International Journal of Design & Nature and Ecodynamics
Vol. 18, No. 2, April, 2023, pp. 421-428
Journal homepage: http://iieta.org/journals/ijdne

Potential, Distribution Pattern and Autecology of *Diospyros celebica* Bakh. in the Maleali Seed Stand Area, Central Sulawesi, Indonesia

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https://doi.org/10.18280/ijdne.180220

Received: 24 November 2022
Accepted: 10 March 2023

Keywords:
rejuvenation, endemic, diospyros celebica Bakh., conservation, seed stand

ABSTRACT

Ebony (*Diospyros celebica* Bakh.) is one of the endemic trees of Sulawesi, which has a high selling value, now its existence is increasingly difficult to find in natural forests. Uncontrolled exploitation without serious development offset makes this plant increasingly on the verge of extinction. Currently, the remaining stands of ebony are threatened by human activities such as illegal logging and conversion to plantation areas. On the other hand, the need for ebony seeds in the context of in-situ and ex-situ conservation efforts is very large, so information is needed about their potential and distribution in nature. The study aims were to determine the potential for rejuvenation and ebony trees in the seed stand area, Maleali, Central Sulawesi, Indonesia. The research was carried out using the vegetation analysis method with Checked Lines. There are 5 observation lines made with a distance of 50 meters between the lines. Data were analyzed by species significance value. The results showed that the highest important value of the ebony species in the area of the Maleali ebony seed stands was the tree level (72.43%), the sapling level (45.63%), the seedling level (24.23%), except for the pole level which was second with a species importance value of 35.68%. Regeneration potential is low, seedling density of 9,300 ha^{-1}, sapling rate of 592 ha^{-1}, pole rate of 76 ha^{-1}, tree level (20-30 cm diameter) 13 trees ha^{-1}, tree level (31-40 cm diameter) 10 trees ha^{-1} and the tree level (diameter 40-50 cm) is only 9 trees ha^{-1}. The distribution pattern of ebony at the seedling, sapling, pole and tree levels is classified as a random distribution pattern. The physical, chemical and biological properties of the soil in the Maleali ebony seed stands also varied between the foothills, ridges and tops of the hills. The data obtained from this study became the basis for in-situ conservation efforts of *D. celebica* and other plant species in these areas.

1. INTRODUCTION

There are about 5000 species of flowering plants in Sulawesi Island, Indonesia, and 15% of them are classified as endemic species [1]. Ebony (*Diospyros celebica* Bakh.) is an endemic species and is known by the public as ebony or ebony. This species is included in the category of vulnerable to extinction (A1cd) on the Red List of the International Union for Conservation of Nature and Natural Resources or IUCN [2]. *D. celebica* Bakh is one of the genera of *Diospyros*, the Ebenacea family, a plant species endemic to the island of Sulawesi. The natural population can only be found in Central and West Sulawesi province. In Central Sulawesi province, natural populations of ebony are found in the districts of Poso, Parigi Moutong, Donggala, Morowali and Tojo Una-una. Ebony produces luxurious wood with high economic value and has been approved as the mascot of the province of Central Sulawesi through a Decree of the Governor of Central Sulawesi No. 660/78/1995, dated February 27th, 1995.

This type produces wood that is classified as luxurious, because the wood core is shiny black interspersed with black-brown lines. This wood can be used for various purposes such as carving, musical instruments, household furniture, luxury furniture, and lumber [3]. Ebony is very important in the world's timber trade, because of its high selling price so logging continues to be carried out, even though in 1990 a regulation was issued prohibiting logging through Decree No.950/IV.TPHH/90 addressed to the Governor of Central Sulawesi regarding the ban on logging of ebony trees. This situation requires that the preservation of ebony must be carried out.

