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Agroforestry suitability evaluation using remote sensing in Jatiyoso Sub-district, Karanganyar District, Central Java, Indonesia

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Abstract. *Negari SIT, Ningtyas SRA, Hanun Z, Sulton MN, Kusumaningrum L, Indrawan M, Sugiyarto, Sutomo, Setyawan AD. 2023. Agroforestry suitability evaluation using remote sensing in Jatiyoso Sub-district, Karanganyar District, Central Java, Indonesia. Biodiversitas 24: 6761-6769.* Agroforestry systems are critical for biodiversity conservation, land degradation mitigation, and climate change mitigation. This agroforestry approach reduces forest degradation, boosts food security, and gradually raises farmers' income. This study uses remote sensing and Geographic Information System (GIS) modeling tools to analyze land potential and agroforestry status in Jatiyoso Sub-district, Karanganyar District, Central Java, Indonesia. The data used in the analysis support data for soil fertility index, rainfall, Shuttle Radar Topography Mission (SRTM) satellite image data, and Normalized Difference Vegetation Index (NDVI). Modeling was done by integrating various thematic layers in the GIS domain. Weighting was also carried out in the analysis of land suitability. The mapping results in Jatiyoso Sub-district, Karanganyar District, showed that 18.1% (13.49 km^2) had high potential as agroforestry areas, 54.9% (40.95 km^2) had medium potential, and 27% (20.18 km^2) had low potential. As a result, using remote sensing and GIS to determine suitable land for agroforestry could significantly impact the community, particularly farmers, landowners, and foresters, in the decision-making process for developing agroforestry systems and practices and estimating important productivity indicators. The most promising and appropriate agroforestry plants developed in Jatiyoso Sub-district are medicinal plants, but agricultural commodities like cloves, bananas, and vegetables are also present.

Keywords: Agroforestry, GIS modeling, soil fertility, thematic layers

INTRODUCTION

Agroforestry is a type of multi-canopy land use that combines trees and shrubs with seasonal crops and animals (livestock, fishery) in one field. (Olivi et al. 2015). This diverse composition makes agroforestry have a role and function closer to forests than agriculture, plantations, vacant land, or abandoned land (Widianto et al. 2003). In its most basic form, agroforestry is planting trees on agricultural land, with farmers or communities as the primary component (Tjatjo et al. 2015). In agroforestry, there are ecological and economic interactions among the components involved. The agroforestry system was established to reduce forest destruction/encroachment activities while increasing farmers' income sustainably. The agroforestry system is important in biodiversity conservation efforts where many local and semi-natural introduced species are found (Atangana et al. 2014). Agroforestry systems emphasize versatile tree species and determine the associations between planted vegetation types. Trees are important in agroforestry and contribute significantly to biodiversity conservation and environmental protection. The domestication of trees on farms not only improves soil fertility but can also help improve microclimate, serve as fences, act as windbreaks, improve the hydrological cycle of the area and increase wildlife diversity. In agroforestry, trees can also produce various products ranging from food, medicine, and timber. Therefore, many agroforestry farmers consider trees as part of their livelihood rather than just a forest resource.

Jatiyoso is one of the sub-districts located in Karanganyar District, Central Java, Indonesia, with an area of 67.16 km2 and an average altitude of 950 meters above sea level (BPS 2021). According to Pujiasmanto et al. (2021), the Jatiyoso Sub-district has land suitable for agriculture, especially agroforestry, with soil types consisting of reddish-brown lithosol, brown andosol complex, and lithosol. They stated that prominent agricultural commodities in Jatiyoso Sub-district include cloves, bananas, vegetables, and medicinal plants. Land in Jatiyoso Sub-district is also used as agroforestry land ranging from rice fields (*sawah*), dry fields (*tegal*), yards/home gardens (*pekarangan*), gardens (*kebon*), ponds (*kolam*), to plantations (*perkebunan*). According to

Pujiasmanto et al. (2021), the Jatiyoso area is a suitable area to be developed as an agroforestry area, especially for medicinal plants. The existence of agroforestry in the Jatiyoso sub-district supports and accelerates the economic growth rate of the Jatiyoso community. According to Martini et al. (2013), the existence of agroforestry extension activities in an area can be used to improve the livelihoods of local communities through the establishment of business entities and to build sustainable alternative livelihoods that contribute to improving the welfare of local communities and improving biodiversity conservation strategies.

