BRIDGING BRAZIL'S EARTH OBSERVATION CHALLENGES WITH DATA TERRA'S DATA AND SERVICES

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A THEMATIC PAPER SUBMITTED IN PARTIAL
FULFILLMENT OF THE REQUIREMENTS FOR
THE DEGREE OF MASTER OF MANAGEMENT
COLLEGE OF MANAGEMENT
MAHIDOL UNIVERSITY
2024

Thematic paper
entitled

BRIDGING BRAZIL'S EARTH OBSERVATION CHALLENGES WITH DATA TERRA'S DATA AND SERVICES

was submitted to the College of Management, Mahidol University
for the degree of Master of Management
on
28 October 2024

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ACKNOWLEDGEMENTS

First and foremost, I would like to express my sincere gratitude to Asst. Prof. Trin Thananusak, Ph.D., my advisor, for his invaluable guidance, insights, and continuous encouragement throughout this journey. His expertise and feedback have been instrumental in shaping the direction and quality of this research.

I extend my heartfelt appreciation to Ms. Ghislaine Abassis from the DATA TERRA communication team, whose unwavering support and expertise as the organization's representative have been crucial to the success of this project. Her prompt responses and assistance helped me, and my team overcome the complexities of this research. A special thank you also goes to Miss Geetika Raaman, a dedicated doctoral student who provided exceptional support for our collaboration with DATA TERRA. Her contributions and advice were invaluable, and her collaborative spirit made this endeavor even more rewarding.

I would also like to thank my team members from Toulouse School of Management, Université Toulouse Capitole I, who made this consulting project a shared success. Their perspectives, cooperation, and enthusiasm were essential in overcoming the challenges we faced as a team.

Finally, I wish to acknowledge the encouragement and support of my friends at the College of Management, Mahidol University, and my beloved family, whose constant motivation and belief in me made this accomplishment possible.

To everyone who participated in this project, thank you for your contributions, support, and belief in this research.

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ABSTRACT

This thematic paper explores the potential of DATA TERRA's satellite data and services to address Brazil's needs in earth observation activities. The research identifies gaps in Brazil's current satellite data capabilities, particularly in disaster management, environmental protection, and agricultural management. The study also explores how DATA TERRA's advanced solutions, such as high-resolution imagery and on-demand processing tools, can support Brazilian organizations like INPE, CEMADEN, and EMBRAPA in overcoming limitations in data quality, analytical capacity, and skilled personnel.

Conducted as part of a consulting internship project between the Toulouse School of Management and DATA TERRA, the study draws on secondary research from scientific publications and government resources. The analysis provides recommendations on how DATA TERRA can tailor its services to Brazil's specific needs, highlighting opportunities for collaboration and strategic planning in natural disaster mitigation, biodiversity conservation, and agricultural efficiency. Moreover, the paper suggests that expanding the application of satellite data to sectors like urban planning and public health can further enhance Brazil's sustainable development goals.

This study provides DATA TERRA with a framework for strengthening its presence in Brazil and aligning its services with national priorities, fostering long-term partnerships that address Brazil's most pressing earth observation challenges.

KEYWORDS: BRAZIL/ EARTH OBSERVATION /DATA TERRA/ SATELLITE / FRANCE

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CHAPTER I
INTRODUCTION

1.1 Background

Earth observation data plays a critical role in understanding and managing the Earth's systems, including the atmosphere, oceans, solid earth, and land surfaces. These observations are crucial to handling global challenges such as climate change, natural disasters, biodiversity loss, and sustainable land management. The effective use of earth observation data requires robust infrastructures that facilitate data collection, processing, and distribution to different stakeholders, including scientists, policymakers, and the public.

DATA TERRA is a French e-research infrastructure focused on Earth systems that operate under the government. It serves as a national platform that offers data and services to researchers, scientific communities, authorities, institutions, and the general public in France and internationally. Through a single portal, users can access four specialized data hubs: AERIS for atmospheric data, ODATIS for oceanic data, FORM@TER for solid earth data, and THEIA for continental surfaces and interfaces (Data Terra, 2022). DATA TERRA actively engages in various national and international projects, including European initiatives, by providing a wide range of multi-source data. This data spans from low to very high spatial resolution and includes research access, data management, and customized data processing.

Based on its mission, DATA TERRA desires to expand its service to broader communities, especially in helping developing countries like South American countries tackle global challenges. With its vast and diverse landscape, Brazil stands out and is considered an interesting country for the initial collaboration. More importantly, Brazil faces various environmental challenges, including natural disasters, biodiversity damage, and agricultural management. The country has increasingly relied on satellite data to support its earth observation activities. For example, satellite imagery is used to monitor deforestation in the Amazon, manage natural disasters such

as floods and landslides, and support agricultural development. However, understanding their areas of need in earth observation is needed to explore further so that DATA TERRA can provide the right services to the country. With close working with DATA TERRA's representative, the consulting team or students from Toulouse School of Management designed a research framework together to explore how DATA TERRA's infrastructure and services can be leveraged to enhance Brazil's earth observation capabilities.

1.2 Problem Statement

With its infrastructure, resources, and services, DATA TERRA could contribute to the needs of other countries at an international level. Apart from its ongoing projects with European and international parties, partnering with countries needing earth systems and environmental data and services would also be one of the strategies for DATA TERRA to expand its service internationally. Therefore, as DATA TERRA perceives South American countries as the first interesting choice for initial collaboration, Brazil stands out among its neighbors with its various landscapes and current problems that need earth observation data and services to help.

However, various factors influencing collaboration are needed to explore, for example, present characteristics of Brazil's satellite data, main actors who leverage these data, areas of needs among Brazil's users, and DATA TERRA's potential to close the gap of Brazil's needs.

1.3 Research Questions

How can DATA TERRA serve Brazil's needs with its satellite data and services?

1.4 Research Objectives

This study aims to understand areas of problems in Brazil that DATA TERRA data and services have the potential to fulfill.

The objective of the research includes:

1. To understand the current capabilities of Brazil's satellite data and services with its main actors who leverage these data into action
2. To explore and identify problems and needs of data and services related to earth observation activities in Brazil
3. To identify DATA TERRA's capabilities that potentially meet the needs of Brazil's earth observation data and service

1.5 Research Scope

This study is based on a consulting internship project from the collaboration between Toulouse School of Management, Université Toulouse Capitole I, and DATA TERRA. This research was conducted as a part of the UE9 International Project Management & Consulting Projects course under the Master 2 International Management program. The consulting assignment was done in Toulouse, France. The project's scope involved researching potential areas in satellite data and services that DATA TERRA could fulfill the needs of Brazil, collected from reliable sources such as research studies and government agencies. The data collection period was from January 3, 2024, to March 31, 2024. The study aims to provide supportive information to DATA TERRA for its international relations team's strategic planning.

1.6 Expected Benefit

The outcome of this study would be beneficial to DATA TERRA and other organizations, both public and private sectors, in understanding the characteristics of Brazil's satellite data and its limitations reflected through the real users, showing the opportunity for potential providers to serve the needs in the right areas of Brazil. In addition, this study will benefit readers who are interested in the current capabilities of satellite data and services from different countries.

CHAPTER II
LITERATURE REVIEW

This chapter explores Brazil-France collaboration in satellite data and earth observation activities, influencing the decision making of DATA TERRA to choose Brazil as its priority country for collaboration outside the region. The chapter also outlines DATA TERRA's role in providing earth observation data across key domains and discusses Brazil's application of this data in disaster management, biodiversity preservation, and agriculture, emphasizing the value of the desired partnership.

2.1 Brazil – France Relations

The major influences that make DATA TERRA choose Brazil as its first country outside the region for collaboration are the recent government-to-government partnership on the Amazon protection and being members of International Charter Space and Major Disasters.

