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POLICY BRIEF

Satellite Remote Sensing and Geographic Information System Technologies for Industrial Tree Plantation Mapping and Monitoring: A Way Forward for the Sustainable Development of the Philippine ITP Industry

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KEY POINTS

- Industrial Tree Plantations (ITPs) are a vital contributor to the Philippines' log and timber production, but these ITPs requires better and more efficient way of characterization and monitoring.
- Current policies require ground validations surveys to monitor ITPs for regulation purposes. However, these approaches are often difficult to conduct, time consuming and expensive.
- Satellite remote sensing (SRS) and Geographic Information System (GIS) technologies offer an efficient alternative to traditional ground surveys for mapping and monitoring ITPs.
- SRS and GIS enable detailed mapping of ITPs, including species-level identification, and provides valuable data for forest resource management and environmental monitoring.
- SRS and GIS technologies should be integrated into existing policies by the Department of Environment and Natural Resources (DENR) to efficiently map, monitor, and manage ITPs in the country, ensuring informed decision-making and sustainable forestry practices.

Keywords: *satellite remote sensing, GIS, industrial tree plantation, mapping, monitoring*

1 Industrial Tree Plantations: How much do we know?

Industrial Tree Plantations (ITPs), often referred to as "tree farms," serve as primary contributors to the Philippines' log and timber production. This role has emerged in response to the increasing demand for logs from wood-based industries, and it underscores a well-established fact: natural forests alone are insufficient to meet this demand (Arguirre-Salado et al. 2015). The pressure on forestlands has escalated due to competing land uses, intensifying the need for plantation forest management (Codilan et al. 2015). Consequently, the significance of ITPs is expected to persist, especially in the Philippines, given the issuance of Executive Order No. 23 in 2011, which imposed a nationwide moratorium on timber cutting and harvesting in natural and residual forests (Philippine Star 2018).

Notably, among all regions in the country, Caraga (Figure 1) has emerged as the foremost producer of significant forest products in the Philippines, earning its reputation as the 'Timber corridor of the country' (Balanay et al. 2022). In the year 2022, this region made an outstanding contribution, accounting for 70% (equivalent to 557,058 m^3) of the nation's total log production, which stood at 797,192 m^3 (FMB 2023). This significant achievement is attributed to the numerous industrial tree plantations in the Caraga region, and this trend has remained steady in recent years (Figure 2). Despite their significance in the country's log and timber production, ITPs have not been adequately characterized in terms of their types, locations, spatial arrangements, and total area. The spatial-temporal aspects of their growth and development, and management dynamics are also not well documented. The limited availability of these information makes it difficult to understand many relevant questions related to ITPs such as their location and extent, species composition, potential areas for expansion, location of processing plants, among others.

Periodic inventories through ground surveys have traditionally been employed to identify the types, locations, spatial arrangements, and total area of forest resources. In the context of ITPs, the current policies established by the country's Department of Environment and Natural Resources (DENR) (Table 1) necessitate ground validation surveys for various purposes, such as verifying tree plantation registrations, validating timber inventory reports for permit applications, and assessing expansion applications by Community-Based Forest Management Agreement (CBFMA) holders (Calub 2005, DENR 1997, 1999, 2000, 2020, 2021). However, conducting ground surveys can

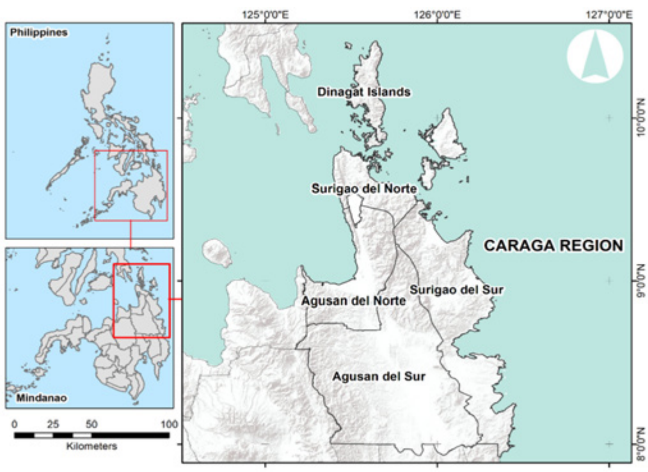

Figure 1. Caraga Region, Mindanao, Philippines. (Credit: Arnaldo C. Gagula, Caraga State University)

