

## THE BRAZILIAN CERRADO PRODUCTION SYSTEM CLASSIFICATION AND ITS IMPLICATION TO AGRICULTURAL LANDSCAPE CONSERVATION

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### ABSTRACT

The Brazilian Cerrado is a biodiversity hotspot, cradle of important watersheds and one of the most important food producer areas. However, it's very explored by production systems that still uses deforestation, burning, low management and soil overexploitation. Because of that, our aim was applying a classification system to entire Cerrado area divided in cells by 10 thousand hectares. Our classification found 11 production systems under de domain of livestock beef and milk and secondarily by agriculture, both systems close to deforestation. Natural systems were identified inside and in the border of protected areas and tree plantation and family farm, beside their importance, has low territorial predominance. With these results we present an important tool to be base of public policies in direction to nature conservancy a sustainable development.

**Key words** — Production systems, sustainability, land use, deforestation.

### 1. INTRODUÇÃO

The Brazilian Cerrado, comprise the second largest biome in the country, occupying around 2 million km<sup>2</sup> which correspond to 24% of the national territory [1]. Its shares ecological transition zones with four of the six Brazilian biomes. The vegetation structure is highly heterogeneous, and the vegetation types are driven by the interaction among several factors such as soil moisture, soil composition, and precipitation [2]. Beyond being considered a global hotspot of biodiversity [3], the Cerrado hosts the headwaters of many important Brazilian hydrographic basins [4]. The biome harbors many traditional communities and indigenous people, who depend directly on environmental conservation. Brazil's agribusiness also depends on Cerrado areas, especially their flat terrains and water availability, which favor mechanization and irrigation of cultures. About 37% of

any Brazilian production or exploration is totally or partially in the Cerrado biome. Half of the agricultural lands and about 35% of the herd of cattle from Brazil are also located in the Cerrado [5]. The region leads production of the major export crops such as soybean, maize, and cotton [6; 7; 8]. Is estimated that 50.6% of the Cerrado has been converted into agricultural lands and planted pastures [9]. Then, one of the main challenges in Cerrado is securing goods production while conserving nature.

Until 2021, is estimated that around 995.460 km<sup>2</sup> of Cerrado native vegetation have been cleaned [10]. Among the potential adverse effects of the conversion of natural to agricultural ecosystems are species extinction due to habitat loss, fragmentation, and degradation [11], landscape simplification [12], and climate change driven by greenhouse gas emissions [13].

It is important to recognize that different productive sectors result in different levels of conversion pressure above natural areas. In this context, to understand the impacts of the different productive sectors in the landscape is important to plan public policies that promote economic and social development in line with environmental conservation [14]. The aim of this study was the identification of the main productive sectors in the Cerrado biome at the sub-municipality level and their implications for landscape connectivity, heterogeneity, diversity, and edge quantity.

### 2. MATERIAL E MÉTODOS

#### 2.1 Landscape land-use thematic map

We divided the entire Cerrado area in 20,392 hexagons of 10,000 ha and applied a decision tree to classify each hexagon according to its predominant economical production system. We did this using two base maps: [15] The 2018 TerraClass Cerrado land use-cover map [15] available in <https://www.terraclass.gov.br/>. This map is based on Landsat-5/TM and MODIS satellite imagery data with 30 m of spatial resolution and 15 classes of land use-land cover. Then we used the 'landscapemetrics' R package [16] to estimate the area covered (ha) in each hexagon by: production

area, which comprised by the sum of areas of the classes Secondary Vegetation (class 2), Silviculture (class 9), Perennial Agriculture (class 12), Semi-perennial Agriculture (class 13), One Cycle Agriculture (class 14), More than Two Circles Agriculture (class 15) and Deforestation in the year (class 19). The area covered by Agriculture cover, comprised by the sum of Perennial Agriculture (class 12), Semi-perennial Agriculture (class 13), One Cycle Agriculture (class 14) and more than Two Circles Agriculture (class 15) classes. The area covered by Forest, comprised by the amount of Silviculture (class 9) class. And the amount of Secondary Vegetation (class 2) class. Second, the 2020 Prodes Cerrado from The Brazilian Monitoring Program by Satellite [17]. This project annually estimates the deforestation rate in the Brazilian Amazon Forest and Cerrado biome creating an incremental map of deforested areas with 30 m spatial resolution and is freely available at TerraBrasilis platform [18] (<http://terrabrasilis.dpi.inpe.br>).

