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Mapping Sentinel-2A Imagery Technology to Provide Legal Protection for Carbon-Absorbing Customary Forests in Central Kalimantan

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ABSTRACT

The inability of indigenous communities to explain and determine the objective boundaries of customary forests has become an anomaly, leaving these forests vulnerable to expansion of oil palm plantations and illegal logging. Furthermore, legal protection that provides certainty for indigenous communities in managing customary forests has not been effective. This study implements the mapping of carbon-absorbing customary forest areas using Sentinel-2A imagery technology as a basis for objectively measuring the extent of customary forests, with the aim of developing a standard concept for legal protection of customary forests. The research employs a combination of Sentinel-2A image mapping methods involving participatory community engagement. Non-doctrinal methods include exploration, observation, and in-depth interviews. Doctrinal methods involve examining issues in legislation at a macro-analytical level. The results of the mapping of Benakitan Village's customary forest identified 20 forest boundary markers based on local community knowledge. The mapping of carbon stock calculations over an area of 1.8645 km^2 revealed variable carbon storage, ranging from low (253,000-4,956,000 kg), medium (4,956,000-10,653,000 kg), to high (10,653,000-46,832,000 kg). The implementation of the mapping results aims to provide legal protection by integrating technology as an early detection monitoring tool, grounded in local wisdom and applicable customary law. Legal protection of customary forests is framed by synchronizing local wisdom values with mapping technology. The concept of legal protection for customary forests based on Sentinel-2A imagery technology interprets values such as: protection of human dignity, safeguarding human rights, pioneering justice, obligating responsibility, and recognition of local wisdom. The application of these values is abstracted into the principles embedded in each law or other regulation.

1. INTRODUCTION

Forests in Indonesia are decreasing every year. In 2024, the Ministry of Forestry reported a net deforestation of 1,754 km^2 [1]. Meanwhile, Auriga Nusantara recorded a loss of 2,615.75 km^2 of natural forest cover [2]. Global Forest Watch also noted a loss of approximately 2.59 km^2 of natural forest [3]. One of the regions experiencing the highest deforestation is Central Kalimantan. According to data from Global Forest Watch, Central Kalimantan lost 4,240 km^2 of natural forest in 2024, resulting in CO_2 emissions of 31.6 billion kg. One consequence of forest deforestation is the loss of customary forest areas that have been traditionally managed by indigenous communities. Customary forests refer to areas used by specific indigenous groups that have been owned, managed, and passed down through generations [4].

Essentially, the ownership of customary forests by an indigenous community represents a system of control that operates alongside their customary law. Indonesia is the third-largest country in the world in terms of tropical forest area and ranks first in the Asia-Pacific region. Indonesian forest areas cover 1,257,953.06 km^2 with boundary lengths of 373,828.44 km, consisting of 284,032.3 km of external boundaries and 89,796.1 km of functional forest boundaries [5]. Under the national Social Forestry initiative, the Indonesian government recognises six Community-Based Forest (CBF) schemes with varying levels of rights and management responsibilities: 1) Community Forests (*Hutan Kemasyarakatan*); 2) Village Forests (*Hutan Desa*); 3) People's Plantation Forests (*Hutan Tanaman Rakyat*); 4) Customary Forests (*Hutan Adat*); 5) Forestry Partnerships (*Kemitraan Kehutanan*); and 6) People's Forests (*Hutan Rakyat*). In general, forest areas have not yet been fully described in terms of their spatial extent, particularly customary forests in Indonesia [6].

The issue of customary forests is complex, compounded by the expansion of oil palm plantations, which threatens the existence of customary forest ecosystems. Indigenous communities within forest areas are directly affected by forest resource utilisation, air quality, and environmental sustainability [7]. Customary forests in Central Kalimantan

maintain pristine conditions and natural ecosystems. For example, the Bukit Benyawai customary forest in Benakitan Village, Batang Kawa District, Lamandau Regency, not only serves as a source of livelihood for the local indigenous community but also hosts herbal and traditional medicinal plants and contains ancestral cultural sites passed down through generations.

The Dayak Tomun people are highly committed to preserving their natural ecosystems, particularly their forests and customary land, which contain natural resources that provide wealth for future generations and sustain the local community [8]. They rely on customary forests and land for their livelihoods, cultivating the land and managing forest resources, including plants, fruits, and animal species [4]. The location of these customary forests is also strategically positioned relative to the expansion of surrounding plantation areas. The following photograph illustrates the threats facing the customary forest ecosystem in Benakitan Village, Batang Kawa District.

Indigenous communities, with their local wisdom, are the original owners and managers of forests, fully committed to ensuring sustainability. Their role in preserving the continuity of flora and fauna within the ecosystem is highly significant. However, their numbers are gradually declining, due either to external interventions or their inability to cope with the complex challenges they face [9]. The satellite image of the customary forest area from 2014 is shown in Figure 1.

Over the past decade, the condition of customary forests has been steadily declining, warranting special attention. There is a need for breakthroughs that can provide strong evidence of the extent of local customary forests, with the goal of establishing concrete certainty over customary forest boundaries through reliable technological approaches. As the highest authority, the state possesses special powers to regulate available natural resources. However, in this context, the state must also be able to delegate certain authorities to indigenous communities to ensure the preservation of forests and natural ecosystems [10].

Article 4, paragraph 3 of Law No. 41 of 1999 on Forestry stipulates that forest ownership must respect the rights of local customary law communities, provided that such communities still exist and their practices do not conflict with national interests [11]. The Minister of Forestry of the Republic of Indonesia, through Ministerial Decree No. 144 of 2025 on the Establishment of a Task Force for the Acceleration of Customary Forest Status, has mandated, among other things, the mapping and assessment of areas with potential to be designated as customary forests. This policy supports efforts to meet legal access distribution targets as outlined in Presidential Regulation No. 23 of 2023 on the Integrated Planning for the Acceleration of Social Forestry Management. On the other hand, the plantation development policy continues to expand, contributing to national revenue, but simultaneously giving rise to a range of environmental, social, and economic problems [12].

