

# Spatial distribution and habitat characteristics of *Macadamia hildebrandii* in the Sintuwu Maroso Protection Forest, Central Sulawesi, Indonesia

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**Abstract.** Akhbar, Nuryanti S, Naharuddin. 2020. *Spatial distribution and habitat characteristics of Macadamia hildebrandii* in the Sintuwu Maroso Protection Forest, Central Sulawesi, Indonesia. *Biodiversitas* 21: 770-779. Research on the spatial distribution of *Macadamia hildebrandii* Steen (*haleka*) tree species is one of the important stages in the preservation of Sulawesi's endemic plants. The purpose of this research was to obtain information regarding the spatial distribution of *M. hildebrandii* in the area of Sintuwu Maroso Forest Management Unit, Central Sulawesi and the relationship between its occurrence with habitat characteristics in term of land and climate variables. Data was collected by establishing sampling plots using stratified systematic sampling based on land cover, namely primary and secondary dryland forests. Index of dispersion was used to calculate the distance between population while the chi-square test was used to investigate the relationship between *M. hildebrandii* population and variables of land and climate. The results showed that the *M. hildebrandii* trees mostly grew in the mountain rain zone ecosystem, clumped in groups according to the characteristics of the dominant natural habitat. The important characteristics of its habitat were it had red-yellow podzolic-lithosol soil type, altitude of  $\geq 1,500$  m asl, slope class of  $\geq 25\%$ , middle slope aspect, tinea volcano rock formation (which is volcanic sedimentary rocks), metamorphic parent material, secondary dryland forests, and rainfall of 1,600-2,000 mm/year. The results of study can be used as baseline information for the conservation and sustainable utilization, including cultivation, of *M. hildebrandii* especially in the montane zone of rain forest ecosystem in Sulawesi.

**Keywords:** Haleka, *Macadamia hildebrandii*, spatial distribution and mountain rain zone

## INTRODUCTION

Indonesia is known for its vast extent of natural forests and a center of world biodiversity especially plant diversity (Astirin 2000). These forests not only provide environmental goods in the form of timber and non-timber products but also deliver ecosystem services (Mac Kinnon 1992). Central Sulawesi Province is one of the regions in Indonesia with state forest area reaching 4.27 million hectares or equal to 65.24% of the province's land area. Spatial distribution and other ecological knowledge is a valuable reference for forest assessment and improve our knowledge by the identification of ecologically (Almulqu et al. 2018).

Macadamia is a genus from the Proteaceae family, consisting of eight plant species and spreading in eastern Australia with 7 species and Sulawesi with 1 species, which is *M. hildebrandii* Steen. *M. hildebrandii* is a small to large tree with height 6-40 meters, the leaves are 6-30 cm long and 2-13 cm wide, the flowers are 10-15 mm with white to purple color, and the fruit has one or two seeds. In the North Lore sub-district, Poso District, Central Sulawesi Province, *M. hildebrandii* is locally known as "haleka". The timber of this species is used for building materials as well as its parts are quite good as raw materials for pulp in terms of fiber dimensions, specific gravity and chemical

components (Siagian and Silitonga 1988). The seeds of this plant could also be eaten like walnut seeds (Hartini and Sahroni 2016) as well as its fruit is palatable (Lukman and Silitonga 1989).

Study showed the dominance of *M. hildebrandii* trees in the mountainous forest areas of the Protection Forest Management Unit (PFMU) for unit X (Sintuwu Maroso) of Central Sulawesi which was indicated with the high Importance Value Index (IVI) (Forest Area Consolidation Centre Region XVI Palu 2018). This is likely caused by the conditions of the habitat deemed suitable for the growth of this species as habitat characteristics influence species abundance (Pribadi 2009).

Spatial distribution of the *M. hildebrandii* tree species dominating the PFMU for unit X (Sintuwu Maroso) natural forest is one of the important stages in the efforts to preserve this Sulawesi's endemic plant, both in their natural habitat (*in-situ*) and in-situ outside their habitat (*ex-situ*). This is because plant distribution patterns is required in order to effectively manage a conservation area (Abywijaya et al. 2014).

The purpose of this research was to obtain information regarding spatial distribution of *M. hildebrandii* in the area of Sintuwu Maroso Forest Management Unit, Central Sulawesi, Indonesia and the relationship between its occurrence with habitat characteristics in term of land and

climate variables. The results of study were expected as baseline information for the conservation and sustainable utilization, including cultivation, especially in the montane zone of rain forest ecosystem in Sulawesi.

## MATERIALS AND METHODS

### Study area and period

This study was conducted in Protection Forest (PF) and Limited Production Forest (LPF) of the Sintuwu Maroso Protection Forest Management Unit (PFMU) X regions of Central Sulawesi in the sub-districts of North Lore, East Lore, South Lore and North Poso Pesisir, Poso District, from January to April 2018 (Figure 1).

