

UTILIZATION OF GIS TECHNOLOGY FOR PRIVATE FOREST DEVELOPMENT IN KEDUANG SUB WATERSHED, WONOGIRI DISTRICT

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ABSTRACT

*Private forest development has a strategic objective, namely to supply logs as raw materials for the timber industry. The research was conducted in the Keduang Sub-watershed, Wonogiri District. The research objective was to determine suitable tree species and locations for Private forest development using a Geographical Information System (GIS). The parameters used were production age, soil texture, elevation, and type of production (wood, Multi-Purpose Tree Species / MPTS). Soil types in the Keduang sub-watershed are Litosol (Entisols), Latosol (Inceptisols), and Mediterranean (Ultisols). To determine suitable tree species and locations for Private forest development, an overlay (with a GIS tool) is carried out between the soil texture map, elevation map, and land cover/use map. Based on the land cover/use map, the area of land suitable for Private forest development is 4,011.95 ha consisting of scrubs (215.51 ha), fields/moor (3,639.84 ha), rainfed fields (114.68 ha), and pasture (41.92 ha). The results of the contour map analysis show that most of the study area has an altitude of <500 m asl (lowland), which is an area of 24,538.02 ha. The soil texture in the study location was dominated by loam, covering an area of 32,153.85 ha. The results of the plant suitability analysis showed that the study location was suitable for Private forest plants such as *Acacia mangium*, *Azadirachta indica* A. Juss, *Melia azedarach*, *Paraserianthes falcataria*, *A. scholaris*, *Gmelina arborea*, *Erythrina variegata*, *Duabanga moluccana*, and *Hibiscus macrophyllus*. While MPTS plants are *Aleurites moluccanus* and *Ceiba pentandra*.*

Keywords: Community Forest, Elevation, Soil Texture, Type of Production, Overlay, GIS

INTRODUCTION

The increase in population has resulted in increasing demand for logs. According to Simon (2010), for rural communities, wood is used as the main component to make houses, agricultural equipment and firewood, while for urban communities, wood is used as a basic material for household furniture and decorative items. These conditions encourage an increase in the demand for wood processing industry so that it can trigger forest encroachment, illegal logging and shifting cultivation which can threaten the sustainability of forest resources. The deforestation rate in Indonesia from 2013 to 2014 was 397,370.9 ha /year (Kementerian Lingkungan Hidup dan Kehutanan Republik Indonesia, 2015). According to Ka'ban (2006), the total area of natural forests in Indonesia currently lives 120.35 million hectares, and the damaged area has reached 59.2 million hectares.

Halawane, et al. (2011) stated that, the amount of national wood demand every year is more than 60 million m³ / year, the amount of wood demand is not possible to only be met from existing natural forests. This shows that, natural forests can no longer be expected to meet the needs of wood, both in local, domestic and international markets. One of the steps that can be taken to meet the needs of wood is the development of private forests (Waluyo, et al, 2010).

Private forests have a very important role not only as a wood supplier for the timber industry but also a source of income to improve the welfare of the community, especially those living in rural areas (Pramono et al, 2010). Private forests are cultivated timber plantations that are developed and planted on private

lands. According to Suprpto (2010), the purpose of private forests development is to increase the productivity of degraded land, improve environmental quality and provide wood for buildings, furniture and firewood. According to Suryatmojo (2017), private forests are divided into 3 types namely pure private forests (consisting of 1 type of tree), mixed private forests (consisting of several types of trees) and agroforestry (a combination of forestry and agricultural crops). Wood demand from private forests is clearly visualized in tree cultivation in various agroforestry patterns. Trees species such as *tectona grandis*, *acacia*, *Swietenia Mahagoni*, *Dalbergia latifolia* and *Albizia chinensis* have been chosen by private forest farmers because its have high economic value in the market (Suryanto, P., Budiadi., and Sabarnurdin, Sambas., M. 2017)

Developments of private forests often face obstacles and risks of failure. The inhibiting factor in private forests development is land unsuitable to grow plants so that plants cannot grow and develop as expected. Simple and practical information of the land suitability for private forest development is very useful for smallholder forest farmers. Therefore, information on the suitability of site to grow forest plants is needed. The high potential of natural resources if it is not supported by the right information and the right technology can cause farmers to not increase income (Bauri et al., 2015). Information on the suitability of site should be practical and simple so that it can be easily used and understood by private forests farmers.

Geographic Information System or often called Geographic Information System (GIS) is a computer-based system that can be used

to store, analyze and recall data quickly and easily. In addition, digital-based GIS technology can be utilized to visualize the suitability of sites on the map with a more attractive appearance. This technology is developing very rapidly and becomes a very effective tool for use in spatial analysis. According to Prahasta (2005), one of the reasons for using GIS is to be able to integrate attribute data and spatial data and visualize them in the form of maps. The purpose of the study is to determine the location of private forest development and the selection of tree species that are appropriate to the characteristics of site. The purpose of this research is to determine tree species and suitable locations for Private forest development using a Geographic Information System (GIS).

MATERIAL AND METHODS

The study area was conducted in the Keduang Sub-watershed. The Keduang Sub-watershed is one of the Gajah Mungkur Reservoir Areas which contributes the largest sedimentation in the amount of 1,218,580 m³ or around 38.33% of the total sedimentation in the Gajah Mungkur Reservoir (JICA, 2007). Geographically, the Keduang sub watershed is located at coordinates 110.96° East Longitude - 111.19° East Longitude and 7.71° South Latitude - 7.86° South Latitude. Administratively, the Keduang sub-watershed is located in Wonogiri Regency, which covers thirteen sub-districts namely Tectona grandisyoso, Bulukerto, Girimarto, Tectona grandispurno, Tectona grandisroto, Tectona grandissrono, Kismantoro, Ngadirojo, Nguntoronadi, Purwantoro, Sidoharjo, Slogohimo and Tirtomoyo (Wuryanta, A. dan Susanti, D., P. 2015).