Firstly, due to Brazil's commitment to protect the forest through satellite data, DATA TERRA recognizes it as the most attractive and potential collaboration among the South American countries. The most recent cooperation took place when the French President, Mr. Emmanuel Macron, have visited Brazil and met Mr. Luis Lula da Silva, President of Brazil from 26 to 28 March 2024. During this visit, both leaders agreed to combat deforestation and protect the Amazon including biodiversity. They committed to work together through Franco-Brazilian roadmap that aims at conserving the forest. The framework includes improving innovative financial tools, and market-based solutions to support the goal of halting deforestation by 2030 (Ministry for Europe and Foreign Affairs, 2024). Moreover, to achieve the mentioned goal, the Brazilian government plans to leverage satellite imagery to monitor illegal activities in the Amazon rainforest and also enhance the management of land ownership records (Goulard, 2024).

Another important factor is both countries being members of the International Charter Space and Major Disasters. This worldwide cooperation has been launched since 2000 and has until now 17 space agencies around the world as members of the charter, including the National Institute for Space Research or INPE of Brazil and National Centre for Space Studies or CNES of France who is the close partner of DATA TERRA (*Data Terra and Space*, 2022). Through this partnership, each member agrees to provide free of charge satellite data and products to each other for disaster management support (*Members of the Charter - News Item - International Disasters Charter*, 2020).

2.2 DATA TERRA

DATA TERRA is a French non-profit research organization under the Ministry for Higher Education, Research, and Innovation. It is dedicated to providing knowledge of the Earth system and environmental areas. The key mission is to enhance a system for accessing and processing data, products, and services related to earth observation. Four main data hubs are offered, each of which represents a compartment of the earth system: atmosphere, solid earth, oceans, and continental surfaces (*IR Data Terra in Short*, 2021). The details are as follows:

1) Atmosphere Dynamics (AERIS): to understand atmospheric physics, climate change, and air quality, as well as monitor air quality, estimate carbon emissions, and analyze the effects of events like forest fires. (www.aeris-data.fr/)
2) Solid Earth (FORM@TER): to explore solid earth by calculating ground deformation, monitoring critical regions, and studying large active fault zones. (www.poleterresolide.fr)
3) Oceans Dynamics (ODATIS): to dive into the depths of the oceans by monitoring coastlines, studying water oxygenation, and ensuring water quality. (www.odatis-ocean.fr)

4) Land Surfaces (THEIA): to observe land surface dynamics and natural resources with themes like agriculture, biodiversity, and climate. (www.theia-land.fr)

DATA TERRA's target users include the scientific communities such as four working groups, namely Science, Tech, European & International, and Communication Working Groups, created by DATA TERRA and related organizations like the National Centre for Space Studies (CNES), French National Centre for Scientific Research (CNRS), as well as public and socio-economic stakeholders free of charge, allowing them to access multi-source data via the one-stop portals (Data Terra, 2020).

Working with over 20 partners from national and international agencies and universities such as the Ministry for Higher Education, Research and Innovation, CNRS, CNES, Sorbonne University, and the University of Montpellier, DATA TERRA's platform offers a variety of data from satellites, ground stations, sounding balloons, and others, including diverse data quality ranging from low to very high spatial resolution (*Data Terra and Space*, 2022).

DATA TERRA not only provides satellite data but also other services related to earth observation activities (*Services Offered by Data Terra*, 2021), namely:

1) Data Discovery and Access Services
   DATA TERRA provides access to a shared catalogue of datasets with vocabularies and ontologies, including its identifiers, allowing users to cite and reuse datasets precisely. The shared data is derived from various sources, including satellite, field, aerial, and experiment data. The four data hubs mentioned also produce data regularly for different scientific applications, such as environmental indicators.
2) On-Demand Processing Services
   DATA TERRA offers a web-based interface service tailored to the needs of each user. Functions of the web include geostatistical analysis, modeling, image analysis and processing, previsualization, and environmental genetics processing. To process this large volume of data, platforms named

Earth System Analytics Labs (ESALs) and Virtual Research Environments (VREs) are developed to assist data processing according to command, and Virtual Research Environments (VREs) are developed to assist data processing according to command, such as geographic and areas of interest.

2.3 Fields of Satellite Data and Service Applications in Brazil

Brazil, one of 12 countries in the South American continent, is ranked fifth in the world by its size and the first in the continent. Its large landscape comprises wetlands, plateaus, long coastal plains, hills, and grasslands, as well as its well-known and the world's most extensive forest, the Amazon, that surrounds the Amazon River (Momsen & Martins, 2024). Due to its large area, Brazil possesses diverse environmental resources, including relying on the agricultural sector and facing unexpected natural disasters. Brazil then leverages the satellite data and service managing their earth observation activities to mitigate and handle risks from natural hazards, protect and manage biodiversity and the environment, and manage agriculture.

2.2.1 Natural Disaster Management

According to the World Bank data on climate change between 1980 and 2020, Brazil faced eight types of natural hazards, as seen in Figure 2.1. Floods have gained over half of the natural disaster events, with 52.68% happening for 20 years compared to all average natural hazard occurrences yearly. The following types are miscellaneous accidents at 13.39%, landslides at 8.48%, epidemics at 7.14%, storm and drought with the same proportion at 6.70%, extreme temperature at 2.23%, wildfire at 1.79%, and earthquakes at 0.89% (*Brazil - Vulnerability | Climate Change Knowledge Portal*, 2019).

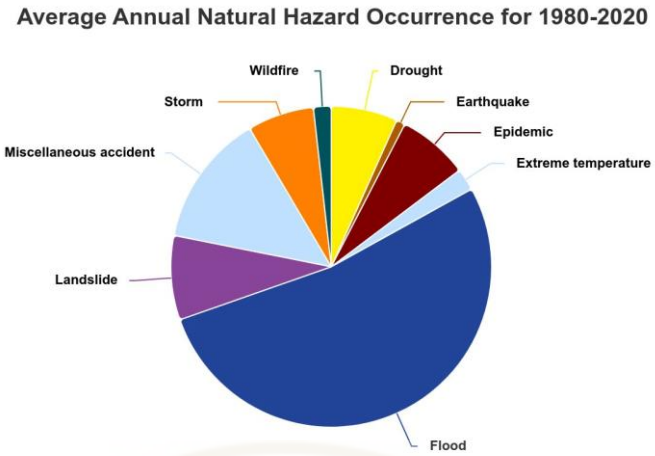

Figure 2.1 A pie chart showing the average number of natural hazard occurrences per year between 1980 and 2020 in Brazil *(*Brazil - Vulnerability | Climate Change Knowledge Portal*, 2019)*

From Figure 2.1, it is evident that floods have been the most significant event affecting the lives of Brazilians for 20 years and are still in need of better management. Recently, in May 2024, Brazil faced one of the most significant catastrophes with the flood in Rio Grande do Sul state, as can be seen in Figure 2.2, causing over 150 killed and over half a million people need to find a new place to live according to Al Jazeera (Al Jazeera, 2024). The root cause of this kind of disaster is climate change, resulting in heavy rainfall (Vijay, 2024). However, apart from the extreme climate, insufficient natural risk management and actions from the government are also the main reasons for the prolonged problems. According to Robert Muggah, co-founder of the Igarape Institute and principal of SecDev, despite high prone to natural risks such as rising rainfall, drought, and increasing temperatures in Brazil, only 14 out of 26 states that have strategies to handle climate change and the government should enhance the early warning system including investment in infrastructure that could resist with flood (*What Will Help Brazil Recover From Deadly Flooding? - The Dialogue*, 2024). Similarly, the lack of management is confirmed by Mr. Fernando Alcoforado, an Engineer and Doctor in Territorial Planning and Regional Development, saying that the root of flooding in Brazil is also the inadequate flood management infrastructure implemented by the government (TheCivilEngineer.org, 2024).

