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MONITORING LAND COVER CHANGE INDICATIVE MAP OF SOCIAL FORESTRY AREA IN PULANG PISAU REGENCY

Ananda Dita Cakrawala Putri[1], Shandy Marcoleos[1], Yogian Pratama[1], Meklie[1], Beni Iskandar[1]*

Study Program of Forestry, Faculty of Agriculture and Forestry, Universitas Muhammadiyah Palangkaraya

*E-mail : beniiskandar@umpr.ac.id

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ABSTRACT

The phenomenon of deforestation and land conversion is important for understanding the dynamics of land cover change. Social forestry programs potentially contribute to reducing the rate of change in forest cover. This study aims to analyze land cover change on the Indicative Map of Social Forestry Area (PIAPS) in Pulang Pisau Regency. The research method used Landsat-7 images recorded in 2000 and Landsat-8 images recorded in 2020, PIAPS data, and land cover classification using the Random Forest model with Quantum GIS and Google Earth Engine (GEE) software. This study found that there has been land cover change over the past three decades in PIAPS of Pulang Pisau Regency. Social Forestry (SF) policies have also contributed significantly to reducing or mitigating deforestation and forest and land fires, compared to greater deforestation and forest and land fires outside the PIAPS. Thus, Social Forestry policies have contributed significantly to maintaining forest cover, reducing deforestation rates and mitigating the risk of forest and land fires in the region. Additional efforts such as law enforcement, education and the use of artificial intelligence technology are also needed to improve the achievements of social forestry programmes.

Keywords: *Deforestation, land cover change, Social Forestry*

INTRODUCTION

The Social Forestry (SF) Program constitutes a policy initiative on the part of the government to address issues within the forestry sector. The program is supported by the planning of the Indicative Map of Social Forestry Area or *Peta Indikatif Area Perhutanan Sosial* (PIAPS) (Anggraeni et al., 2022) . The program's objective is to mitigate tensions between communities and the government concerning forest land administration, enhance community well-being, and promote environmental preservation. The program's implementation has engendered opportunities for communities surrounding the forest to engage in sustainable forest utilization activities. These activities include agroforestry, ecotourism, and other productive activities that do not result in environmental degradation (Rakuasa et al., 2023). Nevertheless, the efficacy of the program is frequently influenced by the dynamics of land cover changes that transpire in the field. These changes can be initiated by internal factors, such as community capacity in land management, as well as external factors, such as the establishment of oil palm plantations, illegal logging, and spatial policies that are inconsistent with sustainability principles (Saharjo et al., 2023).

Pulang Pisau Regency covers an area of 966.71 ha. It is dominated by peat swamp forest ecosystems. Peat swamp forests contribute to carbon storage, biodiversity, and community wellbeing (Hirano et al., 2012; Nath et al., 2017; Posa et al., 2011). As complex ecosystems, Peat swamp forests are important in maintaining the local and global climate balance, regulating water cycles, and providing a habitat for various endemic species of flora and fauna (Papilaya, 2020). Pulang Pisau has 95,917ha of PIAPS. These areas are quite large and randomly distributed from upstream to downstream with the potential to sustain ecology, community economy and culture. However, over the past three decades, there have been significant land cover changes that have degraded the forest ecosystems in PIAPS. In the PIAPS area of Pulang Pisau Regency, monitoring land cover change is one of the indicators used to assess and conserve the forest and community.

The monitoring of land cover change can be achieved through the implementation of a remote sensing approach, which involves the analysis of satellite imagery and geospatial data. This method has been demonstrated to facilitate the accurate and efficient detection of land change dynamics. This technology facilitates extensive monitoring, even in areas with limited accessibility within PIAPS, by employing medium spatial resolution imagery data, specifically Landasat imagery. The technique has the capacity to identify changes in land cover, including deforestation and land conversion. This approach will also provide baseline information that can be used to evaluate the implementation of SF programs in the PIAPS area of Pulang Pisau Regency. The objective of this study is to analyze changes in land cover on the Indicative Map of Social Forestry Area (PIAPS) in Pulang Pisau Regency.