The material used for the study includes basic maps such as the Indonesia Topographic Map (RBI) scale of 1: 25,000 consisting of five layers, namely contours, road networks, river networks, administration and land cover / use. While the thematic maps used are sub-watershed boundary maps and soil maps. All maps (thematic maps and base maps) used are available in digital format. The satellite image used to update the land cover / use is the SPOT 2 satellite image recording in June 19th 2006. Equipment used for research consists of hardware such as computers, software ArcGIS version 10.2. and Microsoft Excel. While equipment for field surveys such as geology hammers, maps and Global Positioning System (GPS).

The data used for the research included the boundary of Keduang Sub-watershed map, road networks map, river networks map, contours and administration map. Land cover / land use data were obtained from RBI map scale of 1: 25,000 printed in 2001 and updated with the SPOT-2 image recorded in June 19th, 2006 and conducted a field check in 14 to 15 May 2019. The number of sample points during field activities is 21 points.

Land cover/land use maps were obtained from RBI scale of 1: 25000 printed in 2001 and that was updated by using spot 2 satellite imagery recorded in June 19th 2006. Sample location points are determined based on land cover/land use maps, sub watershed boundary maps, contour maps and soil type maps. The sample points that have been determined are then checked in the field. Field checking activities were carried out on May 14th and May 15th 2019. Equipment used for field checking were Global Positioning System

(GPS), maps and geological hammers. Data collected during fieldwork were coordinates, elevation, estimation of soil type, estimation of soil texture and land cover / use type. Data obtained during the fieldwork are then used to update land cover / land use maps, update elevation maps and create soil texture maps. Location for private forest development and tree species type that are appropriate to the

characteristics of site can be obtained from overlay between land use/cover map (updated), elevation map (updated), soil texture map and added with information of cutting cycle and exped end yield (wood or MPTS). Selection of Private forestree species based on land characteristics (soil texture, elevation, type of production and cycle age) is presented in Table 1 and Table 2.

Table 1 The Land Characteristics of Short Production Cycle Plants (d" 10 years)

Lowland (≤ 500 meters above sea level)			High Land(> 500 meters above sea level)		
Soil texture	MPTS	Wood	Soil texture	MPTS	Wood
Calcareous	<i>Persea americana</i> <i>M. leucadendron</i>	<i>Dalbergia latifolia</i> <i>Pterocarpus indicus</i> <i>Senna siamea</i> <i>Tectona grandis</i> <i>Swietenia macrophylla</i>	Calcareous	<i>Persea americana</i> <i>M.leucadendron</i>	<i>Pterocarpus indicus</i> <i>Senna siamea</i> <i>Swietenia macrophylla</i>
Loam	<i>Hevea brasiliensis</i> <i>Persea americana</i> <i>Durio zibethinus</i> <i>Artocarpus altilis</i> <i>Mangifera kauki</i> <i>Anacardium occidentale</i> <i>M.leucadendron</i> <i>Pangium edule</i>	<i>Acacia auriculiformis</i> <i>Toona Toona sureni</i> <i>Peronema canescens</i> <i>Dalbergia latifolia</i> <i>Pterocarpus indicus</i> <i>Swietenia macrophylla</i> <i>Khaya anthotheca</i> <i>Schima wallichii</i>	Loam	<i>Elaeocarpus ganitrus</i> <i>Styrax benzoin Dryand</i> <i>Persea americana</i> <i>Durio zibethinus</i> <i>Artocarpus altilis</i> <i>Arenga pinnata</i> <i>M.leucadendron</i>	<i>Manglietia glauca</i> <i>Toona sureni</i> <i>Pterocarpus indicus</i> <i>Senna siamea</i> <i>Swietenia macrophylla</i> <i>Schima wallichii</i> <i>Khaya anthotheca</i> <i>Agathis dammara</i> <i>Pinus merkusii</i> <i>Castanopsis argentea</i> <i>Albizia procera</i>
Sandy	<i>Hevea brasiliensis</i> <i>Persea americana</i> <i>Durio zibethinus</i> <i>Artocarpus altilis</i> <i>Mangifera kauki</i> <i>Anacardium occidentale</i> <i>M.leucadendron</i> <i>Pangium edule</i>	<i>Formis</i> <i>Toona sureni</i> <i>Peronema canescens</i> <i>Dalbergia latifolia</i> <i>Pterocarpus indicus</i> <i>Swietenia macrophylla</i> <i>Khaya anthotheca</i> <i>Schima wallichii</i>	Sandy	<i>Elaeocarpus ganitrus</i> <i>Styrax benzoin Dryand</i> <i>Persea americana</i> <i>Durio zibethinus</i> <i>Artocarpus altilis</i> <i>Arenga pinnataga pinnata</i> <i>M.leucadendron</i>	<i>Swietenia macrophylla</i> <i>Khaya anthotheca</i> <i>Schima wallichii</i> <i>Agathis dammara</i> <i>Toona sureni</i> <i>Castanopsis argentea</i> <i>Altingia excelsa</i>

Data source: Research and Development Center for Agroforestry Technology in 2017

Table 2 The Land Characteristics of Long Production Cycle plants
(> 10 year)

