Application of Geotechnologies in the Development of Sustainable Agriculture in Brazil

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***Abstract* — The global consumption of food, water, fibers and energy is growing at exponential rates. Brazil has become a player of the world economy by becoming an important agricultural producer, and the country has technical and agronomic conditions to produce with quality and sustainability. However, there is a need for more site-specific natural resource management for judicious use of agricultural inputs to promote productivity and ecosystem services. The issue is particularly urgent, as population in rural areas have been migrating to cities for several reasons. Science may decisively contribute to agriculture with sustainability through management procedures that use remote sensing and precision farming. Remote sensing monitoring plays a critical role in supporting strategic decision-making, and to define private and public policies. New researches and innovations have changed rapidly, due to advances in information technology and geotechnology, supported by great data availability, new processing algorithms, data fusion, and developments in data mining. The present review paper aims to present actions of Brazilian Agricultural Research Corporation and collaborating organizations in the application of remote sensing and geospatial databases in the monitoring of Brazilian agriculture.*

***Keywords*— Geotechnology, Natural Resources, Rural Development.**

I. INTRODUCTION

Brazil covers a total area of 8,514,215 km² and presents a variety of soil and climate conditions reflected in the range of its vegetation types. While agriculture is highly performing producing almost 240 million tons of grains per year on 75 million cultivated hectares [1], it is facing numerous challenges to generate human development in rural populations, and to reduce regional socioeconomic contrasts among territories. The combination of soil conditions, climate, relief, science, technology, public policies, and the competence of farmers has made Brazil one of the world leaders in agricultural production and export. The sector represents approximately 25% of Gross Domestic Product (GDP), and 45% of exports [2].

However, the world population growth, continuous urbanization, long life expectancy, and economic power will further increase consumption of food, fiber and energy in the coming years. Thus, Brazil may assume an even greater role in agricultural production and environmental responsibility. An estimated 9.8 billion people on Earth in 2050 [3] brings up the need to increase food production by 50% when compared to 2013. The need for expansion may occur mainly in regions with high productive potential, such as the Cerrado [4].

The sustainable future of rural areas and agricultural livelihoods relies on the combination and connection of different resource-based products, processes, and services. The underlying concept is Multifunctional agriculture, which is rooted in the fact that farms and farmed landscapes may produce a large array of products and ecosystem services. Although the primary role of agriculture is to produce food and fiber, other functions are important, such as land and water conservation, maintenance of landscape structure, sustainable management of natural resources, biodiversity preservation, and contribution to employment and the socioeconomic viability of rural areas [5; 6]. That is in the context of the 2030 Agenda for Sustainable Development adopted by all United Nations Member States [7].

Geotechnologies expand the possibilities of agricultural monitoring and support rural planning in a sustainable way, not limited to agricultural crops, regions, or class of producers. In increasingly dynamic productive regions, remote sensing and geospatial databases are fundamental for mapping and monitoring the processes of expansion, retraction, conversion, intensification, and agricultural diversification [8]. Multisensor analysis with the synergistic use of satellites, such as Landsat 8 and Sentinel

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create innovative and unprecedented opportunities for more accurate mapping and agricultural monitoring [9].

II. POTENTIAL OF GEOTECHNOLOGIES

Brazil has an innovative role in the use of geotechnologies in agriculture. However, processes of agricultural expansion, conversion, degradation, and diversification are complex and require innovative, fast, and accurate approaches to spatial analysis. New approaches are required to plan production, management, harvesting, market access, marketing and transportation of grains, fruit, vegetables, meat, milk, eggs, fiber, and timber. The potential use of remote sensing and geospatial databases is part of the 2030 Agenda, which involves 17 Sustainable Development Objectives [10] in the context of digital agriculture (Figure 1 and Table 1).

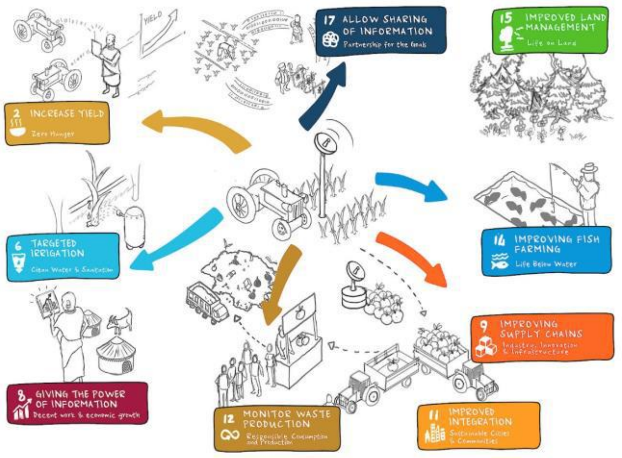

Fig. 1: Digital agriculture has the potential to advance the SDGs [10].

