Spodosols of East Kalimantan: Land Cover Disturbances Induced Degradation of Soil Properties

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Spodosols of East Kalimantan:
Land Cover Disturbances Induced Degradation of Soil Properties

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ABSTRACT
Spodosols are mineral soils derived from sandy to loamy sand parent materials developed under humid or wetter climate condition. Soils are coarse in texture, the acid in reaction and low in water and nutrient retention. In addition, these soils are characterized by a spodic horizon associated with the presence of fragipan or duripan layers at varying depth, limiting not only the growth of plant roots but also water and air availability and movement. The fertility of these soils relies on the SOM of the A layer of the soils. Any disturbance to these soils' land cover may lead to irreversible degradation of soil properties and productivity. Vegetation found on the disturbed lands is mostly pioneer species, *Imperata cylindrica* and fern (*Pteridophyta* sp). Two land cover types, namely natural secondary forest and plantation forest in Semboja District, East Kalimantan, were selected for this study. This study aims to determine Spodosols' properties – morphological, physical and chemical properties – induced by land cover change. For each land cover type, three soil profiles were established for the soil morphological property determination, and eight soil samples were drawn for the soil physical and chemical property analysis. The results show that compared to the soil in natural secondary forest, spodosols soil of plantation forest underwent loss of A horizon, bleaching of E horizon, soil compaction and fine particle leaching enhancement, especially in E layers. Furthermore, land cover disturbances intensify soil acidification and C- and N-organic decomposition.

Keywords: *Spodosols, Parent Materials, Leaching, Acidification.*

1. INTRODUCTION

Spodosols are soil formed from coarse and sour sand or clay. This soil is characterized by the presence of a spodic B horizon or an accumulated horizon of organic and aluminium amorphous materials, with or without iron [1]. Spodosols are widespread in cold, temperate or wet climates. The widest spread is found in Russia, Northern Europe and Canada [2]. In Indonesia, Spodosols' total area is estimated at 2.16 million ha or 1.1% of the Indonesian land area [3]. Although the area only reaches 1.1% of Indonesia's land area, Spodosols are essential because this land is classified as problematic for agricultural land, including the development of plantation forests.

Unspoiled spodosols are land that has a variety of endemic plant species that must be protected, which are "kantung semar" (*Nephentes*) and black orchids (*Coelogyne pandurata*), which are known to grow well on Spodosols soil. At least 36 types of plants live in the soil of Spodosols, which can be used as medicinal ingredients [4]. As a place of extreme growth, making plants that live on Spodosols land transform into a specific vegetation community and can produce secondary metabolites that are the basis of treatment ingredients.

Spodosols that have been burned twice will be very difficult to return to their original form. As a result of community observations, only *Imperata cilindrica* can live in the Spodosols area, which has been repeatedly burned. Therefore, Spodosols' land clearing must be considered carefully to anticipate undesirable possibilities such as erosion, landslides and so on.

