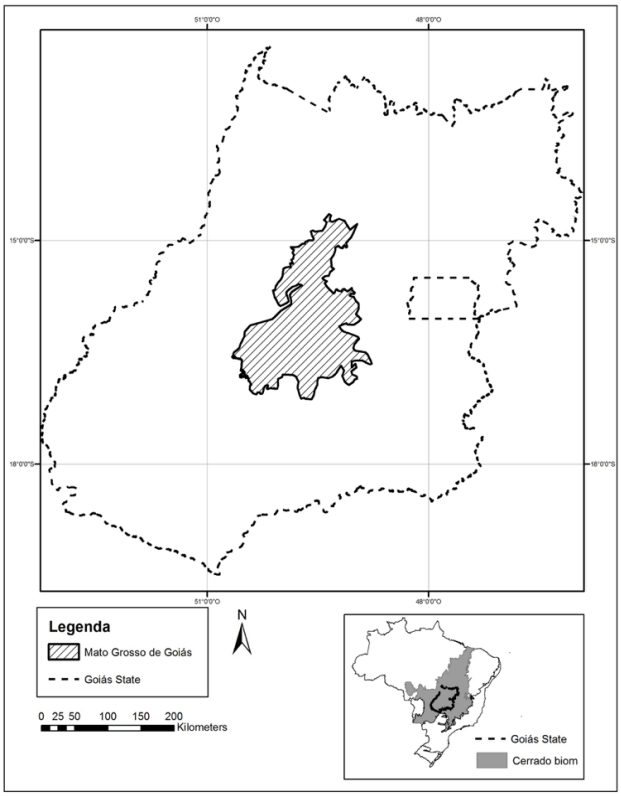


Figure 1 – Location of the Mato Grosso de Goiás in the state of Goiás, in the Cerrado biome, and in Brazil.

Source: SIEG databases and MMA (2006).

The MGG is in the centre of the Brasília Belt, characterized by exposures of the Barro Alto, Niquelândia and Cana Brava mafic-ultramafic complexes (FERREIRA FILHO et al., 2010), of Goiás Magmatic Arc (PIMENTEL and FUCK, 1992; LAUX et al., 2004, 2005), and the Anápolis-Itauçu Complex (PIUZANA et al., 2003; DELLA GIUSTINA et al., 2011) of Archean to Neoproterozoic age (Figure 2).

In these geologic units, igneous rocks predominate, mafic to felsic with sub-vertical foliation, primarily superimposed by high-level metamorphic events. Mafic granulites, tonalites, layered mafic-ultramafic complexes, and various granites are common, in addition to volcanic-sedimentary sequences with several levels of basalts (DANNI et al., 1984; LACERDA FILHO et al., 2000). In the MGG region, which includes portions of the Internal Zone of the Brasília Belt and the Goiás Magmatic Arc, mafic rocks predominate. When weathered, chemical elements from these rocks, such as calcium, magnesium, iron and other micronutrients, serve as important nutrients for vegetation.

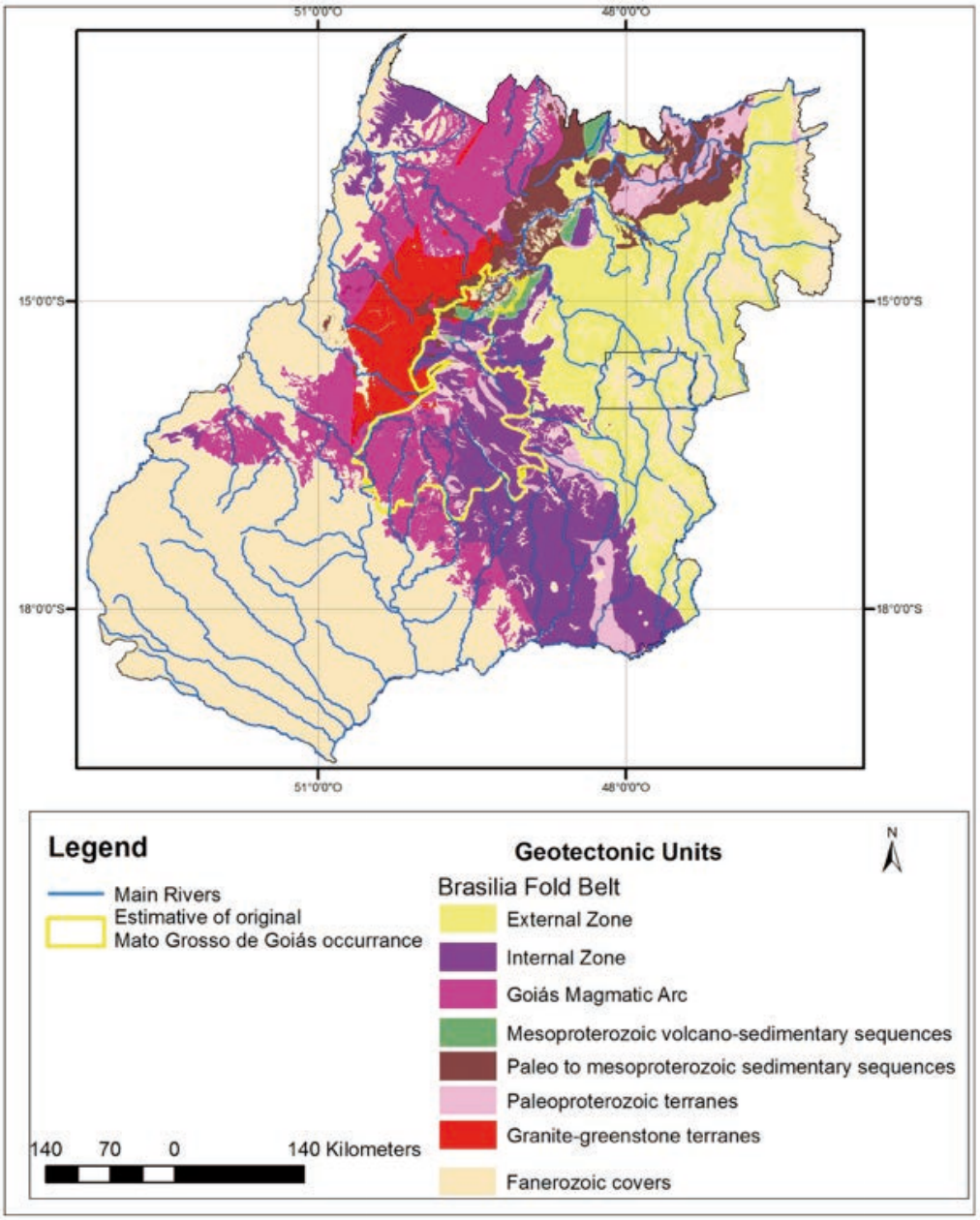


Figure 2 – Geotectonic compartmentalization of the Brasília Belt in the state of Goiás

Source: SIEG database.

To promote an administrative system based on bio-regional management (MILLER, 1997), Arruda et al. (2008) proposed the creation of 21 ecoregions in the Cerrado biome (Figure 3). Those ecoregions were defined based on the main ecosystems and habitats existing in the region. The Brasília Belt is a geotectonic entity that represents the Central Plateau ecoregion. The differences between ecoregions are largely determined directly or indirectly by the regional geologic context. Although MGG is characterized as a forest enclave within a savanna matrix, it is not discriminated as an ecoregion.