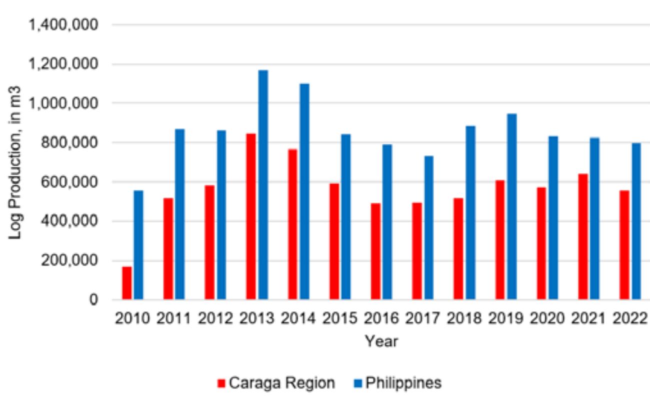

Figure 2. Log production statistics for 2010-2022. Source: Philippine Forestry Statistics, Forest Management Bureau.

Table 1. Some of the policy issuances of the DENR relevant to the ITP industry where SRS and GIS technologies can be incorporated.

Policy Name and Number	Subject	Short name (as used in the paper)
DENR Memorandum Circular No. 97-09	Documentation of Tree Plantations in Private Lands (DENR 1997)	DMC 97-09
DENR Memorandum Order No. 99-20	Supplemental Guidelines Governing the Registration, Harvesting, Transport and Marketing of Timber By-Products Coming from Private Plantations within Private Lands or Tax Declared Alienable or Disposable Lands (DENR 1999)	DMO 99-20
DENR Administrative Order No. 2000-21	Revised Guidelines in the Issuance of Private Land Timber Permit/ Special Private Land Timber Permit (PLTP/SPLTP) (DENR 2000)	DAO 2000-21
DENR Administrative Order No. 2020-18	Promoting Tree Plantation Development and Liberalizing Harvesting and Transport of Planted Trees and Tree Derivatives for Inclusive Growth and Sustainable Development (DENR 2020)	DAO 2020-18
DENR Administrative Order No. 2021 – 42	Guidelines on the Processing of Applications for Expansion of Areas Under Community-based Forest Management Agreement (CBFMA) to cover Adjacent Untenured Areas Within Forestlands (DENR 2021)	DAO 2021-42

be challenging, time-consuming, and expensive. These challenges are particularly pronounced when dealing with ITPs, which can span vast and often inaccessible areas, making it beneficial to explore more efficient and comprehensive approaches for mapping and monitoring.

2 Satellite Remote Sensing and GIS Technologies – A Boon for ITP Mapping and Monitoring

Satellite remote sensing (SRS) is commonly used nowadays as an efficient alternative to ground surveys. Generally, it enables the collection of information about the earth surface through analysis of data acquired by sensors installed in a satellite that is orbiting the Earth.

Essentially, the sensor functions similar to a camera, capturing visual "snapshots" of specific sections of the Earth's surface. Subsequently, these images, or in other words, the acquired data, are transmitted from the satellite and made accessible to potential users. Users then process and analyze the images using Geographic Information System (GIS) software and tools to extract various layers of information that may include vegetation, buildings, roads, rivers, and other land-cover types, among others. GIS, therefore, is crucial for converting raw SRS data into valuable information, enabling a comprehensive understanding of Earth's surface characteristics for various applications.