### Data collection procedure

Data was collected by establishing sampling plots using stratified systematic sampling with random start (Figure 2, left). The area to sample was stratified based on land cover, namely primary and secondary dryland forests. The sampling intensity was 0.056% with the distance between plots was 3 x 3 km. The allocation of the number of sampling plots into each stratum was carried out proportionally by considering its size, for example a large stratum was given a large number of sampling plots.

Sample plots established in dryland forests were in the form of square-shaped cluster sized 100 m x 100 m with five circular plots with size of 0.1 ha (rad = 17.8 m) placed at each corner and the centre of each cluster, reducing the

cluster area to be 0.5 ha (Figure 2, right). Plot numbering in each cluster was done clockwise, where Plot 1 was at the southwest corner while Plot 5 was at the cluster midpoint. The centre point of Plot 1 was also called the cluster centre point.

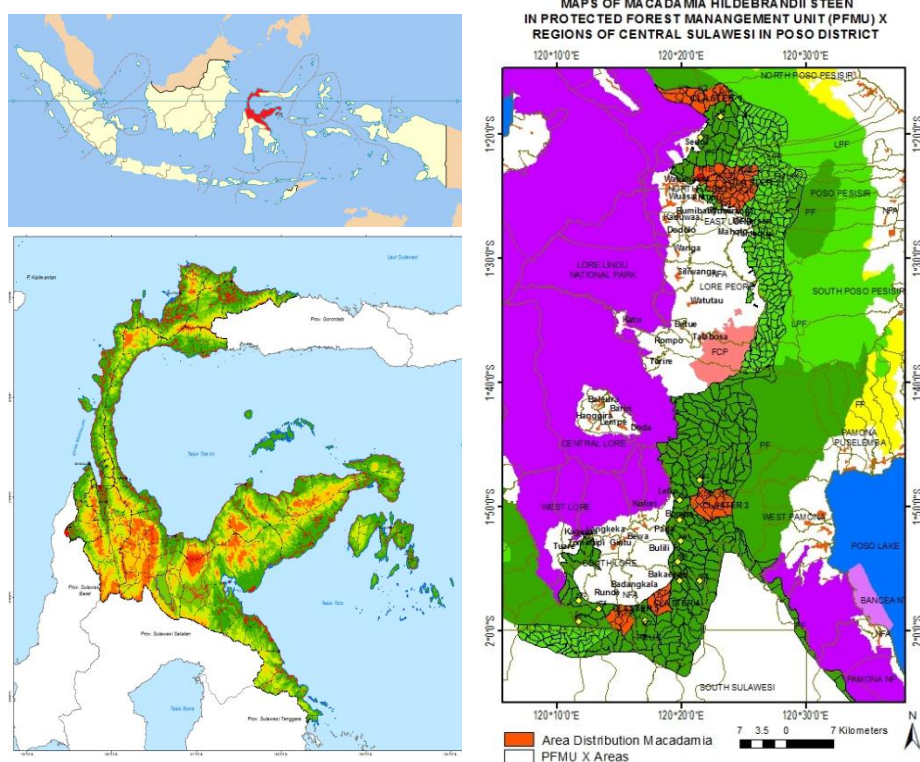
Using the inventory data, the spatial analysis of the *M. hildebrandii* distribution pattern was done by taking into account the characteristics of its habitat, with input data including Government Administration Maps, Watershed Areas, Indonesian Earth Forms, Slope Classes, Forest Ecosystem Zones, Soil Types, Land Systems, Geology, Rainfall Zone, Forest Zone, and Land Cover. *M. hildebrandii* tree occurrence and vegetation data were collected during the inventory survey in January-February 2018 using Global Positioning System (GPS), Roll meters, Cameras, Clinometers, Hagameter, Compass, Raffia ropes, Tally sheets, maps of forest inventory plans, and stationery. In the spatial analysis phase of the *M. hildebrandii* tree distribution, we used Landsat 8 path images/114-61 records 2016-2017, images@2017 DigitalGlobe, map data@2017google, and digital maps.

### Data analysis

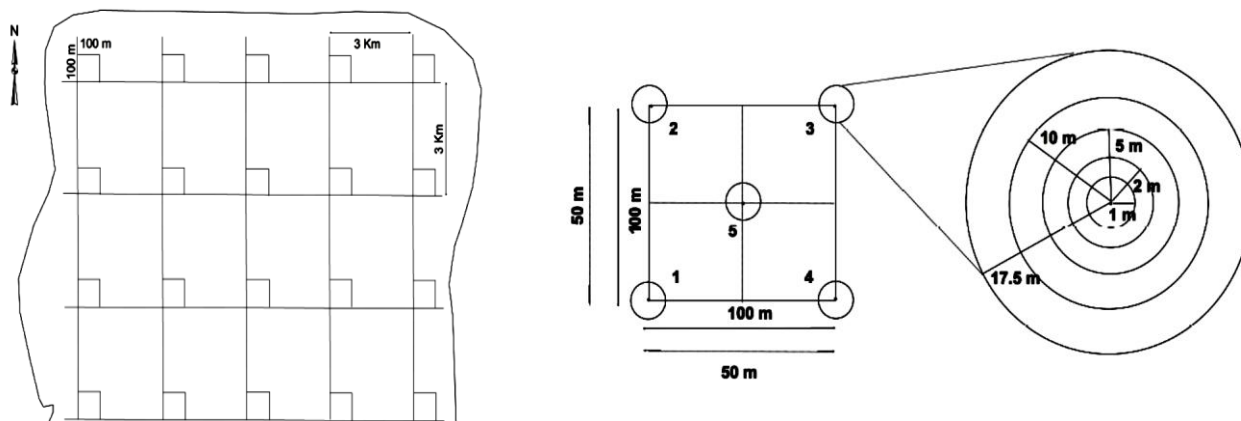
The distance index value of dispersion ( $I_d$ ) (Ludwig et al. 1988) was calculated using formula as follows,