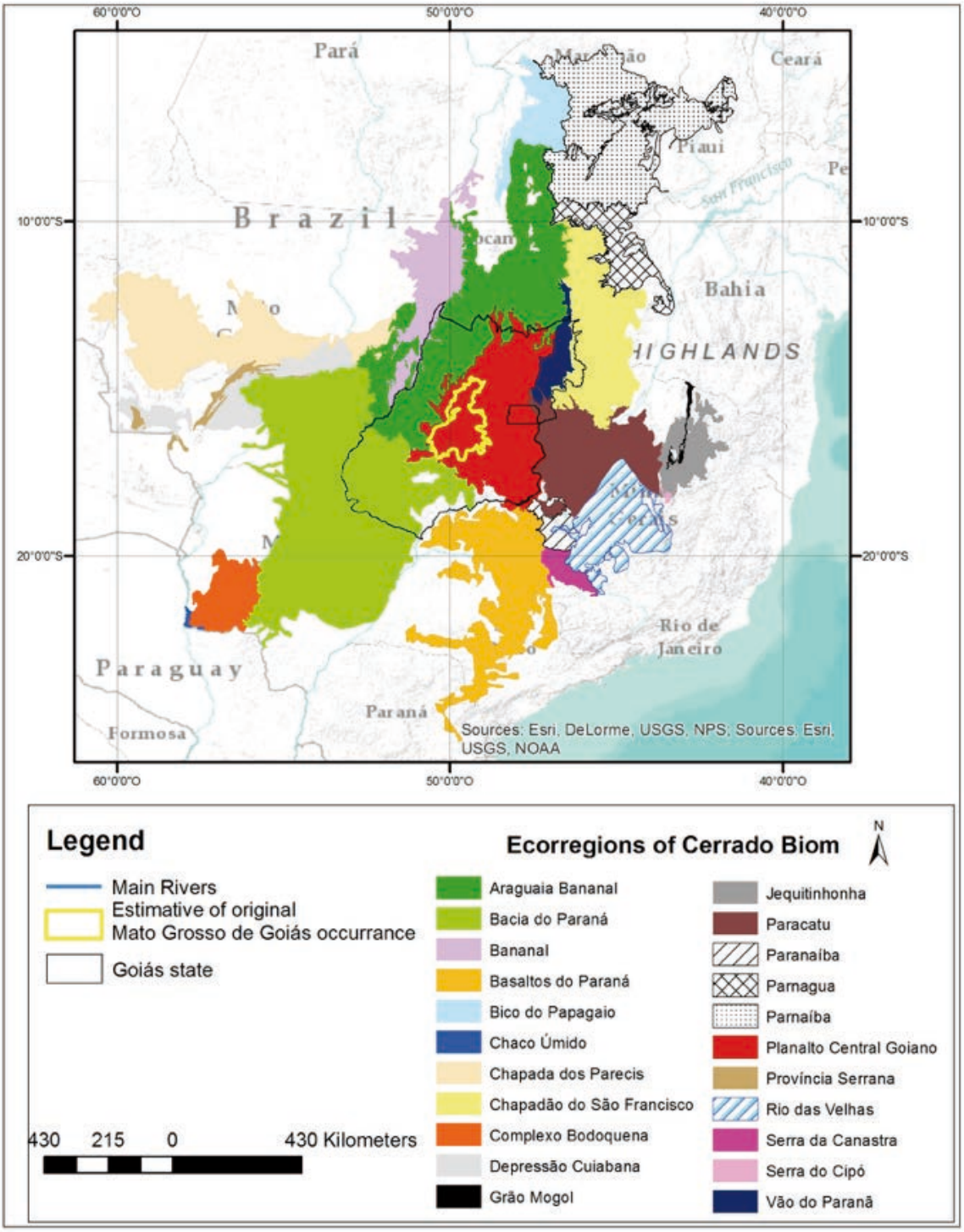


Figure 3 – The MGG and the state of Goiás, with the ecoregions of the Cerrado biome

Source: Adapted from Arruda (2008).

The Central Plateau ecoregion is characterized by residual reliefs of chapadas (plateaus) and intra-plateau depressions. The layers have variable tilt, from horizontal to vertical strata. The layer tilt has a direct relationship with the degree of rock weathering such that the horizontal layers tend to support flat and elevated reliefs, associated with developed soils such as Oxisols (Latosols), whereas greater tilts form desiccated surfaces, favoured the genesis of relatively young soils, such as Nitosols and Cambisols.

The relief in the MGG region is predominantly smooth and undulating, with elevation varying from 500 to 1,000 meters (Figure 4). These conditions suggest that the relief is formed by hills and mountain ranges, in a desiccated depression position.