Table 1: Some examples of geotechnologies of application across a wide variety of sectors [10].

Sustainable Development Objectives	Areas of Application
SDG 2 Zero hunger	▫ Make better farming decisions by supplementing local knowledge developed over generations with real-time, detailed, environmental data. ▫ Increase yield per acre and reduce production loss to help improve food security and increase the food output, required to keep up with population growth. ▫ Improve transparency and sharing of information. By providing quantitative data on factors that have been difficult until now to measure and interpret, farmers will be able to improve their economic models. Financiers and insurers can also better understand risk to protect farmers financially.
SDG 6 Availability and sustainable management of water	▫ Waste less water through a better understanding of soil moisture, crop health and weather forecasting – provide only as much water to the plants as needed. ▫ Reduce chemical use and run-off into local water supplies.
SDG 8 Decent work and economic growth	▫ Give more power to those working in agriculture and support related innovations such as up-to-date agricultural pricing and trading – particularly the ability to facilitate trade without using intermediaries.
SDG 9 Industry, innovation, and infrastructure	▫ Improve resilience and effectiveness of food / farming supply chains through better integrated systems and information sharing.
SDG 11 Sustainable cities and communities	▫ Enable more sustainable city growth through better waste management as a result of improved integration across the food value chain.
SDG 12 Responsible consumption and production	▫ Provide information which allows consumers to be more responsible. ▫ Reduce waste through better decision making across the supply chain, using predictions of harvest yields and quality to improve planning. ▫ Reduce waste in storage through improved planning and by linking agricultural sensors with transport management systems to reduce food spoilage. ▫ Reduce the chemicals used and improve long-term soil management through better planned crop rotations.

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SDG 14 Life below water	▫ Allow increased freshwater fishing by improving water quality with aquaculture technology. ▫ Reduce chemical run-off contaminating oceans.
SDG 15 Life on land	▫ Promote more sustainable land ecosystems through a more considered use of farming land and approach to forestry.
SDG 17 Partnerships for the goals	▫ Allow companies to partner to increase the impact on all the SDGs through improved availability of information.

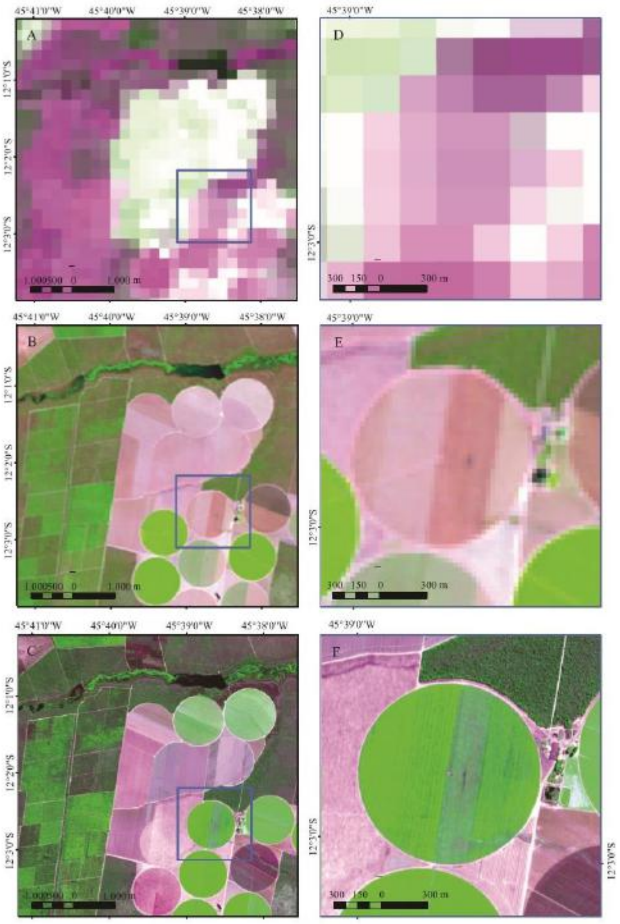

Fig. 2: Satellite images of: i) low spatial (A and D - Terra / Modis); ii) medium spatial resolution (B and E - Landsat = 30 m); and iii) high spatial resolution (C and F - GeoEye 1 = 2 m) of agricultural region in the Municipality of Luiz Eduardo Magalhães (BA) [13].