$$I_d = S^2/\bar{X}$$

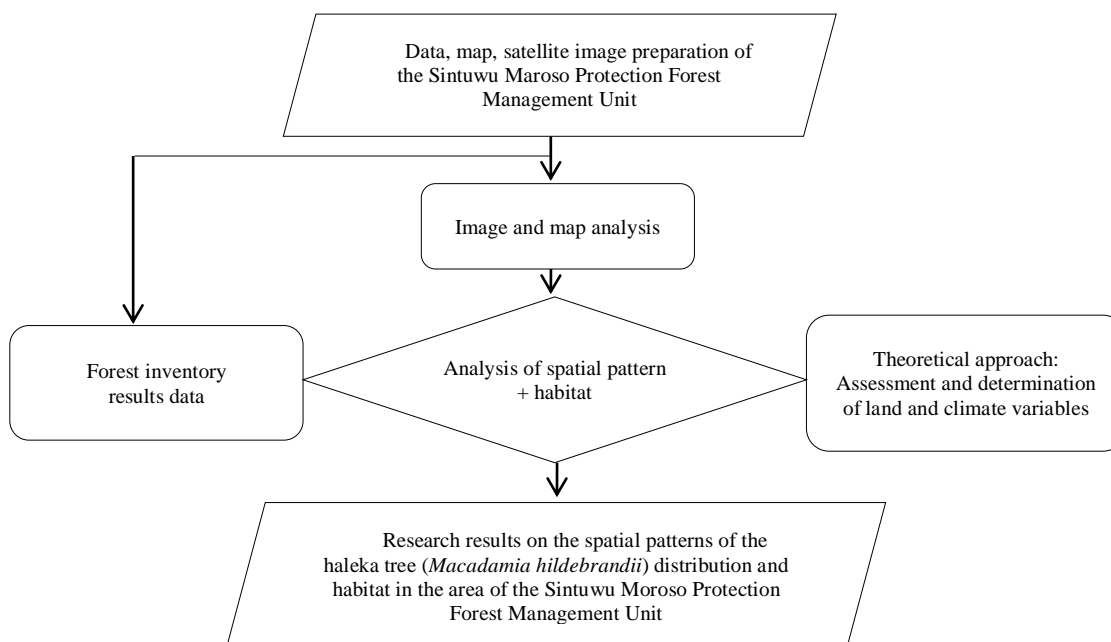
where  $I_d$  = dispersion index,  $S^2$  = variance, and  $\bar{X}$  = average. Species distribution is considered as random if  $I_d = 1$ , uniform if  $I_d < 1$  and clumped if  $I_d > 1$ .



**Figure 1.** The area of study in the Sintuwu Maroso Protection Forest, Central Sulawesi, Indonesia



**Figure 2.** Sampling design for data collection (*left*); diagram of 100 m x 100 m square-shaped cluster design and plot sampling (*right*) (Forest Area Consolidation Centre Region XVI Palu 2018)



**Figure 3.** Analytical framework used in this research

The relationship between the distribution pattern of *M. hildebrandii* tree species with the characteristics of the habitat was tested using the *chi-square* distribution test ( $\chi^2$ ) with contingency table (2 x 2) and the degree of relationship between one factor and another (Sudjana 2005). This spatial analysis is relatively the same as the analysis of species spatial distribution model.

Species distribution model has been widely used in ecology and biogeography. This model is also known as the habitat suitability model by using various environmental predictors to model the spatial distribution of species across landscapes or ecoregions. This model can understand species' ecological requirements and predict habitat suitability (Segurado and Araújo 2004; Moisen and Frescino 2002; Hirzel et al. 2002; Araújo and Peterson 2012; Yudaputra et al. 2019). The analytical framework used in this study is presented in Figure 3.