Efforts to develop ebony require knowledge about the nature of the species, including semi-tolerant growth traits, where initial growth requires shade and subsequent growth does not require shade; the growth of this type is very slow so it often fails [4]. Ebony tree grows very slowly, with a life cycle between 100 up to 200 years. The slow growth of this type of wood, will be an obstacle in its development, besides there is not much data on growth criteria [5]. In addition, the properties of ebony seeds are recalcitrant. Recalcitrant seeds have a high water content, for this reason, the moisture content of the seeds needs to be maintained during storage [6]. The recalcitrant ebony seeds, with increasing time in storage will experience a decrease in their germination power, so that in ebony nurseries it can be done with natural seedlings. To obtain information about ebony seedlings, it is necessary to know their population and distribution under the stands.

Santoso [7] conducted a study on ebony seedling populations, where they found quite a large number around the mother tree, around a 5 meter radius around the mother tree found around 500-4000 ebony seedlings, but the further away from the number of mother trees the ebony seedlings are also decreasing. The results of research by Rukmi [8] also showed ebony seedlings with a density of 19,850 ha^{-1} in the area of the Maleali seed stand. At that time the seed stand area had not been disturbed. The occurrence of illegal logging and theft of ebony trees in this area has caused a change in the composition of the vegetation which in turn is likely to change the ebony in the area. The results of this study are supported by Restu [9] who stated that the natural rejuvenation potential of *D.celebica* is quite good. However, currently, according to Suryawan and Kinho [10], the conditions for ebony in its natural habitat are very limited, both for the stand and for its regeneration. Based on this description, it is necessary to study the population of seedlings in the ebony seed source stands in Maleali, Central Sulawesi, Indonesia.

Currently, research on the potential for regeneration and trees as a source of seeds in Central Sulawesi is still lacking. Completeness of information is an essential factor in formulating a conservation plan and management strategy for living natural resources, so it is necessary to conduct research on the potential for regeneration and trees as a source of ebony seeds in standing areas, which can be used as a source of information and preparation of conservation strategies that can be pursued in future. This research is one of the solutions to overcome this problem, in which gradual exploration activities will be carried out on regeneration and trees which are the source of seeds in the seed stand area of Maleali Village, in Central Sulawesi, Indonesia.

2. MATERIAL AND METHODS

2.1 Time and study sites

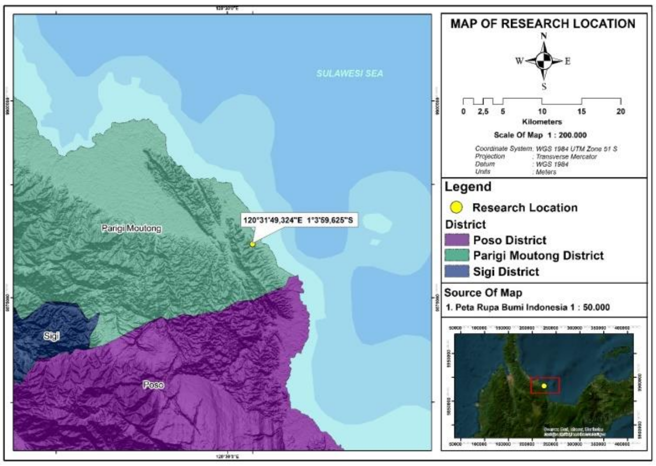

Figure 1. Research locations in the Maleali Seed Stand Area, Central Sulawesi

The research was conducted for 8 months (from March to November 2022) in the Ebony seed stand area in Maleali Village, Sausu District, Parigi Moutong Regency, Central Sulawesi, Indonesia. The choice of time for this study was based on the consideration that the ebony flowering time starts in March-May every year. Then from November to December is the formation of fruit that is physiologically ripe. These fruits have the potential to produce seeds and will germinate in January, so that in March it is hoped that the seedlings have grown and are abundantly available under the stands. The research locations are presented in Figure 1. Analysis of the physical, chemical and biological properties of soil was carried out at the Laboratory of Soil Science, Faculty of Agriculture, Tadulako University, Palu, Indonesia.

The objects of study were the type and number of ebony seedlings and trees. In addition, other plant species associated with ebony species were also collected. The data collected is in the form of primary data and secondary data, the primary data obtained is data from direct observation in the field by observing and collecting data in the form of plant species and the number of seedlings and ebony trees.