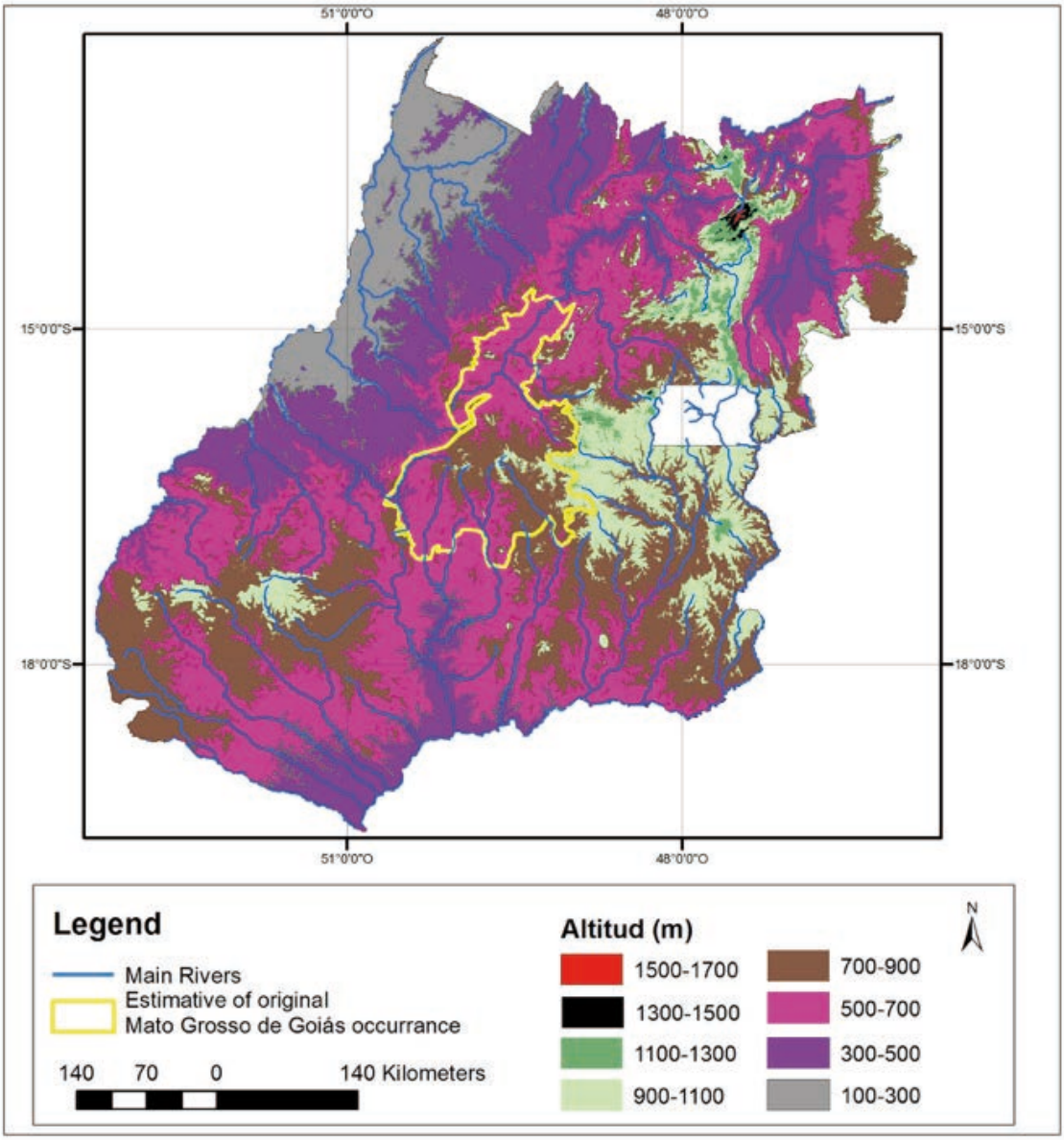


Figure 4 – Hypsometry of the state of Goiás, with the estimated location of the MGG region.

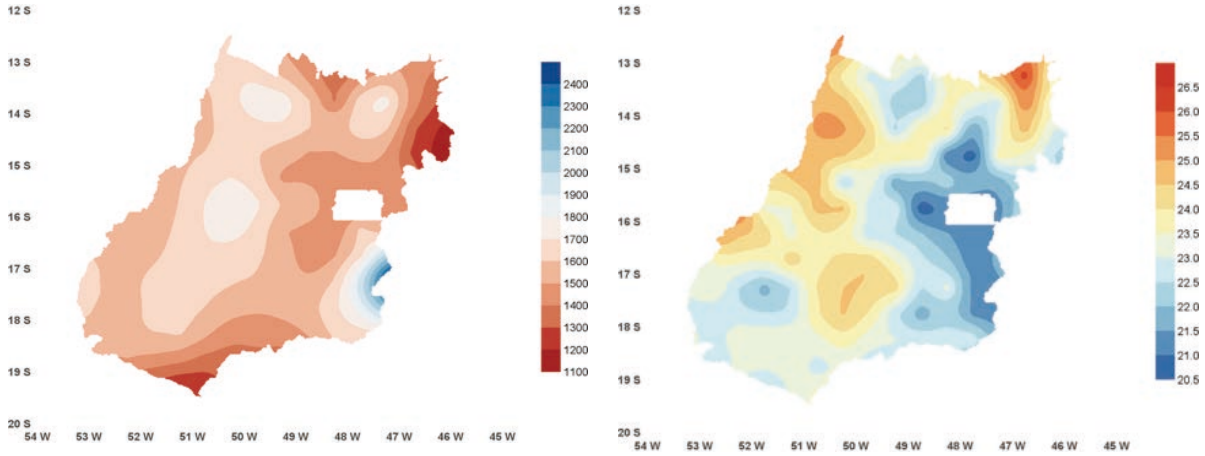
Source: SIEG database.

The climate of the Cerrado in the state of Goiás is Aw, according to the Köppen classification. This is a humid tropical climate with mean temperatures greater than 18ºC during the coldest month, characterized by dry winters and rainy summers (SILVA et al., 2008).

Rainfall is concentrated between October and March, with a peak in January, whereas dry weather predominates throughout the rest of the year. In the state of Goiás, the mean annual rainfall varies between 1,200 mm and 2,000 mm (SILVA et al., 2008).

Data from a historical series of global modelling by University of Delaware (USA) between 1980 and 2010[2] suggest that a positive anomaly exists in the average rainfall of the MGG region. During that period, the mean rainfall in the MGG region was between 1,700 and 1,900 mm, whereas most of the state had less rainfall during the same period (Figure 4a). In a 10-year study of 105 stations, Cardoso et al. (2014) corroborated the possible existence of this anomaly, observing a gradient varying from 1,600 to 2,200 mm in the region of the cities of Goiás and Ceres, in contrast with the mean of the entire state of Goiás, which was 1,500 mm.

The temperature data of the same historical series suggest a westward increase in the mean temperature in the state of Goiás, paralleling the decreasing relief. Figure 4b shows mean temperatures ranging from 20.5ºC to 26ºC from east to west in the MGG region for the same historical data series. Similarly, Cardoso et al. (2014) reported a 7ºC increase in the mean annual temperature between Brasília, with a mean temperature of approximately 20ºC, and the Ceres region, with a mean of 37ºC.



a) b)

Figure 5 – a) Mean rainfall in the period 1980-2010; b) Mean temperature in the period 1980-2010.

Source: Own elaboration, based on global modelling by University of Delaware.

Vegetation matrices typical of savannas and forests associated with watercourses and interfluves predominate in the Cerrado biome; in the interfluves, these matrices are due to certain soil and terrain conditions (GOODLAND, 1979; FELFILI et al., 2004; RIBEIRO and WALTER, 2008). Formerly forested areas predominated in the studied region, classified by the Brazilian Institute of Geography and Statistics as semi-deciduous seasonal forest, surrounded and isolated by vegetation typical of the Cerrado, as shown in Figure 5 (IBGE, 2011). Based on the classification of Ribeiro and Walter (2008), recently updated and developed exclusively for the Brazilian Cerrado, the MGG had a dry woodland vegetation structure.