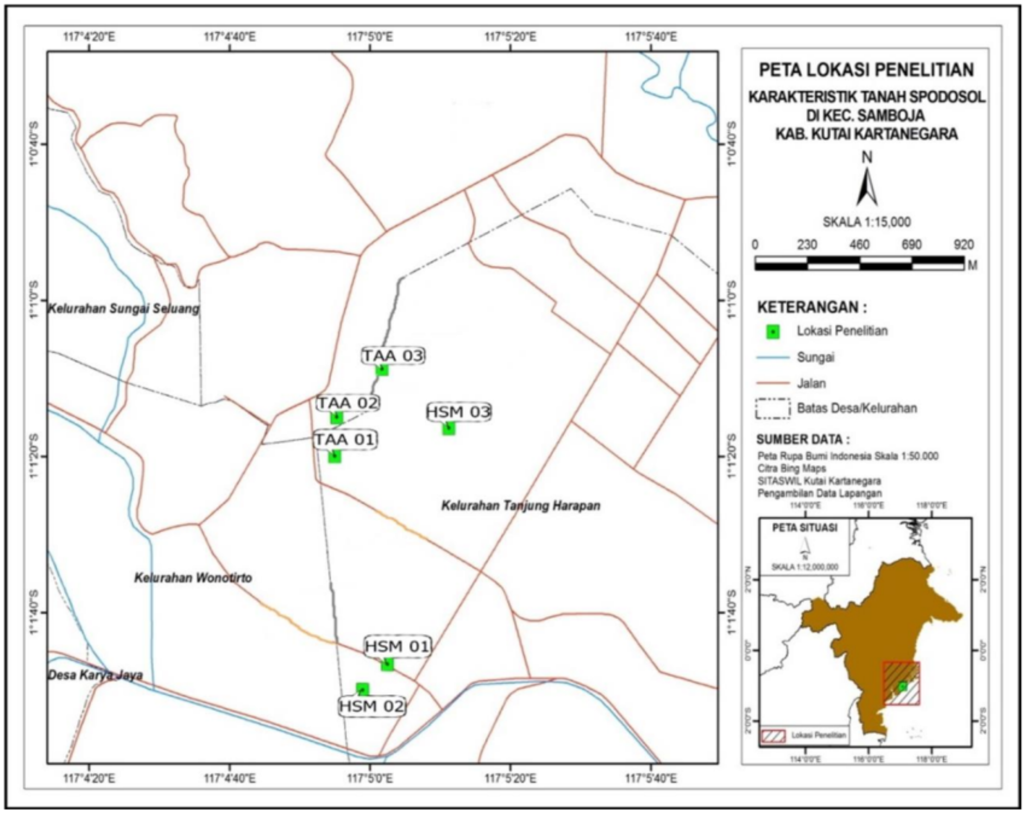

Figure 1 Map of research locations in Samboja, Kutai Kartanegara Regency, East Kalimantan

Spodosols land with natural forest vegetation that is already open either intentionally or due to fire is as difficult to recover as before. Visually several types can still grow on the land, one of which is *Acacia auriculiformis*. This plant can grow well in damaged soil conditions due to its ability to nitrogen fixation. Acacia auriculiformis is also quite tolerant of environmental stress in bare, clay, high-salt soils or inundated soils [5]. Based on this description, research was conducted to determine the characteristics of the soil of Spodosols grown with Acacia auriculiformis compared to the soil character with its natural vegetation.

2. MATERIALS AND METHODS

2.1. Study Area

The study was carried out in Samboja, Kutai Kartanegara Regency, East Kalimantan Province. The area is geographically located at coordinates 116°50' – 117°14' East Longitude and 0°52'-1°08'South Latitude (Figure 1).

2.2. Procedures

Six pedon Spodosols have been used in this study. Three pedons are on the land with stands of Acacia auriculiformis (TAA-01, TAA-02, TAA-03). The rest are in Secondary Forests (HSM-01, HSM-02, HSM-03). The vegetation cover difference is expected to provide a clearer picture of the morphological, physical and chemical properties of disturbed and intact Spodosols. Assuming the three pedons for each vegetation are the same, only Pedon TAA-01 and Pedon HSM-01 will be sampled in a composite manner from 4 points in the Research Measure Plots (PUP) in the soil layer with depth 0-10 cm> 10-20 cm> 20-50 cm and> 50 cm.

A total of 6 soil samples were taken in the field and analyzed for physical and chemical properties in the laboratory. Observation of soil morphological properties in the field was carried out following the instructions of the Soil Survey Manual [6] and land classification following the Land Taxonomy System [7].

Table 1. Some morphological properties of Spodosols from Samboja, East Kalimantan

Types of Stands	Horizon	Depth (cm)		Color	Structure	Consistency	Texture
Acacia auriculiformis Stands	TAA-01 Typic Duraquods						
	E1	0 - 10	10YR8/2	White	Single grained	Not sticky	Sand
	E2	- 15	10YR8/1	White	Solids	Not sticky	Sand
	Bh	- 48	7,5YR7/1	Black	Solids	Not sticky	Sand
	Bhs	- 72	10YR7/6	Brown	Solids	Not sticky	Sand
	C	- 140	10YR8/1	White	Single grained	Not sticky	Sand
	TAA-02 Typic Fragiaquods						
	E1	0 - 30	10YR8/2	White	Single grained	Not sticky	Sand
	Bh	- 69	7,5YR7/1	Black	Solids	Not sticky	Sand
	C	- 143	10YR8/1	White			
	TAA-03 Typic Duraquods						
	E1	0 - 20	10YR8/1	White	Single grained	Not sticky	Sand
	E2	- 31	10YR8/2	White	Solids	Not sticky	Sand
	Bh	- 120	10YR7/6	Reddish brown	Solids	Not sticky	Sand
	Bhs	- 160	7,5YR7/1	Black	Solids	Not sticky	Sand
Secondary Forest	HSM-01 Typic Duraquods						
	A	0 - 10	10YR4/2	Gray dark brown	Single grained	Not sticky	Loamy Sand
	E1	- 43	10YR6/2	Light gray	Single grained	Not sticky	Sand
	E2	- 60	10YR8/1	White	Solids	Not sticky	Sand
	Bh	- 120	7,5YR7/1	Black	Solids	Not sticky	Sand
	HSM-02 Typic Placiaquods						
	E	0 - 25	10YR6/1	Light gray	Single grained	Not sticky	Sand
	Bh	- 55	7,5YR7/1	Black	Solids	Not sticky	Sand
	Bhs	- 71	10YR7/6	Reddish brown	Solids	Not sticky	Sand
	C	- 120	10YR6/2	Light gray	Single grained	Not sticky	Sand
Secondary Forest	HSM-03 Typic Fragiaquods						
	A	0 - 13	10YR4/1	Gray dark brown	Single grained	Not sticky	Sand
	E	- 23	10YR5/1	Dark gray	Single grained	Not sticky	Sand
	Bh	- 45	10YR7/6	Dark Brown	Solids	Not sticky	Sand
	Bhs	- 88	7,5YR17/1	Black	Solids	Not sticky	Sand
	C	- 140	10YR6/2	Light gray	Single grained	Not sticky	Sand