SRS in combination with GIS has emerged as an effective method for mapping and conducting inventories of forest resources over extensive areas (Chen et al. 2016, Fagan et al. 2018). This approach is especially valuable for regions that are challenging and costly to monitor through ground surveys. Consequently, SRS and GIS offer the capability to accurately pinpoint the location and scale of industrial tree plantations (ITPs), as depicted in Figure 4. It can also track the dynamic changes in ITPs, including detailed data down to the level of individual tree species (e.g., as demonstrated by Koukoulas and Blackburn in 2005).

The detailed layers of information about ITPs derived from satellite images can be further analyzed and integrated with other spatial and non-spatial datasets using GIS to derive new information. Some of the analyses that can be performed include determining the environmental characteristics of mapped tree locations, detecting and determining the rate of change of forest resources, and finding areas suitable for establishing tree plantations and processing plants (e.g., Arguirre-Salado et al. 2015, Williamson and Nieuwenhuis 1993).

This integrated information is also valuable for efficient management and monitoring of ITPs in the region. It can be employed for checking if the ITPs fall into alienable and disposable lands, restricted areas such as protected areas, and other land categories. Moreover, this data can be utilized for forecasting wood supply and market trends, developing economic models that consider climate change scenarios, and addressing various needs that demand information related to the wood industry (Balanay et al. 2022). On the other hand, monitoring the extent of ITPs through SRS and GIS is critical for understanding environmental and socioeconomic impacts (Torbick et al. 2016).

3 SRS and GIS for Mapping ITPs: The Case of Caraga Region

The ITP Mapping Project of the ITP Research and Innovation Center of Caraga State University utilized SRS and GIS to map the spatial distribution of ITPs in Caraga Region (Santillan et al. 2021). To exemplify the ease and advantages of SRS and GIS for mapping ITPs, the team used a combination of Sentinel-2 and high-resolution satellite images available on Google Earth. The images were analyzed and then used to map various ITP species throughout Caraga Region in not more than three months' time, a task that may take more than a year using ground surveys. The project focused on mapping ITP species which are used by the lumber, veneer, and plywood industry (DOST PCAARRD 2016), namely Falcata (*Paraserianthes falcataria* (L.) Nielsen), Yemane/Gmelina (*Gmelina arborea* Roxb), Mangium (*Acacia mangium* Wild), and Bagras (*Eucalyptus deglupta* Blume). Among these species, Falcata plantations (Figure 3, Figure 4) were found to be dominant in the region.

The project's mapping methodology can map

Figure 3. A Falcata tree farm in Butuan City, Philippines. (Source: Santillan et al. 2021)

Figure 4. A satellite remote sensing image showing Falcata plantations (in bright green) in Butuan City in Caraga region, Philippines. The image was captured on August 10, 2019. (Credits: Google Earth; Santillan et al. 2021)

tree farms with size of 10x10 m or larger using freely available Sentinel-2 images, with more than 90% accuracy (Santillan and Gesta 2021). Since 10 m x 10 m is relatively coarse, the extent of mapped tree farms was refined by using high resolution satellite images, increasing the detail to almost 1x1 meter, and greatly defining the boundaries of the plantations with other land-cover types (Figure 5).

With the aid of GIS software, relevant maps and statistics can be generated from the results which clearly show in which localities and what ITP species are most commonly planted, and by how much (Figure 6, Figure 7, Table 2). In the past, such maps and statistics were difficult to find. To illustrate the potential applications, mapped ITPs can be integrated with other data in GIS for monitoring and regulatory purposes, such as verifying the compliance of ITPs with restricted land use regulations (Figure 8). Overall, the SRS approach coupled with the integrative power of GIS is a significant way forward for detailed mapping and monitoring of ITPs in the country.