Figure 2.2 The map showing the Rio Grande do Sul state location where flooding happened in May 2024 (Al Jazeera, 2024)

Another disaster that frequently comes after a huge amount of rain is landslides. For example, in February 2023, São Paulo state faced flooding from the heavy rainfall with 680 millimeters or around 26 inches within a day, followed by landslides as soils were saturated with water. This kind of natural hazard usually happens in hilly landscapes and steep slopes. Even though Brazil has collaborated with NASA on a disaster preparedness partnership, agreeing on leveraging NASA's satellite data to improve natural disaster management, such as warning systems for floods and landslides, the agreement is only between NASA and Rio de Janeiro city in the northeast of São Paulo state. It shows that Brazil is still in need of advanced technology like satellite data and collaboration from experts to help prepare for disaster management across the country (Hansen, 2024).

2.2.2 Biodiversity and Environmental Protection

According to the Convention on Biological Diversity, the multilateral treaty indicates that Brazil covers around 15-20% of global biological diversity, with the Atlantic Forest and the Cerrado as its two biodiversity hotspots (SCBD, 2014). However, the biodiversity in Brazil has been at risk due to global warming, wildfire, and human actions like deforestation, farming, and cattle ranching. As collected by Global Forest Watch, the data on Brazil's tree cover rate has decreased by 13% from 2001 to 2023. Additionally, the leading cause of tree cover loss falls into deforestation

as 62% of tree cover loss happened in areas where deforestation is the key factor, as shown in Figure 2.3 below, with red color representing the deforestation rate each year (Global Forest Watch, n.d.).

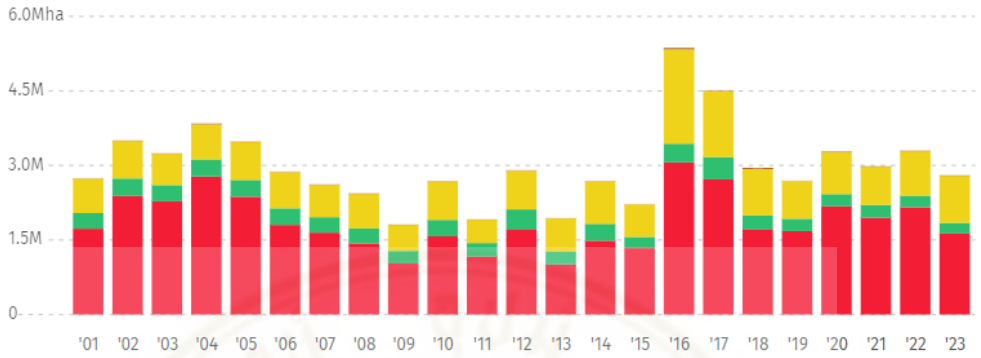

Figure 2.3 A chart showing tree cover loss by dominant drivers in Brazil from 2001 to 2023 *(Global Forest Watch, n.d.)*

Moreover, the main drivers of deforestation are human actions, namely agriculture like cattle ranching and soybean farming. Ranching accounts for around 80% of the Amazon Forest's loss. The activities for doing these agricultures are the root of deforestation as farmers need to clear the land for animals by setting fire, resulting in plants, animals, their habitats, and biodiversity being destroyed (Denicoff & Nielsen, 2024).

Another root cause that leads to biodiversity and environmental loss is wildfire. Even though the fire count rate in Brazil declined 16% in 2023 compared to the previous year, the wildfire count rates in the primary or old-growth Amazon forest are increasing by 152% or 34,012 in 2023 compared to 13,477 in 2022 as monitored by the satellite data according to the research article Global Change Biology (Mataveli et al., 2024).

To tackle and plan to handle these risks of biodiversity loss and environmental damage, satellite data plays a vital role in monitoring and assisting mitigation and prepared planning.

2.2.3 Agriculture Management

Earth observation data also assists in mapping and monitoring croplands and soils, detecting soil characteristics for land evaluation, soil classification, and

agricultural suggestions. According to the data from MapBiomas, agricultural areas in Brazil have increased by 50% from 1985 to 2022, or around 95.1 million hectares. In 2022, the agriculture area covered 282.5 million hectares or around one-third of the country's area, increasing from 187.3 million hectares in 1985 (*MapBiomas Brasil*, 2023). Most of the growth happened in the Amazon forest, with 57.7 million hectares dedicated to pasture areas.

Satellite data plays an essential role in monitoring the agricultural production areas in Brazil. Government sectors also rely on satellite imagery in developing agricultural regions; for example, the Brazilian Agricultural Research Corporation (EMBRAPA) uses satellite images to monitor agrarian areas adopting the integrated Crop-Livestock (ICL) systems as well as double cropping in Brazil to develop protocols, policy, and to support the national low carbon agriculture plan (*Brazil Uses Satellite and Machine Learning to Monitor Agriculture Sustainable Intensification*, 2021). Therefore, with the increase of agricultural areas over decades leading to an impact on the environment, the government should implement more control on land use with satellite imagery and other technologies as tools (Safanelli et al., 2021).

CHAPTER III
RESEARCH METHODOLOGY

This chapter outlines the steps and methods employed for the study with DATA TERRA, comprising four key steps: problem definition, framework development, data collection, and data analysis.

3.1 Research Design

Four students from the Toulouse School of Management (TSM) with different cultural backgrounds were formed into a group to work on the consulting project with DATA TERRA, represented by Ms. Ghislaine Abassis from the communication team. Student team members include:

1) Ms. Ashley Sanchez Santos, from the Dominican Republic;
2) Mr. Bernard Boateng, from the Republic of Ghana;
3) Ms. Pauline Lecoix, from the French Republic; and
4) Ms. Yanapa Chatrakul Na Ayudhya, from the Kingdom of Thailand.

This diversified group contributed to the project's goal with comprehensive perspectives and different experiences, along with assistance from the academic tutor from TSM, Miss Geetika Raaman, a doctoral student.

The project took two months to complete both oral presentation and report, starting from January to February 2024. The consulting meetings took place every two weeks via videoconference with DATA TERRA, including the final presentation.

3.2 Problem Definition

DATA TERRA has shared with the team their idea on the initial topic and areas of interest related to potential aspects that DATA TERRA could contribute to other countries in South America. DATA TERRA already provides resources and services in the country and European countries. DATA TERRA would then like to expand its presence and invite others to make the most of its resources for better management related to the earth. After the first discussion, DATA TERRA and the consulting team concluded that Brazil is the priority for their first collaboration in South America due to its diverse natural resources and proneness to natural risks. DATA TERRA aims to understand more about Brazil's current situation on satellite data and services capabilities. The research seeks to clarify Brazil's areas of needs that DATA TERRA could fulfill with its data and services.

3.3 Framework Development

Even though satellite data and services are widely utilized in South American countries, especially in Brazil, there is still room for improving and strengthening its capability for several uses in disaster, environmental, and agricultural management.

As agreed during the first meeting with DATA TERRA, this project would focus on Brazil's context due to its diverse natural resources and extensive territory. The team aims to provide DATA TERRA recommendations in two main areas: Brazil's areas of need in earth observation activities and how DATA TERRA's service could serve those needs in Brazil.

The team and DATA TERRA then created a conceptual framework as the guideline for this research study. Through the diagram below, the team conducted the research Brazil context using a structured data collection followed by analysis and suggested a potential approach for DATA TERRA in Brazil.