Lowland (≤ 500 meters above sea level)			High Land(> 500 meters above sea level)		
Soil texture	MPTS	Wood	Soil texture	MPTS	Wood
Calcareous	• <i>Persea americana</i> • <i>M. leucadendron</i>	• <i>Dalbergia latifolia</i> • <i>Pterocarpus indicus</i> • <i>Senna siamea</i> • <i>Tectona grandis</i> • <i>Swietenia macrophylla</i>	Calcareous	• <i>Persea americana</i> • <i>M.leucadendron</i>	• <i>Pterocarpus indicus</i> • <i>Senna siamea</i> • <i>Swietenia macrophylla</i>
Loam	• <i>Hevea brasiliensis</i> • <i>Persea americana</i> • <i>Durio zibethinus</i> • <i>Artocarpus altilis</i> • <i>Mangifera kauki</i> • <i>Anacardium occidentale</i> • <i>M.leucadendron</i> • <i>Pangium edule</i>	• <i>Acacia auriculiformis</i> • <i>Toona toona sureni</i> • <i>Peronema canescens</i> • <i>Dalbergia latifolia</i> • <i>Pterocarpus indicus</i> • <i>Swietenia macrophylla</i> • <i>Khaya anthotheca</i> • <i>Schima wallichii</i>	Loam	• <i>Elaeocarpus ganitrus</i> • <i>Styrax benzoin Dryand</i> • <i>Persea americana</i> • <i>Durio zibethinus</i> • <i>Artocarpus altilis</i> • <i>Arenga pinnata</i> • <i>M.leucadendron</i>	• <i>Manglietia glauca</i> • <i>Toona sureni</i> • <i>Pterocarpus indicus</i> • <i>Senna siamea</i> • <i>Swietenia macrophylla</i> • <i>Schima wallichii</i> • <i>Khaya anthotheca</i> • <i>Agathis dammara</i> • <i>Pinus merkusii</i> • <i>Castanopsis argentea</i> • <i>Albizia procera</i>
Sandy	• <i>Hevea brasiliensis</i> • <i>Persea americana</i> • <i>Durio zibethinus</i> • <i>Artocarpus altilis</i> • <i>Mangifera kauki</i> • <i>Anacardium occidentale</i> • <i>M.leucadendron</i> • <i>Pangium edule</i>	• <i>Formis</i> • <i>Toona sureni</i> • <i>Peronema canescens</i> • <i>Dalbergia latifolia</i> • <i>Pterocarpus indicus</i> • <i>Swietenia macrophylla</i> • <i>Khaya anthotheca</i> • <i>Schima wallichii</i>	Sandy	• <i>Elaeocarpus ganitrus</i> • <i>Styrax benzoin Dryand</i> • <i>Persea americana</i> • <i>Durio zibethinus</i> • <i>Artocarpus altilis</i> • <i>Arenga pinnataga pinnata</i> • <i>M.leucadendron</i>	• <i>Swietenia macrophylla</i> • <i>Khaya anthotheca</i> • <i>Schima wallichii</i> • <i>Agathis dammara</i> • <i>Toona sureni</i> • <i>Castanopsis argentea</i> • <i>Altingia excelsa</i>

Information on soil texture at the study site was obtained from soil map scale of 1: 100,000 and a field survey conducted on May 14th to May 15th, 2019. There were three types of soil in the study location, namely Latosol (Inseptisol), Litosol (Entisol) and Mediteran (Ultisol). Field checks were spread over each soil type, elevation and land use/cover. For latosol soil

types (inseptisol) there were 6 sample points, litosol (entisol) types had 6 sample points while mediterranean soil types (ultisol) had 9 sample points. Each sample point was assessed for soil type, soil texture and land use. Maps of soil types and distribution of sample points were presented in Figure 1.

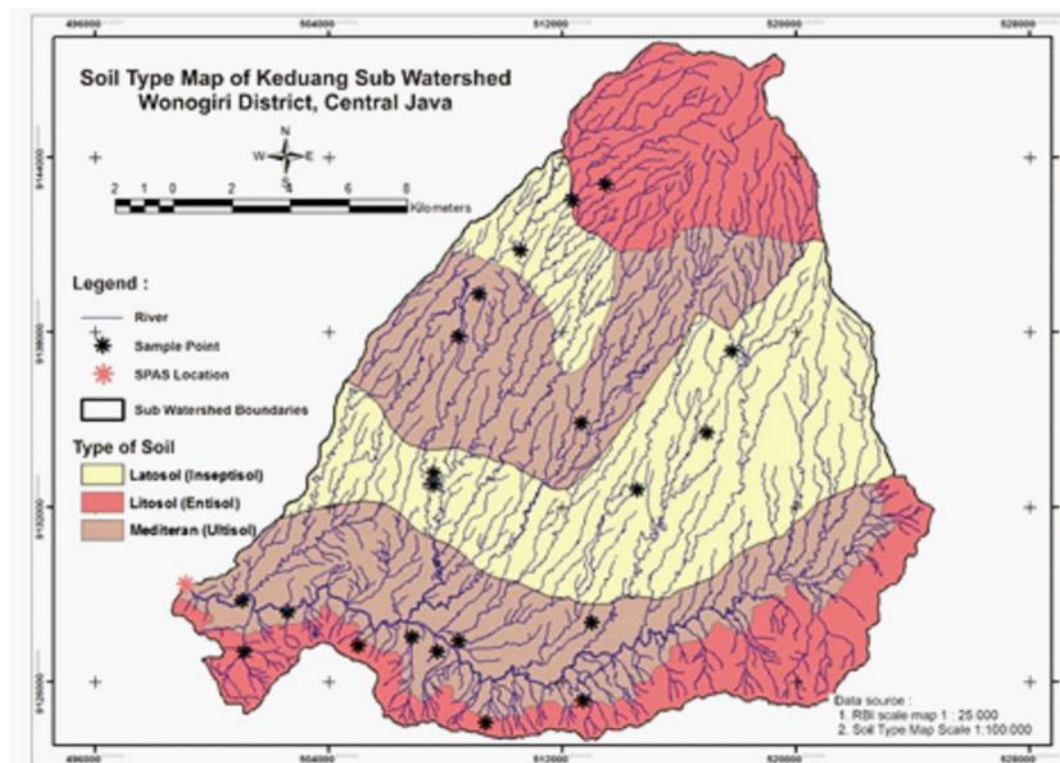


Figure 1 Soil Type Map and Distribution of Sample Point

Based on the results of field checking, the soil texture in the study location was grouped into 2 namely sandy and loam. Loam texture was found in mediterranean (ultisol) and latosol (Inceptisol) soil types, while sandy soil was found in lithosol (entisol) soils. The soil texture classification refers to the classification system of the United States Department of Agriculture (USDA) in 2010. According to Harjadi (2015) soil texture could be recognized and identified from physical characteristics in the field, such as sand-textured soil that would feel rough and difficult to form spheres, while loam-textured soil would feel smooth and easily formed spheres.