## RESULTS AND DISCUSSION

### Population, location and habitat characteristics of *Macadamia hildebrandii* trees

The results of the inventory of *M. hildebrandii* in Sintuwu Maroso Protection Forest Management Unit of Central Sulawesi showed that there were 558 individuals of *M. hildebrandii* across 60 plots in 12 sample clusters (each of which had five plots). This species dominated the observation cluster by 50% of 1,116 trees out of 133 species of natural forest trees. There were nine other dominant species of forest trees after *M. hildebrandii* species, namely damar (*Agathis celebica* (Koord) Warb.), betau (*Calophyllum inophyllum* L.), Kondongia (*Dysoxylum caulostachyum* Miq.), poli (*Quercus* sp.), Dopi (local name), kapa (*Camptostemon philipinensis* Becc.), lebotu (*Duabanga moluccana* Blume), boko (*Palaquium*

*obtusifolium* Burck.), and marambabulu (*Celtis philippinensis* Blanco). This condition demonstrates that Sintuwu Maroso Protection Forest is rich in species of natural forest trees, and *M. hildebrandii* that dominated the location can be associated with other species. Bhandari et al. (2015) stated that species richness and biodiversity enhance above ground productivity although the productivity differs according to environmental conditions and plant physiology.

According to the forest management plan developed by the Sintuwu Maroso Protection Forest Management Unit, the 12 clusters were located in the core and utilisation blocks of protection forest as well as in protection blocks and community empowerment blocks in limited production forest. Administratively, it was located in Sedoa and Alitupu villages (North Lore sub-district), Kilo village (North Poso sub-district), Winowanga and Mekarsari villages (East Lore sub-district), and Bomba, Pada, Bakekau and Badangkaia villages (South Lore sub-district). Based on watersheds, it was located in the Lariang watershed.

There were 11 land and climate variables used to characterize *M. hildebrandii*'s habitat conditions, including land cover, vegetation density, altitude, slope class, slope aspect, land system, soil type, geology, ecosystem type, the morphology of watershed and rainfall/precipitation.

It appears that the distance between trees in a circle plot on average was 6.49-38.93 meters with an average number of trees 3-17 trees per cluster. The distance between clusters was 3 km in which each cluster had rectangular shape. A complete description of the location and condition characteristics of the *M. hildebrandii* tree species in the Sintuwu Maroso Protection Forest Management Unit is presented in Table 1.

#### Spatial distribution pattern of *Macadamia hildebrandii* trees

Spatial analysis of the distribution pattern of *M. hildebrandii* trees both in the protected forest and limited production forest of the Sintuwu Maroso Protection Forest Management Unit resulted index of dispersion (Id) of 6.57. According to Ludwig et al. (1988), if the value of Id > 1, then the distribution is clumped as in the case of *M. hildebrandii* tree distribution in the study area. The analysis of map data and Landsat 8 satellite imagery recorded in 2017 showed that the distance between K3 in Cluster 1 and K18 in Cluster 2 was 12.27 km, the distance between K25 in Cluster 2 and K57 in Cluster 3 was 45.02 km, the distance between K56 in Cluster 3 and K71 in Cluster 4 was 16.11 km and the distance between K71 in Cluster 4 and K76 in Cluster 5 was 6.81 km.

The location of each cluster group indicated that the *M. hildebrandii* trees spread within cluster groups. Figure 4 below shows the distribution pattern of *M. hildebrandii* trees in five cluster groups.

The map of *M. hildebrandii* predicted distribution within each cluster group in forest management block in the Sintuwu Maroso Protection Forest Management Unit is presented in Figure 5.

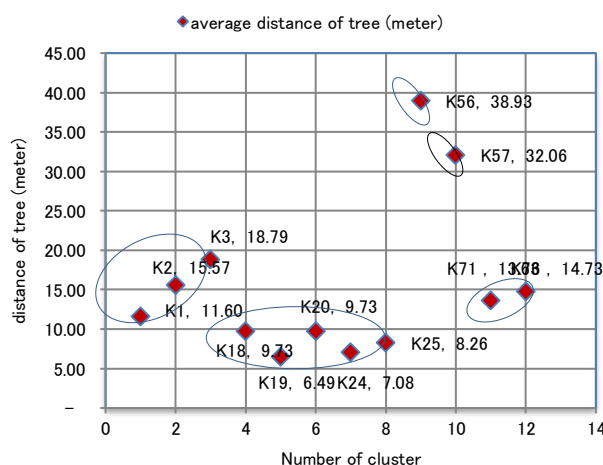
#### The relationships between *M. hildebrandii* distribution and habitat characteristics

The relationship between *M. hildebrandii* tree distribution and habitat characteristics was assessed using

the chi-squared distribution test ( $\chi^2$ ) with contingency table (2 x 2). The distribution was analysed based on the level of population density (i.e. low, medium, and high) while the habitat characteristics were analysed based on the level or type of land and climate variables. The variables of land and climate included cluster location, altitude, slope, aspect, geology, land system, soils, land cover, ecosystem zones, and rainfall. However, the variables of geology, land system and soils were excluded from the chi-square analysis because there were land parameters with a value of 0 (zero).

The results of analysis on seven parameters of land and climates showed that there was relationship between the spatial distribution of *M. hildebrandii* trees based on density level and habitat characteristics in the natural forests of the protected forest and limited production forest in the Sintuwu Maroso Protection Forest Management Unit in Central Sulawesi. The chi-square ( $\chi^2$ ) test results are presented in Table 2.