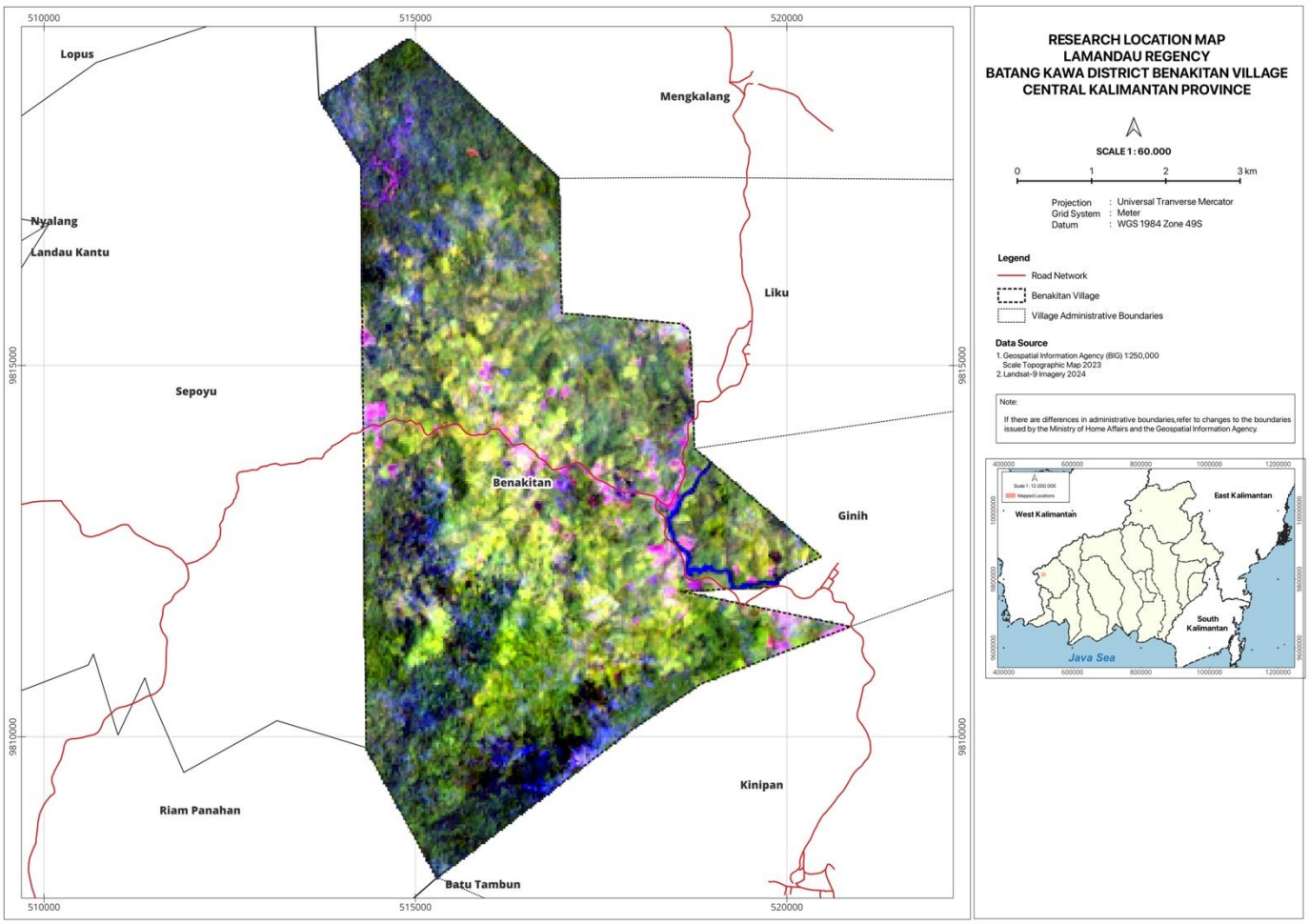

Figure 1. Satellite image of the customary forest area in 2024 at Lamandau Regency

Achieving a balance between preserving the ecosystems of customary forests and boosting economic growth in the oil palm plantation sector must be a primary consideration in drafting clear legal protection concepts and regulations [13]. Many indigenous peoples and local communities live in harmony with natural forests in a sustainable way, often producing positive impacts on ecosystem structures [14]. For instance, people lack awareness on the existence of carbon forests' ecosystems and their benefits in protecting the world from the dangers of carbon dioxide (CO_2). There is a gap in society's understanding of the importance of protecting the forest ecosystems that absorb carbon. This leads to the rampant occurrences of society's support for the investment movement in the plantation sector. It is a legal protection concept that starts by integrating Sentinel 2A-based mapping technology into customary forests, which absorb carbon in Lamandau Regency. This study is the first to refine the mapping of carbon-absorbing customary forests using freely available global satellite data, with forest structure areas sampled from Sentinel-2A imagery [15]. Such innovative breakthroughs play an essential role in achieving the Sustainable Development Goals (SDGs) and controlling carbon emissions [16].

The theory of legal protection serves as the foundation of this concept, which asserts that law and legal systems must actively protect individuals, groups, and rights from harm, arbitrary actions, and violations. This includes preventive measures to stop legal violations and repressive actions to enforce the law and hold perpetrators accountable. The theory emphasises that the state's duty is to provide a regulatory framework and actions that enable communities to enjoy their guaranteed rights and achieve dignity [17]. Furthermore, understanding the intent of legal protection is essential in designing clear, implementable regulations.

A key point of this research is to reveal the objective reality of carbon-absorbing customary forest areas through the application of Sentinel-2A imagery technology. The mapping results are then implemented as a basis for providing legal protection to customary forests, based on spatial representation, resource distribution, and the documented area of the customary forests studied. These mapping results are subsequently conceptualised into a legal protection framework for customary forests, which forms the core focus of this research.