We used the distance of dairy facilities as a proxy to estimate the milk production presence within the hexagons. To estimate these distances, we georeferenced the facilities records from the Management Information System of the Federal Inspection Service (SIGSIF, <http://sigsif.agricultura.gov.br/>) of the Brazilian Ministry of Agriculture, Livestock and Food Supply (MAPA) and associate this to a euclidean distance to each Cerrado hexagon centroid through the 'matrix distance' tool from Qgis software [19].

## 2.2 Production system tree classification

We used a R language algorithm to applicate each rule (fig. 1) to each Cerrado hexagon to three levels of classification, two Domain, three Subdomain and 11 production systems. The two Domain are compressed by Natural Domain, with the Natural Region (NR) and Initial Front (IF) and Production Domain. The three subdomains are Agriculture, Livestock and Tree Plantation.

## 2.3 Landscape structure by production system

We used the 'landscapemetrics' R package to estimate (1) the mean deforestation path area, (2) the deforestation amount between 2000 and 2020 and (3) the forest amount by the amount of natural vegetation area. And used graphical visualization to show how these metrics are correlated to each production system on the landscape.

# 3. RESULTS

## 3.1 Production system classification

From all Cerrado hexagons, 401 (1.96%) were classified as Natural Region and 1738 (8.52%) as Initial front. From the Production Domain, 4446 (21.8%) hexagons were classified as Livestock Beef and 5040 (24.71%) as Livestock Beef and Milk, the most frequent production system, 1947 (9.5%) were classified as Strict Agriculture, 3352 (16.43%) as Dominance Agriculture and 2060 (10.1 %) as Coexistence Agriculture. 266 (1.3%) were classified as Tree Plantation Zone, 150

(0.73%) as Mixed Tree Plantation Zone, the less frequent production system. Finally, 312 (1.53%) were classified as Small Diversified Agriculture and 680 (3.33%) as Mixed Economy Region (fig.2).

## 4. DISCUSSION

Our classification shows that the Brazilian Cerrado is dominated by Livestock subdomain (46.51%) and these production systems are directly linked with the Cerrado deforestation between 2000 and 2020 (fig.3), showing strong correlation between forest loss and cattle raising both to beef or/and milk production. This do not mean that these areas are covered just for cattle pasture, but that cattle raising is the predominant production system in each classified cell. The Strict Agriculture (that means more than 80% of agriculture cover into the production system) and Livestock subdomain area together cover more than 65% of the Cerrado territory. The use of cattle raising and strict agriculture like soy plantation is a known strategy to deforestation front to transform recent opened area in extensive productive land [20]. However, this process frequently is dominated by exotic planted grasses and low soil management and technology, leading to low productivity and large areas of degraded pasture [21]. Where about 250,000 km<sup>2</sup> of planted pastures are degraded and support few cattle because of reduced grass food disponibility, invasion by unpalatable plants, and termites [22].

After the Strict Agriculture, came the Dominance Agriculture (between 30% and 80% of agriculture predominance) as and Coexistence Agriculture (less than 30% of agriculture dominance). These two production systems comprised by more than 26% of the Cerrado territory are also linked with deforestation, but with more diversity of land use classes. This probably happens because most of the times this area, besides agriculture predominance, has the rest part covered by deforestation linked to systems like cattle raising culture. Frequently pasture and extensive agriculture are dominant on the Cerrado land use, and our analysis highlight that together Livestock and Agriculture subdomain cover more than 82% of its territory.