2.2 Observation of *D. celebica* and other plants Rejuvenation Potential

This method is carried out by determining the starting point on the field, after which the path is determined by cutting the contour to the north using a compass. The research method used is the vegetation analysis method, plotted paths [11]. There are 5 observation lines made with a distance of 50 meters between the lines. The length of each path is 200 meters each. In each lane, observation plots measuring 20m x 20m were made which were placed discontinuously with a distance of 25 meters between plots. These plots were used for tree-level observations. Regeneration of species (pole, sapling and seedling levels) was observed in different sized sample plots and placed by nested sampling. The 20m x 20 m observation plots were made to determine the trees. Plots of 10 m x 10 m were established to determine the poles, 5m x 5m were established to determine the saplings and 1m x 1 m quadrates were established to determine the seedlings. In this study the type of data collected consisted of primary data and secondary data. Plant species were identified based on [12-15]. Plant species unknown in the field were collected for herbarium samples and then identified at UPT Biological Resources, Tadulako University, Palu, Indonesia.

For the purposes of analyzing the physical, chemical and biological properties of the soil in the seed stand area, the collection of soil samples was divided into two, namely intact and non-intact soil samples. Incomplete soil samples for the purposes of analyzing the chemical and biological properties of the soil, which were collected as much as 1 kg at 5 sampling points at each study location (valley, ridge and hilltop) on ebony stands at a depth of 30 cm. Soil samples from these five points were collected to obtain composite samples from each of the study locations. The samples were collected separately in plastic bags, labeled and stored at 4°C before further analysis. Intact soil samples for analysis of soil physical properties were taken using soil rings at a depth of 30 cm at three study locations. At each location, three intact soil samples were taken.

Analysis of the physical and chemical properties of the soil followed standard protocols, namely soil pH (digital pH meter), soil texture (Pipet method), C-organic [16], Total N [17], available P [18]. using the Atomic Absorption Spectrophotometer method [19].

Determination of the soil microbial population was carried out based on the study [20]. Potato dextrose agar (PDA) media was used for fungal culture and nutrient agar (NA) was used for bacterial culture. Twenty grams of PDA medium was dissolved with 1000 ml of water and NA medium was prepared with 3 g of beef extract, 5 g of peptone and 15 g of agar in 1 L of water. After autoclaving, the media is poured into the petri dish. The dilution method was used in the calculation of the soil microbial population. The total number of colonies on each petri dish that can be accepted is calculated using a colony counter and the results are expressed as the formation of a unit colony (cfu) according to the study of Clark [21].

2.3 Data analysis

The data was analyzed based on the species Important Value Index (IVI) and Distribution Pattern of Ebony species. Data on the potential of trees and their rejuvenation is carried out in terms of potential per hectare, both at the tree level and at the rejuvenation level (pole, sapling, seedling level). In addition, important value index analysis was carried out.

$$IVI = KR + FR + DR$$

Note: KR: Relative Density
FR: Relative Frequency
DR: Relative Dominance

The distribution pattern of *D. celebica* Bakh was analyzed using the Morisita Index formula ($I\delta$). Morisita index ($I\delta$) is not affected by the area of the sampling station and is very good for comparing distribution patterns [22].

$$I\delta = \frac{n \sum Xi(Xi-1)}{N\ (N-1)}$$

Note:
$I\delta$ = Index of Morisita
N = Number of all individuals in total n
N = Total number of sampling plots
Xi = Number of plants per plot
Morisita index values obtained are interpreted as follows:
$I\delta < 1$, the distribution of n individuals tends to be random
$I\delta = 1$, the distribution of n individuals tends to be even
$I\delta > 1$, the distribution of n individuals tends to cluster