METHOD

Research Location

This research was conducted from October to November of 2024. The research site was the Indicative Map of Social Forestry Area (PIAPS) of Pulang Pisau Regency, Central Kalimantan Province (Figure 1). Based on the geographical location of PIAPS, Pulang Pisau Regency is located at 10° to 0° South latitude and 110° to 120° East longitude.

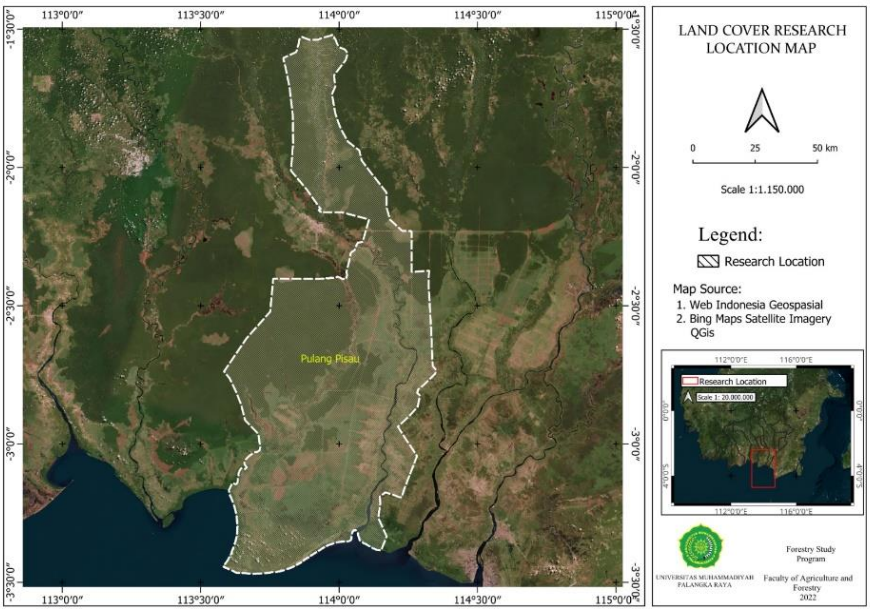


***Figure 1**. Research Location*

Data and Software

This study used data from the Indicative Map of Social Forestry Area (PIAPS), administrative boundaries of Pulang Pisau Regency, Landsat-7 imagery recorded in 2000 and Landsat-8 imagery recorded in 2020 (Table 1). The software used was Quantum GIS and Google Earth Engine.

Table 1. Research Data

No	Data	Scale/Resolution	Source
1	Indicative Map of Social Forestry Area (PIAPS)	1:250.000	Ministry of Environment and Forestry (MoEF)
2	Administrative boundary of Pulang Pisau Regency	1:50.000	Geospatial Information Agency
3	Landsat-7 image in 2000 and Landsat-8 image in 2020	30 m	https://earthexplorer.usgs.gov/

Data Analysis

The general data analysis in (Figure 2) is divided into several steps including land cover interpretation, random forest classification, land cover change analysis and accuracy testing.