Natural Region and Initial Front are the systems dominated by natural areas. NR represent areas with zero economic activity, frequently in the core of protected areas (PAs) or Indigenous Lands (IL). IFs are most concentrated at the border of PAs and ILs with less than 5% of production systems. The cells classified as these systems are naturally not connected to deforestation and together it comprises 10.5% of the Cerrado area and matching the 7.5% of protected area of Cerrado [23]. This is a very low protection to a biodiversity hotspot with high deforestation rate (approx. 1% per year) [23] added to low efficiency of protected areas [24].

Just 2% of Cerrado cells was classified as Tree Plantation subdomain concentrated in small packages in the south of the biome in São Paulo, Mato grosso do Sul and Minas Gerais states. This production system is recognized to aggregate very high technology and because that are concentrated in areas closer to infrastructure, frequently its

uses areas formerly covered for cattle raising and annual agriculture because of this reutilization there are areas with low linkage with Cerrado deforestation with an important amount of Natural vegetation specially in the Mixed Tree Plantation Zone [25].

The last subdomain Mixed Economy Subdomain cover less than 5% of the Cerrado, comprising the Mixed Economy Region and Small Diversified Agriculture cells, distinguished by the presence of secondary forest cover in less and more than 30% respectively. As the Cerrado has a great regeneration capacity, the presence and dominance of secondary vegetation are frequently related to abandoned areas or small family farms with low management or agroecosystems [26]. In Goiás state, in the center of Cerrado Biome family farms represent 65% of the properties number but less than 15% of the agriculture area [26]. In the same line our analysis shows a very low dominance of this production system too, demonstrating that beside to be very numerous, this production system is spread and with low dominance in the Cerrado biome. In addition, this is the least production system linked to deforestation and consequently with more portion of natural areas (fig. 3 C).

### 5. CONCLUSIONS

These results demonstrate the importance of our classification to define the regionalization of production systems and proves to be important to facilitate de understanding of the relationship between spatial economy and its effects on landscape aspects for example the deforestation. Because that, this is a great tool as baseline to visualize and create public policies in direction to more sustainable production systems.

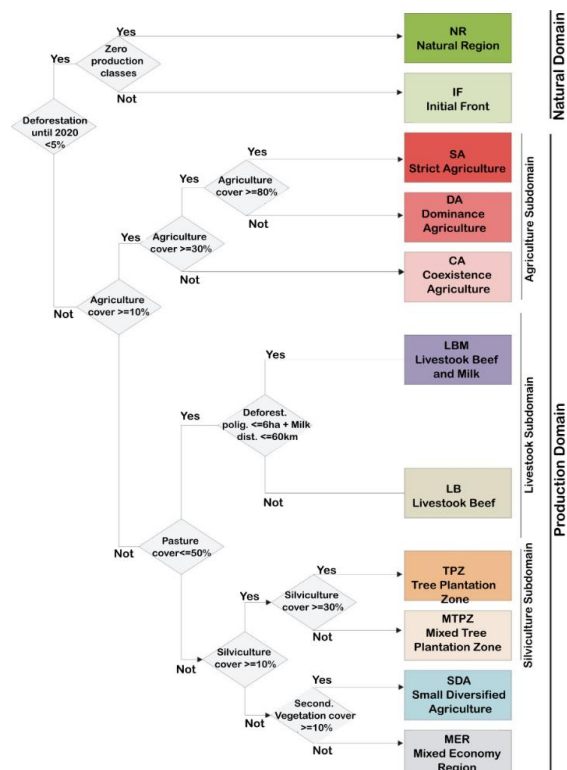


Figure 1. The decision tree used to classify each Cerrado cell in one of the predominant systems.