Table 2. Texture, BD of Spodosols from Samboja, Kutai Kartanegara, East Kalimantan

Depth (cm)	BD (g/cm³)		Sand (%)		Silt (%)		Clay (%)		Tekstur	
	TAA	HSM	TAA	HSM	TAA	HSM	TAA	HSM	TAA	HSM
0 - 10	1.50	1.42	78.95	53.92	17.54	31.68	3.51	14.40	Loamy sand	Sandy loam
- 20	1.52	1.43	76.03	59.39	17.12	30.46	6.85	10.15	Loamy sand	Sandy loam
- 50	1.40	1.48	61.58	68.00	21.34	24.89	17.08	7.11	Sandy loam	Sandy loam
> 50	1.54	1.46	56.04	69.29	39.07	26.87	4.88	3.84	Sandy loam	Sandy loam
Average	1.49	1.44	68.15	62.65	23.76	28.47	8.08	8.87		

Table 3. Some chemical properties of Spodosols from Samboja, East Kalimantan

Depth	pH H_2O		pH KCl		C (%)		N (%)		C/N		P Tersedia (ppm)		K Tersedia (ppm)	
(cm)	TAA	HSM	TAA	HSM	TAA	HSM	TAA	HSM	TAA	HSM	TAA	HSM	TAA	HSM
0 - 10	5.22	4.84	4.43	4.14	1.77	2.48	0.13	0.15	13.62	16.53	20.05	21.00	89.60	151.10
- 20	4.79	5.61	4.59	3.44	1.91	1.21	0.12	0.13	15.92	9.31	22.91	18.14	93.80	112.20
- 50	3.90	5.13	3.08	4.26	5.32	1.64	0.18	0.13	29.56	12.62	28.64	17.19	188.30	162.80
> 50	4.21	4.63	3.07	3.96	6.9	3.21	0.15	0.14	46.00	22.93	27.69	26.73	141.90	149.80
Average	4.53	5.05	3.79	3.95	3.98	2.14	0.15	0.14	26.28	15.35	24.82	20.77	128.40	143.98

Table 4. Interchangeable Cations of Spodosols from Samboja, East Kalimantan

Depth (cm)	Ca (cmol kg-1)		Mg (cmol kg-1)		K (cmol kg-1)		Na (cmol kg-1)		CEC (cmol kg-1)	
	TAA	HSM	TAA	HSM	TAA	HSM	TAA	HSM	TAA	HSM
0 - 10	0.844	0.988	0.209	0.174	0.139	0.171	0.113	0.106	1.96	3.96
- 20	0.982	0.742	0.226	0.274	0.14	0.149	0.063	0.09	1.96	2.72
- 50	1.319	3.604	0.43	0.266	0.164	0.127	0.077	0.092	7.52	4.32
> 50	1.580	1.009	0.401	0.257	0.147	0.156	0.096	0.059	3.48	2.60
Average	1.181	1.586	0.317	0.243	0.148	0.151	0.087	0.087	3.73	3.40

Physical and chemical properties analysis consisted of soil texture analysis with pipette method, BD with the gravimetric method, pH (H_2O and KCl), Organic Carbon with [8], N total with Kjedahl, P2O5 and K2O extracted by Bray 1, Ca, Mg, K, Na and Cation Exchange Capacity (CEC) with a saturation of NH4OAc 1N pH 7. The soil physics and chemical analysis was determined following the method in the [9]. Evaluation of soil chemical properties follows the procedures commonly used by the Soil Research Center and Agroclimate [10].