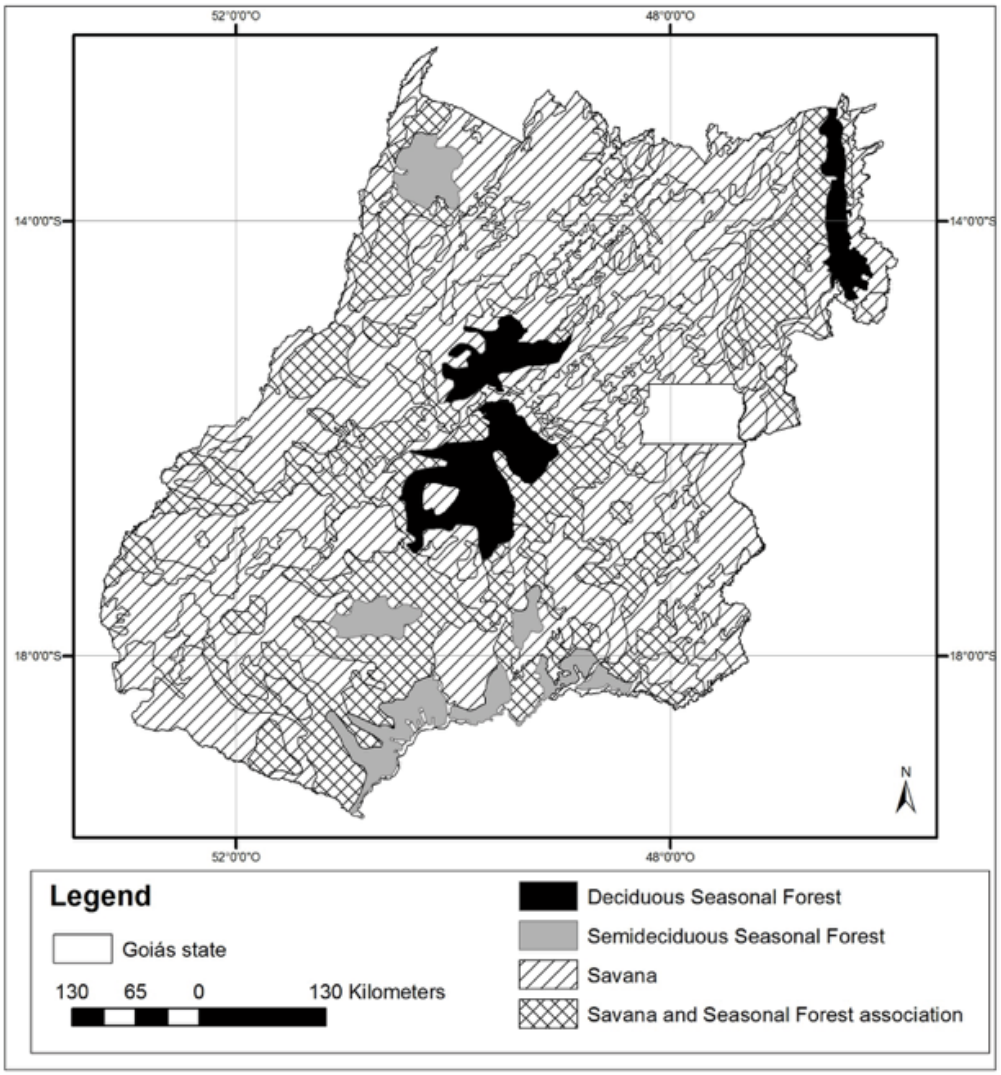


Figure 6 – Descriptive map of the primary vegetation of the state of Goiás

Source: Database IBGE, based on the RADAM Brasil Projects, 1981.

Despite being located in the Cerrado biome, based on the Brazilian classification (MMA, 2008) the MGG differs substantially from a savanna because it is a forest with trees that form a canopy and are larger than those typically found in the Cerrado. Faissol (1952, p.7) completed one of the first and only systematic studies of the region when the landscape was still relatively intact and defined the MGG as a geographical unit with well-defined limits and features that characterize it as the "forested zone" of Goiás. This study estimated that the MGG spanned nearly 20,000 km^2 of relatively continuous forests, suggesting that this landscape was a distinct ecosystem from the standard matrix of landscapes found in the Cerrado biome.

2.2 DATA PROCESSING

To estimate the original extent of the MGG, geology, vegetation, hydrography, locality and soil data from the System of Geographic and Statistical Information of the State of Goiás (*Sistema de Informações Geográficas e Estatísticas do Estado de Goiás* - SIEG[3], base year 2002) were used, in addition to historical accounts (SOUZA, 1949; FAISSOL 1952; SAINT-HILAIRE, 1975; POHL, 1976) and the map produced by Faissol (1952), which was at a 1:1,000,000 scale. Figure 6 illustrates the flow of data processing.

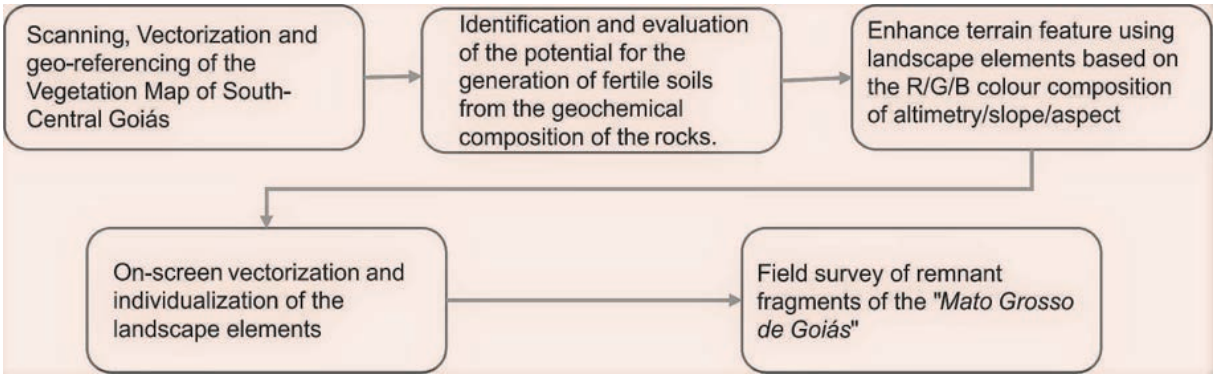


Figure 7 – Flow processing.

Source: Own elaboration.

The Faissol map, reproduced in Figure 7, was produced from the combination of cadastral survey maps of old plantations and field reconnaissance. The initial territory delineation used in this study began with the creation of a 50 km buffer around the map produced by Faissol (1952). The 50 km distance was defined based on satellite images, vegetation maps, field visits, and historical accounts, as the distance at which occurrences of large continuous forested areas possibly associated with MGG are not observed.

The Vegetation Map of South-Central Goiás (Figure 9) produced by Faissol (1952) was first digitized and geo-referenced with the official cartographic database of the state of Goiás (datum SAD 69). The hydrographic and localities cartographic databases were used to fit and evaluate the geographical precision of the elements illustrated on the map.