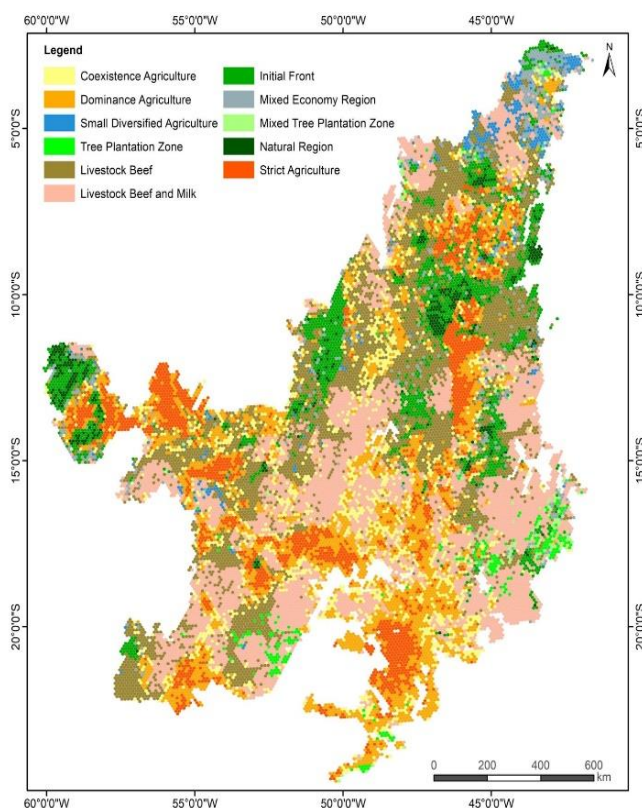
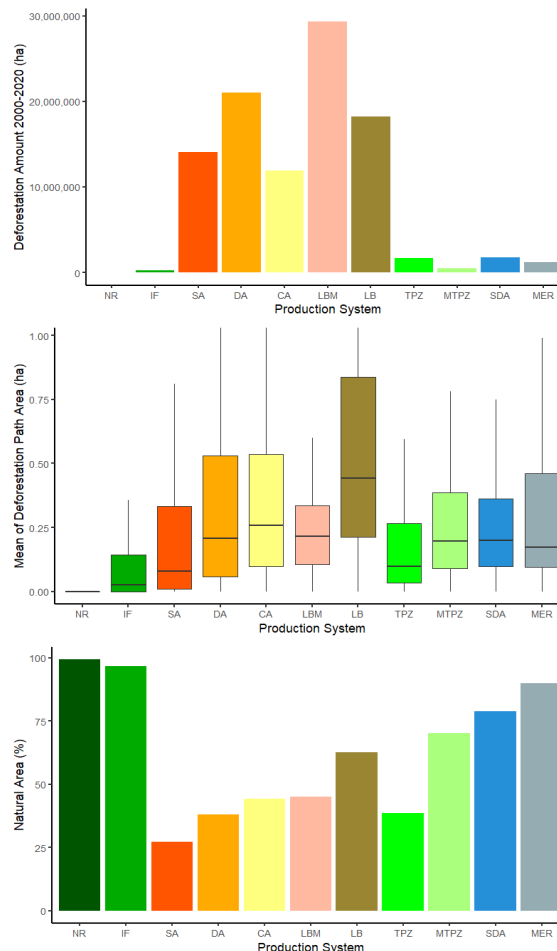


Figure 2. The Cerrado cells classification by each predominant system.





**Figure 3. The relationship between each classified system and the: deforestation amount in hectares between 2000 and 2020 years (A). The mean deforestation patch area in hectares (B). And the percentage of natural area by system. Natural Region- NR, IF- Initial Front, SR- Strict Agriculture, DA- Dominance Agriculture, CA- Coexistence Agriculture, LBM- Livestock Beef and Milk, LB- Livestock Beef, TPZ- Tree Plantation Zone, MTPZ- Mixed Tree Plantation Zone, SDA- Small Diversity Agriculture, MER- Mixed Economy Region.**

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