2. RESEARCH METHODS

This study employed a combination of Sentinel-2A imagery-based mapping methods, non-doctrinal methods, and doctrinal methods. The Sentinel-2A imagery utilised in this research was geometrically corrected and clipped according to the administrative boundaries of Benakitan Village, Batang Kawa District. Geometric correction involves changing the coordinate system projection from the World Geodetic System (WGS) 1985 to Universal Transverse Mercator (UTM). Furthermore, the channel combination used is Channel 11 (SWIR) - Channel 8A (Vegetation Red Edge) - Band 4 (Red). This combination emphasizes bright green vegetation and pink soil, thus facilitating land cover interpretation. The mapping of customary forests using Sentinel-2A imagery applied a participatory mapping approach, actively involving the community. Local residents directly participated in field surveys to collect coordinate points using the Global Positioning System (GPS) to map their customary territory. In addition, the study conducted an analysis of the biophysical conditions of the customary forest based on Sentinel-2 imagery. Coordinate points were obtained using the Avenza Maps application with an accuracy of ± 10 meters. The sample was determined using purposive sampling, taking into account accessibility in the field. The participatory mapping validation method was to match customary forest boundaries with natural boundaries and base maps from the Geospatial Information Agency. The biophysical conditions analysed included land cover or land use and vegetation density [18]. This process was carried out to obtain primary data related to the area of the customary forest, its status, and its carbon stock. Research to estimate carbon stocks in customary forests based on land cover [19]. The estimation of carbon stock utilised allometric equations for accurate calculation. The doctrinal (normative) method was applied to analyse issues concerning legal products and regulations at the macro-analytical level. Meanwhile, the non-doctrinal (empirical) method was employed to examine and address problems conceptualised at the micro-analytical level, capturing symbolic realities within the community context [20]. Field observations and interviews were conducted with local indigenous leaders and community members to gain deeper insights. To obtain data, the authors conducted observation on stakeholders, such as five stakeholders from the government, one customary leader, five customary figures, and thirty members of the local customary community. The authors collected data from observation and in-depth interviews during a data collection process which lasted fifteen days. The Sentinel-2A-based mapping used sample blocks ranging from 10 to 23.62 km^2 to establish the baseline area of customary forests in Batang Kawa District, Lamandau Regency. Detailed configurations of the Sentinel-2A instruments, data collection protocols, and processing steps were implemented systematically. The final maps were designed to provide an objective spatial representation of the area, resources, and size of the customary forest. These mapping results were then conceptualised as the basis for developing a legal protection framework for customary forests, which serves as the core focus of this study.

3. RESULTS AND DISCUSSION

Constitutional guarantees in Indonesia, as stipulated in Article 18B of the 1945 Constitution, as well as in the Forestry Law and other related regulations, serve as the foundation for protecting and strengthening the rights of indigenous peoples over their territories and their management. This protection is realised through the recognition of customary land rights (hak ulayat), the designation of customary forest status, management based on local wisdom, and the active participation of indigenous communities in forest stewardship to ensure ecological sustainability and social well-being. These constitutional guarantees will be further reinforced if the existence of customary forests can be determined with certainty—from their boundaries and ecosystem richness to the resources contained within them.

Although legal protection is constitutionally guaranteed, its implementation in recognising the existence of customary forests remains challenging [21]. The mechanisms currently in place largely focus on protection and management but have yet to comprehensively address the equitable legal access and integrated designation of customary forest status [22].

Based on the research conducted, most of the Dayak Tomun indigenous community inhabiting parts of Lamandau Regency are native residents. The Dayak Tomun are an indigenous group living along the Lamandau River, with this study focusing on community members residing in Sepoyu Village, along the Batang Kawa River, who inhabit and hold rights to the Tompu (*Tanah Arai*) areas. These lands are believed to have been created by *Risak Sakayu Tanah Sakopal* (symbolically meaning a single tree and a handful of soil for every person). Thus, every individual born within the community has the inherent right to utilise the land — both in life and in death.

According to the head of Benakitan Village, until now, no institution or agency has ever conducted customary forest mapping in the area. He expressed that this mapping initiative is highly beneficial as it directly provides clarity on the extent of customary forest areas surrounding Batang Kawa District (Interview, 17 July 2025).

3.1 Mapping carbon-absorbing customary forest areas using Sentinel-2A imagery technology

The development of the customary forest map of Benakitan Village employed a participatory mapping method, in which the indigenous community played a key role in the mapping process. This approach reflects the community's perspective on spatial concepts, ensuring that the maps produced represent their cultural and territorial understanding. This study utilised Sentinel-2A imagery with a spatial resolution of 10-20 metres, providing detailed and reliable information. The research focused on delineating the boundaries of the customary forest area, land cover, and carbon stock estimates.

The findings revealed that there are 20 customary forest boundary markers in Benakitan Village, with each marker named according to the community's local knowledge. The mapping results indicate that the customary forest area of Benakitan Village covers 1.8645 km^2. This is shown in Figure 2 below.

The land cover classification in this study had an Overall Accuracy value of 81.1% and a Kappa Accuracy value of 90.6%. These accuracy values are considered good [23]. The land cover condition is predominantly composed of secondary dryland forest, covering 4.7966 km^2 (40.43%), followed by dryland agriculture mixed with shrubs, covering 3.449 km^2 (29.07%), and shrubland, covering 3.6189 km^2 (30.50%). The image on land cover is shown in Figure 3 below.

Land cover data from 2003, 2014, and 2025 indicate that the structure of the Benakitan Village Customary Forest (HA) has remained relatively stable, dominated by secondary dryland forest (approximately 40%), shrubland (30%), and dryland agriculture mixed with shrubs (29%). The area of secondary dryland forest shows a slight decrease, from 488.10 ha in 2003 to 479.66 ha in 2025, a reduction of less than 2%, suggesting that the forest's ecological functions have been largely preserved. Conversely, the extent of shrubland has shown a slight increase, from 4.7966 to 5.6189 km^2, which may indicate a natural cycle of vegetation regeneration following shifting cultivation or other subsistence activities of the indigenous community. This dynamic is summarised in Table 1 below.

