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Spatial Distribution of Potential Area for Community Forest Development in Grindulu Watershed

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Abstract: *The effect of deforestation on the environmental degradation shifted the orientation of forest management into carrying capacity of the watershed. Based on Law No. 41/1999 on Forestry, mandates adequacy forest area defined minimum of 30% of the watershed area which fulfilled by public forest and private forest. State forest area has limitations, so development of community forests is needs for optimal forest area in a watershed is required. The purpose of this study was to determine spatial distribution of potential area for community forests development in Grindulu Watershed. The potential of community forest was examined through an interpretation of Landsat 8 of 2016 Path/Row 119/668 for land availability and the transformation of NDVI (Normalized Difference Vegetation Index) as the density classifier. The classification of forest density was: Low density class of 5148.12 hectares or 7.20% (NDVI = 0 to 0.356), moderate density class of 12076.39 hectares or 16.88% (NDVI = 0.356 to 0.590), and high-density class of 54294.04 ha or 75.92% (NDVI = 0.590 to 0.841). The land available for prioritised community forest development was 37774.40 hectares (52.82%) in the form of dry-fields, shrubs, grasses, farms, which were located outside the protected areas and production forest. Based on the assessment of field surveys which were conducted proportionally at 89 sample, known good accuracy results by 0.84. Potential area for community forest development was 31281.54 ha (43.74%) including in Pacitan (9 districts) of 29111.98 hectares, Ponorogo (5 districts) of 263.29 hectares, and Wonogiri (2 districts) of 1906.27 hectares.*

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1. INTRODUCTION

Forest is a strategic natural resources (Subekti, 2016) and important for the socio-economic development of societies (Asante et al., 2017). Indonesia is one of the Southeast Asian countries that are experiencing deforestation. During 2000–2010, Sumatra, Kalimantan, Sulawesi, Moluccas, and Papua lost 14.7 Mha of forests in total (Abood et al., 2014). Deforestation leads to degradation and erosion that have an impact on sedimentation on water bodies, thus, forest cover has a crucial function in the socioeconomic development and the ecological balance (Siddiqui et al, 2004). In Indonesia, minimum area of forest cover regulated on the Law No. 41/1999 which mandates the government to determine and maintain forest area extent adequacy and forest coverage for each watershed and or island, to optimise environmental, social and economic benefits for local community at least 30% (thirty percent) of watershed and or area extent at proportional distribution

Deforestation resulting in the depletion of forest cover. Nowadays, the needs for forest cover are fulfilled by public forest and private forest. Public forest is a forest area that grows on land not encumbered property, whereas private forest or community forests are forests growing on land subject to property rights. The extent of state public forest is limited based on forest designation; hence the improvement of community forests to fulfill of optimal forest area in watershed is required. Community forest management has been identified as a win-win option for reducing deforestation while improving the welfare of rural communities in developing countries (Santika et al., 2017). According to the Regulation issued by Minister of Forestry P.03/MENHUT-V/2004, community forests are forests growing on landsubject to property rights or other rights to the provision of a minimum area of 0.25 ha with canopy closure of perennial woody plants and other crops over 50%. The goals of community forests development are: yards, embankments and critical land based on soil and water conservation (Ritohardoyo, 1999).

Community forest development requires mapping to find out the potential location of community forests. Acharya, (2002) said that forest boundary surveying and mapping is an important tool to support community forest. The uses of GIS based technology should be cost effective. The unit analysis used in this study is the watershed. Basically, the orientation of forest management should be targeted on the entire potential of forest resources including to enhance the function and carrying capacity of the watershed. The development of community forests in Pacitan as the dominant district in Grindulu Watershed involved the spatial pattern plan of cultivation area for community forest. Development activities in the Grindulu watershed, both upstream and downstream, are quite intensive and the population pressures are quite high. Pacitan and Wonogiri districts have decreased the ability of land to absorb water, and protect the soil from erosion, which in turn leads to high surface runoff and erosion. The development of community forests in Pacitan as the dominant district in Grindulu Watershed involved the spatial pattern plan of cultivation area for community forest. Criteria for the designation of community forests are forests growing on land subject to property, dominated by annual crops, and area that can be utilised for settlement, agriculture, plantation, community forests, and other silviculture activities (Regional Government of Pacitan Regency, 2011). At present there has been no mapping of the potential of community forests in the grindulu watershed, so that by conducting this research, it can be seen that the potential of community forests can be developed. The purpose of this study was to determine spatial distribution of potential area for community forests development in Grindulu Watershed.