Table 2 shows that of the seven land and climate variables, rainfall and land cover had no significant effect on the 5% test level. In the test of the inter-variable relationship degree, only the variable of cluster location had a relatively high degree of relationship with the density of *M. hildebrandii*, while the others had a small degree of relationship. This means that the level of density of the *M. hildebrandii* tree is influenced by the location where it grows. The observed clusters were on the north (Clusters 1 and 2) which was far ( $\pm 45$  km) from the south ones (Clusters 3, 4, and 5), with densities of *M. hildebrandii* were 450 and 108 trees/hectare, respectively. The high density of in the north was likely due to its mountain rain zone, supported by a diversion of land and climate variables such as altitude, rainfall, geological type, aspects, and slope class. Thus, the more diverse parameters of land and climate will greatly affect the *M. hildebrandii* trees distribution pattern. Shin et al. (2017) stated the incorporation of topological properties will be useful for identifying biotic and abiotic effects on the spatial distribution of plants.



**Figure 4.** Average distance of *Macadamia hildebrandii* tree in the clusters

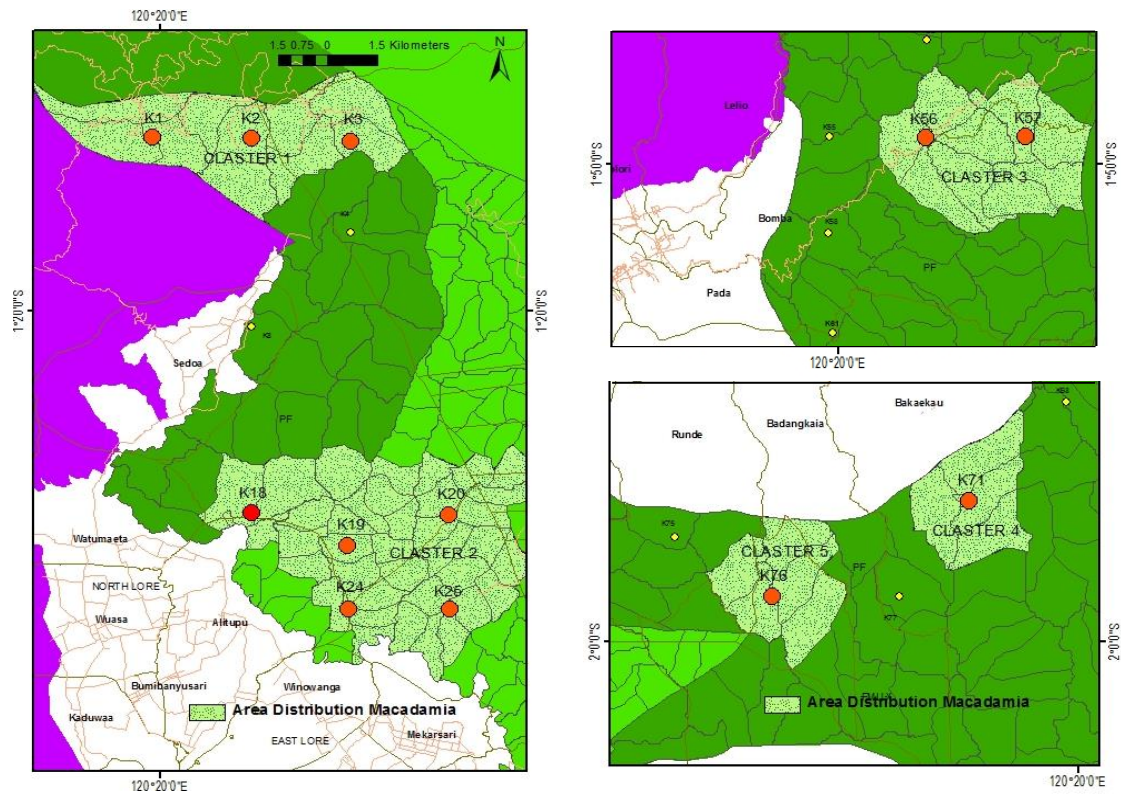


Figure 5. Map of *Macadamia hildebrandii* tree predicted distribution in the management blocks of Sintuwu Maroso Protection Forest Management Unit, Central Sulawesi, Indonesia