3. RESULTS AND DISCUSSION

3.1. Soil Morphology and Classification

Several morphological and soil classification properties according to the Land Taxonomy system [7] are presented in Table 1.

Spodosols with *Acacia auriculiformis* vegetation appear to have an E-B-C horizon arrangement with varying horizon thickness. Horizon E-albic (alluviation) ranges from 15-31 cm, and the Solids layer, i.e. the Bh and Bh horizons, range from 39-129 cm. While Spodosols in Secondary Forest, the horizon arrangement is A-E-B-C except for Pedon HSM-02, which does not have an A horizon. The horizon thickness range from 10-13 cm, horizon E ranges from 23-50 cm, and horizon B ranges from 46-65 cm.

The E-albic horizon in Spodosols in white colours in Acacia auriculiformis stands in the secondary Secondary Forest light grey. The colour of the B-spodic horizon for both is reddish-brown to black. [11] found the same thing for Spodosols in Central Kalimantan. The upper layer covering horizons A and E1 is sandy to clay sand, single grained and not sticky. Furthermore, the layer below is a layer of Solids which includes horizon E2, Bh and Bhs.

The three pedons studied with *Acacia auriculiformis* have albic horizons characterized by colour values eight and chroma 2 to 1. In contrast, in Secondary Forests, the value horizon is smaller, 6 and 5, with chroma 1. Besides, the six pedons studied have a spodic horizon at a depth of <200 cm, with a hue of 7.5 YR, value 7, chroma 1. Thus the six pedons studied fulfilled the requirements to be classified as Spodosols and included in the suborder of aquods.

Pedon TAA-02 and HSM-03 have albic horizons which form a hard layer and are easily destroyed when soaked in water. This characteristic is an indication that the layer is fragmented so that the land in both pedons is classified as Typic Fragiaquods [7]. Furthermore, other pedons, except for pedon HSM-02, because the hard layer is not destroyed if submerged in water or form a durian layer, pedons are classified as Typic Duraquods. Pedon HSM-02 has a weak hard layer that does not break if soaked in water, so that the pedon is classified as Typic Placiaquods.

3.2. Physical and Chemical Soil Properties

Soil samples that are taken and composted are then analyzed in a laboratory presented in Table 2, Table 3 and Table 4.

Spodosols that have been disturbed and overgrown with *Acacia auriculiformis* have greater Bulk Density (BD) than those in Secondary Forests, which is 1.49 g/cm3 compared to 1.44 g/cm^3. Soil Spodosols are still included in the range that is still in the value of mineral soils in general, namely 1.10-1.60 g/cm^3 [12]. This is in line with sand fraction, especially for the top 20 cm layer, with Spodosols overgrown with *Acacia auriculformis* having a coarser texture, namely Loamy sand compared to sandy loam in Spodosols with Secondary Forest vegetation. But for layers > 20 cm, both have the same texture, namely loamy sand. Based on the percentage in Table 2, the sand fraction dominates at all the representative points of both Spodosols overgrown with *Acacia auriculiformis* (TAA) with a percentage of 68.15% and 62.65% in Secondary Forests (HSM).

In Table 3, some chemical analysis results have been presented previously. Spodosols in the study area reacted slightly sour to very acidic, with pH values of 3.90 to 5.61. The spodosols' pH value grown with *Acacia auriculiformis* (TAA) ranged from 3.90 to 5.22, with the highest value in the 0-10 cm layer, which was 5.22 and the lowest in the -50 cm layer, which was 3.90. Simultaneously, the pH in Secondary Forest (HSM) ranged from 4.63 to 5.61, with the highest value at the -50 cm layer, which is 5.61 and the lowest at the> 50 cm layer, which is 4.63.

Organic Carbon content appears to vary in each layer of soil spodosols overgrown with Acacia auriculiformis and Secondary Forest. In Spodosols soil overgrown with *Acacia auriculiformis*, the Organic Carbon content increases with the increase in the depth of the soil layer> 50 cm has the highest organic carbon content, which is 6.90%, while the lowest organic Carbon content is in the 0-10 cm layer which is 1.77%. While the highest Secondary Forest Organic Carbon content is at> 50 cm layer, which is 3.21%, and the lowest is in the 10-20 cm layer with 1.21% value. The C/N comparison value on Spodosols soil overgrown with *Acacia auriculiformis* ranged from 13.62 to 46.00, whereas in Secondary Forests ranging from 9.31 to 22.93.