2. DATA AND METHODS

2.1. Time and Study Area

This study was conducted in Grindulu Watershed in 2016. Grindulu Watershed has an area of 71518.54 hectares. Administratively, Grindulu Watershed consist of three districts, which is dominated by Pacitan District of 64708.48 ha (90.48%) covering 9 subdistricts and 97 villages; Ponorogo Districtof 2715.46 ha (3.80%) comprising of 5 subdistricts and 10 villages; and Wonogiri Districtof 4094.60 ha (5.73%) covering 3 subdistricts and 7 villages. Grindulu Watershed is one of the prioritised watersheds, ranging from the upstream of *Gunung Sewu*, Mount Lawu, and Wonogiri karsts to the downstream in Pacitan Regency as the outlet. The study area is presented in Figure 1.

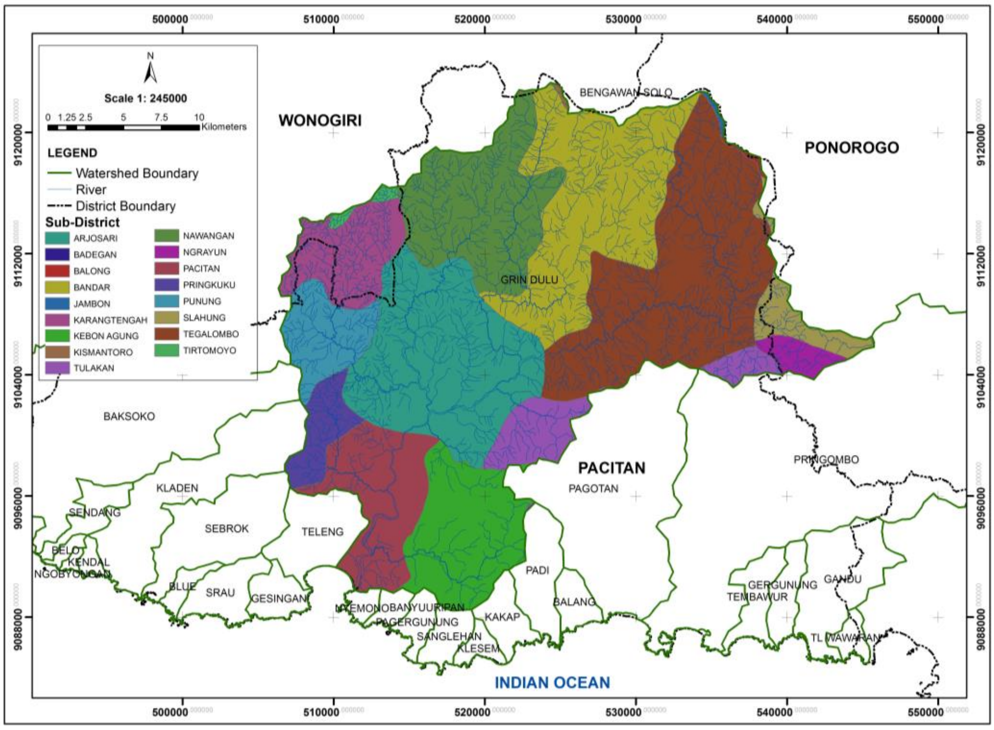

Figure 1.Study Area of Grindulu Watershed (*Data analysis, 2017*)

The climate of Grindulu Watershed is classified as type C based on Schmidt and Ferguson. The rainfall in Grindulu Watershed is 2165 mm/yr with an average temperature of 27.4%. The average solar radiation is 10.8 hours/day, the average wind velocity is 1.4 m/sec, and the average evapotranspiration is 4.33 mm/day. Evaporation is amounted to 1584 mm/yr and precipitation is 1938 mm/yr.

The topography of Grindulu Watershed is dominated by hilly to mountainous with an extent of 32.93% and 30.25% situated at a slope of 15-25% and >25%, respectively. There is also an undulating topography with a slope of 8-15% of 22.36% and a flat topography with a slope of 0-8% of 14.46%.