3. RESULTS AND DISCUSSIONS

3.1 Species significant value index

The dominance and role of a species in a community can be predicted from the species' importance value. The type with the highest species importance value indicates the dominant species in an ecosystem. Important Value The highest ten plant species in the Maleali ebony seed stand area based on their growth rate, namely trees, poles, saplings and seedlings are presented in Table 1. The types of plants found based on their growth rate were: trees (28 species), poles (46 species), saplings (46 species) and seedlings (56 species). The difference in the number of species at various growth levels is caused by the dynamics of vegetation. Each population has different characteristics from other populations [23]. Vegetation dynamics can be described by changes in plant composition both quantitatively and qualitatively. These changes are partly caused by plant reproduction or the death of a plant species. In addition, it is caused by illegal encroachment. Population characteristics include density, birth rate, mortality, population increase rate, age and sex ratio, and aggregation [24].

Table 1. The highest species importance values of ten plant species at various growth rates in the Maleali seed stand area, Parigi Moutong Regency, Central Sulawesi

No.	Plants species	Important Value of Species (%)			
		Tree	Pole	Sapling	Seedling
1	*Diospyros celebica* Bakh.	72.43	20.77	45.63	24.24
2	*Cananga odorata* Hook F.	28.24	19.02	14.62	13.36
3	*Antocephalus cadamba* Miq.	26.88	15.13	-	-
4	*Antiaris toxicaria* Lesh.	24.87	13.81	13.19	7.28
5	*Homalium foetidum* Benth.	15.97	16.41	13.31	12.22
6	*Antocephalus macrophyllus* Roxb.	13.93	-	-	-
7	*Duabanga molucana* BL.	13.41	-	-	-
8	*Octomeles sumatrana* Miq.	11.02	16.10	-	-
9	*Artocarpus elasticus* Bl.	10.46	-	14.27	7.52
10	*Pometia pinnata* Forb.	10.43	-	17.55	8.35
11	*Canarium littorale* BL.	-	35.68	18.02	9.30
12	*Terrietia javanica* BL.	-	12.02	10.59	
13	*Arenga pinnata* Merr	-	-	-	15.66
14	*Koodersiodendron pinnatum* Merr	-	-	15.06	-
15	*Pterospermum celebicum* Miq.	-	15.51	15.26	11.29
16	*Corypha utan* Lam	-	-	-	8.82

The results in Table 1 show that the species that dominates at all growth stages in the ebony maleali seed stand area at all growth stages is *Diospyros celebica* Bakh. (eboni), although at pole level it ranks second after *Cananga odorata* Hook F. Ten Dominant Species those present at every growth stage apart from the ebony species were *Cananga odorata* Hook F., *Antiaris toxicaria* Lesh., *Antocephalus cadamba* Miq, *Homalium foetidum* Benth. The species that were only dominant at the tree level were Antocephalus macrophyllus Roxb., *Duabanga molucana* BL. While the dominant species only at the seedling level are Arenga pinnata Merr and *Corypha utan* Lam. The species that dominate the level of trees and poles only. The species that dominated the seedling, sapling and pole stages was *Canarium littorale* BL. and *Pterospermum celebicum* Miq. Furthermore, the species that dominate the 10 main species for the tree level is 72.43%, the pole level is 19.02%, the sapling level is 45.63% and the seedling level is only 24.24%. The results of this study are different from the results of a study by (8) in the same area, which found important species values for the tree stage on a gentle slope of 83%, 122.36% pole level, 124.31% sapling level and 93.25% seedling level. This indicates a drastic decrease in value for the current condition of the Maleali seed stand. This change occurred as a result of illegal logging of trees with large diameters for all types, so that the trees that dominated the ten main species were small pioneer species.

Species density, frequency, species diversity and importance value have been used to measure the occurrence or dominance of plant species [25, 26]. A high IVI value indicates that the density of species in an area is also high. In addition, the distribution is even and the dominance is also high. The dominance of a species at each growth level can also be caused by the ability of that species to adapt to its environment, especially with changes in a short time due to illegal logging. Logging activities and other human activities in the forest [27]. The construction of logging roads increases accessibility to logged areas, and is therefore considered a driver of forest degradation and subsequent deforestation [28]. This was confirmed by Ogwu et al. [29, 30] who reported that species abundance decreased as a result of human activity, indicating that a forest area requires continuous surveys and monitoring. The existence of illegal logging will cause an open space that provides an opportunity for seeds to germinate, so that sometimes there is a change in the type that grows. This is in accordance with the opinion of Gobal and Bhardwaj [24], that changes that occur in a plant community are often in the form of replacement of one community by another.