Soil texture in Keduang Sub-watershed consisted of Sandy Loam Loam (SCL), Silty Loam Loam (SiCL), Loam (L), Silty Loam (SiL), Silty Loam (SiC) and Sandy Loam

(SC). Loam texture (SCL, SiCL, SiC and SC) occupied the most extensive area in the Keduang Sub-watershed, which was 32,153.85 ha (87.5% of the total area of the Keduang Sub-watershed). Whereas sandy soil texture (L and SiL) occupied an area of 4,591.46 ha (12.49% of the total area of the Keduang watershed). The area of each type of soil in the Keduang watershed was presented in Table 3.

Based on Table 3, the Mediterranean (Ultisol) soil type occupied the most extensive area in the Keduang sub-watershed, which was 14,850.38 ha, while the Latosol (inceptisol) type occupied an area of 12,671.18 ha. Inceptisol soil types could be found in the equatorial region to the tundra region. Incepticol soil types were usually found on mountain slopes (USDA, 1999). According to Sutanto (2005), entisol soil types were

Table 3 Area of each soil type and soil texture

No.	Soil Type	USDA	Texture	Texture group	Area (Ha)
1	Litosol	Entisol	SCL,SiCL	Loam	4.632,29
2	Litosol	Entisol	L,SiL	Sandy	4.591,46
3	Mediterranean	Ultisol	SiC,SiCL	Loam	8.079,97
4	Latosol	Inceptisol	SiCL	Loam	1.857,52
5	Mediterranean	Ultisol	SC	Loam	6.770,41
6	Latosol	Inceptisol	SiC,SiCL	Loam	10.813,67
Area					36.745,31

Data source: soil type map and field check



Figure 2 Inceptisol Soil Type With Loam Texture



Figure 3 Entisol soil type with sandy texture

newly developed soils (young soils). Latosol (inceptisol) soil types with loam (loam) texture were presented in Figure 2. While lithosol (entisol) soil types with sandy (sandy) texture were presented in Figure 3.

B. Elevation

Elevation could affect the variability, distribution and structure of vegetation (Al-Robai, et al. 2018). According to Titshall et al. (2000), topographic factors consisting of elevation, aspects and slope were three topographic factors that greatly affect the distribution and pattern of vegetation in mountainous regions. Among these three factors, elevation was the dominant and most important factor in determining the distribution of vegetation. According to Oke and Thompson (2015), differences in elevation indicated differences in microclimates. In addition, elevation was often associated with local rainfall and temperature which were important factors for determining the

distribution of species in mountainous habitats. The elevation in the Keduang subwatershed was analyzed from contour map scale of 1: 25,000 with a contour interval of 12.5 m. Elevation was divided into 2 regions, namely lowlands (≤ 500 msl) and highlands (> 500 msl). The division of the elevation area was adjusted to the parameters used in the Rapid Investigation of the Selection of Private forests Tree Types for Farmers. The elevation map was presented in Figure 4. Based on the results of the area calculation, 66.8% of the Keduang subwatershed had an elevation of ≤ 500 msl (lowland). While highlands (> 500 msl) occupied an area of 12,207.29 ha (33.2% of the Keduang subwatershed area). According to Gebrehiwot et al (2019), species richness and distribution of plants at various heights could also be influenced by other factors such as intensity of management, anthropogenic disturbance and spatial diversity.