Geologically, Grindulu Watershed is divided into three zones, namely: a) Miocene Sedimentary Facies (Alluvial Plains), which covers the upstream (north) in Nawangan District and Bandar District to the southern coast of the eastern part of the watershed. The material consists of lithosol and complex red lathosol; b) Structural Hills (Andesite). The structural hills are part of the line overgrown by quater nary volcanoes. In Grindulu Watershed, structural hills spread around Pacitan sub district and Arjosari sub district. Materials of structural hills are basaltic andesite and dacite that constituted Arjosari Formation. The results of weathering of andesite and dacite are complex reddish brown lathosoland volcanic lithosol; and c) Gunung Sewu thousand mountains (Limestone). In Grindulu Watershed, Pringkuku, Tulakan, and Kebon Agung sub district are dominated by limestone. It is generally made up of Mediterranean soil and association of lithosol and reddish-brown Mediterranean soil.

2.2. Material and Tools

The materials required in this study included Map of Grindulu Watershed, RBI map scale 1: 25000, Landsat 8 of 2016 Path/Row 119/66, map of protected forest and production forest, the spatial planning document of Pacitan in 2009-2028. Furthermore, GPS, ASUS Notebook Core i3 capacity of 6 GB RAM, and 500GB HDD, ArcGIS 10.2 Software, were employed tools.

2.3. Data Processing and Analysis

This study modified the results of community forest analysis carried out previously by BPKH XI and MFP II 2009. The potential of community forests in the area of Grindulu Watershed was analysed by performing Landsat 8 imagery interpretation for land use analysis to determine the availability area for community forest and transformation of NDVI (Normalized Difference Vegetation Index) for density classification.

The initial image processing was done to obtain the radiometric calibrated image, hence the value of surface reflectance was generated. Land use was obtainedby updating RBI scale 1: 25.000 with the 432 image composite. Land use map was made to identify the potential area for community forests.

Vegetation detection was carried out based on the transformation of the NDVI vegetation index. NDVI is a measure of vegetative cover based on remotely sensed data (Bluffstone et al., 2018). Vegetation index is a spectral transformation applied on the multi-bandimages to highlight the density aspect, e.g., biomass, leaf area index (LAI), chlorophyll concentration, and so forth. Vegetation index as mathematical transformation involves multiple bands simultaneously to produce a new image that is more representative in providing the aspects related to vegetation (Danoedoro, 2012). Basically, formula for calculating NDVI is as follows:

$$NDVI = \frac{NIR - RED}{NIR + RED}$$

where:
NIR : infrared band (band 5).
RED : red band (band 4).

The results of the formula range from –1 to +1 where the value of –1 indicates that the red band has the maximum reflectance value and the infrared band has the minimum reflection. It demonstrates the non-vegetation area. Vice versa, the value of +1 indicates the maximum reflection occurs in the infrared band and the minimum reflectance in the red band, showing vegetated area with a high density. Furthermore, based on NDVI values and the result of field study, density classification was defined into low, moderate, and high. Community forest assessment was done with restrictions: 1) the class density was high-density forest (the vegetation cover>50%), 2) the high-density forest with land available for community forest was selected, 3) the extent of minimum community forest (>0.25 ha) was determined.

3. RESULTS AND DISCUSSION

Based on NDVI analysis, a range of -0.319 to 0.084 was generated. The values of -0.319 to 0 were eliminated since they indicated non-vegetated areas or open area. Tovar, (2011) NDVI values below 0.1 correspond to bodies of water and bare ground, while higher values are indicators of high photosynthetic activity linked to scrub land, temperate forest, rain forest and agricultural activity. NDVI values remained within the 0.8 to 0.9 range for the native forests (Cristiano et al., 2014). NDVI classes were classified into three classes, namely low, moderate, and high. Sample coordinates were 89 points that represented each density class proportionately. In accordance to the estimation of field surveys, the accuracy result was 0.84. Grindulu Watershed was dominated by high-density classamounted to 54294.04 ha (75.92%). This class was dominated by monoculture and mixed forest without any association with other land uses. NDVI classification and density classes are illustrated in Table 1 and sample location in Figure 2.

Table 1. NDVI Classification and Density Classes.