3.2 Rejuvenation and tree potential of *Diospyros celebica* Bakh. in the Maleali seed stand area

The rejuvenation potential of ebony trees in the Maleali ebony stand area of Central Sulawesi is presented in Table 2. The results in the table show that the density of ebony species/ha both at rejuvenation and tree level is low when compared to the results of Rukmi's research [8], ebony rejuvenation at the seedling level reached 19,850 seedlings ha^{-1}, sapling rate 952 ha^{-1}, pole rate 598 ha^{-1} and tree level 112 ha^{-1}. The results of research by Rukmi [31] in the forest group of Tambarana Village, Poso Pesisir Utara District, Poso Regency showed that the seedling rate was 19,850 ha^{-1}, the sapling rate was 952 ha^{-1}, the pole level was 112 ha^{-1} and the tree level (diameter 20-29 cm) 2, 08 ha^{-1}, diameter 30-39 cm 2.08 ha^{-1}, diameter 40-49cm 1.67 ha^{-1} and diameter 50-59cm 1.25 ha^{-1}. The low number of ebony species is due to a change in species composition due to the encroachment of species with large diameters, both ebony and other species which are natural vegetation in the Maleali ebony seed stand area. In addition, no longer found a diameter measuring more than 50 cm.

Table 2. Species density of *D. celebica* Bakh. at various growth rate

Growth rate	Density (Ha^{-1})
Seedling	9300
Sapling	592
Pole	76
Pohon (Diameter 20-30cm)	13
Pohon (Diameter 31-40cm)	10
Pohon (Diameter 41-50cm)	9

Changes in the structure of vegetation cause more open space so as to provide opportunities for undergrowth to grow more. The development of undergrowth causes the humidity of the surface layer of the soil to become moister which can result in the ebony fruit being attacked by fungus and unable to germinate. Ebony seeds are recalcitrant, their germination power decreases quickly and they are easily attacked by the fungus *Penicilopsis clafariaeformis* [25]. This change in vegetation structure is also caused by many factors. Many studies have reported on regeneration in natural forests [32]. Open forests provide opportunities for light to enter, thereby affecting forest regeneration [33]. Entry of light in forests is affected by the degree of slope in the forest. Zhang et al. [34] reported that steep slopes have lower diversity compared to gentle slopes due to differences in solar radiation intensity.

Ebony can germinate well in areas where seeds and undergrowth do not grow, although not all seeds can germinate completely. Ebony seeds are a type of recalcitrant seed, meaning they do not have a dormancy period, so they cannot be stored for a long time. Once dropped on the forest floor, it will soon germinate if germination factors are available. One week after falling on the forest floor, the seeds began to germinate which was indicated by the seeds being lifted from the media and the seed coat being separated from the cotyledons. Ebony sprouts have a long hypocotyl, with large and heavy cotyledons. These cotyledons will later fall off leaving two leaves which are known as seedlings. Stages of new leaf growth after the next six months. The growth of the seedlings can be seen in Figure 2.

Figure 2. Growth phases of ebony seedlings on a forest floor lacking undergrowth

3.3 Distribution pattern of ebony species

The distribution of species within a community can provide an overview of the relationships between species and the relationships between individuals in a plant species. The distribution pattern of ebony species at each growth level is presented in Table 3.