The land suitability index could determine the land suitability level for agroforestry systems (Widiyanto and Suhartono 2017). Land suitability describes the level of suitability of a piece of land for a particular use. Meanwhile, land suitability evaluation is defined as estimating the level of land suitability for various alternative land uses, both agricultural and non-agricultural (Ritung et al. 2011). Satellite imaging, often known as remote sensing, is one way that can be used to assess land suitability. According to Lillesand and Ralph (2002), remote sensing requires analysis and interpretation to acquire data about an object, area, or phenomenon without observing the object directly. Evaluating land suitability requires spatial data in maps to classify land suitability with statistical data using Geographic Information Systems (GIS). Remote sensing and GIS play a role in presenting all land use data.

Furthermore, spatial data can be presented and informed in a computerized system using software that can provide information quickly and accurately (Rehmamana et al. 2020). Thus, this research was conducted to assess the potential and status of agroforestry in Jatiyoso Sub-district, Karanganyar District, using remote sensing. We expect that the findings of this study will be useful to policymakers in improving agroforestry in the study area.

MATERIALS AND METHODS

Study area

This research was conducted from June to July 2023 in Jatiyoso Sub-district, Karanganyar District, Central Java, Indonesia (7°41'21.98"-7°45'26.30"S and 111°3'0.75"-111°11'11.69"E) by remote sensing approach (Figure 1). In this research, the author did direct observations in the location to ground check and needed spatial data of the Jatiyoso Sub-district area to be processed (Table 1). The Jatiyoso Sub-district has an area of 67.16 km^2 with an altitude of ± 950 meters above sea level (m asl.). This sub-district borders Tawangmangu Sub-district to the north, Jatipurna Sub-district to the east, Girimarto Sub-district to the south, and Jumapolo Sub-district to the west. Land use in the Jatiyoso Sub-district consists of natural forests, rice fields, and mixed gardens (BPS 2021). The land in this sub-district is mostly agricultural, with good potential for the growth and development of agro-industrial plants. Crops generally cultivated are rice, corn, cassava, and peanuts or other beans (Mujiyo et al. 2022). Animal husbandry, including cattle, goats, sheep, chickens, and rabbits, is common in the Jatiyoso Sub-district (BPS 2021).

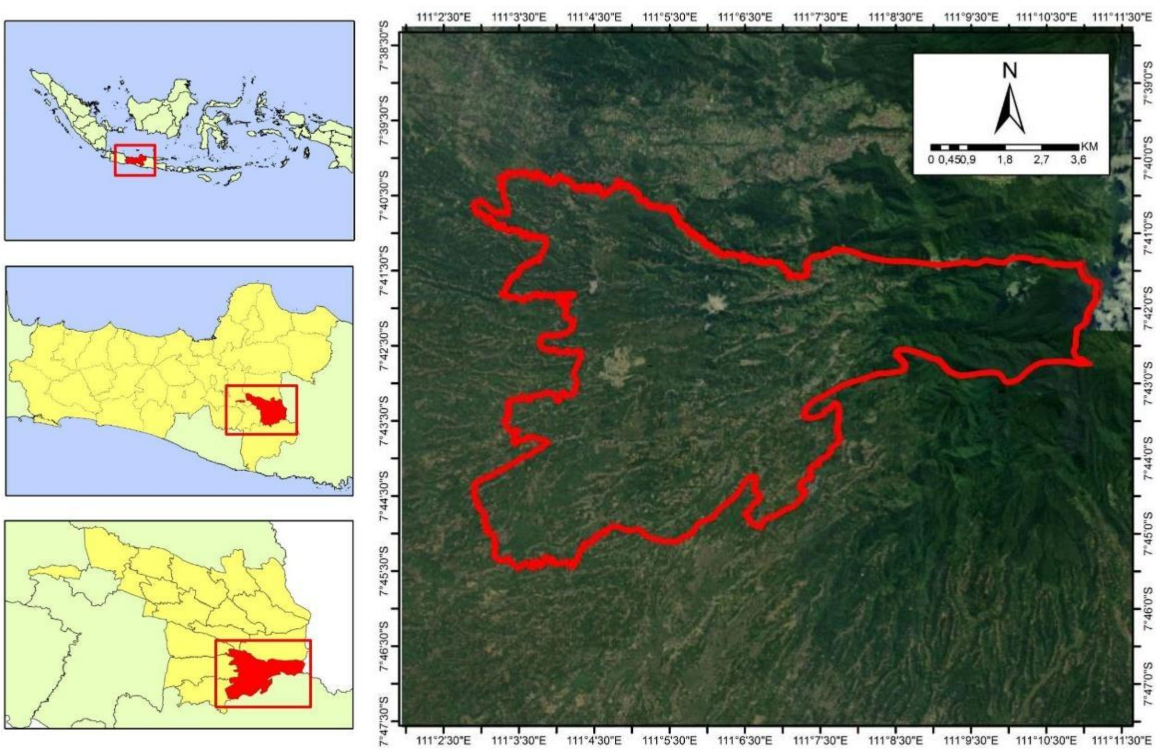


Figure 1. Study area in Jatiyoso Sub-district, Karanganyar District, Central Java, Indonesia