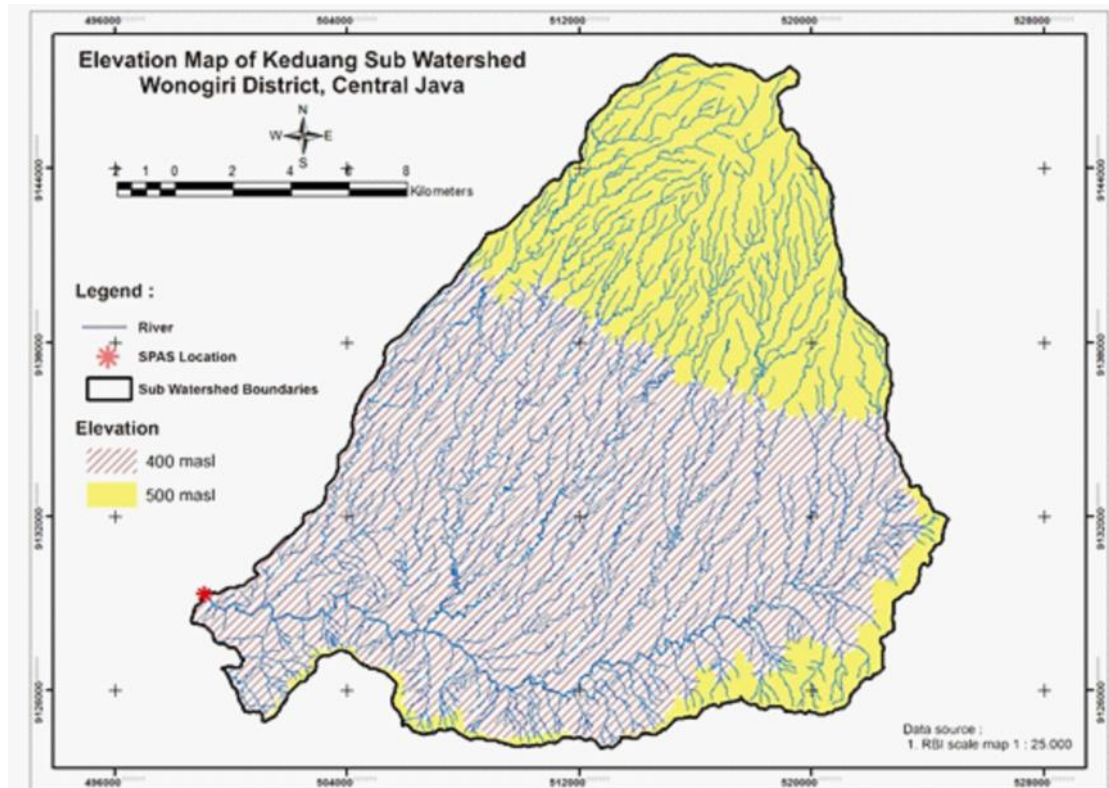


Figure 4 Elevation Map of Keduang Sub Watershed

C. Determination of Tree Types for Private Forest Development in the Keduang Sub-watershed

Determination of tree types for private forests development is based on the Quick Investigation of the Selection of Private forests Tree Types for Farmers. The parameters used are the cycle (age of production), elevation, soil type in this case the soil texture and type of production. The cycle (age of production) is divided into 2 namely short cycle (≤ 10 years) and long cycle (> 10 years), elevation is divided into 2 namely lowlands (≤ 500 msl) and highlands (> 500 msl), soil texture is divided into 3 namely sandy, loam and calcareous while the final type of production is wood producer and Multi-Purpose Tree Species (MPTS). The results of the analysis of determining short

and long-cycle productive trees for private forests development in the Keduang sub-watershed were presented in Table 4 and Table 5. Meanwhile, the spatial distribution for MPTS and wood-producing plants (short and long production cycles) in the Keduang sub watershed is presented in Figures 5 to 8.

For the purpose of developing plant or tree species on a large scale, it is necessary to consider several aspects of feasibility such as socially feasible, economically feasible and technically feasible. Farmers who already have experience with certain tree species (social aspects), tend to choose that type for further development (Hai & Huong, 2018). The development of plant species without considering social aspects can result in failure because farmers are not interested in managing these types of plants. Farmers'

lack of interest in managing certain types of crops could be due to the price being too low so that they do not benefit economically, or farmers do not understand the silvicultural technology yet. If the economic aspect is ignored, then the development of the plant will be in vain because it is not sold in the market. While the social aspect is not always related to the economic aspect, that is, even though the plant to be developed is of high value, however, farmers are not necessarily willing to develop the plant because they do not know the type. Meanwhile, the technical

aspect (mastery of silvicultural technology) is the aspect that determines plant productivity.

To maintain environmental stability, tree development needs to consider the tree harvesting cycle according to the landscape. Long-cycle trees harvesting should be planted in high land (upstream areas) because logging activities are rarely carried out, so they do not disturb the stability of the slopes, (Ranius et al., 2016). Multi Purpose Tree Speciest (MPTS) that produce fruit, latex and bark are suitable for planting in the upstream watershed area, because harvesting

Table 4 Types of wood-producing plants and MPTS for short production cycles (≤ 10 years) in the Keduang subwatershed

Soil type	Soil Texture	Elevation	Wood (short production cycle)	MPTS (short production cycle)	Area (ha)
Latosol	Loam	Lowland	A.mangium,Azadirachta indica A. Juss.,Melia azedarach L,Albizia chinensis,Alstonia scholaris,Gmelina arborea,Erythrina variegata, Duabanga moluccana, Hibiscus macrophyllus	Aleurites moluccana, Ceiba pentandra	8.600,66