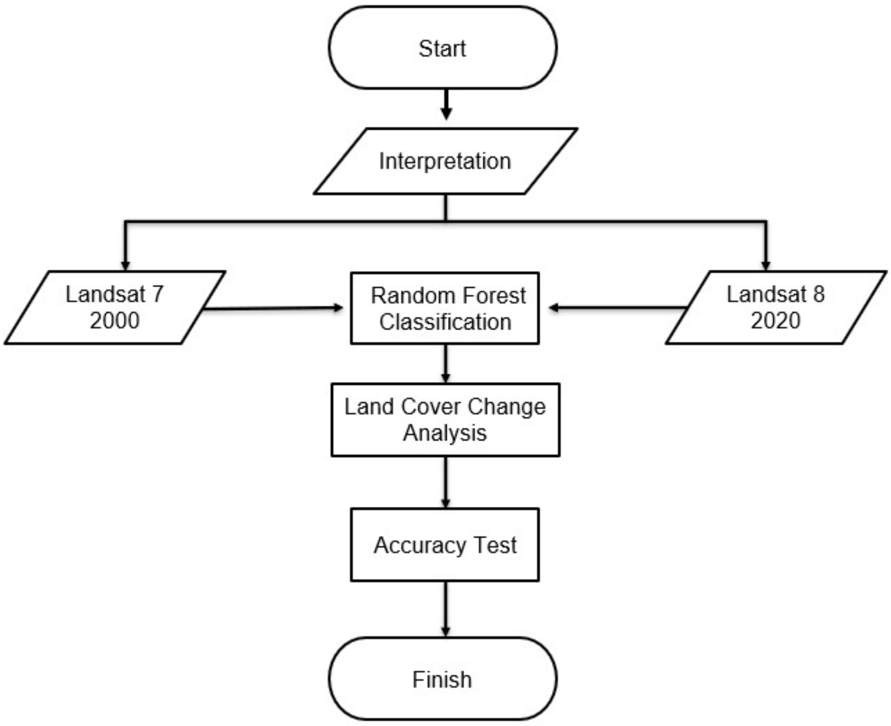


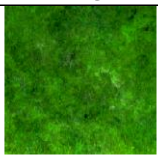
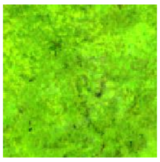
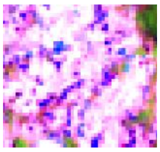
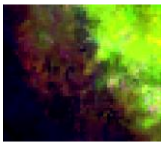
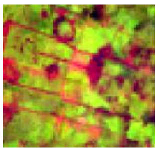
***Figure 2**. Research Flow Chart*

Land Cover Interpretation

Interpretation of land cover at systematically taken interpretation points of 100 x 100 m on PIAPS. A total of 961 points were interpreted at a scale of 1:25,000 on Landsat-7 and Landsat-

8 imagery. Land cover classes in PIAPS consist of forest, shrubs, bare land, water body and agriculture (Table 2).

Table 2. Land Cover Classes

No	Image	Land cover	Description
1		Forest	Forests are all forest cover that includes swamp forests and dryland forests.
2		Shrubs	Shrubs are plants that grow naturally such as swamp shrubs and bushes.
3		Bare Land	Bare land is cultivated land, such as mining or open land that is not cultivated, such as former forest and land fires.
4		Water Body	A water body is a collection of water found on the earth's surface such as rivers and swamps.
5		Agriculture	Agriculture is a place used for agricultural activities, including land planted with food crops such as dryland farming and plantations.

Random Forest Classification

The land cover classification process uses the Random Forest (RF) algorithm on Google Earth Engine (GEE) with the JavaScript programming language to produce land cover maps. RF algorithm is a machine learning algorithm with ensemble technique (Sukristiyanti et al., 2022). This technique combines techniques from several algorithms, namely Decision Tree (DT). DT is an algorithm with a tree structure in decision making (Sukristiyanti et al., 2022). RF will generate many decision trees for land cover class classification. After that, the final land cover class classification is done by the most votes from the decision tree that has been formed. Land cover classification parameters use bands B1, B2, B3, B4, B5, B6, and B7 on Landsat-7 and Landsat-8 images. Interpretation points are the points used to automatically build the land cover classification (Gifari et al., 2023).

Land Cover Analysis

The land cover analysis is an overlay between 2000 and 2020 land cover. This analysis uses a popular change matrix used to measure land cover change (Table 3) (Purwanto et al., 2015).