A recent review on the future of Brazilian agriculture [11] identifies megatrends associated with the need for technological and knowledge convergences in agriculture by 2030. The convergences pointed out in geotechnological area are determinant instruments to support decision making of public actions and private activities of rural planning. The remote sensing play an important role in the field, especially in diagnostics as yield estimate, nutritional assessment, detection of pests and diseases, weather forecast, and assessment of plants and water requirement in site-specific [12].

Crop information obtained in a non-destructive, fast, and sometimes at a distance, have become essential to obtain and process agriculture field data. The multiscale and multisensor analyzes offer a myriad of potential benefits in terms of crop yield monitoring, environmental protection, sustainability, food security, and rural economic development (Fig. 2).

III. APPLICATION OF GEOTECHNOLOGIES

The results of geotechnology applications, such as remote sensing and database multiscale analyzes, will be presented in agriculture monitoring to different regions in Brazil involving the themes: pasture conditions, agricultural mapping, systems of agroforestry mapping, and integrated land-use and land-cover characteristics.

The Brazilian Savanna covers 203.4 million hectares (24% of the country territory), and about 55 million hectares are cultivated with pastures (Figure 3). The study aimed to evaluate the conditions of cultivated pastures. Geoprocessing techniques and Normalized Difference Vegetation Index (NDVI) timeseries data, derived from Spot-Vegetation sensor were applied.

The time-series data indicated 35% of their cultivated pastures under some degradation process. The analyzes were relevant to evaluate the conditions of cultivated pastures, and corroborate to strategic territorial intelligence, as well as the implementation of public and private actions to potential productive pastures [14].

The following study produced land-use and land-cover mapping of the Savannas based on Landsat-8 Operational Land Imager (OLI) images. The results showed that 43.4% of the study area (88.5 million hectares) were already converted into agricultural, urban, and mining areas. The annual croplands represented 8.5% the total area. The red circles indicate traditional agricultural frontiers: western Bahia, southwestern Goiás, and the central part of Mato Grosso. The circle in southern Piauí and Maranhão is the new agricultural frontier (Figure 4) [15].

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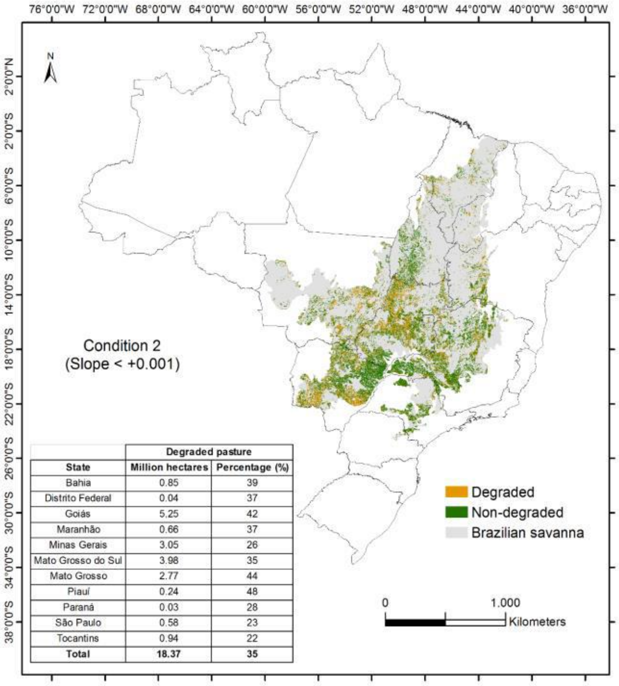

	Degraded pasture	
State	Million hectares	Percentage (%)
Bahia	0.85	39
Distrito Federal	0.04	37
Goiás	5.25	42
Maranhão	0.66	37
Minas Gerais	3.05	26
Mato Grosso do Sul	3.98	35
Mato Grosso	2.77	44
Piauí	0.24	48
Paraná	0.03	28
São Paulo	0.58	23
Tocantins	0.94	22
Total	**18.37**	**35**

Fig. 3: Spatial distribution of cultivated pastures degraded and no-degraded in the Brazilian Savanna in 2013 [14].