Procedures

The data used to determine the potential of agroforestry are soil fertility, slope, rainfall, NDVI, and elevation. Table 1 shows the data required to process soil fertility, slope, rainfall, NDVI, and elevation. Our study did not include soil moisture or wetness index as a separate factor affecting land suitability for agroforestry. Soil moisture is a hydrological variable associated with vegetation growth (Swain et al. 2013) and has a linear relationship with NDVI (Mohamed et al. 2020) and rainfall (Ahmad et al. 2019). NDVI indicates vegetation density, where vegetation plays a role in preventing excessive water runoff (Zhang et al. 2018) so that water tends to be retained in the soil. High rainfall will also support the availability of large amounts of water in an area. So, looking at land conditions with dense vegetation and high rainfall indirectly indicates soil moisture conditions. A flow diagram of agroforestry potential analysis is shown in Figure 2.

Soil fertility

Soil fertility consists of several important indicators, including the elements nitrogen (N), phosphorus (P), and potassium (K), which are required in large quantities for plant growth. The soil's pH range also affects the availability of nutrients for plants. Data on the percentage of organic carbon is also needed, as organic carbon helps improve soil structure, resulting in a higher release of nutrients for plant growth. Data related to nitrogen, phosphorus, potassium, soil pH, and organic carbon in Jatiyoso Sub-district, Karanganyar District, were obtained from secondary data from research by Mujiyo et al. (2022) on the Soil Fertility Index based on altitude located in Jatiyoso Sub-district, Karanganyar District. In this research, there were several soil indicators observed, including pH, organic carbon, total nitrogen, available phosphorus (Av-P), available potassium (Av-K), cation exchange capacity (CEC), base saturation, exchangeable calcium (Ex-Ca), and exchangeable magnesium (Ex-Mg). We analyzed the results of Mujiyo et al. (2022) to create a raster dataset specific to our study location.

Slope

The slope shows the natural appearance of the difference in elevation between two places (change in land elevation per unit distance) on delicate surfaces or slopes because water can be stored longer and provide sufficient moisture for plant growth. Conversely, water will flow faster on steep slopes, so very little water can be stored in the soil. SRTM (Shuttle Radar Topography Mission) data (https://earthexplorer.usgs.gov) obtained through the USGS Earth Explorer portal was used to calculate the slope.

Rainfall

Rainfall is an important parameter, where its spatial variation has a positive relationship with the FAO crop growth matrix in land resource assessment. Spatial rainfall patterns were processed with ArcGIS software using the Kriging interpolation method. Rainfall data from the beginning of rainfall observation until 2022 was obtained through the Water Resources Information and Data Service by the Bengawan Solo River Basin Agency (pers. comm.).

Normalized Difference Vegetation Index (NDVI)

The Normalized Difference Vegetation Index (NDVI) is a widely used vegetation index that accurately describes vegetation's health and vigor through remote sensing data. NDVI data in the form of Landsat Image data taken on 28 May 2023. NDVI data can be obtained through the USGS Earth Explorer portal at https://earthexplorer.usgs.gov. Based on Sulton et al. (2023), to determine the area of vegetation with non-vegetation, the following formula is used:

$$NDVI = (NIR-RED)/(NIR+RED)$$

Where:
NDVI : Normalized Difference Vegetation Index
NIR : Near infrared channel reflectance
RED : Red channel reflectance

Altitude

Elevation data is necessary because it is one of the important factors affecting plant growth. Based on the tree line concept, as altitude increases, temperature and vegetation will decrease (Subedi et al. 2022). In the process of photosynthesis and plant respiration, temperature has a significant influence on plant growth and development. SRTM (Shuttle Radar Topography Mission) data was used to calculate the slope (https://earthexplorer.usgs.gov) from the USGS Earth Explorer portal.