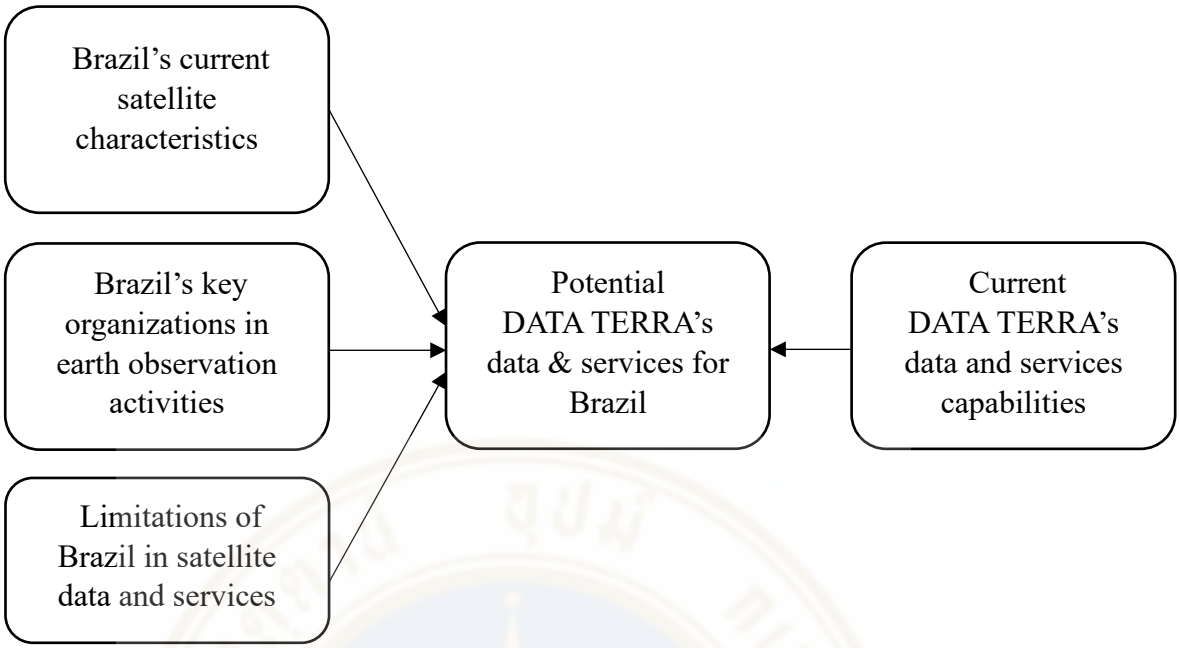

Figure 3.1 Research Framework

3.4 Data Collection

The primary source of this study is secondary research derived from journal articles via online and open scientific study exchange platforms, such as SpringerLink, which are online scientific, technological, and medical journals and book collections platforms, to gather information on Brazil's capabilities and characteristics of its satellite data and services. The crucial sources we have relied on are online papers dedicated to earth observation data utilization for sustainable development in Brazil. Official websites of involved government organizations that leverage satellite data for Brazil's natural disaster, environmental, and agricultural management, namely the National Institute for Space Research (INPE) and Brazilian Agricultural Research Corporation (EMBRAPA), are considered reliable sources.

3.5 Data Analysis

After gaining all necessary data related to Brazil's current capabilities on earth observation activities, the team then analyzed these data to recommend potential data and services of DATA TERRA that could fill the gap for Brazil. The details are as follows:

3.5.1 The first step of data analysis includes gathering and extracting related data gained from secondary research, such as online journal articles and data published through Brazil's government organizations that are involved in implementing natural disaster, agricultural, and environmental management for the country. This step aims to understand the current earth observation capabilities of Brazil through its satellite characteristics, key organizations in earth observation activities, and also its limitations in satellite data and services.

3.5.2 The second step is to understand DATA TERRA's data and services about its characteristics and capabilities, including areas of application in earth observation activities, to analyze and find the potential service that DATA TERRA could match with Brazil's needs.

3.5.3 For the last step or recommendation, we synthesize all gathered information and extract the key findings from online resources to identify Brazil's areas of need as well as to match data and services that DATA TERRA could meet those needs from resources provided by the organization's representative and from its official online resource.

CHAPTER IV
FINDINGS

This chapter indicates the findings from secondary research and group analysis, with three key findings on Brazil's current capabilities of earth observation data and services, DATA TERRA's data and services characteristics, and potential solutions DATA TERRA could offer to fulfill the needs of Brazil.

4.1 Brazil's Current Earth Observation Capabilities

To understand the current conditions and abilities of Brazil on earth observation activities, the present characteristics of satellites used in earth observation are explored, including main actors who leverage these satellite data for policy making and implementation regarding disaster management, environmental protection, land-use planning, and agricultural management. The areas of need reflected through satellite data and the service's real users among Brazil's authorities are also indicated.

4.1.1 Brazil's Satellite Characteristics

Brazil's earth observation activities currently rely on six satellites, namely CBERS-4, CBERS-4A, Amazonia-1, Landsat series, MODIS, and Sentinel-2. All data are freely available for public use. The first two satellites operated under the China-Brazil Earth Resources Satellites (CBERS) program, and their image data are accessible through the National Institute for Space Research (INPE)'s catalog. Both satellites also possess cameras, namely, Multispectral Camera (MUX), and Wide-Field Imager Camera (WFI). INPE also owns the first earth observation satellite entirely built by Brazil called Amazonia-1. Brazil also leverages data from the Landsat program provided by the United States Geological Survey (USGS) and NASA (National Aeronautics and Space Administration). Moderate Resolution Imaging Spectroradiometer (MODIS) data are also freely provided by NASA satellites. Lastly,

the Sentinel-2 mission operated by the European Space Agency under the Copernicus program also offers the data publicly (*BDC Input Data — Brazil Data Cube*, 2020).

Furthermore, each satellite has different characteristics, including spatial and temporal resolution. However, all of them provide medium (10-30 meters per pixel) to low-resolution images (over 30 meters per pixel), as shown in Table 4.1 below:

Satellites / Features	CBERS-4	CBERS-4A	Amazonia-1	Landsat-8	MODIS	Sentinel-2
Spatial Resolution (m)	64 (WFI) 20 (MUX)	55	64	30	250, 500, 1000	10, 20, 60
Temporal Resolution (days)	5 (WFI) 26 (MUX)	5	5	16	2	5

Table 4.1 A table shows Brazil's current satellite features *(*BDC Input Data — Brazil Data Cube*, 2020)*

4.1.2 Key Organizations in Earth Observation Activities

Several key organizations play significant roles in earth observation in Brazil, each contributing to environmental monitoring, disaster management, and agricultural research. The leading organizations comprise:

4.1.2.1 National Institute for Space Research (INPE)

INPE, a research unit, was founded in 1971 under the Ministry of Science, Technology, and Innovation with the mission to leverage space science and technology for satellite monitoring and research on the environment and climate (*50 Years INPE - National Institute for Space Research*, 2020). Its main programs related to earth observation include:

1) Amazon Deforestation Monitoring Project (PRODES):

PRODES project, started in 1988, aims at using satellite data to monitor deforestation in the Brazilian Amazon rainforest and provide annual deforestation rates, to be used by the government for policy making. The annual estimations are first produced every December, and consolidated data is produced

during the first half of the following year (*PRODES — General Coordination for Earth Observation*, 2019).

The images used in the program are derived from Landsat satellites with a spatial resolution of 20-30 meters and a revisit rate every 16 days. The space mapped by the project is 6.25 hectares at minimum.

2) Near Real Time Deforestation Detection System (DETER)

DETER is a satellite-based monitoring system in Brazil that was launched in 2004. It is designed to provide near real-time alerts on deforestation activities, primarily in the Amazon rainforest.