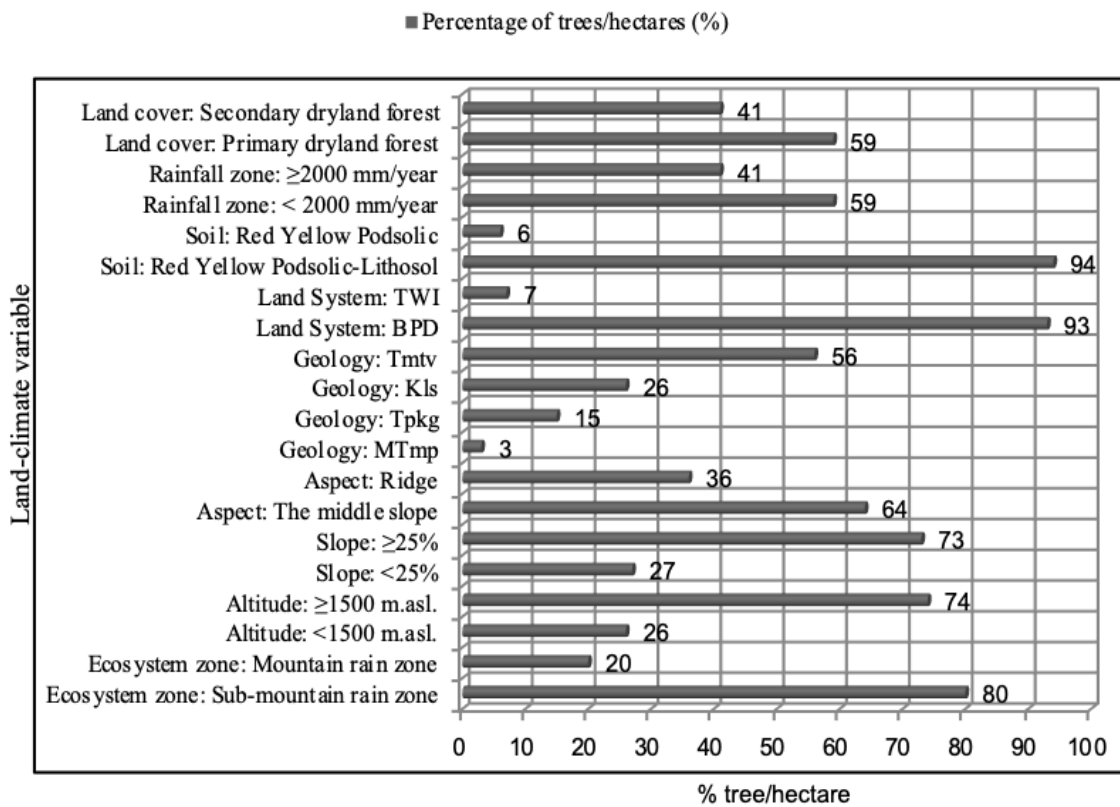


Figure 6. The composition of *Macadamia hildebrandii* trees population based on land and climate variables

**Table 1.** Results of identification of location, habitat characteristics and density of *Macadamia hildebrandii* trees

Location code	District/village	Forest functions	Management block	Coordinate location	The total number of trees (trees/ha)	Number of trees (trees/ha)	Land cover	Vegetation density	Average number of (trees/hectares (ha <sup>-1</sup> ))*
Cluster group 1					222	111			
K1	North Lore/Sedoa	Protected forest	Core block	120° 19' 52.59" E; 1° 16' 59.90" S	94	47	Secondary dryland forest	High	9.40
K2	North Lore/Sedoa	Protected forest	Core block	120° 21' 29.58" E; 1° 17' 00.20" S	70	35	Secondary dryland forest	Medium	7.00
K3	North Poso Pesisir/Kilo	Protected forest	Utilisation block	120° 23' 06.34" E; 1° 17' 04.62" S	58	29	Secondary dryland forest	Medium	5.80
Cluster group 2					678	339			
K18	North Lore/Alitupu	Protected forest	Utilisation block	120° 21' 29.69" E; 1° 23' 30.77" S	112	56	Primary dryland forest	High	11.20
K19	North Lore/Alitupu	Limited production forest	Block of community empowerment	120° 23' 04.47" E; 1° 24' 02.83" S	168	84	Secondary dryland forest	High	16.80
K20	East Lore/Wino-wanga	Limited production forest	Protection block	120° 24' 43.07" E; 1° 23' 30.66" S	112	56	Primary dryland forest	High	11.20
K24	East Lore/Wino-wanga	Limited production forest	Block of community empowerment	120° 23' 05.90" E; 1° 25' 08.18" S	154	77	Primary dryland forest	High	15.40
K25	East Lore/Mekarsari	Limited production forest	Block of community empowerment	120° 24' 43.04" E; 1° 25' 08.10" S	132	66	Secondary dryland forest	High	13.20
Cluster group 3					62	31			
K56	South Lore/Bomba	Protected forest	Utilisation block	120° 21' 26.58" E; 1° 49' 31.33" S	28	14	Secondary dryland forest	Low	2.80
K57	South Lore/Pada	Protected forest	Utilisation block	120° 23' 04.30" E; 1° 49' 32.21" S	34	17	Primary dryland forest	Low	3.40
Cluster groups 4					80	40			
K71	South Lore/Bakekau	Protected forest	Core block	120° 18' 12.26" E; 1° 57' 39.86" S	80	40	Primary dryland forest	High	8.00
Cluster groups 5					74	37			
K76	South Lore/Badang-kaia	Protected forest	Core block	120° 14' 57.83" E; 1° 59' 16.99" S	74	37	Primary dryland forest	Medium	7.40
Sum					1116	558			

**Table 1.** Results of identification of location, habitat characteristics and density of *Macadamia hildebrandii* trees (con't)