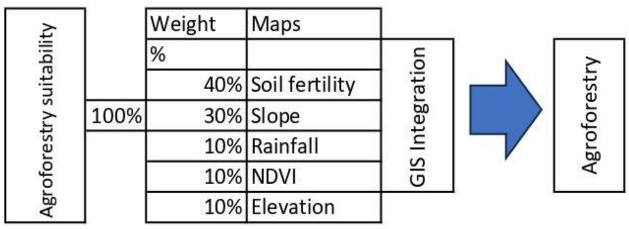


Figure 2. Flow chart of agroforestry potential analysis

Table 1. Collected datasets in the study

Dataset	File type	Data type	Spatial resolution	Sources
Study area boundary	Shp	Polygon		GADM
Soil fertility	Tiff	Raster	30 m	Mujiyo et al. (2022)
SRTM	Tiff	Raster	30 m	USGS Earth Explorer (https://earthexplorer.usgs.gov)
NDVI	Tiff	Raster	30 m	USGS Earth Explorer (https://earthexplorer.usgs.gov)
Rainfall data	excl			Bengawan Solo River Basin Agency (pers. comm.)

Data analysis

Mapping agroforestry potential

The potential of the agroforestry map was generated by integrating soil fertility, slope, rainfall, NDVI, and altitude in a GIS modeling concept, giving weights and ratings to each parameter (Subedi et al. 2020).

$$Ap = 40\%Sf+30\%S+10\%R+10\%NDVI+10\%E$$

Where:
Ap : Potential of agroforestry
S : Slope
R : Rainfall
NDVI : Normalized Difference Vegetation Index
E : Elevation

Validation of results

Results are validated to show the accuracy of the classification based on available geographic data. Validation of the results was carried out by selecting 36 sample points consisting of sample points with high, medium, and low categories based on the results of mapping the potential of agroforestry with each category; there are 12 sample points and comparing them with Google Earth data (Ahmad et al. 2021). Validation of the image results is necessary to determine how accurate the resulting classification is based on the available geographic data by conducting field checks against a sample of reference images used for analysis (Taloor et al. 2020). The validation assessment was conducted using a confusion matrix by calculating the Kappa coefficient and overall accuracy. The Kappa coefficient has long been used to express image classification accuracy to produce thematic maps (Foody 2020). The Kappa coefficient formula was used to determine the overall accuracy level (Rwanga and Ndambuki 2017) and user accuracy as follows:

Overall accuracy (%) = (Number of correct pixels/Total number of pixels) x 100%
User's accuracy (%) = (correctly classified pixels/Total pixels classified) x 100%
Kappa coefficient (K) = (Po-Pe)/(1-Pe)

Where:
Po: Proportion of correctly classified pixels
Pe: Proportion of correctly classified pixels expected by chance

RESULTS AND DISCUSSION

Agroforestry suitability mapping

Soil fertility map

Soil fertility is the ability of soil to provide sufficient nutrients for plant growth and yield (Anna 2021). The assessment's contribution to this variable is highest when compared to other variables since soil fertility is the element that is thought to have the greatest impact on the appropriateness of agroforestry land. Healthy soil conditions are the most important resource for ecosystems and agricultural activities, especially for the growth and development of plants that are important in regulating metabolic activities (Ahmad et al. 2020); hence, they can support the provision of food production and other ecosystem services (Dollinger and Jose 2018). In soil fertility mapping (Table 2), a weighting of 40% is carried out with a classification in 5 categories, namely the very low category (<0.25), low category (0.25-0.50), medium category (0.50-0.75), high category (0.75-0.90), and very high category (0.90-1.00). Based on the results of the soil fertility map (Figure 3.A), it can be seen that soil fertility in eastern Jatiyoso is in the medium class, and in western Jatiyoso is in the high class. So, looking at the soil fertility level, the research area is very suitable for agroforestry activities.

Slope map

The slope is the surface of the earth that has a certain angle of inclination to a flat plane. The slope is the ratio between height difference and distance. One alternative method often applied to map slopes is utilizing elevation from DEM SRTM and ASTER data, which is considered the height of the land surface (Mahmudi et al. 2015). The data is then used for slope extraction and then reclassified into five categories, namely very high category (<2^o), high category (2-8^o), moderate category (8-16^o), low category (16-24^o), and very low category (>24^o) (Subedi et al. 2022). Based on the soil fertility map results (Figure 3.B), it can be seen that most of the slope levels in the research location fall into the very low category of >24^o.