Table 3. Land Cover Change Matrix

t_1 \ t_0	A	B	C	D	**Total t_0 (ha)**
A	At_0t_1	-	-	-	
B	-	Bt_0t_1	-	-	
C	-	-	Ct_0t_1	-	
D	-	-	-	Dt_0t_1	

Total t_1 (ha)

Description: A-D: land cover; t0 dan t1: years; Xt_0t_1: no change; dan -: change

Land Cover Accuracy Test

The land cover accuracy test is used to measure how accurate a land cover map is to the actual conditions (Aziz et al., 2022).This accuracy test uses a comparison between the interpretation point as reference data and the results of land cover classification in 2000 and 2020. The land cover accuracy test uses an confusion matrix (Table 4). Based on this table, the *Overall Accuracy* (OA) dan *Kappa Accuracy* (KA) values can be calculated (Jaya et al., 2021)

Table 4. Confusion Matrix

Reference Data	Classified to class					Total	Producer's Accuracy
	A	B	C	D	E		
A	X_{11}	X_{12}	X_{13}	X_{14}	X_{15}	X_{1+}	X_{11}/X_{1+}
B	X_{21}	X_{22}	X_{23}	X_{24}	X_{25}	X_{2+}	X_{22}/X_{2+}
C	X_{31}	X_{32}	X_{33}	X_{34}	X_{35}	X_{3+}	X_{33}/X_{3+}
D	X_{41}	X_{42}	X_{43}	X_{44}	X_{45}	X_{4+}	X_{44}/X_{4+}
E	X_{51}	X_{52}	X_{53}	X_{54}	X_{55}	X_{5+}	X_{55}/X_{5+}
Total	X_{+1}	X_{+2}	X_{+3}	X_{+4}	X_{+5}	N	
User's Accuracy	X_{11}/X_{+1}	X_{22}/X_{+2}	X_{33}/X_{+3}	X_{44}/X_{+4}	X_{55}/X_{+5}		

$$\mathrm{OA} = \frac{\sum_{\mathrm{i=1}}^{\mathrm{r}} X_{ii}}{N} 100$$

$$KA = \frac{N\sum_{i=1}^{r} X_{ii} - \sum_{i=1}^{r} X_{+i}\, X_{i+}}{N^2 - \sum_{i=1}^{r} X_{+i}\, X_{i+}} 100\%$$

Where OA is Overall Accucracy, KA is Kappa Accucracy, Xii is the diagonal value of the i-th row and i-th column, X+i is the sum of area X+I and Xi+ and N is the total area.

RESULTS and DISCUSSION

Pulang Pisau Regency, located in Central Kalimantan Province, is one of the regions with abundant natural resources, particularly forests (Uda et al., 2022). The region is of great concern, particularly in the context of forest management and land cover change. Like many other regions in Indonesia, Pulang Pisau Regency faces challenges related to land cover change due to various human activities, both legal and illegal (Wibowo et al., 2019). The study determined that the 2000 imagery could be categorized into four distinct land cover classes forest, bare land, shrubs, and water body. This classification shows that the most dominant shrub cover covers an area of 50,449 ha, or 52.70% of the total area. In contrast, water body cover is the smallest, covering only 1,621 ha or 1.69% of the total (Table 5). Shrubs are areas dominated by woody plants that are smaller than trees, such as shrubs, bushes and shrubs which are generally overgrown with plants between 0.5 and 5 meters high. Shrubs are a key indicator of ongoing forest succession in the area which can be forest regeneration. Land cover in Kalimantan is mostly dominated by shrubs that can become forest through natural or human assisted regrowth (Iskandar, Hanafi, et al., 2022; Purwanto et al., 2015). According to (Indira et al., 2024) shrub cover is dominant in Pulang Pisau Regency. Spatial distribution of land cover 2000 (Figure 3).

Table 5. Land Cover in 2000

No	Land Cover	Area (Ha)	Percentage (%)
1	Forest	41,149	42,98
2	Bare land	2,515	2,63
3	Shrubs	50,449	52,70
4	Water Body	1,621	1,69
	Total (ha)	**95,733**	**100**

Source: Data analysis 2024

Landcover in 2020 was found to be similar to landcover in 2000 with one additional class, agricultural. Agriculture is land dominated by the activities of growing plants and/or animals to produce food, fiber, or other raw materials, or in other languages, agriculture is a form of land use that involves the process of converting the natural environment to produce useful products. In 2020, forest cover is projected to decrease to 33,887 ha, or 35.40%, while shrub cover increases to 57,753 ha, or 60.33%, and agricultural covers 1,931 ha, or 2.02% (Table 6). In Central Kalimantan, forest cover tends to be converted to shrub, plantations and agriculture (Segah et al., 2023). Spatial distribution of land cover in 2020 (Figure 4).