The data used was derived from the Moderate Resolution Imaging Spectroradiometer (MODIS) sensor on the Terra satellite with 250 meters of spatial resolution. The system provides nearly daily data, mapping the clear-cut deforestation areas larger than 25 hectares. The result data will be sent to the Brazilian Institute of Environment and Renewable Natural Resources (IBAMA), which is in charge of deforestation surveillance (Diniz et al., 2015).

3) TerraClass

The project aims to classify land use and land cover in deforested areas of the Brazilian Amazon, partnering with the Brazilian Agricultural Research Corporation (EMBRAPA). The data are from deforestation areas mapped by the PRODES program. It provides details of how deforested land is utilized, which is crucial for understanding the dynamics of land use change, such as pasture, agriculture, urban areas, and others, and developing strategies for sustainable land management (INPE, 2024).

4.1.2.2 National Center for Monitoring and Early Warning of Natural Disasters (CEMADEN)

CEMADEN focuses on monitoring and providing early warnings for natural disasters such as floods and landslides as well as doing research to improve the early warning system. It uses satellite data, including geotechnical sensors, weather radars, and other technologies, to predict and mitigate natural disasters and develops systems to alert communities and authorities about possible disasters (*Cemaden - weADAPT*, 2019).

4.1.2.3 Brazilian Institute of Environment and Renewable Natural Resources (IBAMA)

IBAMA is an organization under the Ministry of Environment, responsible for implementing policies on the environment and monitoring and controlling the environment, including illegal deforestation in the Brazilian Amazon. The authorities will receive alerts of suspected actions from INPE's DETER system before execution on the field (*Empowering Environmental Monitoring and Control in Order to Combat Illegal Deforestation in the Brazilian Amazon*, 2020).

4.1.2.4 Brazilian Agricultural Research Corporation (EMBRAPA)

EMBRAPA is a leading Brazilian organization dedicated to agricultural research and development. Established in 1973, EMBRAPA operates under the Ministry of Agriculture, Livestock, and Food Supply and plays a vital role in enhancing Brazil's agricultural productivity, sustainability, and technological advancement. One of its missions includes using satellite data for agricultural research, environmental monitoring, and sustainable land management (*Brazilian Agricultural Research Corporation (Embrapa)*, 2024). The TerraClass project, providing land use and cover data mapping in deforested areas, implemented by EMBRAPA is also under collaboration with INPE as mentioned above (*GeoPortal - TerraClass - Portal Embrapa*, 2022).

4.1.3 Limitations of Brazil in Satellite Data and Services

After doing secondary research on Brazil's areas of needs related to earth observation activities, the results show that Brazil's key organizations in environmental, disaster, and agricultural management do have access to necessary data on earth observation. However, 3 main problems hindering the full capacity of satellite data use among authorities emerged in the country. The key findings derive from 2 main existing research, consisting of *Challenges in Using Earth Observation (EO) Data to Support Environmental Management in Brazil* (2020); *and Information from Earth Observation for the Management of Sustainable Land Use and Land Cover in Brazil: An Analysis of User Needs* (2020). The details are as follows:

a) Lack of Skilled Personnel

The inadequate number of people with skills in satellite technology emerges as the first limitation among real users in Brazil. As indicated in the research *Challenges in Using Earth Observation (EO) Data to Support Environmental Management in Brazil*, the lack of personnel is ranked first as the reason for limitation in earth observation data use among 49 respondents. These samples are from the main actors in leveraging the earth observation data for management in the country, for example, the Ministry of Environment, Chico Mendes Institute for Biodiversity Conservation (ICMBIO), University of Acre. Coupled with the data from *Earth Observation for the Management of Sustainable Land Use and Land Cover in Brazil: An Analysis of User Needs*, the main problem shown is even though a lot of earth observation data are accessible, the problem exists is the lack of people who have the skill to process these data into information (Cerbaro et al., 2020).

Examples of inadequate skilled personnel explained by related parties from *Earth Observation for the Management of Sustainable Land Use and Land Cover in Brazil: An Analysis of User Needs* include a statement mentioned by the Senior Director at EMBRAPA, Rio Branco saying, "*However, we have too much EO data available and only limited information based on the EO data… In my view we need to improve people skills so they can extract information from the EO data for the final decision-making process."* A Senior Researcher at INPE also commented: "*Now, the problem is processing EO data, the intellectual capacity of users, personnel available in institutions, and the capacity of institutions to manage big EO data and all the information derived from EO data."* Meanwhile, a Senior Manager at ICMBIO stated, "EO data are not a problem, *and we use a lot of data; the problem we have here at ICMBIO is the institutional capacity to use and process all the data available*."

The insufficient skills in the workforce are also reflected in the article *Challenges in Using Earth Observation (EO) Data to Support Environmental Management in Brazil; for* example, the General coordinator at ICMBIO indicated that *"I think the use of EO data is systematic (PRODES, DETER, Fire). In my opinion, the main gap is that there is information available, but the problem is the lack of people to process it. High demand and a few people to do the work."* A PhD student at the

University of Acre, Rio Branco also reflected on the "*Lack of knowledge to use radar images. For example: the high number of clouds in the Amazon region. It would be useful, but we need proper training to process this type of data*."

Moreover, from a similar study, the result shows that over 70% of participants stated that the main limitation is to process and interpret radar data. Therefore, the lack of skilled people with the technical capability is the highest priority for removing the limitations of leveraging satellite data.

b) Insufficient Data Quality

From the same studies mentioned before, another factor causing the limited use of earth observation data in Brazil is the data quality or spatial resolution, which is not high enough. Findings from both studies suggest that high-resolution data providing less than 2 meters of spatial resolution are required for activities such as rural land registration, urban fire monitoring, and land-use planning. The studies revealed that the high-resolution data should be publicly available, especially through INPE, allowing any involved authorities to access and use it. The instances of suggestions from related authorities shown in the article *Information from Earth Observation for the Management of Sustainable Land Use and Land Cover in Brazil: An Analysis of User Needs* include "*We need EO data with high resolution for the Rural Land Registration (CAR) and high-frequency EO data for the Amazon region. It would be great to have both data available for public access via INPE*," mentioned by Environmental project analyst, Brazilian Forest Service. A Senior Director B at the Brazilian Institute of Environment and Renewable Natural Resources IBAMA also explained, "*Now, we are proposing the acquisition of images of high resolution for small properties [agriculture land areas between 1 and 2 hectares] of 1 m resolution or better. They need to be part of the Rural Land Registration (CAR). The images of Rapid eye 5m resolution is not enough and do not address all our needs."*

Reflections from *Challenges in Using Earth Observation (EO) Data to Support Environmental Management in Brazil* also presents the need for higher quality data, which includes the statement mentioned by an Environmental analyst at the Brazilian Forest Service, saying that "*We need EO data with high resolution and*

high frequency available for public access." Meanwhile, a senior director from the Land Institute of Acre indicated that "*It would be great to have access to high-resolution EO data of 1 m or 2 m. It would help the state of Acre to monitor public land and to monitor fiscalization. For example, problems of land conflicts, landless movements, land invasions and overlapping land areas registered with the different owner*."