Table 2. Weight, value, and rating assigned to determine the potential of agroforestry

Agroforestry Suitability Mapping	Weights %	Value/ Description	Ranks	Suitability
Soil fertility	40%	<0.25	1	Very low
		0.25-0.50	2	Low
		0.50-0.75	3	Medium
		0.75-0.90	4	High
		0.90-1.00	5	Very high
Slope	30%	<2 degrees	5	Very high
		2-8 degrees	4	High
		8-16 degrees	3	Medium
		16-24 degrees	2	Low
		> 24 degrees	1	Very low
Rainfall	10%	<1500 mm	3	Medium
		1500 mm	4	High
NDVI	10%	<0.4	1	Very low
		0.4-0.5	2	Low
		0.5-0.6	3	Medium
		0.6-0.7	4	High
		>0.7	5	Very high
Elevation	10%	< 200 m	5	Very high
		200-400 m	4	High
		400-674 m	3	Medium
		674-954 m	2	Low
		954-1489 m	1	Very low

Source: Ritung et al. (2007), Ahmad et al. (2017), and Mujiyo et al. (2022)

Rainfall

Rainfall is a variable associated with climate. Rainfall is classified into two categories, namely medium (<1,500 mm) and high (1,500 mm). Based on the map, results show that rainfall in all research locations is above 1,500 mm per year or is included in the high category (Figure 3.C). So, based on rainfall, the entire research area is very suitable for agroforestry activities.

Normalized Difference Vegetation Index (NDVI)

NDVI in this study was categorized into five classes: very low if <0.4, low between 0.4-0.5, medium between 0.5-0.6, high between 0.6-0.7, and very high if >0.7 (Subedi et al. 2022). NDVI is used as an indicator of greenness that indicates the quantity and quality of vegetation and is an indicator of the degradation of an ecosystem, so the NDVI variable is used to produce ecological suitability maps (Nath et al. 2021). Based on the map results, most of the study area is in the very high category (Figure 3.D). That means the vegetation cover in the study area is still very dense and very suitable for the provisions of agroforestry development. Agroforestry in areas with high NDVI has low erosion potential and is adequate for plant growth (Ahmad et al. 2019)

Elevation

The elevation or height of an area is also a factor considered in agroforestry development. Elevation is categorized into five classes for agroforestry potential suitability, i.e., very low, low, medium, high, and very high (Subedi et al. 2022). Based on the mapping that has been done, it can be seen that the research area is categorized into three classes almost equally, namely very low for an altitude of 954-1489 m asl., low for an altitude of 674-954 m asl., and medium at an altitude of 400-674 m asl. (Figure 3.E).

Potential of agroforestry map

Factors contributing to the potential of agroforestry are soil fertility, slope, rainfall, NDVI, and altitude, where weights are selected based on empirical results from various findings (Subedi et al. 2022; Sharma et al. 2022). Modica et al. (2016) argue that land suitability classification requires comparing land use types' requirements with land units' components and integrating them with location, environmental data components, and land conditions. For example, the mapping of agroforestry potential in the Jatiyoso Sub-district showed a suitability of 18.1% as high potential of agroforestry area, 54.9% as medium potential (moderate) of agroforestry area, and 27% as low potential of agroforestry area (Figures 3.F and 4).