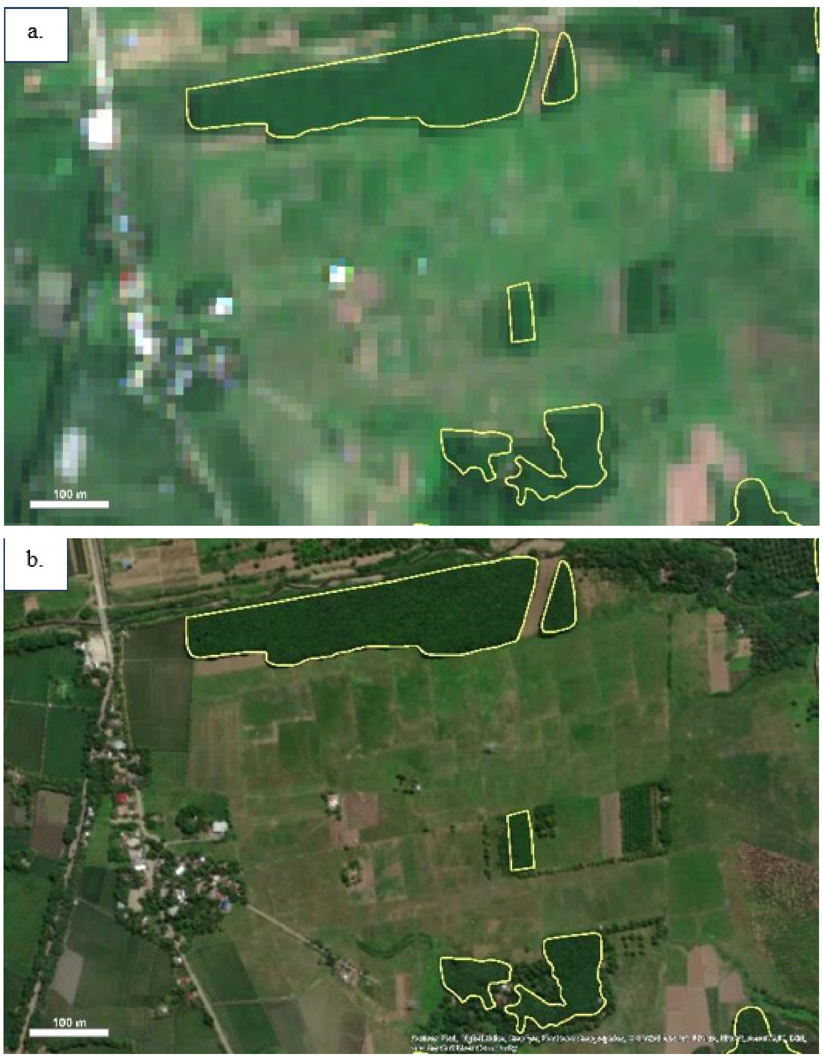

Figure 5. Falcata plantations as can be seen in a 10-m resolution Sentinel-2 image (a) and in a ~1-m resolution Google Earth image (b). (Credits: European Space Agency; Google Earth; Santillan et al. 2021)