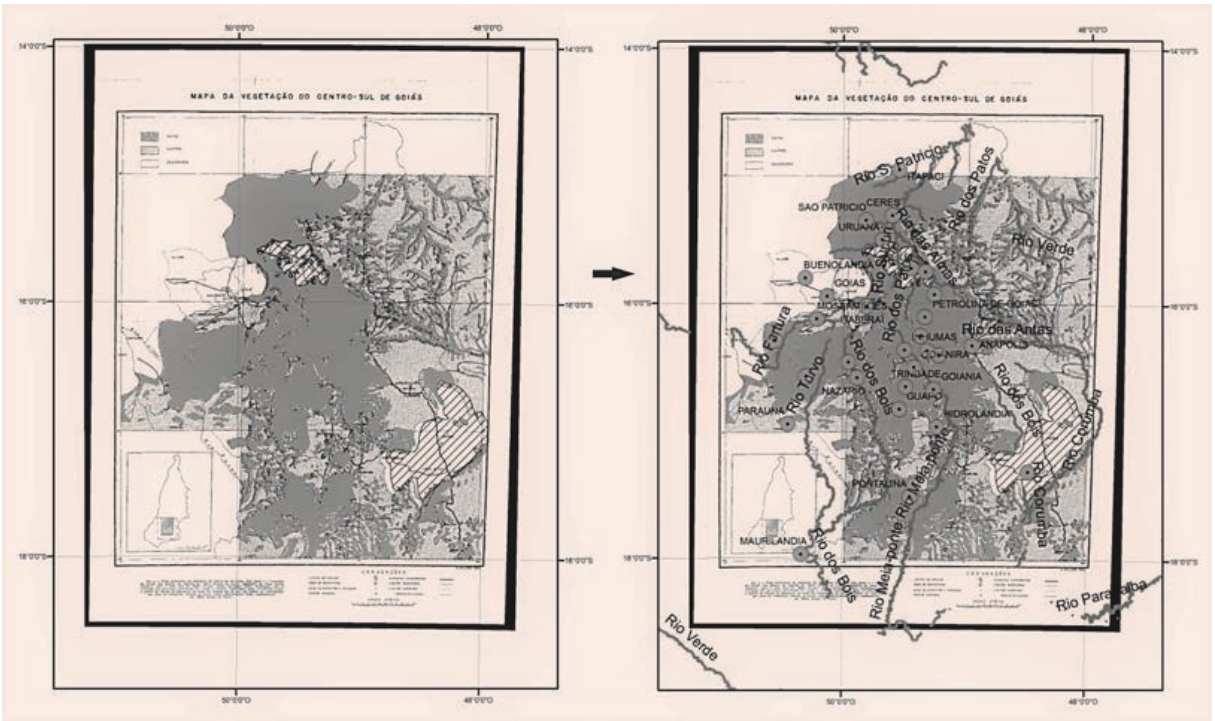


Figure 8 - a) Vectorization and geo-referencing of the Vegetation Map of South-Central Goiás produced by Faissol (1952). The digitized forested areas are shown in green. b) GIS with vectorized vegetation data and layers available from the SIEG (hydrography and localities).

Source: Own elaboration, based on Faissol (1952) and SIEG data base.

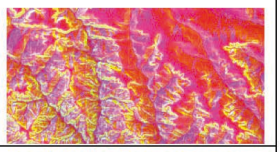
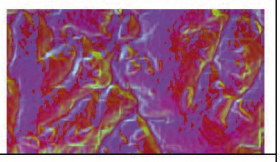
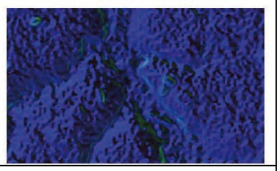
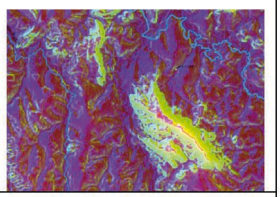
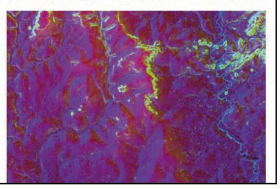
These data were processed and analyzed using geographical information system (GIS) through the following process:

- Identification and evaluation of the potential for the generation of fertile soils from the geochemical composition of the rocks, according to the geological map of Goiás (DANNI et al., 1984; LACERDA FILHO et al., 2000). The available vectorized geological cartography consists of a compilation of several maps in scales ranging from 1:25,000 to 1: 250,000.

Subsequently, the terrain features were enhanced using landscape elements based on the R/G/B colour composition of altimetry/slope/aspect using ArcMap 10.3, following the specific methodology in Castro et al. (2009, 2010); Hermuche et al. (2002); Lima et al., (2009, 2010); Passo et al. (2010); and Sena-Souza, et al. (2013). The landscape elements were obtained from the DTM (Digital Terrain Model) at a spatial resolution of 30 m from the Topodata website[4].

The on-screen vectorization and individualization of the landscape elements were performed based on the feature enhancement, separating similar colours corresponding to the region of the MGG, according to standard model illustrated on Table 1. Data on the geography, hydrography, localities and remaining native vegetation were used to assist in the delimitation of the MGG. The digital number (DN) values of the pixels were analysed using ArcGIS 10.3 to generate the altitude and slope histograms of the study area. Rainfall and temperature maps were generated in Surfer based on the interpolation and homogenization of quadrangle (LEGATES and WILLMOTT, 1990a, 1990b) with historical data series from 1980 to 2010.

Table 1 – Standards models based on the R/G/B colour composition of altimetry/slope/aspect.

Geomorphologic Units	Characteristics	Color composition patterns
Plateaus	Dissected uplands with residual plateaus	
MGG	Dissected uplands with hilly landforms	
Araguaia valley	Low altitudes and low relief amplitudes	
Cerrado island in the MGG	Isolated mesas associated with escarpments	
Transition areas	Erosion levels between Plateaus and MGG	

Source: Own elaboration

Finally, a field survey of remnant fragments of the MGG and comparison of official vegetation data from Goiás State were performed to confirm the estimated limits. The inclusion of areas of continuous forested located in interfluves was a premise for the proposed limit of the MGG. Small savanna fragments insulated in extensive forested areas were included in the MGG to maintain geographic continuity. Thus, the estimated limits of the MGG correspond to the separation of predominantly forested areas from those where savanna predominates.

3 RESULTS AND DISCUSSION

In the Cerrado biome, the vegetation configuration constitutes a mosaic of grassland, savanna and forest formations (RIBEIRO and WALTER, 2008), being defined by dry climate alternations. Specifically, forest formations of this biome are related to climatic and lithological factors.

Geology, for example, has been used in scientific studies to estimate environmental variations (DAHLIN et al., 2014). However, other factors, such as relief, soil and climate, also determine the configuration of the two types of vegetation that occur in a given landscape matrix.

Rock structure also plays a fundamental role. The presence of mafic rocks is not sufficient for the development of fertile soils; their structure must also include a strong layer dip. Foliations with high-angle dips, as in the MGG, favour intermediate soil development conditions: not excessively leached such that only aluminium and iron oxides and hydroxides remain and not so young that the minerals would be in their primary form and thus unavailable to plants.

The configuration of vegetation domains is generally related to multiple natural phenomena that may be controlled by environmental or stochastic factors (CLARK, 2009; HUBBELL, 2001; ROSINDELL et. al., 2012). In general, in the Cerrado, the grassland formations occur on slopes with low fertility soils, especially Cambisols. Savanna formations, in turn, occur on flat areas over latosols of similarly low fertility. Savanna formations have greater areal extents of vegetation cover (REATTO et al., 2008). The development of forest formations is mainly related to two physical aspects: water availability and soil fertility (RIBEIRO and WALTER, 2008). The former factor is responsible for the development of riparian and gallery forests at the margins of water bodies, whereas the latter causes the formation of dry woodlands in interfluves.

Therefore, the MGG can be characterized as a continuous association of tropical forests of dry woodlands and gallery forests, even though this concept was originally conceived as a popular name and thus without strict or scientific classification or cartographic criteria.

On his map, Faissol (1952, p. 7) estimated the area of the MGG to be 20,000 km2. He reported that the area should be larger than that, given that his study included only plantations that had previously been surveyed at that time. Faissol also stated that the MGG began in the outskirts of the city of Anápolis and extended towards the base of Serra Dourada, in the region of the Ouro River, and up to the northern city of Itapaci in the Brazilian state of Goiás. Portions of the municipalities of Pirenópolis, Jaraguá, Anicuns, Goiás, Mataúna, Itaberaí and Itapaci would be included in the MGG, and the municipalities of Trindade and Inhumas would be located completely inside the MGG.

The polygon delimited in this study for the MGG region spans 26,391 km2, as illustrated in Figure 10. Using the R/G/B colour composition for altitude/slope/aspect, the flat and elevated areas — normally with altitudes exceeding 950 m — are represented by pink hues. In contrast, low areas with altitudes predominantly below 500 m are represented by blue. The region delimited as the MGG has steeper slopes than these regions, with intermediate altitudes between 500 and 950 m. Dry woodlands merge with riparian forests along the hillsides surrounding the MGG, which may explain their occurrence in more elevated areas outside the basic geological context.