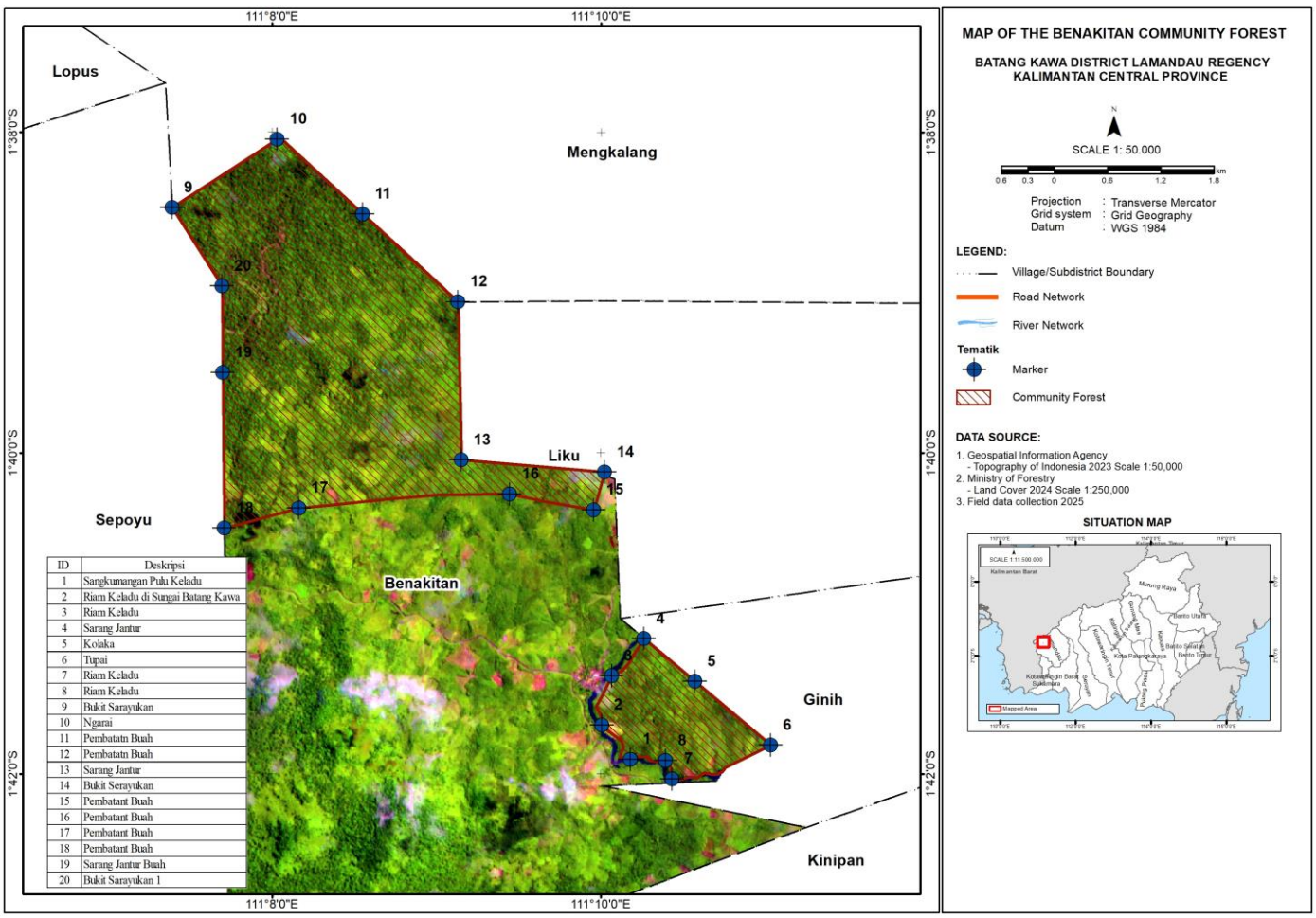

Figure 2. Benakitan Village customary forest

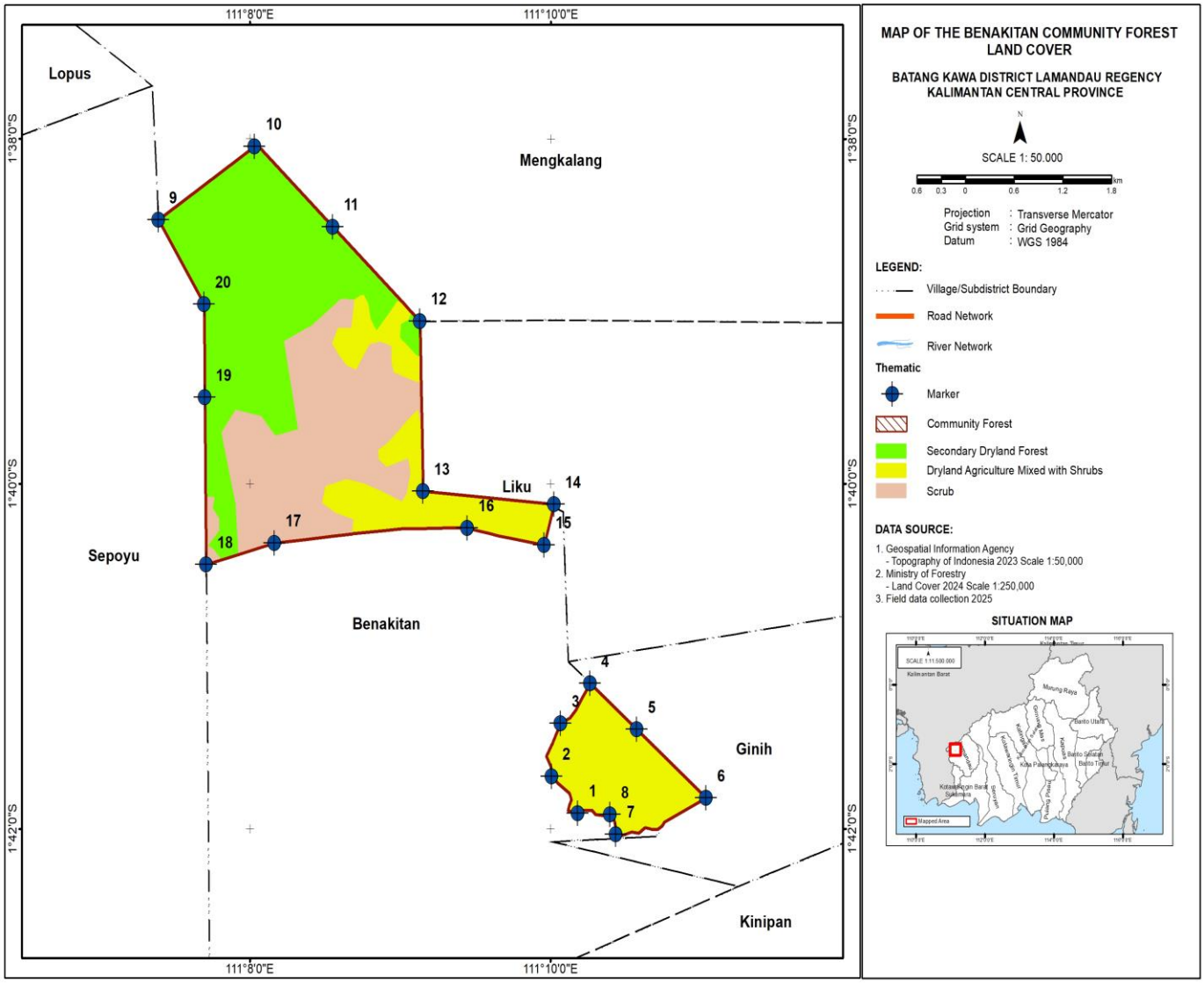

Figure 3. Land cover map

Table 1. Changes in land cover of Benakitan Village customary forest

2003		
Land Cover Type	**Area (km^2)**	**%**
Secondary dryland forest	4.88	41
Shrubland	3.53	30
Water bodies	0	0
Dryland agriculture mixed with shrubs	3.45	29
2014		
Land Cover Type	**Area**	**%**
Secondary dryland forest	4.86	41
Shrubland	3.56	30
Water bodies	0	0
Dryland agriculture mixed with shrubs	3.45	29
2025		
Land Cover Type	**Area**	**%**
Secondary dryland forest	4.80	40
Shrubland	3.62	31
Water bodies	0	0
Dryland agriculture mixed with shrubs	3.45	29
Total	**11.86**	**100**

Source: Compiled by the author, Land Cover Changes of Benakitan Village Customary Forest, 2025.

The area of dryland agriculture mixed with shrubs has remained unchanged, indicating a practice of sustainable traditional agriculture that does not impose significant additional pressure on the forest. When linked to the local wisdom of the indigenous community, this pattern reflects a land management system based on traditional knowledge, such as shifting cultivation, which maintains a balance between food needs and forest conservation. The secondary forest is preserved as a habitat for wildlife, a source of water, and a provider of non-timber forest products. Meanwhile, areas of dryland agriculture mixed with shrubs illustrate the community's distinctive "landscape mosaic" management, where gardens, shrubs, and forests are managed side by side. The increase in shrubland can also be interpreted as evidence that the community allows fallow land to regenerate naturally—a form of traditional restoration consistent with modern ecological concepts. Thus, these data not only depict the dynamics of land cover but also demonstrate how local ecological knowledge has contributed to the long-term sustainability of the customary forest.

The carbon stock map of Benakitan Customary Forest in 2025 shows that the area of 1.8645 km^2 stores carbon with varying distributions, ranging from low (253,000-4,956,000 kg), medium (4,956,000-10,653,000 kg), to high (10,653,000-46,832,000 kg). This is shown in Figure 4 below.