Table 3. Distribution pattern of *D. celebica* Bakh. at various growth rates in the Maleali seed stand area

Growth rate	Morisita Index Value	Distribution pattern
Seedling	0.51	Random
Sapling	0.50	Random
Pole	-0.21	Random
Tree	-0.19	Random

The table above shows that the distribution pattern of ebony (*Diospyros celebica* Bakh.) seedling, sapling, pole and tree levels is in the random distribution pattern category. The distribution pattern of the ebony is different from the distribution pattern of ebony in the Educational Forest of Hasanudin University, Maros Regency [22] and in the Tombolo forest area, Bantimurung Bulusaraung National Park, South Sulawesi, Indonesia [35]. The results of their research indicated that the distribution pattern of ebony at all growth stages was clustered. It was further explained that this type of ebony is a semi-shade tolerant species, has excellent natural regeneration, its saplings can grow better and reach mature trees, if they are spread far from their parent trees. However, it is different from the results of research on the seed stand area in Maleali, Central Sulawesi, which is a random distribution pattern. Random distribution patterns are relatively rare in nature, where the environment is very uniform and there is a tendency to gather [36]. The existence of a random distribution pattern in the seed stand area in Maleali can be caused by the ebony seeds which are included in the buni fruit which are highly favored by birds. Birds take ripe fruit, fly and perch on a flat branch, so that the ebony seeds are scattered randomly. Birds taking fruit and directly perching on other trees is caused by the architecture of the ebony tree which tends to nod, making it difficult for birds to eat fruit from ebony trees, especially birds with large stature such as hornbills. Seed dispersal by birds is the cause of the random distribution pattern of ebony seedlings in the Maleali seed stand area. Apart from that, the random pattern is also caused by large-scale changes in the level of trees with large diameters, so that sunlight can penetrate to the forest floor. This allows the undergrowth in the form of weeds to grow freely, thereby covering the forest floor where the ebony pods are located. Even if there are seeds that can germinate, the undergrowth that propagates and twists causes subsequent growth failure, and many even die. In this condition, the fruit that falls under the tree is not clustered.

The distribution of plants is controlled by micro-environmental factors such as light conditions, soil moisture and the nutrients of their habitat [37]. In addition, elevation gradients often limit the distribution of tree species by decreasing soil moisture and nutrient levels [38] and otherwise aid species dispersal via strong winds at high elevations [34].

3.4 Physical, chemical and biological properties of soil in Maleali Ebony Seed Stands

The results of the analysis of the physical, chemical and biological properties of the soil in the ebony seed stands showed that the parameters varied between the three study locations (Table 4). The table shows that the soil texture of the three locations is sandy loam. The results of research by Rukmi [31] in this area are on gentle slopes with a clay texture, on steep slopes with a sandy loam texture. Total N content is low, organic C is very low except for slope positions in the low category. Likewise, P at the foot of hills and slopes is in the very low category, at the peak position is in the low category, while the pH is in the slightly acidic category for the three locations.

Soil with a sandy texture certainly facilitates the movement of water and air more, even though this condition does not hold water so it is easier to experience drought. Soil permeability in the fast and medium category is influenced by the presence of a soil texture that contains a lot of sand. The high content of sand and low clay at the foot of the hill causes high bulk density and fast soil permeability. Siregar et al. [39] stated that the measurement of soil permeability is very important for several interests in agriculture such as the entry of water into the soil, the movement of water to plant roots, the flow of drainage water, and the evaporation of water on the soil surface. Fast soil permeability shows the ability of the soil to pass water quickly which can lead to low water storage capacity in the soil. Although the porosity of the soil at the foot of the hill is lowest compared to the slopes and peaks, the fast permeability of the soil indicates that the dominance of macropores is higher at the foot of the hill.