Apart from these 2 studies, the demand for high-resolution data in Brazil is reflected in the article "*Contributions of the Brazil's National Institute for Space Research (INPE) to emergency response in the International Space and Major Disasters Charter*" in 2024. The article mentioned that most of the requests from the Charter are for the highest spatial resolution image, but the ones given by INPE are mostly the lowest resolution data. The publication also reveals the reason why the images from INPE were not requested as often as other participants is because of the limitation of the spectral band with no thermal bands and blue spectral range, causing limited detailed images (Boscolo et al., 2024).

c) Inadequate Analytical and Processing Capacity

One more important limitation found through the existing studies is the need for a ready-to-use system that can analyze, process, and provide useful information for the actors, helping them make decisions on policy and plan. As mentioned by the real users, they expect the service providers to improve systems with the ability to process data into easy-to-understand information for unskilled personnel, especially for the policymakers and politicians from the government sector. They prefer to have convenient tools that don't need more technical support from service providers. The examples of the *Challenges in Using Earth Observation (EO) Data to Support Environmental Management in Brazil* include a Senior coordinator at IBAMA who said, "*We want products ready to use without the need of additional technical support from EO providers."* In the meantime, a Land analyst at the Federation of Agriculture and Livestock of the state of Mato Grosso (FAMATO), Cuiaba, pointed out that "*EO providers should improve systems to transform complex EO information into simple information for the farmers."*

An Infrastructure Analyst at the Ministry of Mines and Energy, Brasilia, also mentioned that *"The minister will not know all the technical GIS and EO terms. The minister needs to know what information is available and the potential to use the information generated from EO data and GIS. What I noticed related to information derived from EO data to support environmental policies and decisions when I worked at IBAMA are the challenges to implement the use of new information within public institutions*" in *Information from Earth Observation for the Management of Sustainable Land Use and Land Cover in Brazil: An Analysis of User Needs* article. This factor is, therefore, linked to the first limitation, as people tend to require ready-to-use information to deal with inadequately skilled people.

4.2 DATA TERRA's Data and Services

DATA TERRA offers 4 main themes of data and services related to the atmosphere, solid earth, ocean, and land surface. Its data is derived from several sources such as satellites, on-ground stations, sounding balloons, aircraft, and vessels. Partnering with 26 organizations and universities, such as the French national space agency or Centre National d'Etudes Spatiales (CNES), allows DATA TERRA to get access to various types of data (*IR Data Terra in Short*, 2021). From the secondary research, key strengths of DATA TERRA that could serve the needs of Brazil in earth observation activities include:

4.2.1 DATA TERRA's High-Resolution Data

Compared to the current capabilities of Brazil's satellites, DATA TERRA's data could complement the limited features of Brazil's data in terms of spatial resolution. Benefitting from its cooperation with various infrastructures, DATA TERRA can provide data ranging from low to very high resolution. Under its "THEIA" platform, land surfaces data and services hub, DATA TERRA offers high-resolution data concerning biodiversity, forests, agricultural areas, water, buildings, natural hazards, coastline, and snow and ice (*THEIA Services and Observation Data Centres –*

Theia, 2015). Another platform called "ForM@Ter" also generates access to ground deformation, seismology, geology, volcanology, and others related to solid earth.

More importantly, DATA TERRA offers very-high-resolution (VHR) satellite data through the DINAMIS (Dispositif Institutionnel National d'Approvisionnement Mutualisé en Imagerie Satellitaire) or National structure for shared procurement of satellite imagery platform, to THEIA, and ForM@Ter as well. The spatial resolution provided under DINAMIS is around 2 meters to 50 cm. The data was derived from Pléiades satellites and SPOT-6 and SPOT-7 with a daily revisit capability (*DINAMIS Cross-Cutting Service*, 2021).

The high-resolution satellite image plays an important role in better disaster management during each phase starting from pre-disaster phase to event phase, and to post-disaster phase. An instance for pre-disaster phase is in California, USA, where officials have leveraged high-resolution data to enhance their wildfire prevention strategies ahead of the fire season. NASA's Ecosystem Spaceborne Thermal Radiometer Experiment on Space Station or ECOSTRESS mission, which provides high-resolution temperature image and data on plant stress levels, helps pinpoint high-risk areas. This information enhance prevention measure like controlled burns and public awareness initiatives in areas at risk (Buczkowski, 2023).

The use of very-high-resolution imagery in landslide mapping is also the most effective method claimed by Niklas Heiss from Ludwig Maximilian University of Munich who did the research on using the different types of resolution image varied from 1 m, 10 m, to 50 cm resolution, for creating hazard map. The result is that method used with 50 cm resolution image created the most precise result for mapping small-scale landslides, identifying related indices such as debris flows, gullies, and slope dynamics (Heiss, 2022). Another research "*The importance of input data on landslide susceptibility mapping,*" also concluded that the susceptibility models created with 1-meter resolution are more accurate and precise than those using 15-meter resolution digital elevation models (DEMs). Visual analysis of these high-resolution models shows detailed variations in landslide probability and susceptibility both along and across slopes, making them better suited for applications in urban planning, land

management, and ensuring safe human settlement after the event (Gaidzik & Ramírez-Herrera, 2021).

To summarize, integrating DATA TERRA's high-resolution and very-high-resolution satellite data with Brazil's current earth observation capabilities could significantly enhance disaster management, land management, and urban planning. Platforms like THEIA, ForM@Ter, and DINAMIS offer a wide range of data with spatial resolutions from 50 cm to 2 meters, enabling precise mapping of biodiversity, land use, and hazards such as landslides. Research has shown that high-resolution imagery is crucial in accurately assessing risks and identifying vulnerable areas, from wildfire prevention to detailed landslide susceptibility mapping in Europe. Leveraging such data would allow Brazil to improve its hazard preparedness, response, and recovery efforts, ensuring more resilient infrastructure and safer human settlements.

4.2.2 On-demand Processing Services

DATA TERRA processing tools allow both skilled and unskilled personnel to leverage the data. DATA TERRA runs its data on eight Tier2 high-performance computing (HPC) data centers across the country, allowing the organization to manage and analyze a very large volume of data remotely. Moreover, DATA TERRA has its labs, namely Earth System Analytics Labs (ESALs) and Virtual Research Environments (VREs), that support data analysis and processing based on demands such as temporal and geographic areas and data running in sequence and backup. A web-based interface is also provided so that the users will be able to learn using features by themselves, for example, geostatistical analysis, modeling, image analysis and processing, environmental genetics processing, etc. Personnel equipped with programming skills can customize the code through ESALs while people with no coding skills can develop their workflows through the graphic interface of VREs (*Services Offered by Data Terra*, 2021).

Another ready-to-use tool offered by DATA TERRA is DSM-OPT (Digital Surface Models from OPTical stereoscopic very high-resolution imagery). The platform provides on-demand processing service under ForM@Ter with Theia and DINAMIS. Therefore, users can access very high spatial resolution images from

Pléiades images and the DINAMIS catalog and design their own set of data processing. The platform facilitates the calculation of Digital Surface Models into 3D models for both unskilled and experts, allowing them to create the predefined parameters as well as do the parameterization. The models can be applied to natural hazard monitoring such as earthquakes, landslides, flooding, and volcanic eruptions, which also result in 3D models (*DSM-OPT Service – FormaTerre*, 2022).

In conclusion, the findings revealed that DATA TERRA's data and services align with the needs of Brazil in Earth observation activities. DATA TERRA offers a variety of spatial resolutions, including very high resolutions that could match the needs of Brazil's users. DATA TERRA on-demand services that allow unskilled workers to design the model from high-quality data can also remove the limitations on Brazil's side.

4.3 Potential Solutions Provided by DATA TERRA to Brazil

DATA TERRA could provide its services to Brazil through collaborations with potential and involved organizations consisting of INPE, CEMADEN, and EMBRAPA who are the main actors for environmental protection, natural disaster management, and agricultural management respectively. Data and services DATA TERRA could offer to these 3 organizations to meet the needs and fulfill the lack in skilled personnel, insufficient data quality, and analytical and processing capacity of Brazil, including:

4.3.1 To Provide ForM@Ter Service

As mentioned above, CEMADEN is in charge of monitoring and providing early warnings for natural disasters; offering access to the ForM@Ter service that is equipped with a ready-to-use tool generating a high-resolution model called DSM-OPT will remove all three problems of inadequate skilled personnel including insufficient analytical and processing tool, as well as not enough resolution for satellite image. It will allow authorities to design their own set of data processing with 3D models through a web-based interface and to use high-resolution images with 2 meters

to 50 cm from Pléiades images and DINAMIS catalog compared to the current satellite's capability of Brazil at 10 m as the highest resolution, hence more efficient for natural disaster warnings and management especially for monitoring and mitigation of impact from floodings and landslides.