As observed in historical accounts, more elevated areas with altitudes in excess of 900 m and shallow slopes (below 2%) occur within the delimited region; these areas are represented by red hues in Figure 8 These conditions determine the distribution of savannas within the MGG by favouring the formation

of developed and consequently low fertility soils. Thus, in this delimitation proposal, these areas were included within the MGG, as they were considered savanna enclaves among the forests.

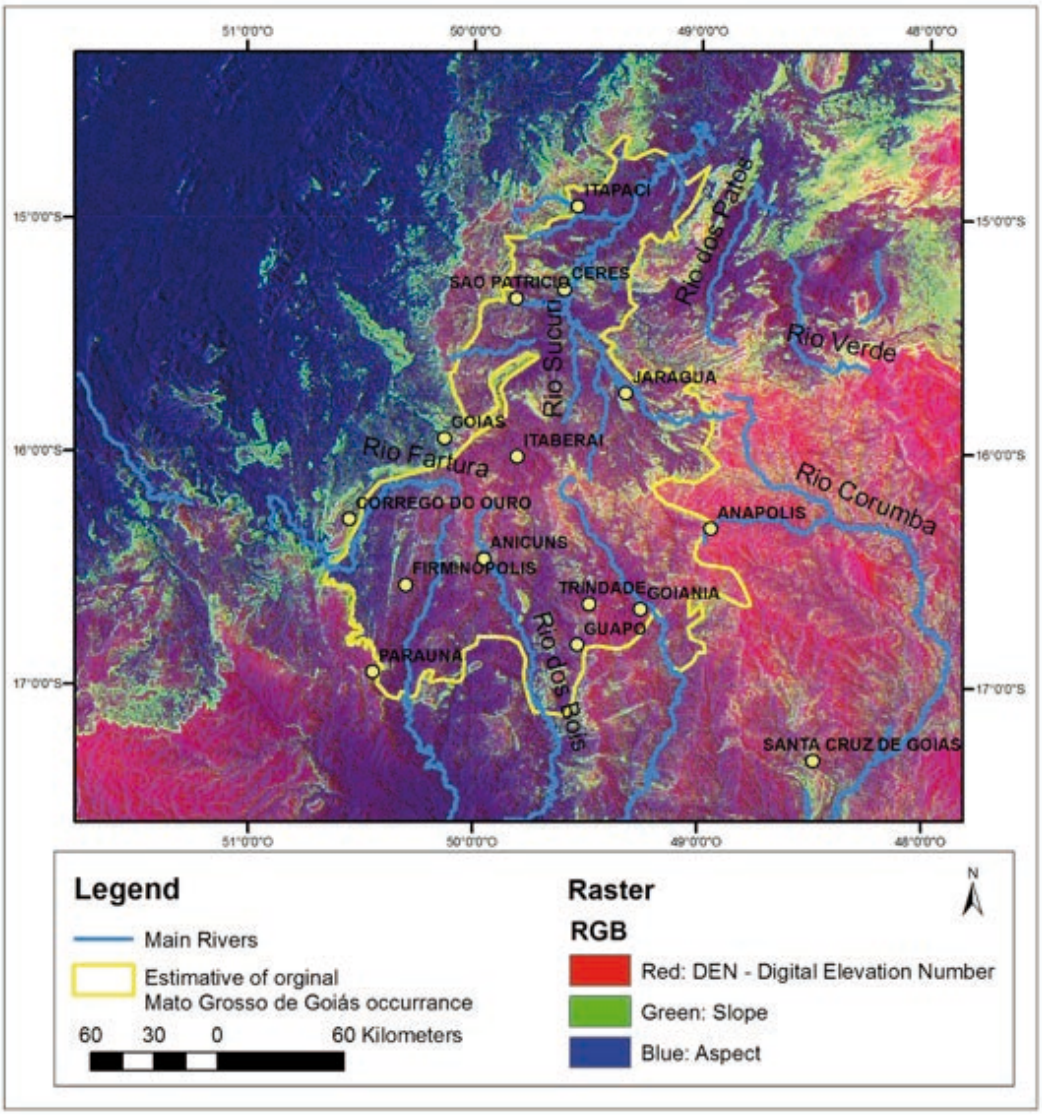


Figure 9 – Estimation of the extent of the MGG, with the coloured composition of the enhanced terrain elements.

Source: Own elaboration.

In the context of the Cerrado biome, the natural occurrence of fertile soils in dissociated areas of watercourses is directly conditioned by paedogenesis, deriving from the weathering of rocks whose chemical composition includes important nutrients for plants: calcium, magnesium, potassium, phosphorous (macronutrients), molybdenum, copper, manganese, iron, nickel, and zinc (micronutrients). These elements are remobilized into the soil by weathering processes of mineral dissolution. Therefore, fertile soils exhibit greater primary productivity than low-fertility soils, thus favouring the growth of forests (SMIL, 2013). Examples of such rocks are limestone, igneous rocks (volcanic and plutonic) and some types of metamorphic lithotypes (mafic and ultramafic) (LEONARDOS et al., 2000; STRATEEN, 2007; ROKADE, 2014).

The existence of forests was an indicator of high soil fertility during the time of the colonization of the Brazilian interior. Therefore, those areas were chosen for the establishment of agrarian colonies, as in the MGG (FAISSOL, 1952; JAMES, 1953).

The geological units that predominate in the proposed polygon and that retain the aforementioned geochemical characteristics are described below.

- Anápolis-Itauçu Granulitic Complex, formed by metatonalites, metagranites, serpentinites, metanorites, metapyroxenites, paragranulites and metagabbros. In general, these rocks possess high concentrations of calcium, magnesium and various micronutrients in their chemical composition.

- Barro Alto and Serra da Malacacheta Suite Mafic-ultramafic Complexes: formed by metagabbronorites, metapyroxenites, metatroctolites and metaperidotites. All of these rocks are rich in magnesium, calcium and important micronutrients for plants.

- Goiás Magmatic Arc Plutonic Complex, formed by orthogneisses of tonalitic and granitic composition. These rocks comprise chemical elements such as calcium, magnesium, potassium and micronutrients.

- American-type Brazilian Mafic-Ultramafic Suite and Anicuns-Santa Bárbara Suite, predominantly composed of dunites, peridotites, pyroxenites and gabbronorites.

- Anicuns-Itaberaí Metavolcanosedimentary Sequence, composed of schists, amphibolites and marbles.

- Rio do Peixe Metavolcanosedimentary Sequence - Unit 1, predominantly composed of metabasalts, metaperidotites, amphibolites and epidote-amphibolites.

- Araxá Group - Unit B, composed of schists, chlorite-schists, muscovite-biotite-schists and amphibolite and marble lenses.

Although rocks of the same nature also occur in other regions of Goiás, they occur in the highest concentrations and in continuous form in the South-Central region. In conjunction with the specific terrain, soil and climate conditions, this certainly facilitated the formation of the MGG as a distinct landscape from the others found in the same state.