Latosol	Loam	High Land	Azadirachta indica A. Juss.,Melia azedarach L,Albizia chinensis,Maesopsis,Alstonia scholaris,Gmelina arborea,Duabanga moluccana, Hibiscus macrophyllus, Erythrina variegata	Aleurites moluccana, Ceiba pentandra	0,63
Latosol	Loam	High Land	Azadirachta indica A. Juss.,Melia azedarach L,Albizia chinensis,Maesopsis,Alstonia scholaris,Gmelina arborea,Duabanga moluccana, Hibiscus macrophyllus, Erythrina variegata	Aleurites moluccana, Ceiba pentandra	2.212,37
Latosol	Loam	Lowland	A.mangium,Azadirachta indica A. Juss.,Melia azedarach L,Albizia chinensis,Alstonia scholaris,Gmelina arborea,Erythrina variegata, Duabanga moluccana, Hibiscus macrophyllus	Aleurites moluccana, Ceiba pentandra	352,38
Latosol	Loam	High Land	Azadirachta indica A. Juss.,Melia azedarach L,Albizia chinensis,Maesopsis,Alstonia scholaris,Gmelina arborea,Duabanga moluccana, Hibiscus macrophyllus, Erythrina variegata	Aleurites moluccana, Ceiba pentandra	1.505,14
Litosol	Sandy	Lowland	A.mangium,A.krasikarpa,Azadirachta indica A. Juss.,Melia azedarach L,Albizia chinensis,Alstonia scholaris,Gmelina arborea, Duabanga moluccana, Hibiscus macrophyllus, Erythrina variegata	Aleurites moluccana, Ceiba pentandra	2.678,93
Litosol	Sandy	High Land	Azadirachta indica A. Juss.,Melia azedarach L,Albizia chinensis,Alstonia scholaris,Gmelina arborea,Duabanga moluccana,Hibiscus macrophyllus,Erythrina variegata	Aleurites moluccana, Ceiba pentandra	13,58
Litosol	Sandy	High Land	Azadirachta indica A. Juss.,Melia azedarach L,Albizia chinensis,Alstonia scholaris,Gmelina arborea,Duabanga moluccana,Hibiscus macrophyllus,Erythrina variegata	Aleurites moluccana, Ceiba pentandra	66,78
Litosol	Sandy	High Land	Azadirachta indica A. Juss.,Melia azedarach L,Albizia chinensis,Alstonia scholaris,Gmelina arborea,Duabanga moluccana,Hibiscus macrophyllus,Erythrina variegata	Aleurites moluccana, Ceiba pentandra	260,72
Litosol	Sandy	High Land	Azadirachta indica A. Juss.,Melia azedarach L,Albizia chinensis,Alstonia scholaris,Gmelina arborea,Duabanga moluccana,Hibiscus macrophyllus,Erythrina variegata	Aleurites moluccana, Ceiba pentandra	1.571,46
Litosol	Loam	High Land	Azadirachta indica A. Juss.,Melia azedarach L,Albizia chinensis,Maesopsis,Alstonia scholaris,Gmelina arborea,Duabanga moluccana, Hibiscus macrophyllus, Erythrina variegata	Aleurites moluccana, Ceiba pentandra	4.632,29
Mediteran	Loam	Lowland	A.mangium,Azadirachta indica A. Juss.,Melia azedarach L,Albizia chinensis,Alstonia scholaris,Gmelina arborea,Erythrina variegata, Duabanga moluccana, Hibiscus macrophyllus	Aleurites moluccana, Ceiba pentandra	4.826,09
Mediteran	Loam	High Land	Azadirachta indica A. Juss.,Melia azedarach L,Albizia chinensis,Maesopsis,Alstonia scholaris,Gmelina arborea,Duabanga moluccana, Hibiscus macrophyllus, Erythrina variegata	Aleurites moluccana, Ceiba pentandra	1.944,32
Mediteran	Loam	Lowland	A.mangium,Azadirachta indica A. Juss.,Melia azedarach L,Albizia chinensis,Alstonia scholaris,Gmelina arborea,Erythrina variegata, Duabanga moluccana, Hibiscus macrophyllus	Aleurites moluccana, Ceiba pentandra	8.079,97
Total Area					36.745,31