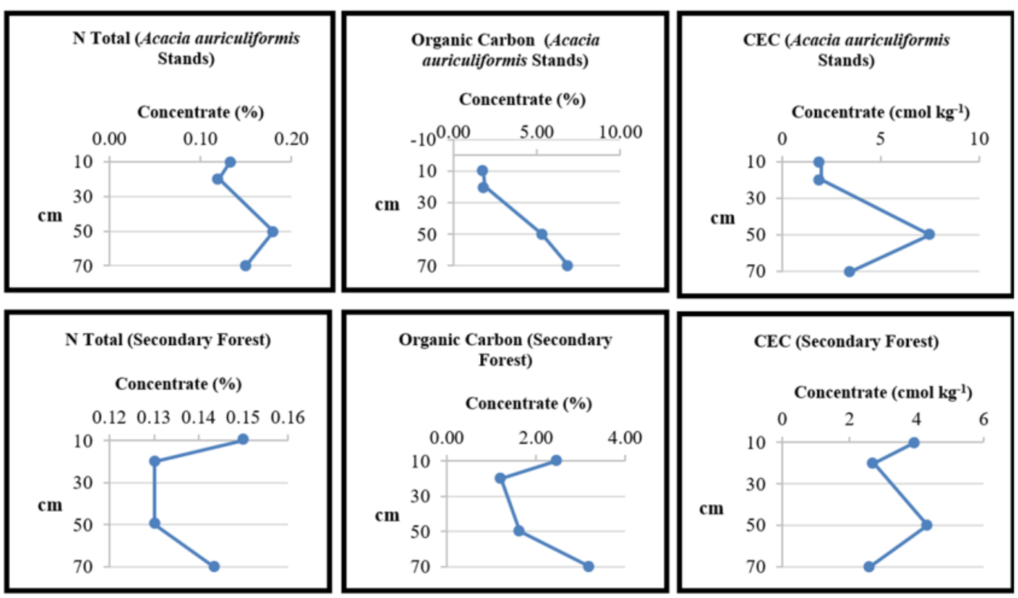

Figure 2 Pattern of Organic Carbon Concentration, Total N and Cation Exchange Capacity (CEC) of Spodosols Soil which are overgrown with *Acacia auriculiformis* and Secondary Forest

Table 5. Results of inventory of stand on Spodosols Soil overgrown with *Acacia auriculiformis* (TAA) and Secondary Forest (HSM) in Samboja, East Kalimantan

Code	No	Species	Diameter (cm)	Height (m)	Code	No	Species	Diameter (cm)	Height (m)
TAA-01	1	*Acacia auriculiformis*	17.50	6.00	HSM-01	1	*Acacia auriculiformis*	12.10	4.00
	2	*Acacia auriculiformis*	15.50	7.00		2	*Shorea* sp.	15.28	5.00
	3	*Acacia auriculiformis*	17.10	7.00		3	*Piper aduncum* L.	12.10	4.00
	4	*Acacia auriculiformis*	19.00	8.00		4	*Anacardium ocidentale*	17.51	5.00
	5	*Acacia mangium*	15.20	7.00		5	*Acacia auriculiformis*	21.96	5.00
	6	*Acacia auriculiformis*	18.10	6.00		6	*Acacia mangium*	14.64	6.00
	7	*Acacia mangium*	17.50	6.00		7	*Piper aduncum* L.	16.23	4.00
	8	*Acacia mangium*	18.40	5.00	Average			15.69	5.27
Average			17.29	6.50	HSM-02	1	*Terminalia catapa*	14.64	5.00
TAA-02	1	*Acacia auriculiformis*	15.50	6.00		2	*Acacia auriculiformis*	18.14	7.00
	2	*Acacia auriculiformis*	17.10	7.00		3	*Shorea* sp.	15.28	5.00
	3	*Acacia auriculiformis*	18.40	7.00		4	*Piper aduncum* L.	12.04	4.00
	4	*Acacia auriculiformis*	19.00	8.00		5	*Anacardium ocidentale*	16.55	5.00
	5	*Acacia mangium*	15.20	6.00		6	*Acacia auriculiformis*	20.69	5.00
	6	*Acacia auriculiformis*	17.50	6.00		7	*Acacia auriculiformis*	19.10	7.00
	7	*Acacia auriculiformis*	18.10	6.00		8	*Acacia auriculiformis*	14.96	6.00
	8	*Acacia auriculiformis*	20.60	7.00	Average			16.42	5.50
	9	*Acacia auriculiformis*	16.20	7.00	HSM-03	1	*Acacia auriculiformis*	14.96	5.00
Average			17.51	6.67		2	*Acacia mangium*	12.10	4.00
TAA-03	1	*Acacia auriculiformis*	20.60	7.00		3	*Acacia auriculiformis*	15.28	5.00
	2	*Acacia auriculiformis*	21.60	7.00		4	*Terminalia catappa*	18.14	6.00
	3	*Acacia auriculiformis*	16.80	7.00		5	*Anacardium ocidentale*	18.78	7.00
	4	*Acacia auriculiformis*	14.30	6.00		6	*Acacia mangium*	16.55	6.00
	5	*Acacia auriculiformis*	20.00	6.00		7	*Shorea* sp.	18.14	6.00
	6	*Acacia auriculiformis*	20.60	6.00		8	*Acacia auriculiformis*	16.23	5.00
	7	*Acacia auriculiformis*	18.10	6.00	Average			16.27	5.50
	8	*Acacia mangium*	14.90	5.00					
	9	*Acacia auriculiformis*	19.00	8.00					
Average			18.43	6.44					