Table 2 presents the physiographic characteristics of each geotectonic unit in the state of Goiás. The Internal Zone of the Brazilian Belt is the only unit that combines favourable terrain conditions, i.e., a partially desiccated planation surface with intermediate altitude, with favourable geology and appropriate nutrient availability for plant growth.

Table 2 – Predominant physiographic characteristics in the different geotectonic units in the state of Goiás and their relationship to the eco-regions.

Geotectonic Units	*Lithology*	*Altitude*	*Terrain*	*Minerals*	*Bioavailable elements*	*Vegetation*
External Zone	*Metasedimentary rocks: quartzites, pelites*	*1000-1500*	*Plateau*	*Quartz, clay minerals 1:1; iron and aluminium oxi-hydroxides*	*Iron, aluminium*	*Typical Cerrado, forest over calcareous minerals*
Internal Zone	*Mafic rocks*	*500-1000*	*Partially desiccated planation surface*	*Pyroxenes, amphiboles, feldspar, clay minerals 2:1*	*Magnesium, iron, and calcium*	*Forest*
Magmatic Arc	*Felsic rocks: gneiss, tonalite and granite*	*300-500*	*Planation surface with wide, convex and flat tops*	*Quartz, feldspar, clay minerals 1:1, iron and aluminium oxi-hydroxides*	*calcium, potassium, silicon*	*Cerrado grassland*
Paleo Proterozoic terrains	*Felsic rocks: tonalites, garnet biotite granites, and muscovite granites*	*300-700*	*Planation surface with wide, convex and flat tops*	*Quartz, feldspar, biotite, muscovite, clay minerals 1;1, iron and aluminium oxi-hydroxides*	*potassium, calcium, and silicon*	*Rocky cerrado*
Granite Greenstone	*Tonalites, granite-gneisses, and serpentinites*	*300-500*	*Planation surface with wide, convex and flat tops*	*Quartz, feldspar, biotite, olivine, pyroxene, amphiboles, clay minerals 2:1*	*calcium, potassium, magnesium, iron, silicon*	*Rocky cerrado*
Volcano sedimentary sequences	*Biotite gneisses and schist*	*500-700*	*Partially desiccated planation surface*	*Quartz, feldspar, biotite, pyroxene and amphiboles, clay minerals 1:1 and 2:1*	*Calcium, magnesium, iron, silicon*	*Forest*

Paleo-Mesoproterozoic sedimentary sequences	*Schists, graphite schists (to the north) and metatonalites and granites in the MGG region*	*500-900*	*Partially desiccated planation surface*	*Quartz, feldspar, biotite, pyroxene and amphiboles, clay minerals 1:1 and 2:1*	*Calcium, magnesium, iron, silicon*	*Forest*
Phanerozoic Covers	*Sandstones and basalts (Southwest portion of the state of Goiás) and unconsolidated sediments*		*Plateau with concordant sedimentary structure (sandstones and basalts)/ Plain (unconsolidated sediments)*	*Quartz, feldspar, pyroxene, olivine, clay minerals 1:1, iron and aluminium oxi-hydroxides*	*Iron, aluminium*	*Cerrado on the plateau and fields and fields of the cerrado grassland in unconsolidated sediments*

Source: Own elaboration

The map in Figure 9 demonstrates that the estimated polygon for the original area of the MGG satisfactorily discriminates between areas of predominantly forest fragments and surrounding areas of predominantly savanna. The forest fragments inside the MGG polygon span 637 km2, representing 2.4% of the total area.

The savanna formation fragments inside the estimated polygon of the MGG have flat and elevated terrains and were retained within the area to preserve the geographic continuity of this unit and because historical texts cite the existence of such enclaves of Cerrado among the MGG (FAISSOL, 1951). The savanna patches extend over 1,700 km^2, corresponding to 6.5% of the total area.

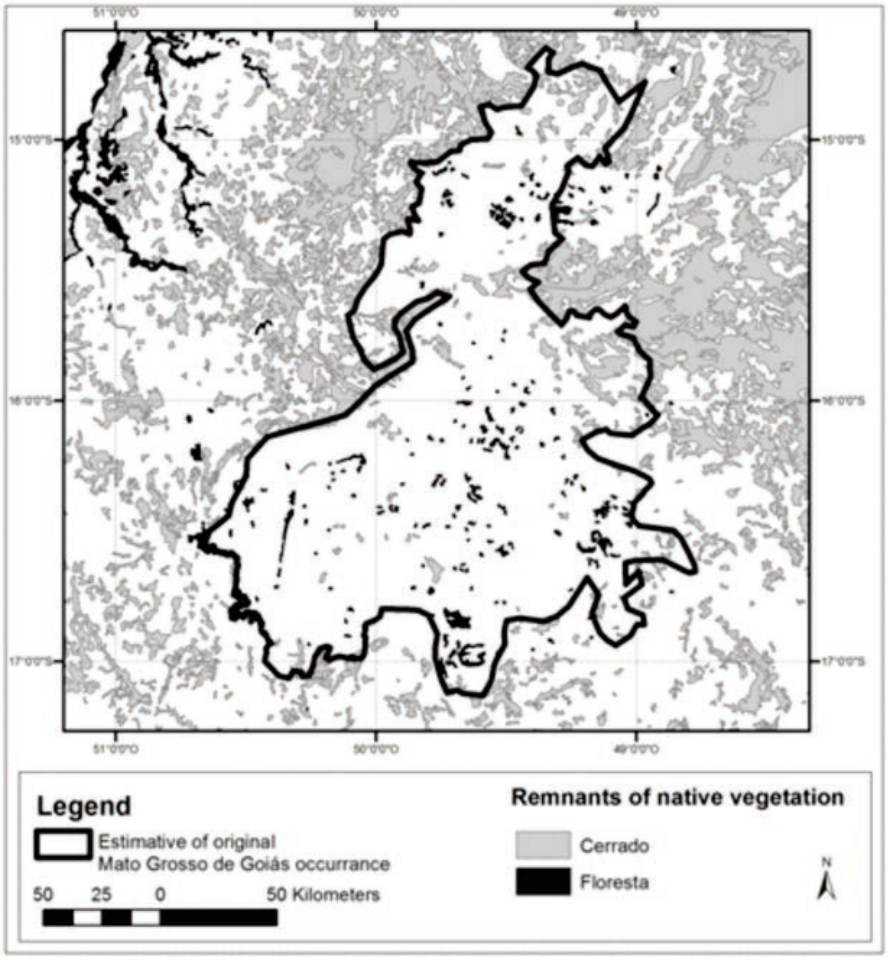


Figure 10 – Estimated area of the MGG with the remnant vegetation formations

Source: Base year 2002, SIEG database.

Figure 10 illustrates the altitude distribution in the region delimited in Figure 10 (a), and the altitude within the estimated polygon for the MGG (b) in the same image. The first histogram has a bimodal distribution, whereas the second has a normal distribution. The altitudes within 2 standard deviations (SD) (95%) of the samples in (b) are between 463 and 935 m. Altitudes greater than this range correspond to elevated enclaves, where Cerrado is located inside the MGG.

Given this perspective, the histograms in Figure 10 (c)(d) demonstrate that the MGG has a slightly higher proportion of sloped areas than does the total area, given that the modes of the data sets are 2% and 1%, respectively. Slopes within one standard deviation between 0.79 and 8% are obtained for the MGG polygon.