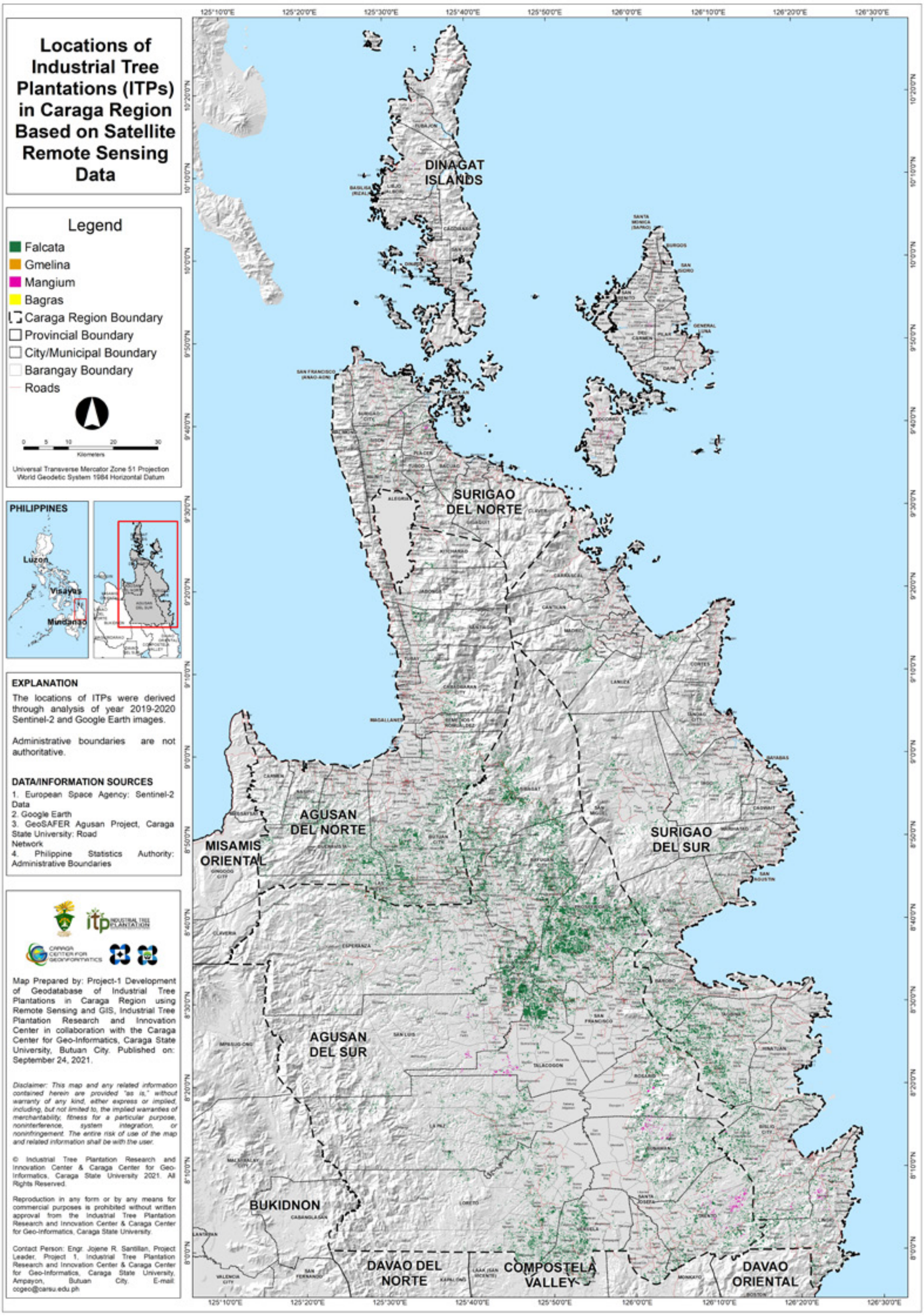

Figure 6. A map of ITPs in Caraga Region generated from year 2019-2020 satellite remote sensing images. Falcata plantations (in dark green) are dominant, especially in the provinces of Agusan del Norte, Agusan del Sur, and Surigao del Sur. A high-resolution version of this map is available at https://tinyurl.com/caraga-itp-map.