Table 4. Physical, chemical and biological properties of the soil at the three study locations

Parameters	Sampling sites		
	Foothill	**Ridge**	**Hilltop**
Sand (%)	68.2	58.8	67.0
Silt (%)	17.5	22.5	17.9
Clay (%)	14.3	18.7	15.1
Texstur	Sandy loam	Sandy loam	Sandy loam
Permeability (cm $hour^{-1}$)	12.78 (Fast)	5.99 (Moderate)	2.67 (Moderate)
Bulk density (gr cm^3)	1.70	1.38	1.60
Porosity (%)	35.82	48.08	39.65
pH H2O (1:2.5)	5.89 (Slightly acid)	5.76 (Slightly acid)	6.05 (Slightly acid)
Organik-C (%)	0.97 (Very low)	1.00 (low)	0.62 (Very low)
Total-N (%)	0.22 (low)	0.21 (low)	0.20 (low)
CEC (c mol (+) kg^{-1})	24.50 (moderate)	28.91(high)	33.98 (high)
P2O5 (ppm)	19.40	29.60	11.26
Total of Bacteria (cfu)	2.89×10^8	2.42×10^8	3.56×10^8
Total of Fungi (cfu)	4.58×10^6	4.09×10^6	5.14×10^6

The bulk density of the soil on the slopes is lower than that of the soil at the top and foot of the hill. This is caused by the lowest content of the sand fraction and the highest content of organic matter. According to Nuraida et al. [40] the value of soil bulk density can describe the content of soil organic matter, minerals, porosity, water holding capacity, drainage properties and the ease with which the soil can be penetrated by roots. Sarief [41] stated that clay-textured soils have a smaller soil bulk density and sand-textured soils have a large bulk density value. Based on this, it can be said that the high bulk density value of the soil at the foot of the hill is influenced by the high content of the sand fraction and very low organic matter. Fast soil permeability indicates that the capacity of the soil to store water is low and the soil is easily penetrated by roots.

The actual pH (H_2O) of the soil at the top is higher (6.05) than at the foot of the hill (5.89) and the slope (5.76). Soil pH value is an indicator of soil fertility, because it relates to the availability of nutrients in the soil. PH indicates the concentration of H+ ions present in the soil solution. Kusuma and Yanti [42] state that soil acidity (pH) describes the level of availability of macro and micro nutrients in the soil for plant growth. Soil pH that is in the neutral range can provide the availability of soil nutrients at the optimum level because most of the nutrients are easily soluble in water. Availability of optimal macro and micro nutrients in the range of pH 6-7, and still sufficiently available in the range of pH 5.5-6 or 7-7.5. Based on this, the actual pH value of the soil at the top, slope and foot of the hill is still in the pH range that can provide nutrients in the sufficient category. According to Miah [20] that lower pH in forest soils may be caused by more accumulation of organic matter, which makes the soil more acidic.

Moderate to low total N content with very low organic matter content can be a limiting factor for plant growth in Maleali seed stands. Cation exchange capacity (CEC) related to the ability of the soil to absorb and exchange cations. A high soil CEC value indicates a high ability of the soil to absorb and exchange cations. The cations resulting from the mineralization process can be adsorbed on the surface of the colloid and can be released into the soil solution if there is a concentration gradient between the soil solution and the adsorption surface (soil colloid). Conversely, if the CEC of the soil is low, the capacity of the soil to absorb and exchange cations is low. Some of the cations resulting from mineralization will be leached from the soil so that they cannot be used by plants. The results of soil analysis showed that the soil CEC was high on the peaks and slopes, whereas at the foot of the hills the soil CEC was moderate. This means that the ability of the soil to absorb and exchange cations is moderate to high. Dissolved cations can be adsorbed and exchanged on the surface of the colloid.

The results of soil analysis showed that available P (Olsen) was very high on the slopes, high at the foot of the hills and moderate at the top. According to Surya and Suyono [43] the Olsen method can be used on acidic and alkaline soils, so that primary orthophosphate ions ($H_2PO_4^-$) and secondary orthophosphate (HPO_4^{2-}) and phosphate ions (PO_4^{3-}) can be read. The three ionic forms, if they are in soil solution, are called available P. In other words, available P (Olsen) is the primary orthophosphate ion, secondary orthophosphate ion and phosphate ion which are in the soil solution ready to be absorbed by plants. Among the three ions, primary orthophosphate ions and secondary orthophosphate ions are more easily absorbed by plants. Umaternate et al. [44] stated that although the P test results provided by the Olsen method were high, they could not be used as a benchmark for P availability due to interference from the high soil pH and the presence of a readable form of phosphate which was still difficult for plants to absorb, namely PO_4^{3-}. It was also stated that the Olsen method was more effective in determining available P than the Bray method for paddy soil samples. Plants will grow well if the availability of P in the soil is sufficient [45].