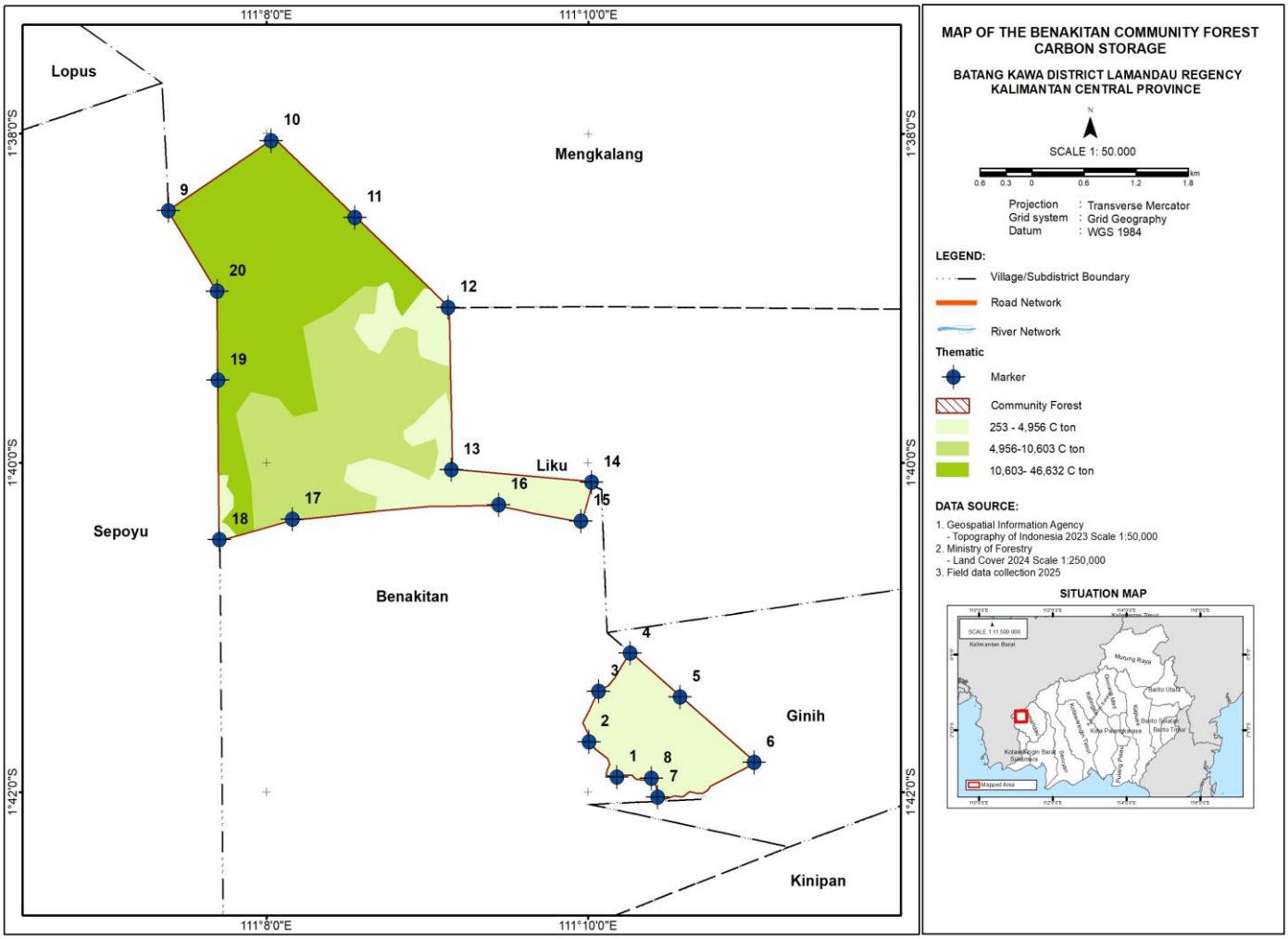

Figure 4. Carbon stock map

Table 2. Changes in carbon stock in the Benakitan customary forest area

2003		
Land Cover Type	**C (kg)**	**%**
Secondary dryland forest	48,244	77
Shrubland	10,603	17
Water bodies	0	0
Dryland agriculture mixed with shrubs	3,449	6
Total	**62,297**	**100**
2014		
Land Cover Type	**C (kg)**	**%**
Secondary dryland forest	48,015	70
Shrubland	10,673	15
Water bodies	0	0
Dryland agriculture mixed with shrubs	10,347	15
Total	**69,035**	**100**
2025		
Land Cover Type	**C (kg)**	**%**
Secondary dryland forest	47,409	69
Shrubland	10,857	16
Water bodies	0	0
Dryland agriculture mixed with shrubs	10,347	15
Total	**68,613**	**100**

Source: Compiled by the author, Changes in Carbon Stock of Benakitan Village Customary Forest, 2025.

Carbon stock data based on land cover for the years 2003, 2014, and 2025 can be better understood when integrated with the concept of customary forest management. Overall, carbon stocks increased from 62,297,000 kg in 2003 to 69,035,000 kg in 2014, with a slight decline to 68,613,000 kg in 2025. Secondary dryland forest remains the largest carbon sink (ranging from 69% to 77%), underscoring its critical role as the primary reservoir of carbon storage. Interestingly, the role of dryland agriculture mixed with shrubs showed a significant increase in carbon stock—from just 6% in 2003 to 15% in 2014, a proportion that remained consistent through 2025. These dynamics are summarised in Table 2.

The table above reflects the Dayak Tomun community's customary knowledge-based forest management, where traditional agroforestry systems not only provide food but also create a mosaic landscape that maintains vegetation cover, facilitates shrub regeneration, and enhances carbon stocks. In the context of customary forest management, land is not strictly divided into separate zones—forest, farmland, and shrubland—but is managed holistically, balancing human needs with ecological preservation [24]. This indicates that the stability of secondary forest cover and the increase in carbon storage within mixed dryland agriculture areas serve as evidence that customary knowledge-based management plays a significant role in safeguarding carbon reserves, while simultaneously supporting the ecological and social sustainability of the community [25]. This research is in line with the Dayak Iban Customary Forest of West Kalimantan which provides significant ecosystem service contributions including carbon storage [26]. In addition, Sentinel-2 imagery is also able to predict carbon stocks in the Special Purpose Forest Area of Central Kalimantan [27].

3.2 Implementation of Sentinel-2A imagery mapping in legal protection efforts

The utilisation of Sentinel-2A satellite imagery in mapping customary forests offers significant opportunities to strengthen the legal protection of the Dayak Tomun community in Lamandau Regency. The mapping results clearly delineate customary territorial boundaries, forest area extent, and the relatively preserved condition of land cover. Such spatial information can serve as objective evidence during the legal recognition process of customary forests, whether through local regulations or national government decrees. By incorporating technology-driven evidence, the community's territorial claims are supported not only by traditional knowledge but also by scientifically recognised data.

In addition, the carbon stock maps derived from Sentinel-2A imagery can inform ecologically grounded protection policies. Data on carbon storage within customary forests presents a compelling argument for recognising the area's role in climate change mitigation. This evidence could serve as a legal basis for integrating customary forests into environmental protection schemes, such as social forestry programmes, Reducing Emissions from Deforestation and forest Degradation (REDD+) mechanisms, or carbon financing systems. In this way, the indigenous community gains both legal legitimacy and access to economic benefits from sustainable forest management. Empirically, local wisdom has effectively prevented environmental degradation. However, such wisdom is often dismissed as outdated, leading to the neglect and degradation of natural resources, the loss of water sources, and the deterioration of forest ecosystems—despite forests being a fundamental necessity for all living beings [28].