Table 6. Land Cover in 2020

No	Land Cover	Area (Ha)	Percentage (%)
1	Forest	33,887	35,40
2	Bare land	1,414	1,48
3	Agriculture	1,931	2.02
4	Shrubs	57,753	60,33
5	Water Body	748	0,78
	Total (ha)	**95,733**	33,887

Source: Data analysis 2024

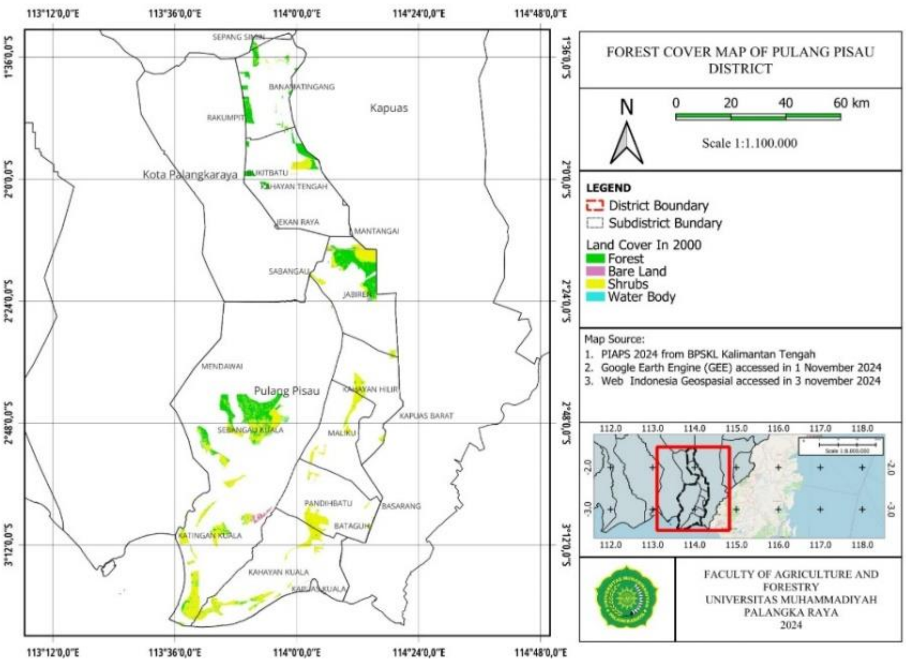


***Figure 3**. Land Cover Map of 2000*

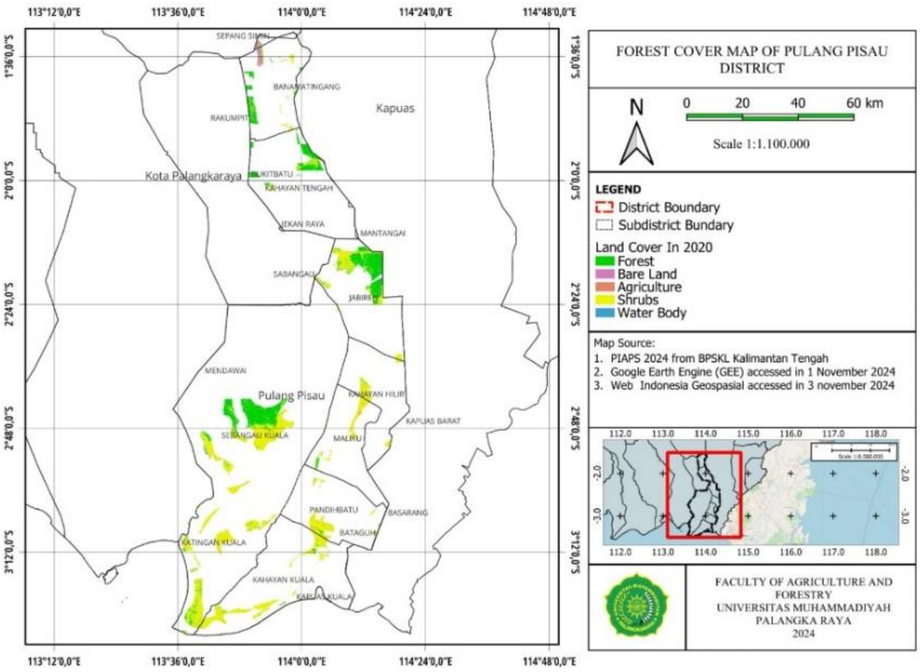


***Figure 4**. Land Cover Map of 2020*

In the year 2000, the total area of forest cover was approximately 41.149 ha while deforestation reached approximately 17.312 ha. This led to a conversion of forests into other land uses, including bare land, agricultural land, shrubs, and water body. By 2020, the remaining forest area was approximately 23.836 ha, as shown in (Table 7). Significant conversions are shrubs and bare land. In conformity with the findings of the research conducted by (Meichia et al., 2021) the conversion of shrubs transpired because of forest and land fires in 2015 and 2019, in conjunction with substantial community gold mining and the conversion of agricultural land (Neneng Liswara et al., 2022). Land cover has been dynamic over the last 30 years in PIAPS Pulang Pisau Regency. The rate of deforestation within PIAPS is comparatively low, in contrast to the high rate of deforestation occurring in areas external to PIAPS, which encompasses an area of 151.442 ha. Furthermore, the phenomenon of land cover change triggered by forest and land fires has decreased. Data indicates that PIAPS experienced 13.895 ha of forest fires in 2015, while PIAPS records of forest and land fires in 2019 showed 3.229 ha. The implementation of SF policies has been identified as a potential strategy for mitigating forest degradation and deforestation. However, numerous challenges have been highlighted, including difficulties in enhancing community involvement and fortifying SF institutions (Mulyana et al., 2022). Therefore, the SF program possesses considerable potential to prevent or reduce deforestation. Moreover, the SF program invites communities to become involved in preventing and reducing the risk of forest and land fires in the future.