the produce does not need to be cut down. Meanwhile, short-cycle trees are more suitable to be planted in the downstream area (lowland) because of the small impact of

forest product harvesting and soil processing activities.

The tree production cycle is positively correlated with financial benefits, the longer

Table 5 Types of wood-producing plants and MPTS for long production (> 10 years) cycles in the Keduang subwatershed

Soil Type	Soil Texture	Elevation	Wood (Long production Cycle)	MPTS (Long production Cycle)	Area (Ha)
Latosol	Loam	Lowland	<i>A. auriculiformis</i> , <i>Toona sinensis</i> , <i>Peronema canescens</i> , <i>Dalbergia latifolia</i> , <i>Pterocarpus indicus</i> , <i>Swietenia mahagoni</i> , <i>Khaya anthotheca</i> , <i>Schima wallichii</i>	<i>Hevea brasiliensis</i> , <i>Persea americana</i> , <i>Durio zibethinus</i> , <i>Artocarpus altitis</i> , <i>Manilkara kauki</i> , <i>Anacardium occidentale</i> , <i>Melaleuca leucadendra</i> , <i>Pangium edule</i>	8.600,66
Latosol	Loam	High land	<i>Magnolia champaca</i> , <i>Toona sinensis</i> , <i>Pterocarpus indicus</i> , <i>Senna siamea</i> , <i>Swietenia mahagoni</i> , <i>Schima wallichii</i> , <i>Khaya anthotheca</i> , <i>Agathis dammara</i> , <i>Pinus mercurii</i> , <i>Castanopsis argentea</i> , <i>Albizia procera</i>	<i>Elaeocarpus ganitrus</i> , <i>Styrax benzoin</i> Dryand, <i>Persea americana</i> , <i>Durio zibethinus</i> , <i>Artocarpus altitis</i> , <i>Arenga pinnata</i> , <i>Melaleuca leucadendra</i>	0,63
Latosol	Loam	High land	<i>Magnolia champaca</i> , <i>Toona sinensis</i> , <i>Pterocarpus indicus</i> , <i>Senna siamea</i> , <i>Swietenia mahagoni</i> , <i>Schima wallichii</i> , <i>Khaya anthotheca</i> , <i>Agathis dammarapinus</i> , <i>Castanopsis argentea</i> , <i>Albizia procera</i>	<i>Elaeocarpus ganitrus</i> , <i>Styrax benzoin</i> Dryand, <i>Persea americana</i> , <i>Durio zibethinus</i> , <i>Artocarpus altitis</i> , <i>Arenga pinnata</i> , <i>Melaleuca leucadendra</i>	2.212,37
Latosol	Loam	Lowland	<i>A. auriculiformis</i> , <i>Toona sinensis</i> , <i>Peronema canescens</i> , <i>Dalbergia latifolia</i> , <i>Pterocarpus indicus</i> , <i>Swietenia mahagoni</i> , <i>Khaya anthotheca</i> , <i>Schima wallichii</i>	<i>Hevea brasiliensis</i> , <i>Persea americana</i> , <i>Durio zibethinus</i> , <i>Artocarpus altitis</i> , <i>Manilkara kauki</i> , <i>Anacardium occidentale</i> , <i>Melaleuca leucadendra</i> , <i>Pangium edule</i>	352,38
Latosol	Loam	High land	<i>Magnolia champaca</i> , <i>Toona sinensis</i> , <i>Pterocarpus indicus</i> , <i>Senna siamea</i> , <i>Swietenia mahagoni</i> , <i>Schima wallichii</i> , <i>Khaya anthotheca</i> , <i>Agathis dammara</i> , <i>Pinus mercurii</i> , <i>Castanopsis argentea</i> , <i>Albizia procera</i>	<i>Elaeocarpus ganitrus</i> , <i>Styrax benzoin</i> Dryand, <i>Persea americana</i> , <i>Durio zibethinus</i> , <i>Artocarpus altitis</i> , <i>Arenga pinnata</i> , <i>Melaleuca leucadendra</i>	1.505,14
Litosol	Sandy	Lowland	<i>A. auriculiformis</i> , <i>Toona sinensis</i> , <i>Peronema canescens</i> , <i>Dalbergia latifolia</i> , <i>Pterocarpus indicus</i> , <i>Swietenia mahagoni</i> , <i>Schima wallichii</i> , <i>Khaya anthotheca</i>	<i>Hevea brasiliensis</i> , <i>Persea americana</i> , <i>Durio zibethinus</i> , <i>Artocarpus altitis</i> , <i>Manilkara kauki</i> , <i>Anacardium occidentale</i> , <i>Melaleuca leucadendra</i> , <i>Pangium edule</i>	2.678,93
Litosol	Sandy	High land	<i>Swietenia mahagoni</i> , <i>Khaya anthotheca</i> , <i>Schima wallichii</i> , <i>Agathis dammara</i> , <i>Toona sinensis</i> , <i>Castanopsis argentea</i> , <i>Altingia excelsa</i>	<i>Elaeocarpus ganitrus</i> , <i>Styrax benzoin</i> Dryand, <i>Persea americana</i> , <i>Durio zibethinus</i> , <i>Artocarpus altitis</i> , <i>Arenga pinnata</i> , <i>Melaleuca leucadendra</i>	13,58
Litosol	Sandy	High land	<i>Swietenia mahagoni</i> , <i>Khaya anthotheca</i> , <i>Schima wallichii</i> , <i>Agathis dammara</i> , <i>Toona sinensis</i> , <i>Castanopsis argentea</i> , <i>Altingia excelsa</i>	<i>Elaeocarpus ganitrus</i> , <i>Styrax benzoin</i> Dryand, <i>Persea americana</i> , <i>Durio zibethinus</i> , <i>Artocarpus altitis</i> , <i>Arenga pinnata</i> , <i>Melaleuca leucadendra</i>	66,78
Litosol	Sandy	High land	<i>Swietenia mahagoni</i> , <i>Khaya anthotheca</i> , <i>Schima wallichii</i> , <i>Agathis dammara</i> , <i>Toona sinensis</i> , <i>Castanopsis argentea</i> , <i>Altingia excelsa</i>	<i>Elaeocarpus ganitrus</i> , <i>Styrax benzoin</i> Dryand, <i>Persea americana</i> , <i>Durio zibethinus</i> , <i>Artocarpus altitis</i> , <i>Arenga pinnata</i> , <i>Melaleuca leucadendra</i>	260,72
Litosol	Sandy	High land	<i>Swietenia mahagoni</i> , <i>Khaya anthotheca</i> , <i>Schima wallichii</i> , <i>Agathis dammara</i> , <i>Toona sinensis</i> , <i>Castanopsis argentea</i> , <i>Altingia excelsa</i>	<i>Elaeocarpus ganitrus</i> , <i>Styrax benzoin</i> Dryand, <i>Persea americana</i> , <i>Durio zibethinus</i> , <i>Artocarpus altitis</i> , <i>Arenga pinnata</i> , <i>Melaleuca leucadendra</i>	1.571,46
Litosol	Loam	High land	<i>Magnolia champaca</i> , <i>Toona sinensis</i> , <i>Pterocarpus indicus</i> , <i>Senna siamea</i> , <i>Swietenia mahagoni</i> , <i>Schima wallichii</i> , <i>Khaya anthotheca</i> , <i>Agathis dammarapinus</i> , <i>Castanopsis argentea</i> , <i>Albizia procera</i>	<i>Elaeocarpus ganitrus</i> , <i>Styrax benzoin</i> Dryand, <i>Persea americana</i> , <i>Durio zibethinus</i> , <i>Artocarpus altitis</i> , <i>Arenga pinnata</i> , <i>Melaleuca leucadendra</i>	4.632,29
Mediterranean	Loam	Lowland	<i>A. auriculiformis</i> , <i>Toona sinensis</i> , <i>Peronema canescens</i> , <i>Dalbergia latifolia</i> , <i>Pterocarpus indicus</i> , <i>Swietenia mahagoni</i> , <i>Khaya anthotheca</i> , <i>Schima wallichii</i>	<i>Hevea brasiliensis</i> , <i>Persea americana</i> , <i>Durio zibethinus</i> , <i>Artocarpus altitis</i> , <i>Manilkara kauki</i> , <i>Anacardium occidentale</i> , <i>Melaleuca leucadendra</i> , <i>Pangium edule</i>	4.826,09
Mediterranean	Loam	High land	<i>Magnolia champaca</i> , <i>Toona sinensis</i> , <i>Pterocarpus indicus</i> , <i>Senna siamea</i> , <i>Swietenia mahagoni</i> , <i>Schima wallichii</i> , <i>Khaya anthotheca</i> , <i>Agathis dammarapinus</i> , <i>Castanopsis argentea</i> , <i>Albizia procera</i>	<i>Elaeocarpus ganitrus</i> , <i>Styrax benzoin</i> Dryand, <i>Persea americana</i> , <i>Durio zibethinus</i> , <i>Artocarpus altitis</i> , <i>Arenga pinnata</i> , <i>Melaleuca leucadendra</i>	1.944,32
Mediterranean	Loam	Lowland	<i>A. auriculiformis</i> , <i>Toona sinensis</i> , <i>Peronema canescens</i> , <i>Dalbergia latifolia</i> , <i>Pterocarpus indicus</i> , <i>Swietenia mahagoni</i> , <i>Khaya anthotheca</i> , <i>Schima wallichii</i>	<i>Hevea brasiliensis</i> , <i>Persea americana</i> , <i>Durio zibethinus</i> , <i>Artocarpus altitis</i> , <i>Manilkara kauki</i> , <i>Anacardium occidentale</i> , <i>Melaleuca leucadendra</i> , <i>Pangium edule</i>	8.079,97
Total Area					36.745,31