Furthermore, the implementation of mapping results is also critical for legal enforcement. Sentinel-2A-based maps can be used as monitoring tools to detect changes in land cover, such as conversion to plantations or illegal logging activities [27]. With such spatial evidence, customary communities, in collaboration with the government, have a strong legal foundation to pursue action against violations that threaten the integrity of their customary forests. Thus, the integration of satellite imagery technology and local wisdom not only clarifies territorial boundaries but also reinforces the legal standing of indigenous communities in protecting their forests from external pressures [29]. This aligns with John Locke's concept of state-provided legal protection, where governmental power, distributed through a social contract, is not absolute but is instead exercised to safeguard the fundamental rights of individuals from both internal and external threats [30].

A diagram illustrating the implementation framework of Sentinel-2A-based mapping technology for legal protection is provided in Figure 5.

By integrating technology as a monitoring tool, the role of this integration becomes pivotal in the implementation of legal protection. It reflects the true essence of using technology to formulate approaches that harmonise local wisdom with customary legal norms [31].

The future of local wisdom largely depends on how communities strive to preserve their existing cultural knowledge, while also adapting their mindset to a more holistic perspective [32]. This ensures that natural resources and the environment are utilised and conserved without disrupting their balance [33].

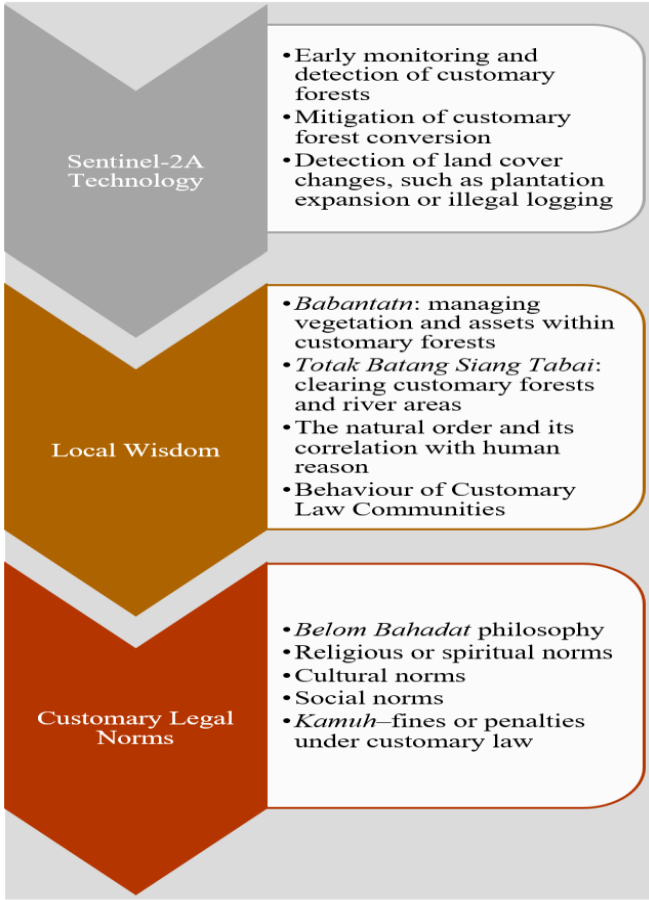

Figure 5. Integration of technology, local wisdom, and customary legal norms

3.3 The concept of legal protection for customary forest areas mapped using Sentinel-2A imagery

A legal review is necessary for the government to formulate regulations that are substantially aligned with the conception and philosophy of the Indonesian state. This also applies to the legal system, which serves as a distinguishing factor between national cultures [34]. The legal system operates as a subsystem within the broader social or communal structure [35]. In the context of the legal protection of customary forests, the Dayak Tomun community has developed a concept of forest protection rooted in local values derived from the natural order and its correlation with reason, local wisdom, behavioural norms, and legal principles embedded in the daily lives of the community. These values are deeply integrated into cultural practices passed down through generations by their leaders [36].

The aforementioned terms represent mechanisms of protection that foster interconnectedness among customary communities as managers of the forest through the demarcation of forest boundaries, the identification of naturally growing plants, and genealogical ties within the Dayak Tomun tribe. Their relatively simple yet effective protection methods, grounded in local wisdom, symbolise the philosophical meaning of *belom behadat* (living in accordance with customary laws and traditions) and the human responsibility to safeguard nature from destruction.

The legal protection of customary forests, based on the Dayak Tomun community's local values, is preserved because it carries intrinsic legal significance—reflecting the *volkgeist* or the spirit of the people [37]. This can be observed in the

characteristics of customary forests, such as the diversity of plant species, familial genealogies reinforced by written records detailing the origins and history of land ownership. These legal values are drawn from religion or belief systems, customary norms maintained over generations, and the socio-cultural values of the community [38]. By successfully integrating these seemingly disparate domains, collective experience within the culture becomes not only logical and clear but also inherent and natural [39].

The Dayak Tomun people are highly committed to preserving their natural ecosystems, particularly their forests and customary land, which contain natural resources that provide wealth for future generations and sustain the local community. They rely on customary land for their livelihoods, cultivating the land and managing forest resources, including plants, fruits, and animal species.