Land cover classification using the forest algorithm model showed an overall accuracy of 96% and kappa curation of 93% in 2000, while the overall accuracy was 94% and kappa accuracy was 90% in 2020. The random forest model has a reliable performance for land cover classification of PIAPS Pulang Pisau Regency. A kappa accuracy of more than 80% indicates good accuracy (Foody, 2002). The classification has been tested reliable for deforestation detection in the tropical rainforests of Indonesian Borneo with kappa accuracy above 80% (Iskandar & Hanafi, 2022).

Table 7. Land Cover Matrix

Years	Land Cover	2020					Total (ha)
		Forest	Bare Land	Agriculture	Shrubs	Water Body	
2000	Forest	23,836	1,074	433	15,710	95	41,149
	Bare land	258	12	62	2,053	130	2,515
	Shrubs	9,557	299	1,416	38,794	383	50,449
	Water Body	236	29	20	1,197	140	1,621
Total (ha)		**33,887**	**1,414**	**1,931**	**57.753**	**748**	95,733

Source: Data analysis 2024

CONCLUSIONS and RECOMMENDATIONS

This study found that there has been land cover change over the past three decades in PIAPS of Pulang Pisau Regency. PIAPS policies have also contributed significantly to reducing or mitigating deforestation and forest and land fires, compared to greater deforestation and forest and land fires outside the PIAPS. Intensive SF activities are needed to maintain the existing forest cover.Intensive efforts are strong law enforcement against illegal land conversion, community-based approaches with incentives for SF actors and training and capacity building of SF farmer groups as well as trials of various artificial intelligence-based algorithms for monitoring land cover change, predicting land cover change, and recommending crop suitability for agriculture and forestry in the PIAPS area.

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