4.3.2 To Provide THEIA Service

Similarly, recommending THEIA service to INPE, IBAMA, and EMBRAPA could complement what Brazil needs in environmental protection and agricultural management. THEIA platform offers on-demand processing software and tools in 8 fields, including biodiversity, evapotranspiration, land cover, snow, surface reflectance, risks associated with infectious diseases, vegetation, and water. Under each field, the organizations could access online processing tools with high-resolution imagery and design their data. For example, as INPE is the main authority that monitors deforestation in the Amazon, leveraging biodiversity and land cover processing tools under the THEIA platform will enhance the quality of satellite data and make it easier to analyze the data for operation for INPE. Moreover, since organizations like EMBRAPA and IBAMA still utilize INPE's data or their operation, applying THEIA platform will improve their data quality and also less dependent on INPE's data that are not sufficient and on skilled personnel, leading to more efficient and faster operation on the field.

CHAPTER V
CONCLUSION AND RECOMMENDATION

5.1 Conclusion

To achieve the goal of this consulting internship project with DATA TERRA, our team has studied and researched information based on our framework to gain reliable resources and synthesize recommendations as comprehensively as possible. From our study, we have provided key findings from the analysis of Brazil's current capabilities in earth observation and the potential solutions offered by DATA TERRA. The study revealed that Brazil's authorities rely on a network of satellites, such as CBERS, Amazonia-1, and Sentinel-2, whose spatial resolution of 10 m is the highest quality, to support critical activities, including disaster management, environmental protection, and agricultural management. Despite having access to necessary satellite data, Brazil faces significant challenges in fully leveraging these resources due to limitations in skilled personnel, data quality, and analytical capacity.

However, DATA TERRA's advanced data and services, particularly its high-resolution imagery and on-demand processing tools, have the potential to address these limitations effectively. By collaborating with key Brazilian organizations like INPE, CEMADEN, and EMBRAPA, DATA TERRA can enhance Brazil's earth observation capabilities, providing tailored solutions that improve data quality and accessibility while mitigating the skills gap. These partnerships could lead to more efficient environmental monitoring, disaster management, and agricultural planning, leading to sustainable development and resilience in Brazil.

5.2 Recommendations

To enhance the effectiveness and applicability of DATA TERRA's services in Brazil, the organization could consider expanding its works as follows:

5.2.1 Expand Scope to Other Sectors

Apart from three key fields of satellite data applications, namely natural disaster management, biodiversity and environmental protection, and agricultural management, DATA TERRA could broaden the scope of analysis to include sectors beyond these three areas. Urban planning, public health, and energy management are also vital areas that could significantly benefit from enhanced earth observation data. For example, exploring the application of DATA TERRA's high-resolution data in urban planning projects, such as infrastructure development, transportation networks, and land-use planning in rapidly growing cities in Brazil could improve the efficiency and sustainability of urban development. Studying how DATA TERRA's services can be used for public health monitoring, such as tracking the spread of infectious diseases, monitoring air and water quality, and assessing environmental factors that affect public health could provide new insights and opportunities for improving public health outcomes. By exploring these additional sectors, DATA TERRA can identify new opportunities for collaboration and ensure that their services are aligned with a wider range of national priorities, therefore maximizing their impact in Brazil.

5.2.2 Strengthen Collaboration and Relationship with Locals

To deeply understand the capabilities and needs of real users in Brazil, DATA TERRA could develop relationships with related organizations and institutions who rely on the earth observation data for their operation. DATA TERRA could strengthen engagement with both government and non-governmental organizations in Brazil to align DATA TERRA's services with national priorities and social needs to ensure broader adoption and integration of earth observation data into various sectors. The organization could also collaborate with Brazilian universities and research institutes to enhance the research and application of earth observation data in Brazil to be more aligned with what they need. This can also help strengthen local skills and ensure that the projects are sustainable in the long run.

5.2.3 Enhance Technical Capabilities and Training

To maximize the efficiency of DATA TERRA's service, the organization could join hands with Brazilian stakeholders developing customized training programs on how to effectively use DATA TERRA's analytical and processing tools and services. This can include workshops, online tutorials, and hands-on training sessions that are designed to match different skill levels of personnel.

5.3 Limitations of this Study

Even though this study has gathered information as comprehensive and recent as possible, the study heavily relies on secondary data sources to analyze Brazil's current earth observation capabilities from only specific key organizations, including the limitations or gaps that the country needs to improve. This may limit the depth of understanding and accuracy since the data might not capture the most recent developments, overlook specific challenges faced by smaller, less-represented entities, and lack primary empirical data, such as interviews or surveys conducted directly with stakeholders in Brazil. The study also focuses on only technical limitations but does not address potential cultural and institutional barriers in Brazil that might hinder the effective use of DATA TERRA's services. Issues like organizational inertia, resistance to change, different languages, and lack of policy and financial support could be significant obstacles.

5.4 Future Work

To overcome the limitations identified in this study, DATA TERRA could consider working further to support Brazil's earth observation capabilities as follows:

First, DATA TERRA should implement primary data collection methods such as interviews, surveys, and direct engagement with involved stakeholders in Brazil. This approach would provide a more understanding aspect of the specific challenges and needs of various organizations, including smaller entities that might be

overlooked in secondary data sources. The result from primary data would help ensure that the solutions offered by DATA TERRA will be designed based on the current requirements of users, rather than relying on possibly outdated or incomplete secondary data.

Second, DATA TERRA should expand beyond technical limitations to explore cultural and institutional barriers that might hinder the effective adoption of DATA TERRA's services in Brazil. Factors such as organizational inertia, resistance to change, language differences, and the lack of policy or financial support are critical aspects that need to be addressed. Understanding these obstacles would enable DATA TERRA to develop specific strategies to facilitate smoother integration and more effective use of their services within Brazilian institutions.

REFERENCES

50 years INPE - National Institute for Space Research. (2020, November 26). http://www3.inpe.br/50anos/english/presentation.php

Al Jazeera. (2024, August 5). *Brazil flooding death toll hits 100 as government pledges aid*. https://www.aljazeera.com/news/2024/5/8/brazil-flooding-death-toll-hits-100-as-government-pledges-aid

BDC Input Data—Brazil Data Cube. (2020). https://brazil-data-cube.github.io/specifications/input-data.html

Boscolo, H. K., Körting, T. S., Namikawa, L. M., & Homem de Mello, A. J. (2024). Contributions of the Brazil's National Institute for Space Research (INPE) to emergency response in the International Space and Major Disasters Charter. *Discover Applied Sciences*, *6*(4), 178. https://doi.org/10.1007/s42452-024-05831-3

Brazil uses satellite and machine learning to monitor agriculture sustainable intensification. (2021, September 28). https://www.embrapa.br/busca-de-noticias/-/noticia/65083648/monitoramento-remoto-ira-mapear-a-intensificacao-sustentavel-da-agricultura-brasileira

Brazilian Agricultural Research Corporation (Embrapa). (2024, February 1). https://www.abc.gov.br/training/informacoes/InstituicaoEMBRAPA_en.aspx

Brazil—Vulnerability | Climate Change Knowledge Portal. (2019, December 3). https://climateknowledgeportal.worldbank.org/country/brazil/vulnerability

REFERENCES (Cont.)