No	Density class	NDVI values	Area (ha)	Percentage (%)	Description
1	Low	0 – 0.356	5148.12	7.20	Community forest mixed with settlement.
2	Moderate	0.356 –0.590	12076.39	16.88	Community forest mixed with wet/dryland agriculture and settlement
3	High	0.590 – 0.841	54294.04	75.92	Community forest of fulltrees.
	Total		71518.54	100.00	

Source: Data processing, 2017.

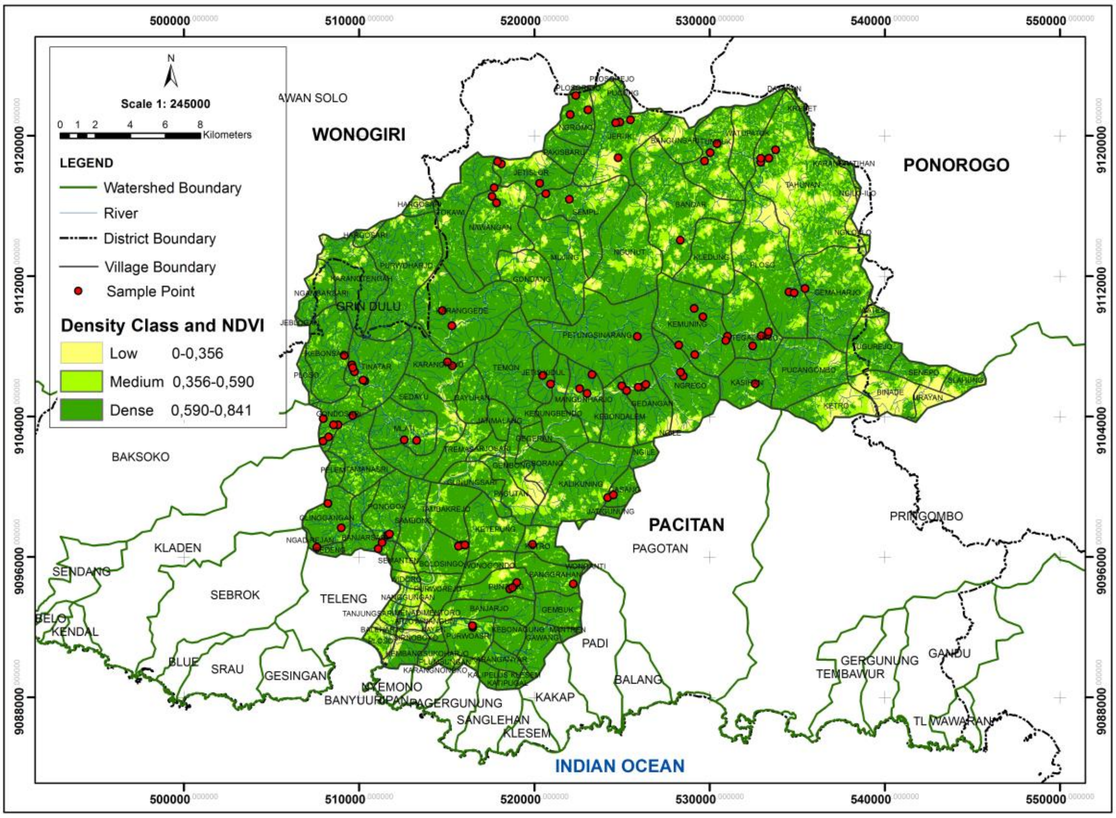

Figure 2. Sample Location and NDVI Classification and Vegetation Density (*Data Analysis, 2017*)

Potential areaof community forest development in Grindulu Watershed was estimated based on the high-density class with NDVI values from 0.590 to 0.841 on available area for the development of

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community forests with an area of >0.25 ha. Potential area for the prioritised community forest development is 37774.40 ha (52.82%) in the form of dryland agriculture, shrubs, grasses, plantation, and situated outside the protected and production forests. The extensive areas available for community forest are particularly includedin Tegal ombo sub-district of 10014.42 ha and Arjosari sub-district of 8736.60 ha. Figure 3 demonstrates the potential area for community forest and the forest area extent. The extent of potential community forest area in Grindulu Watershed as presented in Table 2 was estimatedin accordance with the high-density class of potential area, which is 31281.54 ha (43.74%). The most extensive potential areas for the community forest development are located in Tegal ombo sub-district of 8017.45 ha and Arjosari sub-district of 8017.45 ha.