Deforestation alters the soil microbial community which can certainly affect the nature of the ecosystem as a whole because microbes play an important role in determining the sustainable status of soil fertility, decomposition of organic matter, mineralization and conservation of nutrients in tropical ecosystems [46]. Deforestation causes the habitat of the organisms to be damaged so that they move elsewhere and eventually die due to insufficient resources to support their survival [44]. Forest conversion and clearing to other land uses often results in low microbial populations [47].

The research results of Saragih et al. [48] showed that there was a negative correlation between soil pH and total soil bacteria on observations one day before soybean harvest; an increase in soil pH, with a range of 5-5.5, will decrease the total soil bacteria. In contrast to the results of this study, an increase in soil pH increased total bacteria and total fungi. The soil pH on the slopes is 5.76, the total bacteria 2.42×10^8 cfu and total of fungi 4.09×10^8 cfu. At the foot of the hill, the soil pH 5.89, total bacteria 2.89×10^8 cfu and total of fungi 4.54×10^8 cfu. At the top of hill, the soil pH 6.05, total bacteria 3.56×10^8 cfu and the total of fungi 5.14×10^8 cfu.

According to Thammanu et al. [49] that environmental factors affect the distribution and composition of plant species in the forest. Soil fertility greatly affects the distribution of plant species in ecosystems and also changes their structural pattern in the forest [2, 27, 21, 50-52]. Nutrient deficiencies can stunt the growth of mature trees [53, 54]. In addition, the slope of the slope also affects regeneration in the forest, which of course also differs in the level of soil fertility. According to Shacha et al. [27] that the slope of the slope gives a negative correlation with the regeneration process where regeneration decreases with increasing slope.

4. CONCLUSIONS

The results showed that the important value of the species *Diospyros celebica* Bakh. in the area of the Maleali ebony stands the highest was the tree level (72.43%), the sapling level (45.63%), the seedling level (24.23%), except for the pole level which was second with a species importance value of 35.68%. Regeneration potential is low, seedling density of 9,300 ha^{-1}, sapling rate of 592 ha^{-1}, pole rate of 76 ha^{-1}, tree level (20-30 cm diameter) 13 trees ha^{-1}, tree level (31-40 cm diameter) 10 trees ha^{-1} and the tree level (diameter 40-50 cm) is only 9 trees ha^{-1}. The distribution pattern of Ebony (*D. celebica* Bakh.) at the Seedling, Sapling, Pole and Tree levels is classified as a random distribution pattern. The physical-chemical properties of the soil in the seed stand area, namely the texture of the soil at the three locations were sandy loam, the total N content was low, the organic C was very low except on the slopes which were in the low category. Furthermore, P at the hillfoot and ridge is in the very low category, at the hilltop is in the low category, while the pH is in the slightly acidic category for the three locations. The data obtained from this study became the basis for in-situ conservation efforts of *D. celebica* and other plant species in these areas.

It is suggested that further research be carried out on the number of seedlings in each parent tree as well as a comparison of the potential and pattern of distribution of trees and seedlings between peaks, ridges and valleys, as well as in agroforestry areas considering that this species is also cultivated by the wider community in Central Sulawesi Province through agroforestry patterns. Special care must be taken to minimize disturbance by human activities, as severe disturbance has been found to impair ebony regeneration in nature. Extensive studies focusing on these factors will help provide important information for the comprehensive management of ebony stands and for understanding their ecological reactions to such disturbance in nature.

ACKNOWLEDGMENT

The author would like to thank the Rector of Tadulako University for this Excellent Research Fund through the Faculty DIPA, Postgraduate, PSDKU Tojo Una-Una and University, The Ministry of Education and Culture, Tadulako University, No. 742.q/UN28.2/PL/2022, April 11, 2022.

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