Buczkowski, A. (2023, October 12). *Revolutionizing disaster response with very high–resolution satellite data tasking*. Geoawesome. https://geoawesome.com/revolutionizing-disaster-response-with-very-high-resolution-satellite-data-tasking/

Cemaden—weADAPT. (2019, June 9). https://weadapt.org/organisation/cemaden/

Cerbaro, M., Morse, S., Murphy, R., Lynch, J., & Griffiths, G. (2020). Challenges in Using Earth Observation (EO) Data to Support Environmental Management in Brazil. *Sustainability*, *12*(24), Article 24. https://doi.org/10.3390/su122410411

Data Terra. (2020, July 23). *Working group coordination*. Dataterra. https://www.data-terra.org/en/working-group-coordination/

Data Terra. (2022, June 14). *DATA TERRA, A THEMATIC RESEARCH CENTER EARTH SYSTEM AND ENVIRONMENT #RECHERCHEDATAGOUV*. Dataterra. https://www.data-terra.org/en/news/thematic-research-center/

Data Terra and space. (2022, January 17). Dataterra. https://www.data-terra.org/en/about-data-terra/data-terra-and-space/

Denicoff, J., & Nielsen, M. (2024, September 7). *Generation 2030: How Cattle Ranching in Brazil Could Lead to the End of the Amazon* [SDG Knowledge Hub | IISD]. http://sdg.iisd.org/commentary/generation-2030/how-cattle-ranching-in-brazil-could-lead-to-the-end-of-the-amazon/

DINAMIS cross-cutting service. (2021, June 17). Dataterra. https://www.data-terra.org/en/data-hubs-cross-cutting-structures/dinamis/

REFERENCES (Cont.)

Diniz, C. G., Souza, A. A. D. A., Santos, D. C., Dias, M. C., Luz, N. C. D., Moraes, D. R. V. D., Maia, J. S. A., Gomes, A. R., Narvaes, I. D. S., Valeriano, D. M., Maurano, L. E. P., & Adami, M. (2015). DETER-B: The New Amazon Near Real-Time Deforestation Detection System. *IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing*, *8*(7), 3619–3628. https://doi.org/10.1109/JSTARS.2015.2437075

DSM-OPT service – FormaTerre. (2022, September 23). https://en.poleterresolide.fr/dsm-opt-service/#

Empowering Environmental Monitoring and Control in order to Combat Illegal Deforestation in the Brazilian Amazon. (2020, July 13). https://www.amazonfund.gov.br/en/projeto/Empowering-Environmental-Monitoring-and-Control-in-order-to-Combat-Illegal-Deforestation-in-the-Brazilian-Amazon/

Gaidzik, K., & Ramírez-Herrera, M. T. (2021). The importance of input data on landslide susceptibility mapping. *Scientific Reports*, *11*(1), 19334. https://doi.org/10.1038/s41598-021-98830-y

GeoPortal—TerraClass—Portal Embrapa. (2022, June 30). https://www.embrapa.br/en/busca-de-solucoes-tecnologicas/-/produto-servico/5159/geoportal---terraclass

REFERENCES (Cont.)

Global Forest Watch. (n.d.). *Brazil*. Global Forest Watch. https://www.globalforestwatch.org/dashboards/country/BRA/?location=WyJjb3VudHJ5IiwiQlJBIl0%3D

Goulard, S. (2024, May 6). The Franco-Brazilian Plan for the Amazon. *Global Connectvities*. https://globalconnectivities.com/2024/05/franco-brazilian-plan-amazon/

Hansen, K. (2024, February 26). *Landslides in São Paulo, Brazil*. https://earthobservatory.nasa.gov/images/151051/landslides-in-sao-paulo-brazil

Heiss, N. (2022, February 28). *Remote Sensing Of Mass Movements In The Bavarian Alps | European Space Imaging*. https://www.euspaceimaging.com/blog/2022/02/28/remote-sensing-of-mass-movements-in-the-bavarian-alps/

INPE. (2024, March 20). *Project Research TerraClass*. http://www.inpe.br/cra/projetos_pesquisas/dados_terraclass.php

IR Data Terra in short. (2021, December 25). Dataterra. https://www.data-terra.org/en/ir-data-terra-in-short/

MapBiomas Brasil. (2023, June 10). https://brasil.mapbiomas.org/en/2023/10/06/area-de-agropecuaria-no-brasil-cresceu-50-nos-ultimos-38-anos/

Mataveli, G., Jones, M. W., Carmenta, R., Sanchez, A., Dutra, D. J., Chaves, M., de Oliveira, G., Anderson, L. O., & Aragão, L. E. O. C. (2024). Deforestation falls but rise of wildfires continues degrading Brazilian Amazon forests. *Global Change Biology*, *30*(2), e17202. https://doi.org/10.1111/gcb.17202

REFERENCES (Cont.)

Members of the Charter—News Item—International Disasters Charter. (2020, March 20). https://disasterscharter.org/web/guest/-/members-of-the-charter?redirect=https%3A%2F%2Fdisasterscharter.org%2Fweb%2Fguest%2Fhome%3Fp_p_id%3D101_INSTANCE_wXneVGJumy2r%26p_p_lifecycle%3D0%26p_p_state%3Dnormal%26p_p_mode%3Dview%26p_p_col_id%3Dcolumn-3%26p_p_col_count%3D1

Ministry for Europe and Foreign Affairs. (2024, March 29). *France-Brazil Call for climate ambition from Paris to Belém – and beyond*. France Diplomacy - Ministry for Europe and Foreign Affairs. https://www.diplomatie.gouv.fr/en/country-files/brazil/news/article/france-brazil-call-for-climate-ambition-from-paris-to-belem-and-beyond-29-03-24

Momsen, R., & Martins, L. (2024, August 24). *Brazil | History, Map, Culture, Population, & Facts | Britannica*. https://www.britannica.com/place/Brazil

PRODES — General Coordination for Earth Observation. (2019, September 4). http://www.obt.inpe.br/OBT/assuntos/programas/amazonia/prodes

Safanelli, J. L., Demattê, J. A. M., Chabrillat, S., Poppiel, R. R., Rizzo, R., Dotto, A. C., Silvero, N. E. Q., Mendes, W. de S., Bonfatti, B. R., Ruiz, L. F. C., ten Caten, A., & Dalmolin, R. S. D. (2021). Leveraging the application of Earth observation data for mapping cropland soils in Brazil. *Geoderma*, *396*, 115042. https://doi.org/10.1016/j.geoderma.2021.115042

REFERENCES (Cont.)

SCBD. (2014, October 24). *Brazil—Country Profile*. Secretariat of the Convention on Biological Diversity. https://www.cbd.int/countries/profile?country=br

Services offered by Data Terra. (2021, December 29). Dataterra. https://www.data-terra.org/en/services/

TheCivilEngineer.org. (2024, May 20). *The Devastating Impact and Solutions to Flooding in Brazil | TheCivilEngineer.org*. https://www.thecivilengineer.org/news/the-devastating-impact-and-solutions-to-flooding-in-brazil

THEIA Services and Observation Data Centres – Theia. (2015, January 27). https://www.theia-land.fr/en/services-and-data-infrastructure/

Vijay. (2024, May 30). *Brazil's Flood of Austerity and Climate Catastrophe: The Twenty-Second Newsletter (2024)*. https://thetricontinental.org/newsletterissue/brazil-flood-mst/

What Will Help Brazil Recover From Deadly Flooding? - The Dialogue. (2024, May 30). THEDIALOGUE. https://www.thedialogue.org/analysis/what-will-help-brazil-recover-from-deadly-flooding/