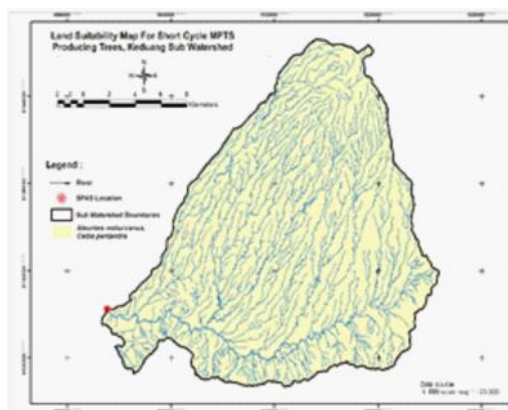


Figure 5 Map of land suitability for MPTS, Short production cycle

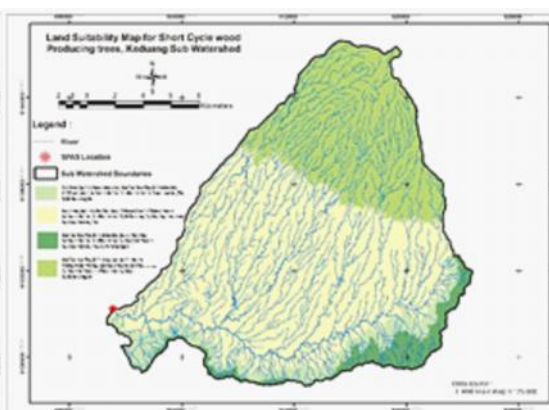


Figure 6 Map of land suitability for wood, Short production cycle

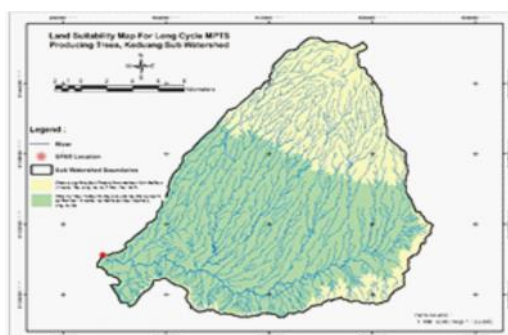


Figure 7 Map of land suitability for MPTS, long production cycle

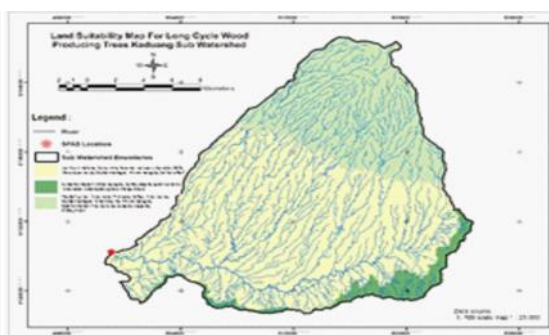


Figure 8 Map of land suitability for wood, long production cycle

of tree production cycle, the financial benefits will be higher (Nakajima et al., 2017) However, trees with short production cycles are preferred by farmers because they produce more quickly, even though the profits are small. Based on these considerations, in the high land (upstream area) of the Keduang subwatershed which has loam soil texture, long production cycle trees and high economic value can be developed, including *Swietenia macrophylla*, *Manglietia glauca*, *Altingia excelsa* and *Schima wallichii*. MPTS plants, species such as *Elaeocarpus ganitrus*, *Persea americana*, *Durio zibethinus*, *Arenga pinnata*, *Artocarpus altilis* can be planted. Lowland areas in the Keduang subwatershed where the soil texture is loam, high economic value trees with short cycles

can be planted, including *Albizia chinensis*, *Acacia mangium*, *Gmelina arborea*, *Neolamarckia cadamba*, and *Alstonia scholaris*. Determination of the crop cycle is actually very closely related to economic predictions where the optimal cycle is defined as a comparison between maintenance costs and the economic value of tree stand growth (P³otkowski et al., 2016). Farmers with a limited area usually prefer to choose short-cycle plants, while farmers who have large areas can freely combine long and short-cycle plants (Pradesh et al., 2015).

Based on Table 4, *Aleurites moluccana* and *Ceiba pentandra* are suitable for planting in all areas of the Keduang subwatershed. *Aleurites moluccana* and *Ceiba pentandra* are wood and non-timber producing trees

(MPTS) with short production cycles (≤ 10 years). Meanwhile, wood producing trees with short production cycles (≤ 10 years), such as *A. mangium*, *Azadirachta indica* A. Juss., *Melia azedarach* L, *Albizia chinensis*, *Alstonia scholaris*, *Gmelina arborea*, *Erythrina variegata*, *Duabanga moluccana* and *Hibiscus macrophyllus* can be planted in the Lowland area with texture loam. Lowland area with sandy texture it is suitable for plants such as *A. mangium*, *A. krasikarpa*, *Azadirachta indica* A. Juss., *Melia azedarach* L, *Albizia chinensis*, *Alstonia scholaris*, *Gmelina arborea*, *Duabanga moluccana*, *Hibiscus macrophyllus* and *Erythrina variegata*.

CONCLUSIONS

The Keduang sub watershed has an area of 36,745.31 ha. The Mediterranean soil type (Ultisol) occupies the largest area in the Keduang sub watershed, which is 14,850.38 ha (40.41%) of the total area of the Keduang sub watershed. While the Latosol soil types (Inceptisol) and Litosol (Entisol) occupy an area of 12,671.18 ha and 9,223.74 ha, respectively. The soil texture in the Keduang sub watershed is dominated by loam, covering an area of 32,153.85 ha, while the rest is sandy. Based on contour map analysis, 66.8% of the Keduang sub watershed area has an altitude of ≤ 500 masl (Lowland), while the rest is > 500 masl (high land). *Aleurites moluccana* and *Ceiba pentandra* are MPTS tree species with short production cycles that are suitable for planting throughout the Keduang sub-watershed. Types of wood-producing trees with short production cycles that are suitable for the study site is *Acacia mangium*, *Azadirachta*

indica A. Juss. (*Azadirachta indica* A. Juss), *Melia azedarach* L (*Melia azedarach*), *Albizia chinensis* (*Paraserianthes falcataria*), *Alstonia scholaris* (*A. scholaris*), *Gmelina arborea* (*Gmelina arborea*), *Erythrina variegata* (*Erythrina variegata moluccana*), *Dua*) and *Hibiscus macrophyllus* (*Hibiscus macrophyllus*).

Suggestion

Several factors that need to be considered in the development of private forests are social feasibility factors, economic feasibility factors and technical feasibility factors.

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