Table 2. The Extents of Potential Community Forest Area of Each Sub-District in Grindulu Watershed.

No	District/Sub District	Available Area (ha)	Potential Community Forest Area (ha)
A	Pacitan	34732.51	29111.98
1	Arjosari	8736.60	7878.34
2	Bandar	3888.54	3132.57
3	KebonAgung	2246.06	1835.86
4	Nawangan	2853.06	2245.10
5	Pacitan	2327.02	2123.79
6	Pringkuku	800.03	736.79
7	Punung	1497.23	1445.13
8	Tegalombo	10014.42	8017.45
9	Tulakan	2369.55	1696.94
B	Ponorogo	875.15	263.29
1	Badegan	2.47	0.01
2	Balong	22.77	15.63
3	Jambon	48.70	27.80
4	Ngrayun	323.18	18.51
5	Slahung	478.04	201.35
C	Wonogiri	2166.73	1906.27
1	Karangtengah	2126.86	1876.53
2	Kismantoro	39.87	29.74
	Total	37774.40	31281.54

Source: Data Processing, 2017.

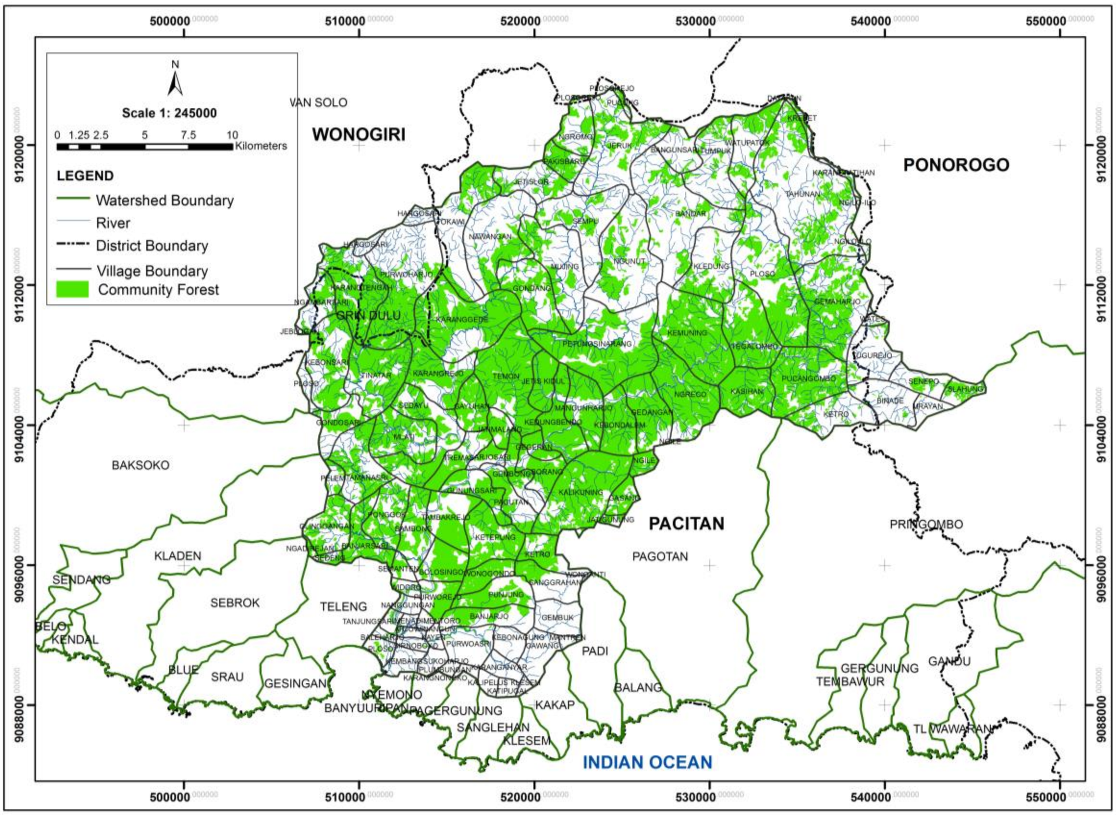

Figure 3. Spatial Distribution of Potential Area for Community Forest (*Data Analysis, 2017*)