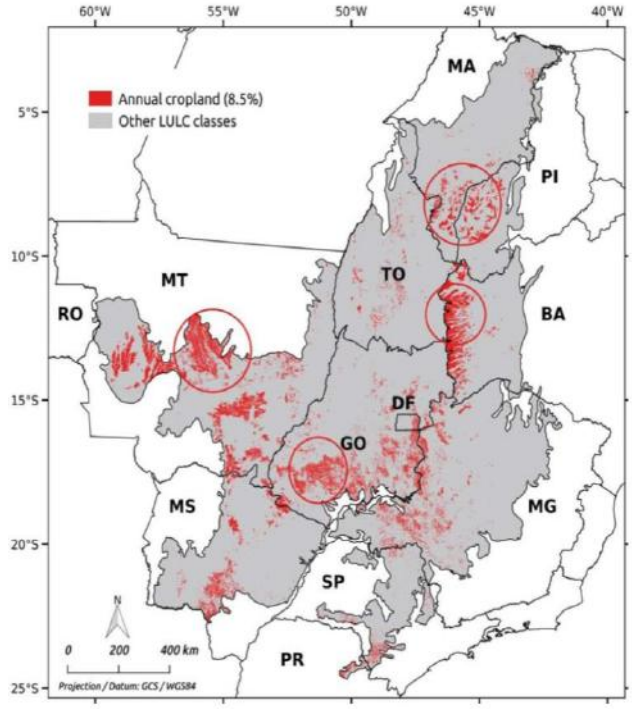

Fig. 4: Spatial distribution of annual croplands in the Brazilian Savanna in 2013 [15].

The region known as MATOPIBA (Maranhão, Tocantins, Piauí, and Bahia), in the North/Northeast of Brazil, has become an important agriculture frontier. However, it is important to guarantee that the agricultural expansion in the region happens in a sustainable way. Thus, integrated analyzes of social, biophysical, infrastructure, rural credit, and economical characteristics play important role in establishing regional public policies [16].

This work analyzed the agricultural expansion in the region, and geospatial datasets presenting some conditions - rural settlements, traditional communities, state conservation units, federal conservation units, and indigenous areas (Figure 5).

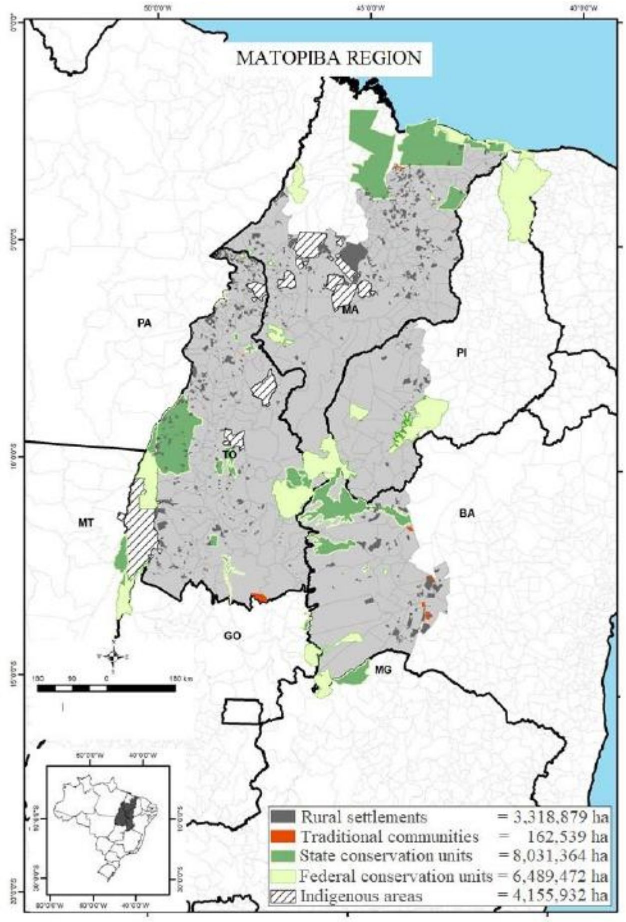

Fig. 5: Spatial distribution of rural and environmental areas in the MATOPIBA region in 2016 [16].