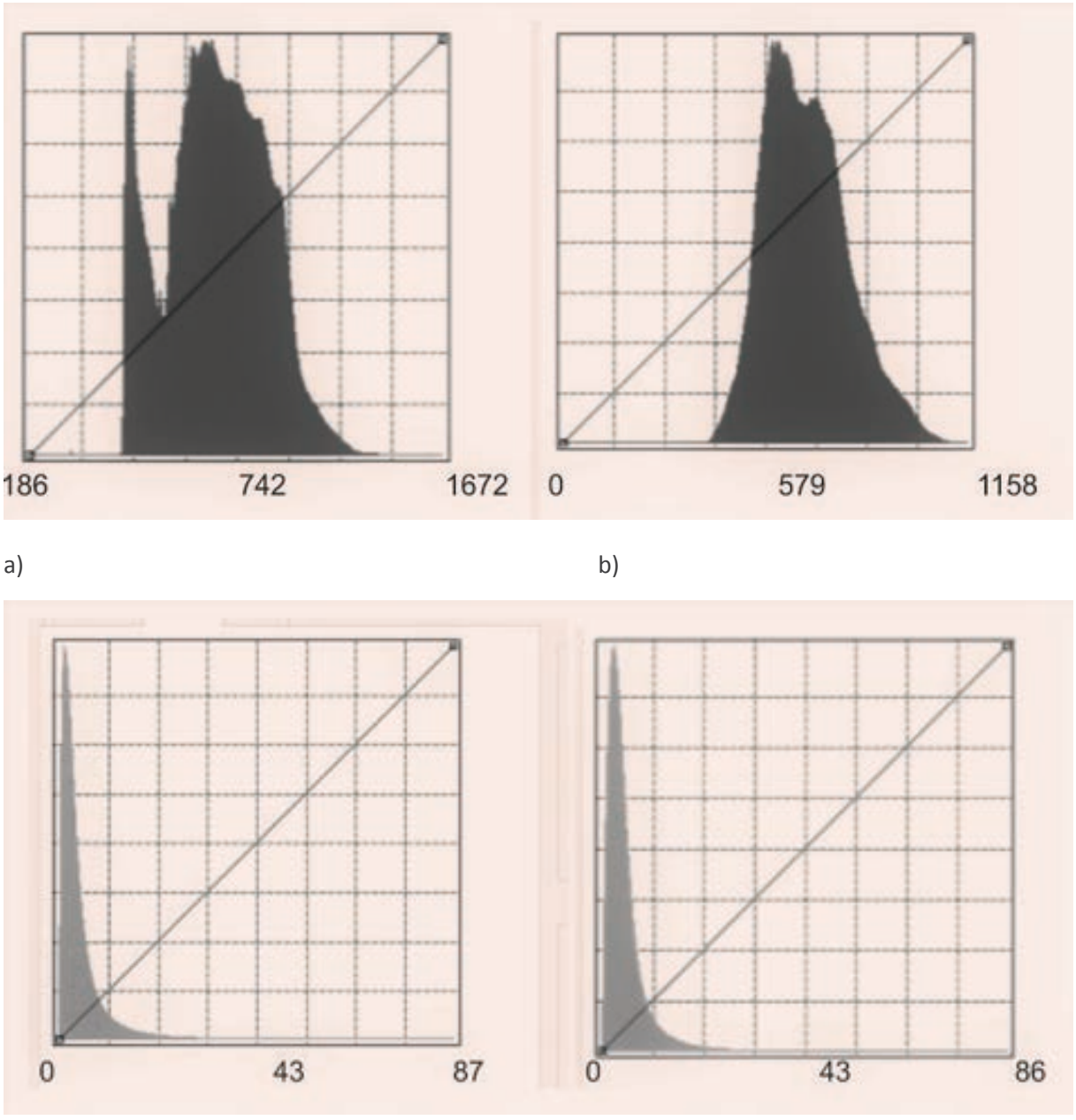


Figure 11 - a) Altitudes of the region delimited by the window, with two normal modes; minimum altitude 215 m; maximum 1,300 m; mean 650 m; SD 227. The first mode corresponds to the pixels located to the west, in the valley of the Araguaia River. b) Altitudes inside the polygon estimated for the MGG, with normal distribution around 1 mode; minimum 417 m; maximum 1158 m; mean 699 m; SD 118. Histograms for (c) the full window and (d) the polygon proposed for the MGG.

Source: Own elaboration.

As demonstrated, strong evidence exists that the genesis of a forested landscape in the southwestern region of the state of Goiás is directly related to physical aspects of the landscape. The main physical determinant is the occurrence of predominantly mafic and ultramafic rocks with subvertical foliation, associated with smooth and undulating terrain. This geological association, notably structured by a predominantly subvertical foliation, results in the development of fertile soils, which also contributes to the development of the forest.

Although further climatic information is needed, indications exist of a positive rainfall anomaly and a trend of increasing temperature towards the west of the state of Goiás, which may have contributed to the development of the forest. The combination of these three factors (geologic, geomorphologic and climatic) explain the formation of such an anomalous landscape. In addition, although the biogeographic aspect was not considered in this study, it certainly also exerts a strong influence on the distribution of the MGG.

4 CONCLUSION

In Goiás, soils originating from the weathering of mafic rocks, broadly distributed throughout southwestern Goiás, coincide with the location of the “Mato Grosso de Goiás”, partially mapped by Speridião Faissol. These occurrences, associated with certain young terrain conditions and probably also with anomalous meteorological conditions, particularly higher rainfall and temperatures than in other areas of the biome, determined the development of a tropical forest enclave in the middle of the Brazilian savanna. The present study estimates an original area of 26,391 km2.

The objective of this study was to estimate the original extent of a regional vegetation domain. This estimation contributed to better evaluating the destruction of the Goiás natural resources and to suggesting conservation strategies, such as defining MGG region Protected Areas and setting a new ecoregion for bio-regional management in the Cerrado biome.

Because this is an estimation with uncertainties and approximations, some reservations must be considered. First, the expression “Mato Grosso de Goiás” is a popular name and therefore lacks strict classification criteria from a scientific point of view. Originally, the expression only characterized the observed physiognomy of the vegetation and was historically used by any individual, scientist or not, to denominate the wide forested region of Goiás. As previously discussed, the formation of forests within the Cerrado biome does not depend exclusively on geology; factors such as relief and water regime are also fundamental, in addition to soil type, climate and biogeography.

Nevertheless, the MGG must be considered as an integrated system, and in general, geology is the determinant factor for all these components. Another important aspect is the scale of the geological map (1:250,000), which may result in inaccuracies in analyses at larger scales.

The proposal presented herein may support conservation policy and scientific studies and serve as a methodological reference for similar analyses.

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The organization of the data that results maps of precipitation and temperature (Figure 5 and Figure 6) has made by Professor José Tadeu Garcia Tomaselli - Universidade Estadual Paulista - UNESP.

NOTES

[1](CMD/AHU-ACL-N-Goias 2158 No. Catalogue: 1539 - Available at http://www.cmd.unb.br/biblioteca.html)

[2]http://research.jisao.washington.edu/data_sets/ud/

[3]SIEG is the official cartographic database of the state of Goiás (available at: www.sieg.go.gov.br.)

[4] http://www.dsr.inpe.br/topodata

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