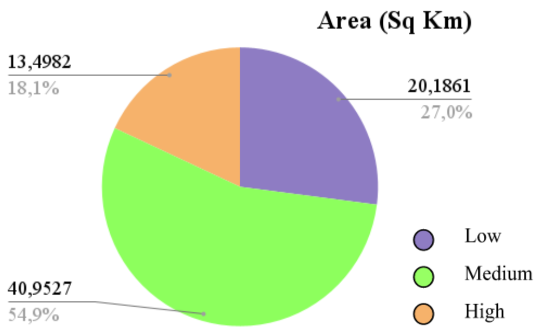


Figure 4. Potential of agroforestry area

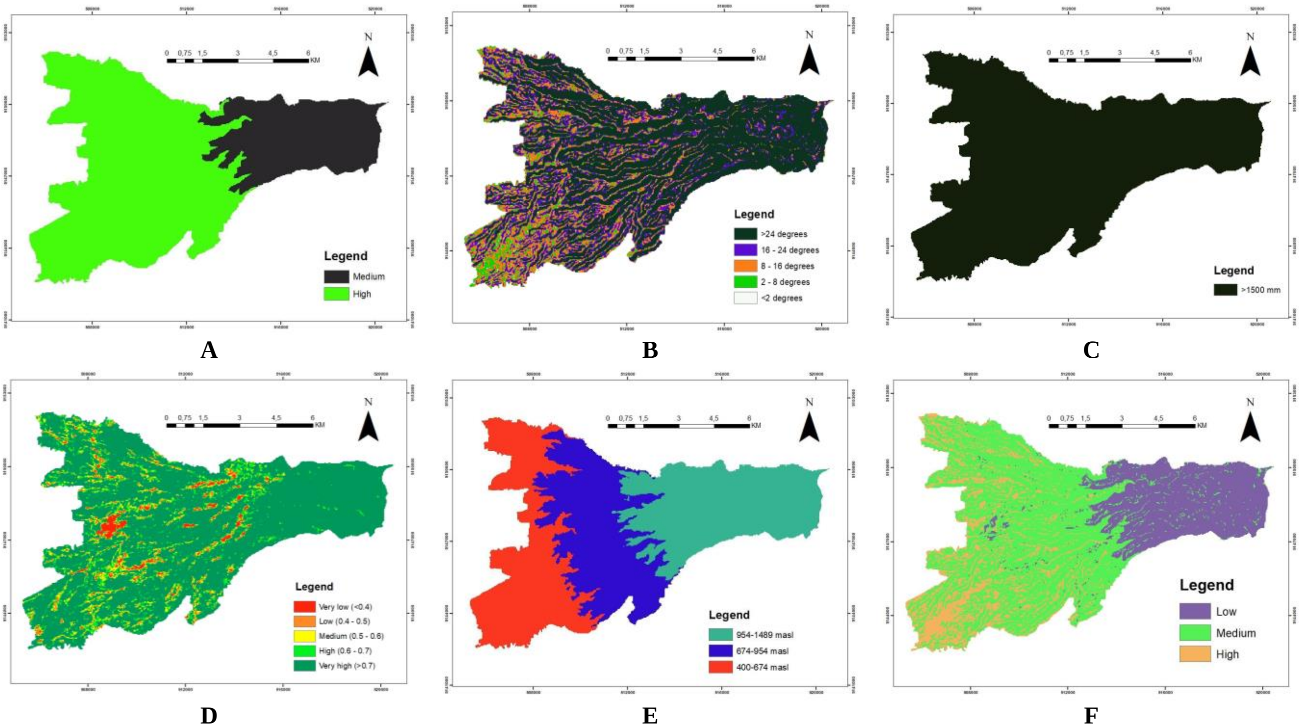


Figure 3. Soil and climate characteristics, and potential of agroforestry. A. Soil fertility map, B. Slope map, C. Rainfall map, D. NDVI map, E. Elevation map, F. Potential of agroforestry map

Discussion

Based on the results of agroforestry potential mapping (Figures 3.F and 4), it is known that there are three classifications of land suitability, namely low, medium, and high categories. Therefore, to test the accuracy of the classification mapping results, a validation test was conducted comparing the classification results on the potential of agroforestry mapping (user's accuracy) with the actual land conditions (producer's accuracy) through satellite imagery. Based on the results of the validation test (Table 3), it is known that the producer's accuracy for the classification of low-category land suitability is 76.92% with a total of 13 suitable sample points, the medium category is 50% with a total of 10 suitable sample points, and the high category is 53% with a total of 13 suitable sample points. Then, the user accuracy is known for the classification of low-category land suitability obtained at 83.33%, medium category at 41.67% and high category at 58.33%. The value obtained from the kappa coefficient shows the level of agreement with estimates that arise by chance until almost perfect agreement is obtained from classifications that meet the requested accuracy target (de Raadt et al. 2021). The agreement value between the producer's accuracy (correctly classified) and the user's accuracy (correctly classified expected by chance) is obtained through the kappa coefficient (Dettori and Norvell 2020). The value of the kappa coefficient reflects not only the agreement in labeling but also the nature of the population under study and is interpreted relative to a scale (Foody 2020); in the field of remote sensing, the interpretation scale by Landis and Koch (1977) is generally used, which consists of the scale categories of poor, fair, moderate or sufficient, good, and excellent. Based on the kappa coefficient analysis of the results of agroforestry potential mapping (Tables 3 and 4), the accuracy value of the feasibility agreement is 0.42, which indicates that the results of mapping potential of agroforestry in Jatiyoso Sub-district are included in the moderate or sufficient category.