The last example analyzes agroforestry systems in Brazilian Amazon. Agroforestry has large potential for carbon sequestration while providing many economical, ecological and social benefits via its diversified products.

The study used Airborne lidar considered as the most accurate technology for mapping aboveground biomass (AGB) over landscape levels. Figure 6 shows maps of vegetation type (a); and AGB predicted with mixed-effect model (b); and fixed-effect model (c); and the difference between AGB predicted with fixed - and mixed - effect models (d). Black color indicates the area masked for analysis [17].

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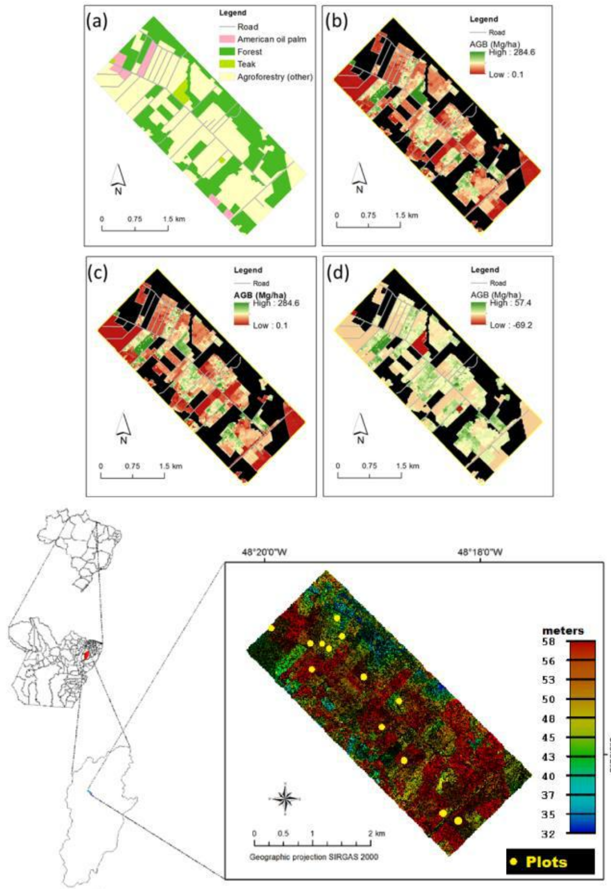

Fig. 6: Spatial distribution of agroforestry systems in the Tomé-Açu (Amazonia region) in 2016 [17].

The examples of geospatial monitoring of agriculture by remote sensing presented above support the conservation, recovery, and sustainable use of terrestrial ecosystems. They support the implementation of sustainable management of agricultural crops, pastures, and agroforestry. They enhance the activities of rural environmental register, precision agriculture and agricultural zoning. They also intensify the application of environmental certification of properties, the management of animal welfare, and geotracking, raising food quality and safety. They collaborate planning land-use and occupation with more resilient agricultural practices, such as agroforestry systems.

Geospatial databases store information on plant and animal genetic resources (native and exotic), registration of traditional knowledge, local products and a catalog of attractions that promote rural tourism. They also serve as database for new applications and support decision-making on numerous practices involving animal and plant breeding, as well as to understand the meteorological conditions, such as droughts and floods, collaborating preventively to soil maintenance, water and air quality. Yet, they allow identifying, monitoring and reducing the incidence of pests and diseases in agricultural crops.

Thus, spatial analyzes of mapping and agricultural monitoring assume strategic role in farm planning and to the benefit of more sustainable rural development in a regional way.

IV. FINAL CONSIDERATIONS

Over the last decades, Brazil has become one of the global leaders in agricultural production. The review paper analyzed how remote sensing and geospatial database may subside and support sustainable development for the country. The results of these actions support public and private decision-making in rural planning and collaborate with the 17 Sustainable Development Goals (SDGs).

Highlighting: i) technology & innovation knowledge to adopt techniques and technologies with adequate agricultural and environmental management; ii) integrated applications of remote sensing and geodatabase providing solutions and information to plan and implement public and private agricultural projects; and iii) use and applications of the emerging space technologies like LiDAR and BigData for agricultural planning and monitoring natural resources towards sustainable rural practices.

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