Location code	Average distance of trees/hectare (m ha <sup>-1</sup> )	Description	Land system	Altitude (m asl)	Slope	Aspect	Type of soil	Geology	Rainfall (mm/year)	Type of ecosystem	Morphology of watershed
Cluster group 1											
K1	12	Clumped	BPD	1870	25-<40%	Middle slope	Red-yellow podzolic-lithosol	Tpkg	1800-2000	Mountain rain zone	Upstream
K2	16	Clumped	BPD	1739	>=40%	Ridge	Red-yellow podzolic-lithosol	Kls	1600-1800	Mountain rain zone	Upstream
K3	19	Clumped	BPD	1905	25-<40%	Ridge	Red-yellow podzolic-lithosol	Kls	1600-1800	Mountain rain zone	Upstream
Cluster group 2											
K18	10	Clumped	BPD	1323	25-<40%	Middle slope	Red-yellow podzolic-lithosol	Tmtv	1600-1800	Sub-mountain rain zone	Upstream
K19	6	Clumped	BPD	1597	25-<40%	Middle slope	Red-yellow podzolic-lithosol	Tmtv	1800-2000	Mountain rain zone	Upstream
K20	10	Clumped	BPD	1779	15-<25%	Ridge	Red yellow podsolic-lithosol	Kls	2000-2200	Mountain rain zone	Upstream
K24	7	Clumped	BPD	1530	15-<25%	Middle slope	Red-yellow podzolic-lithosol	Tmtv	1800-2000	Mountain rain zone	Upstream
K25	8	Clumped	BPD	1694	25-<40%	Ridge	Red-yellow podzolic-lithosol	Kls	2000-2200	Mountain rain zone	Upstream
Cluster group 3											
K56	39	Clumped	BPD	1273	>=40%	Middle slope	Red-yellow podzolic-lithosol	Kls	2200-2400	Sub-mountain rain zone	Upstream
K57	32	Clumped	BPD	1830	8-<15%	Ridge	Red-yellow podzolic-lithosol	Mtmp	2000-2200	Mountain rain zone	Upstream
Cluster groups 4											
K71	14	Clumped	BPD	1294	>=40%	Middle slope	Red-yellow podzolic-lithosol	Tmtv	2400-2600	Sub-mountain rain zone	Upstream
Cluster groups 5											
K76	15	Clumped	TWI	1404	>=40%	Middle slope	Red-yellow podzolic-lithosol	Tpkg	2200-2400	Mountain rain zone	Upstream
Sum											

Note: BPD (Bukit Pandan); TWI (Telawi); Tpkg (kambuno granite); Tmtv (tinebavolcanics rocks); Kls (latimojong formation); MTmp (pompangeo complex). \*) average number of trees per plot in a cluster (5 plots / cluster).

**Table 2.** The relationship between *Macadamia hildebrandii* tree density and habitat characteristics the Sintuwu Maroso Protection Forest Management Unit, Central Sulawesi, Indonesia

Population density	Variables Land & climate variables	Degree of freedom (DF)	Statistic value ( $\chi^2$ )	Yates correction ( $\chi^2$ )	Critical value $\chi^2$ -table	$\alpha_{5\%}$	Degree of relationship		
							C	Cmax	
Tree density: 2 levels:	Cluster location: 2 groups (Cluster 1+2; Cluster 3+4+5)	1	114.57	111.89	3.84	Significant	0.413	0.707	Appreciable
	Low-medium density: <40 trees/ hectare;	1	13.46	12.65	3.84	Significant	0.153	0.707	Small
High density: $\geq 40$ trees/ hectare.	Altitude (m. asl.): 2 levels (<1500; $\geq 1500$ )	1	3.48	3.07	3.84	Not significant	0.079	0.707	Small
	Rainfall zone (mm/year): 2 levels (<2000; $\geq 2000$ )	1	17.25	16.33	3.84	Significant	0.173	0.707	Small
	Slope class: 2 levels (<25%; $\geq 25\%$ )	1	0.49	0.36	3.84	Not significant	0.030	0.707	Small
	Land cover: 2 levels (primary dryland forest; secondary dryland forest)	1	46.63	45.23	3.84	Significant	0.278	0.707	Small
	Aspect: 2 levels (The middle slope; Ridge)	1	9.06	8.32	3.84	Significant	0.126	0.707	Small
	Ecosystem zone: 2 levels (Sub-mountain rain zone; Mountain rain zone)	1							

Note: The division of parameters into two levels on each variable of land and climate was aimed to meet the statistical analysis requirements in the chi-square test ( $\chi^2$ ). The classification of *M. hildebrandii* tree density per hectare is based on field data

In a more detailed spatial analysis, there were pattern which likely associated with land and climatic variables (Figure 6). Based on ecosystem zone, 80% of *M. hildebrandii* populations grew in the mountain rain zone while 20% grew in the sub-mountain rain zone. According to altitude, 74% were found at an altitude of  $\geq 1,500$  masl while 26% were at of <1,500 masl. Based on slope class, 73% were recorded on slope class of  $\geq 25\%$ , while 27% were on that of <25%. In term of slope aspect, 64% grew on the middle slope, while 36% on the upper slope (ridge). Our results strengthen the findings by Whitten et al. (2002) in which *Macadamia hildebrandii* was found on Mount Nokilalaki and Rorakatimbu in Central Sulawesi which have topographical similarities with the areas where the majority of *M. hildebrandii* population were found in our study.