The Dayak Tomun tribe places great importance on maintaining the natural ecosystem, especially their customary forests and ancestral lands, which hold natural resources vital for future generations and sustain the livelihoods of local customary communities. They rely on these lands for agriculture and for harvesting forest products, including plants, fruits, and various animal species. According to their customary practices, the Dayak Tomun indigenous community explains various terms used in the protection of customary forests based on local wisdom. Based on an interview with Mr Martin Kukung, a Dayak Tomun customary leader (personal communication, 18 July 2025), these terms are explained as follows:

1) *Babantatn* - a form of legal protection carried out by local customary leaders (*pebantatn*) by managing the vegetation or assets within the customary forest through traditional Dayak Tomun ceremonies. This ritual serves to protect the village from various threats, such as disease or natural disasters, to maintain environmental balance, and to foster the community's love for their ancestral cultural heritage. This ritual also symbolises an expression of gratitude and a supplication for protection addressed to the Creator and the ancestral spirits. It is also an expression of gratitude and a plea for protection to the Creator and the ancestors. Related derivative activities include:
    a) *Mahalu* - a thanksgiving celebration for the fruits and plants in the customary forest that provide sustenance for the community.
    b) *bMadah* - an announcement or public notification to the village or settlements surrounding the customary forest.
    c) *Mulakan* - a customary thanksgiving ritual for the resources harvested from the forest.

This locally grounded legal protection of customary forests can also be synchronised with the mapping technology utilised, specifically Sentinel-2A imagery. When reinforced by local values, treating the forest as a sacred space becomes a crucial factor in ensuring its preservation. The theoretical framework of this conceptual finding is illustrated as follows in Figure 6:

The context of local wisdom in the protection of customary forests for the Dayak Tomun community can be synchronised by integrating technology with the values of local wisdom embedded in their lives, which are fundamentally oriented towards delivering justice for all people and the universe. This unification of technology and values can be realised by exploring and identifying laws within the lived realities of the community, reaching towards the essence of justice. The regularity that generates the concept of an object, in reality, constitutes an absolute condition for understanding the object as a singular representation and for assigning a definite form to diverse phenomena [40]. According to Tyson, in efforts to seek recognition, the local community (or those acting on its behalf) must be represented, and political representation is, by nature, a contested process that drives various forms of mobilisation based on the meanings and interpretations of customary practices translated into written law [41].

This technology- and local wisdom-based approach can serve as a significant element in providing tangible evidence of the existence and spatial extent of customary forests in Indonesia. This aligns with the government's initiative, as outlined in the Minister of Forestry Decree No. 144 of 2025, concerning the formation of a task force to accelerate the determination of customary forest status. Efforts to protect customary forests include preventing and safeguarding them from damage caused by unlawful occupation, misuse of the forest beyond its intended functions, and irresponsible exploitation.

This can be abstracted into the concept of an ideal legal framework for customary forest protection, one that upholds values of dignity, responsibility, and recognition of the rights and interests inherent to the legal subjects involved [42].

The state adjusts to the dynamic nature of the legal system in two ways [43]: first, in a preventive manner, by adopting the latest technological advancements prior to issuing definitive decisions; and second, in a repressive manner, by preserving the values of local wisdom within the community to resolve social and legal issues.

Figure 6. Synchronisation of mapping technology and local wisdom

These two approaches are highly relevant as a fundamental foundation for formulating legal mechanisms capable of ensuring justice, legal certainty, and social utility. In detail, the concept of legal protection for customary forests based on Sentinel-2A satellite imagery technology can be understood

through the following philosophical values:

1) Protection of human dignity, by recognising the human rights inherent in every individual or group. Dignity represents the highest level of human nobility, embodying value and quality as God's creation endowed with intellect, emotion, will, as well as fundamental rights and responsibilities.
2) Safeguarding of human rights, by protecting the rights that every individual or group inherently possesses from birth.
3) Advocacy of justice, by ensuring full fairness in the interests of the community concerning legal objects and the surrounding environmental ecosystem.
4) Imposition of responsibility, by fostering justice, safety, legal certainty, and integrity in delivering outcomes that can keep pace with technological progress while being grounded in prevailing legal norms.
5) Recognition of local wisdom, by safeguarding the positive values that live and develop within the community, deeply embedded and passed down through generations to regulate and guide life in the dimensions of customary practices, ethics, culture, worldviews, social behaviour, and environmental stewardship.

A legal framework aimed at protecting customary forests in a just manner must integrate these principles as foundational norms within statutes or other regulatory instruments [44]. Law must return to its philosophical core: law exists for humanity. From this perspective, humans become the determinant and central orientation of law. In this view, law serves humanity [45], not the other way around, and its quality is measured by its ability to enhance human welfare [46]. This notion drives progressive legal thinking to embrace the ideology of justice-oriented and people-centred law [47].

4. CONCLUSION

Mapping carbon-sequestering customary forests using Sentinel-2A imagery technology is highly beneficial for Indigenous communities in preserving forest sustainability and natural ecosystems. This approach aims to establish a stronger legal foundation for protecting customary forests by integrating technology to accurately determine the area and boundaries of these lands. This customary forest management system promotes sustainable ecosystem functions by combining traditional, local wisdom-based land management with technological applications for assessing forest density and available carbon stocks. Through the participatory mapping method used in creating the Customary Forest Map of Benakitan Village, local Indigenous communities were directly involved in critical stages of the mapping process. The results identified 20 boundary markers for the customary forest, based on local knowledge. The total area of the Benakitan customary forest was determined to be 11.8645 km^2. The carbon reserve map of the Benakitan customary forest, as of July 2025, indicates that this 1.8645 km^2 area stores carbon at varying levels, ranging from low (253,000-4,956,000 kg), medium (4,956,000-10,653,000 kg), to high (10,653,000-46,832,000 kg). In terms of implementation, the mapping results provide a technological foundation for legal protection by integrating advanced monitoring and early detection systems with local wisdom and prevailing customary laws. Legal protection of customary forests involves harmonizing local wisdom terminologies with modern mapping technologies. The concept of legal protection for customary forests is based on Sentinel-2A imagery technology interprets values such as: protection of human dignity, safeguarding human rights, pioneering justice, obligating responsibility, and recognition of local wisdom. These values must be incorporated as fundamental principles in all laws or regulations concerning the management and protection of customary forests.

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NOMENCLATURE

km^2	width of an area
kg	weight