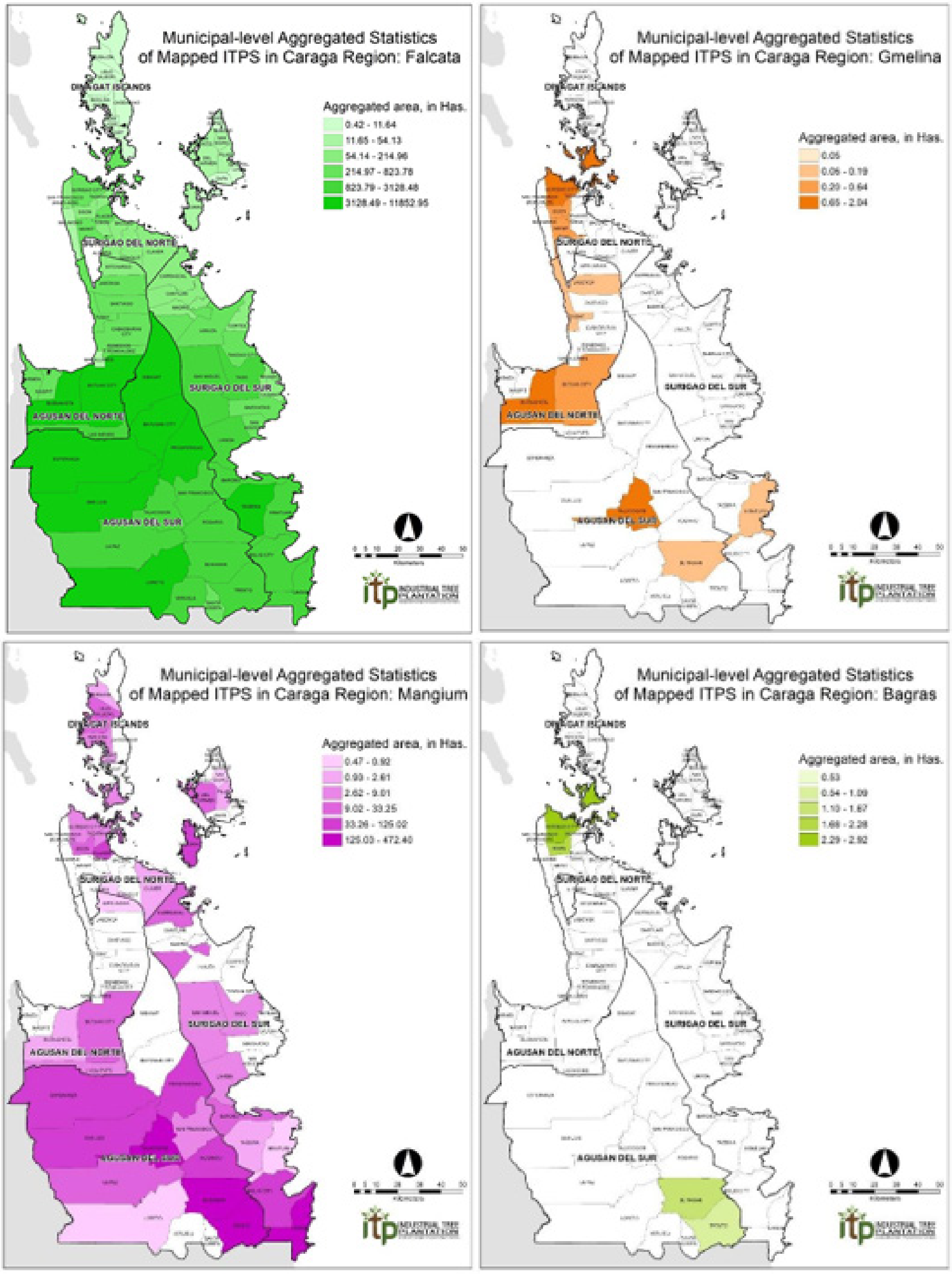

Figure 7. Maps illustrating the municipal-level aggregated areas of mapped ITPs from year 2019-2020 satellite remote sensing images. These maps highlight those cities and municipalities where the ITP species are planted, including where they are least/most abundant.

Table 2. Area of ITPs in the provinces of Caraga Region mapped using SRS and GIS. The areas, in hectares, are estimated for the years 2019-2020.