Based on soil type, 93% of *M. hildebrandii* population were found on red-yellow podzolic-lithosol while only 7% were on red-yellow podzolic soils. *Macadamia* grows well on well-drained soils with mild to moderate clay texture with soil depths of more than 0.5 m, and pH of 5.5-6.0 (Puspitojati et al. (2014), Directorate General of Plantations 2006).

Based on rock type (geology), 56% of *M. hildebrandii* population were located on tinea volcanic rock formations (Tmtv), which are volcanic sedimentary rocks, while 26% were on the latimojong (Kls) formation, which is a sedimentary rock; 15% were on kambuno granite (Tpkg), which is igneous/breakthrough rock, and 3% were in pompangeo complex (MTmp), which is a poor rock. The fact that the majority of Halika population were found in tinea volcanic rock formation is in line with Puspitojati et al. (2014) and Directorate General of Plantations (2006) which stated that *Macadamia* grows well on volcanic soils.

This is important to note as geological variations are considered as determinants of relatively large tree species variations in forest areas (Siregar et al. 2019).

Based on land system, 93% of *M. hildebrandii* population grew on the Bukit Pandan land system (BPD) while only 7% on the Telawi land system (TWI). BPD is a landform from this mountain system that includes land facets that have metamorphic parent material while TWI has the acid igneous rock. BPD is a steep mountain slope on metamorphic rocks with an amplitude of > 300 m, having steep slopes, usually thin soil solum, and metamorphic igneous lithology. TWI is a steep mountain slope on acid igneous rocks with an amplitude of > 300 m, steep slopes, usually thin soil solum, and acid igneous lithology (Nuwadjedi 2000).

According to forest land cover, 56% of *M. hildebrandii* population were found in secondary dryland forests while 44% grew in primary ones. The results of Nurfiana and Sulaeman research (2014) showed that in secondary forests, tree species were more abundant and diverse with density of each species was very high. Besides, there was a succession process that had not yet reached a climax state. Therefore, the dominant trees were those intolerant, which require a lot of sunlight for their growth.

Based on rainfall, 59% of *M. hildebrandii* populations grew on areas with rainfall <2,000 mm/year (1,600-2,000 mm/year) while 41% grew on areas with rainfall zone  $\geq 2,000$  mm/year (2,000-2,600 mm/year). This finding is still within the range stated by Puspitojati et al. (2014) and Directorate General of Plantations (2006) in which *Macadamia* grows well in area with rainfall of 1,500-3,000 mm/year.

From the results above, it can be summarized that *M. hildebrandii* trees predominantly grow in the ecosystem of

mountain rain zone with red yellow podzolic-lithosol soil, altitude of  $\geq 1,500$  m asl, slope class of  $\geq 25\%$ , middle slope aspect, the tinea volcano rock formation (Tmtv, which is sedimentary rock volcanic), metamorphic parent material, in secondary dryland forests, and rainfall 1,600-2,000 mm/year. Regarding the observation cluster location, the dominant *M. hildebrandii* trees grew in Cluster 2 (61%), followed by Cluster 1 (20%), Cluster 4 and 5 (7% for each), and Cluster 4 (6%). The dominance occurrence of *M. hildebrandii* in Cluster 2 is supported by habitat characteristics of altitude 1,300-1,800 m asl, rainfall zone of 1,600-2,200 mm/yr, and geology (Tmtv, Kls, Tpkg), and the dominant mountainous rain zone ecosystems. According to Whitten et al. (1987), natural vegetation that grows in certain areas depends on various factors such as soil chemistry, groundwater, climate, altitude, distance from the sea, and distance from areas that have similar conditions.

The information obtained from the results of this study can certainly be used as a reference in *M. hildebrandii* plant cultivation and conservation efforts by considering environmental factors that need special attention. The scope of this study was still limited to macro (general) environmental factors so it is deemed necessary to conduct further researches to identify the magnitude or condition of habitat variables on a micro-scale (specific) related to the growth of *M. hildebrandii* trees, such as texture and soil fertility, temperature, and the most optimal air humidity to spur the growth.

In conclusion, the spatial distribution pattern of *M. hildebrandii* trees in the mountain rain zone ecosystem in the Sintuwu Maroso Protection Forest Management Unit of Central Sulawesi spread in groups according to the characteristics of its natural habitat. *M. hildebrandii* trees in its natural habitat in the mountain rain zone ecosystem dominantly grew on red-yellow podzolic-lithosol soil with an altitude of 1,500 m asl, slope class of  $\geq 25\%$ , middle slope aspect, tinea volcano rock formation (Tmtv, which is a volcanic sedimentary rock), metamorphic parent material, secondary dryland forest, and a rainfall zone of 1,600-2,000 mm/year. The more diverse parameters of land and climate will significantly affect the distribution pattern of *M. hildebrandii* trees.

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