Soil fertility, altitude, slope, rainfall patterns, and NDVI are important in determining the suitability of agroforestry potential areas. High agroforestry suitability can be observed through several factors, namely high soil fertility levels, high annual rainfall, NDVI or high vegetation cover density, and low levels of slope and altitude (Subedi et al. 2022). However, agroforestry can also be applied to degraded areas with certain types of vegetation that are suitable for the land characteristics of the area (Nurida et al. 2018). It will be effective if farmers and communities are fully involved in planning and implementation (Sharma et al. 2017). Potential agroforestry areas have low altitudes (de Mendonca et al. 2022). This is because the altitude of an area affects the temperature, which is an important environmental factor for tree growth (de Resseguier et al. 2020; Stovall et al. 2019; Cabon et al. 2020). The environmental temperature will be inversely proportional to the height of the region where the higher an area, the lower the ambient temperature, and this becomes a limiting factor for plant growth and development so that vegetation density will decrease with increasing altitude (Ahmad et al. 2017). In addition to temperature, the decline in vegetation growth at higher altitudes is also caused by air pressure and low carbon dioxide levels (Ahmad and Goparaju 2017). Meanwhile, carbon dioxide is important for plant photosynthesis (Ahmed and Ahmad 2019). So, areas located in the highlands are not recommended as agroforestry areas. In addition to temperature, other climatic factors, such as rainfall, are also factors that greatly affect the growth of a plant species (Ahmad et al. 2020). In this study, rainfall data did not have a significant effect because the entire Jatiyoso Sub-district area had a similar average rainfall of >1,500 mm per year (Figure 3.D). Based on Ahmad et al. (2022), areas with more than 1,300 mm of rainfall are very suitable for agroforestry. Rainfall intensity is considered an essential climate parameter in vegetation productivity, where increased rainfall is positively correlated to plant growth and is widely used in mapping agroforestry suitability (Ahmad and Goparaju 2017). Humid-perhumid ecosystems characterized by sufficient rainfall intensity, high soil fertility, and adequate soil moisture retention capacity are common in tropical and subtropical regions and are suitable for agroforestry practices (Ahmad et al. 2019).

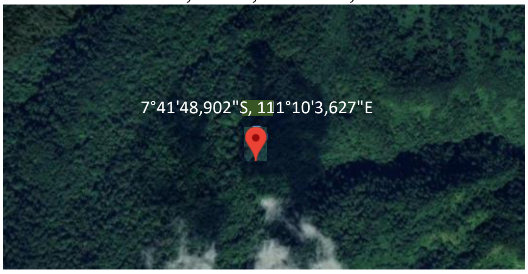
Based on the mapping of agroforestry potential suitability in the Jatiyoso Sub-district, it shows that 13.49 km^2 (18.1%) area with high suitability, 40.95 km^2 (54.9%) area with medium suitability, and 20.18 km^2 (27%) area with low suitability (Figures 3.F and 4). Areas with high suitability potential are found in areas with very high and high vegetation cover, high soil fertility, low (<2°) to moderate (8-16°) slope, and low to moderate elevation (400-954 m asl.). Areas with high potential levels of agroforestry suitability are mostly found in the western part of the Jatiyoso Sub-district (around 13.49% of the area). These conditions are suitable for agroforestry practices with an agrosilvopastoral system in the form of a combination of timber plants, feed crops, and livestock, as well as agricultural cultivation crops such as vegetables, rice, corn, coffee, tea, and cacao that can grow in conditions of humidity and water availability following the conditions of the rainfall pattern (Tsufac et al. 2021).

Table 3. Accuracy and Kappa coefficient

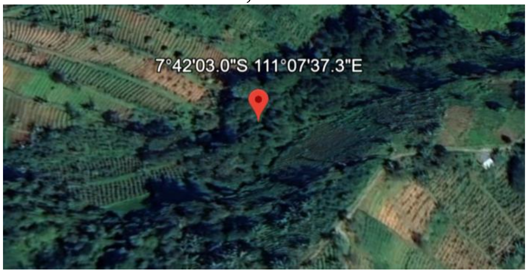
Ground Truth	Low	Medium	High	Total	User's Accuracy (%)
Low	10	1	1	12	83.33
Medium	2	5	5	12	41.67
High	1	4	7	12	58.33
Producer's accuracy (%)	76.92	50	53.85		
Kappa coefficient	0.42				Overall accuracy= 61.11%

Note: The overall accuracy was 61.11%, while the kappa coefficient was 0.42. Since the classified maps' Kappa value was within 0.61-0.8, they are good or substantial and meet the accuracy assessment. Landis and Koch 1977 consider <0.20 to be poor, 0.21-0.40 to be fair, 0.41-0.60 to moderate, 0.61-0.80 to be good, and 0.81-1.00 to very good. *) In the table above, there is no Undefined category because the location at the sample points determined in this study there are no land conditions that are unclear to distinguish

Table 4. Ground truth data using Google Earth

<table>
<tr><th>Category potential</th><th colspan="2">Coordinate & Satellite Image View</th></tr>
<tr><td>Low</td><td>7°41'48,902"S, 111°10'3,627"E