Province	Falcata	Bagras	Yemane ("Gmelina")	Mangium
Agusan del Norte	14,593.16	-	1.63	20.15
Agusan del Sur	55,337.99	2.40	1.07	1,102.43
Dinagat Islands	20.32	-	-	16.84
Surigao del Norte	2,376.39	4.67	2.82	197.37
Surigao del Sur	21,308.64	-	0.13	331.53
Total Area	93,636.50	7.07	5.65	1,668.32

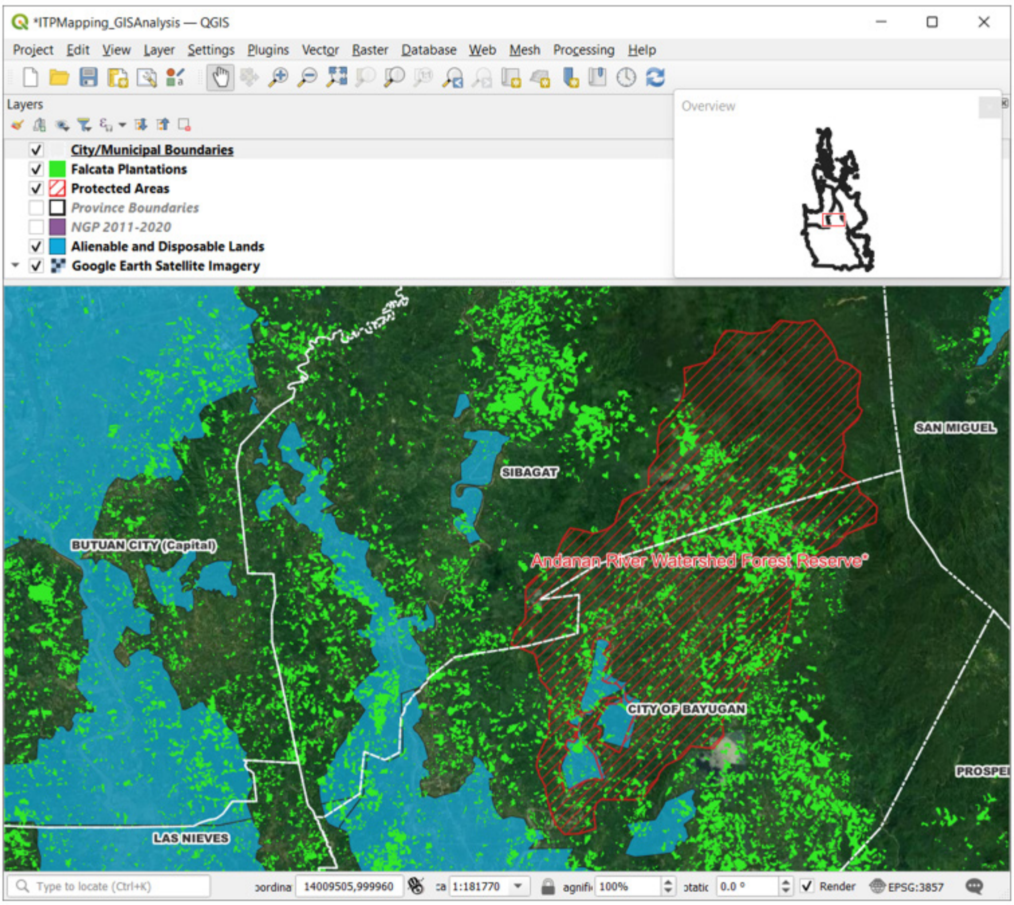

Figure 8. This example demonstrates the practical application of mapped ITPs by integrating it with other datasets in a GIS environment. It involves overlaying the mapped Falcata plantations with administrative boundaries and land classification data, including alienable and disposable (A&D) lands and protected areas. This illustration underscores the capacity of satellite remote sensing coupled with GIS in verifying compliance with land use regulations, revealing instances where plantations are situated both within and outside A&D lands, as well as within protected areas. (Sources of illustrated data: Santillan et al., 2021; DENR Region 13; Caraga Center for Geo-Informatics – Caraga State University).

4 Implications and Policy Recommendations

Mapping and monitoring ITPs in the country can be enhanced by taking advantage of SRS and GIS. These technologies are recommended for the use of the Community Environment and Natural Resources Office (CENROs) and Provincial Environment and Natural Resources Office (PENROs) of the DENR as a better alternative to the laborious and expensive ground surveys, and to complement their existing tree plantation-related registration and monitoring activities.