Both observation plots (soil of spodosols overgrown with *Acacia auriculiformis* and Secondary Forest) showed P and K's value varied from low to high. Same as Organic Carbon content, on soil, Spodosols overgrown with Acacia auriculiformis have P and K available values increasing as soil depth increases. The highest P-value for Spodosols grown with *Acacia auriculiformis* was 27.69 ppm, and the lowest was 20.05 ppm. Whereas in the Secondary Forest, the Available P-value varied, the highest at a depth of >50 cm, i.e. 26.73 ppm and the lowest at a depth of -50 cm, 17.19 ppm. The highest available K content at -50 cm depth is 162.80 ppm, and the lowest at -20 cm depth is 112.20 ppm.

The content of base cations and Cation Exchange Capacity (CEC) in soil samples taken and analyzed in the laboratory are presented in Table 4. The values of exchangeable cations such as Ca, Mg, K and Na are low to very low in all layers and observation plots with values of Ca, Mg, K and Na respectively on spodosols overgrown with *Acacia auriculiformis* are 1,181 cmol kg-1 ; 0,317 cmol kg-1; 0,148 cmol kg-1 and 0,087 cmol kg-1, whereas in Secondary Forests have values of Ca, Mg, K and Na respectively 1,586 cmol kg-1; 0,243 cmol kg-1; 0,151 cmol kg-1 and 0,087 cmol kg-1. Cation Exchange Capacity (CEC) value is classified as low to very low, namely 1.96 to 7.52 cmol kg-1 in spodosols that are overgrown with *Acacia auriculiformis* and 2.60 to 4.32 cmol kg-1 in Secondary Forests.

3.3. Stands Growth

Inventory data from the field shows that the average tree diameter and stand conditions, and tree height vary widely. The results of the inventory can be seen in Table 5. Based on the inventory of standing trees in the research plot (Spodosols grown with *Acacia* *auriculiformis* and Secondary Forest) in Table 5, the mean height and diameter of trees were higher in Spodosols overgrown with *Acacia auriculiformis* compared to Secondary Forests. This is because *Acacia* is a type that can grow well in damaged soil conditions, with the ability to nitrogen fixation in bare, cluttered land, high salinity soil or soil that is submerged in water, in bare land, clay, high salinity or soil saturated [5]. Even though the growth of vegetation in Secondary Forests is no better than Spodosols overgrown with *Acacia auriculiformis*, the species in Secondary Forests are more diverse. *Shorea* sp., *Terminalia catappa* and cashew (*Anacardium ocidentale*) are also found in the area.

4. CONCLUSION

The morphology of Spodosols soil in Secondary Forest has horizon A and has a darker horizon colour surface (grey-brown 10YR4/2), whereas, on soil that is overgrown with *Acacia auriculiformis* directly on E-albik horizon, B-spodik and C and soil washing occurs more intensively with 10 YR7/4 colour notation to 10 YR 7/2. Physically, Spodosols in Secondary Forests and overgrown soil *Acacia auriculiformis* are both sandy and Sandy loam with solids soil structure and non-sticky consistency, slightly acidic to very acidic soil reaction, moderate to low nutrient content, reserves low to deficient nutrient levels and low to very low CEC, dominated by sand fractions which indicate less potential as agricultural land. Spodosols' low nutrient has, it is better if the stand above it is not cut down and used as a protected or conservation area.

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