Community forest types based on the results of field survey was dominated by monoculture and mixed forest without any association with other land uses. In addition, the most common plants consisted of Sengon (*Paraserianthes falcataria*), Mahogany (*Swietenia macrophylla*), Teak (*Tectona grandis*), Acacia (*Acacia mangium*) and Jabon (*Anthocephalus cadamba*). In mixed community forest, there were 16 species planted between the lines of staple crops. The associations of the crops in the community forest in Grindulu Watershed are kelapa (*Cocos nucifera*), pisang (*Musa paradisiaca*), kopi (*Coffee arabica*), ketela pohon (*Manihot esculenta*), coklat (*Theobroma cacao*), kacang tanah (*Arachis hypogaea*), kacang panjang (*Vigna cylindrica*), jagung (*Zea mays*), cabai (*Capsicum frutescens*), bamboo (*Bambusa sp*), ubi (*Ipomoea batatas*), padi gogo (*Oryza sativa*), papaya (*Carica papaya*), lengkuas (*Alpinia galangal*), porang (*Amorphophallus muelleri*) dan Janggelan (*Mesona palustris*).

Species selected in the development of community forests should have criteria of adaptive to the ecosystem, fast-growing, high commercial value, uncomplicated procurement of high-quality seeds and seedlings, and market demand-oriented. In addition, they should have economic viability and can produce commodities such as fruits, fodder, and others in a short term. Fast-growing species are opted due to their high commercial value, uncomplicated seedling nursery and high-quality seeds, and market demand-oriented. Another advantage of community forest development in addition to degraded land and environmental rehabilitation is the economic benefits.

The target of community forest development is prioritized on land identified as critical land. Based on data obtained from (Solo Watershed and Protection Forest Management Center, 2011), the critical condition levels of Grindulu Watershed consisted of potential critical of 7132.95 ha (9.97%), slightly critical of 48248.72 ha (67.5%), critical of 15333.96 ha (21.44%) and very critical of 20.42 ha (0.02%). In appropriate improvement and rehabilitation effort would worsen the critical degree and reduce watershed functionality and carrying capacity. One of the attempts to address the critical area is the development program of community forest as suggested by (Suherdi et al., 2015). Another advantage of community forest development in addition to degraded land and environmental rehabilitation is the economic benefits. (Waluyo et al., 2010) reported the increased timber utilisation of community forest program to meet the market demand for timber. Species selected in the development of community forests should have criteria of adaptive to the ecosystem, fast-growing, high commercial value, uncomplicated procurement of high-quality seeds and seedlings, and market demand-oriented. In addition, they should have economic viability and can produce commodities such as fruits, fodder, and others in a short term. Community forest with agroforestry concept can be applied to the rehabilitation of the region. Agroforestry is land use system that combines woody plants (trees, shrubs, bamboo, rattan, etc.) and non woody plants or grasses, or components of livestock or other animals (bees, fish) to form ecological and economical interaction between woody plants with other components (McAdam, 2000).

In this study only limited physical data on land use and cover, but did not consider aspects of information from the community regarding land ownership. Even though information about local communities is very useful in the accuracy of the data produced. Natural resource management must take community-based approach to succeed by considering conservation and development goals. The concept of this region must be designed with map based on local knowledge resources based how the community perceives its resources can be managed (Etongo & Glover, 2012). Based on research Peters-Guarin and (Peters-Guarin & McCall, 2010) the contribution of local communities in the acquisition of data useful for activities related to forest management and carbon sequestration. Utilization of GIS technology for mapping community forests should be cost effective. It is recommended to explore the potentiality of combining existing surveying system and GIS based techniques in community forest mapping surveying to improve accuracy and valid information.

4. CONCLUSION

Community forest mapping is an important tool to support community forest development. Utilization of NDVI data combined with field data survey can be used as an alternative in distribution mapping of community forests. Based on the assessment of field surveys which were conducted proportionally at 89 sample, known good accuracy results by 0.84. The spatial distribution of potential area for community forest development in Grindulu Watershed was 31281.54 ha (43.74%) that was dispersed in Pacitan District (9 sub-districts) of 29111.98 ha, Ponorogo District (5 sub-districts) of 263.29 ha, and Wonogiri District (2 sub-districts) of 1906.27 ha. To determine the location of community forests, it is necessary more discussion and interpretation to add a combination of participatory mapping methods to represent the spatial knowledge of local communities.

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