Specifically, the use of SRS and GIS will benefit the CENRO/PENROs in the following ways:

● Generate detailed maps and statistics on the location and area of ITPs at the regional, provincial, municipal and barangay levels.

● Permit yearly or even monthly monitoring of ITPs, including planting and logging/harvesting activities.

● Identify and limit potential areas for establishing ITPs.

● Verify the locations of areas being applied for certificates of tree plantation registration and ownership.

● Generate ITP-level timber harvest and wood supply projections.

To realize these benefits, existing DENR policies, rules, and regulations relevant to the ITPs industry (Table 1) should be amended for the integration of SRS and GIS technologies and derivative maps (e.g., ITP maps). Among the recommended amendments are as follows:

● DMC 97-09, DMO 99-20, and DAO 2020-18 should be amended to include sections/ subsections on the SRS andGIS-based mapping of tree plantations to be undertaken by the CENROs/ PENROs to complement their yearly private land tree plantation registration activities. The maps derived from this mapping activity should be utilized in several ways, such as (i.) to verify tree plantation registration applications prior to the issuance of Certificate of Registrations and Certificate of Tree Plantation Ownership; (ii.) to become part of the database on tree plantation records; and (iii.) as supporting documentation for the annual report submitted by the CENRO to the DENR Secretary, especially on the total area planted by species.

● Section 6 of DAO 2000-21 should be updated to incorporate the use of satellite remote sensing-derived ITP map to cross-check/validate the timber inventory report required for the timber permit application. The ITP map can aid in verifying the location and existence of trees/forest resources being applied for a timber permit.

● Section 5 of DAO 2021-42 should be updated to incorporate the most up-to-date ITP map derived from SRS, along with GIS-derived maps of relevant land classification and tenurial instruments. The inclusion of ITP maps is crucial as they transcend administrative boundaries, tenurial jurisdictions, and land classifications. These maps are valuable in providing the information needed to fulfill the requirements outlined in Section 5. For instance, they aid in verifying whether the CBFMA holder has fully developed their existing plantable area and whether adjacent, untendered areas host existing plantations.

● In consonance with the previous recommendation, Section 7 of DAO 2021-42 should be updated such that the most up-to-date ITP map derived from SRS is utilized when the CENRO or the implementing PENRO reviews and evaluates the application for expansion by a CBFMA holder in accordance with the provisions of Section 5. Likewise, the ITP map can complement, if not avoid, the need for ground validation surveys.

With these policy recommendations, there is a need to recognize SRS and GIS as more than mere mapping tools. These technologies, alongside the ITP maps and other data/information layers they generate, should be considered as integral and inseparable components of the proposed policy advocacy for the sustainable development of the ITP industry. The utilization of these technologies presents a comprehensive approach that surpasses traditional mapping practices. By recognizing SRS and GIS as integral parts of the advocacy, we underscore the paramount importance of these technological advancements in guiding amendments of ITP-related policies.

Furthermore, it is also crucial to acknowledge that the operational use of SRS and GIS in the Philippines for ITP assessment is long overdue.

There have been considerable evolution and significant improvements in the accuracy of these technologies over the last few decades. Integrating these technologies with advances and innovations in Information and Communication Technology (ICT), including data science, data analytics, and artificial intelligence can optimize the assessment process. It can also ensure that ITP mapping and monitoring processes leverage state-of-the-art technologies. By embracing these innovations, a holistic approach is established that aligns with the latest technological advancements, ultimately benefiting the DENR and its CENROs and PENROs, and the overall ITP industry.

5 Acknowledgement

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Statement of Conflict of Interest

The author declares no potential conflict of interest.

Data Availability

Data supporting the formulation of this policy brief, including all outputs of the project, are publicly available at https://tinyurl.com/csu-itp-project.

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