</td><td>7°42'6.856"S, 111°9'4.57"E

</td></tr>
<tr><td></td><td>7°42'3.454"S, 111°8'24.766"E

</td><td>7°42'3.042"S, 111°7'37.258"E

</td></tr>
<tr><td>Medium</td><td>7°41'40.432"S, 111°6'31.769"E

</td><td>7°42'52.596"S, 111°5'46.419"E

</td></tr>
<tr><td></td><td>7°43'39.963"S, 111°7'17.17"E

</td><td>7°41'14.409"S, 111°4'58.035"E

</td></tr>
<tr><td>High</td><td>7°44'58.142"S, 111°3'27.333"E

</td><td>7°42'40.658"S, 111°4'24.667"E

</td></tr>
<tr><td></td><td>7°42'0.942"S, 111°5'19.871"E

</td><td>7°44'24.826"S, 111°4'53.363"E

</td></tr>
</table>

Then, areas with moderate suitability potential, found in areas with very high to moderate vegetation cover, high soil fertility levels, moderate to very high slope, and low to moderate elevation (400-954 m asl.), provide quite good support conditions for plant growth, accounting for about 40.95% of the entire study area. Areas with these conditions suit agroforestry practices with silvopastoral and agrosilvopastoral systems. The silvopastoral agroforestry system will suit soils with a slope category of 18-50%, making it possible for farmers to cultivate arable land/or in areas with poor soil conditions (Sharma et al. 2022). Finally, areas with low agroforestry suitability potential or less suitable for agroforestry practices are found in the eastern part of Jatiyoso Sub-district (around 20.18% of the area) with very high and high vegetation cover, moderate soil fertility, moderate to very high slope, and high elevation ranging from 954-1,489 m asl.

By considering the site conditions of the research area, several agroforestry systems can be effectively practiced and utilized, including agrosilviculture (a combination of forestry trees and agricultural crops), silvopastoral (a combination of forestry trees, fodder crops, and livestock), and agrosilvopastoral (a combination of forestry trees, agricultural crops, and livestock) (Maponya et al. 2022, Lemes et al. 2021, Nyong et al. 2020). Agroforestry is an agricultural practice combining woody plants among crops (Kay et al. 2019) with tree components such as fruit, timber, or shade trees. Based on Jatiyoso Sub-district in Figures 2021 (BPS 2021), it is known that several types of fruit trees are commodities with high yields, indicating that these tree species are suitable for the conditions of the Jatiyoso Sub-district, namely durian and avocado. In addition to fruit tree species, trees with ecological functions, such as *Tectona grandis* L.f., *Delonix regia* (Bojer ex Hook.) Raf., *Swietenia mahagoni* (L.) Jacq., *Cassia siamea* Lam., and *Samanea saman* (Jacq.) Merr. were found to grow in the downstream to upstream areas in Beruk Village, Jatiyoso Sub-district (Maridi et al. 2015). These trees have the characteristics of large canopies and strong roots that are important in retaining rainwater (Maridi et al. 2015) and preventing soil erosion (Cahyono et al. 2021), so the application of agroforestry can be a mitigation solution against landslides (Priyono and Maulida 2021).

Overall, this research raised various themes from various sources of information related to agroforestry systems. Computer-based data processing and spatial analysis using geographic information systems is one of the developments in the decision-making process (Sharma et al. 2022), for example, for landowners, foresters, and farmers to fulfill the purpose of mapping potential of agroforestry suitability (Ahmad et al. 2020). The mapping results in Jatiyoso Sub-district, Karanganyar District, showed that 18.1% (13.49 km^2) had high potential as agroforestry areas, 54.9% (40.95 km^2) had medium potential as agroforestry areas, and 27% (20.18 km^2) had low potential as agroforestry areas; this shows that almost half of the area in the Jatiyoso Sub-district has medium potential as an area suitable for agroforestry practices because most of the topographic conditions are mountainous slopes and plateaus.

The potential agroforestry plants that can be cultivated in the Jatiyoso Sub-district are medicinal plants such as red ginger (*Zingiber officinale* Roscoe) (Pujiasmanto et al. 2021). Red ginger development can be empowered in the homegarden area as a cultivation crop to improve the community's economy (Fatmawati and Diana 2022), especially in Jatiyoso Sub-district. There is also the potential for vegetable crops to become a basic commodity in the Jatiyoso Sub-district, including cabbage, mustard greens, eggplant, beans, and carrots (Harinta et al. 2018). In addition, another type of crop that has the potential to be cultivated in Jatiyoso Sub-district is cloves. This can be seen from the income of farmer households, the majority of which is obtained from clove yields (Barokah et al. 2015). Cahyono et al. (2021) revealed that agroforestry planting in the Jatiyoso Sub-district impacts efforts to reduce landslides by involving local community knowledge. Suitable plants to reduce erosion, such as pine and coffee, with intercrops in grasses that can be used as animal feed.

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