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# Potential and regeneration of tree species used as roosting habitat by Sulawesi fruit bats *Acerodon celebensis* in Jenetaesa, Maros Regency

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**Abstract.** Sulawesi fruit bat (*Acerodon celebensis*) is an endemic fruit bat species of Sulawesi Island. Fruit bats have many important roles in the ecosystem where they act as seed dispersing agents, natural pollinating agents of flowering plants, and assist in forest regeneration. The purpose of this research is to determine their potential roosting tree species and their regeneration for *A. celebensis* in Jenetaesa, Maros Regency. This research was conducted for 3 months (May-July) in 2018 by initially identifying roosting tree species on the roosting site followed by surveying potential roost trees in 11.5 ha with the employment of 230 subplots. The results showed that in the area observed, the Sulawesi fruit bat has utilized 142 individuals of 21 tree species as roosting tree. Of 230 plots, there were a total of 234 individuals of 56 tree species found. However, based on species recorded to be used by the bats, only 56 individuals of 9 tree species and 11 bamboo clumps were found as potential roosting trees. Regeneration of *A. celebensis* roosting trees in an area of 11.5 ha was classified as low with only 7 species found and 32 individuals in average on each of growing stages.

## 1. Introduction

The only mammals with the ability of flying are bats and thus are known to be the most widely distributed animals in the world [1]. The animals have high species richness with 18 families, 192 genera, and more than 1,400 species [2,3]. The high diversity of bats in the world portrays various beneficial roles of bats for human survival and the environment [4,5,6]. For example, as seeds dispersing agents and pollinator of many flowering plants, bats in particular fruit bats have positively contributed in maintaining stability, diversity, and regeneration of forest [7,8,9]. In agricultural sector, bats also play a role in controlling the number of insect pests and reduce risks in crop harvesting [10]. In addition, from an economic point of view, bats produce manure called guano, which is a fertilizer with high phosphorus and nitrogen content [11]. While in some areas, the animals have positively contributed to both economic and agricultural sectors by increasing production of many agricultural commodities as well as uplifting the economic of the locals [12,13,14].

At present, reduced number of bat populations from many parts of the world are reported. Most human-related threats are due to hunting and trading of bat meat for consumption, persecution or



eradication as the animals were suspected as fruit-crop raiders and also virus carriers [15,16,17]. It is also highlighted that habitat loss or modification and roost site loss or disturbance caused by agriculture expansions which include forest and tree clearing are recognised as the major threats towards bats across the globe [18]. Forest and its trees have provided bats not only foraging sites but also for roosting in particular fruit bats of suborder *Megachiroptera*.

Bats spend 50 percent of the day time hanging in roost. Roosting site plays important roles for bats as it serves complex functions such as for mating, hibernation, providing environments for nurturing and rearing young, promoting social interactions between individuals, as well as offering protection towards extreme weather and most importantly from predators [19,20]. Therefore, the existence of roost site is crucial for bat's survivability and reproduction ability [21]. Roosting site can be varied depending on species. Some can be found roosting in caves, rock crevices, tree cavities, and man-made structures [19]. For *Megachiroptera*, most of the species are exclusively known to establish external roosts like on tree branches due to inability to echolocate except for Genus *Rousettus*.

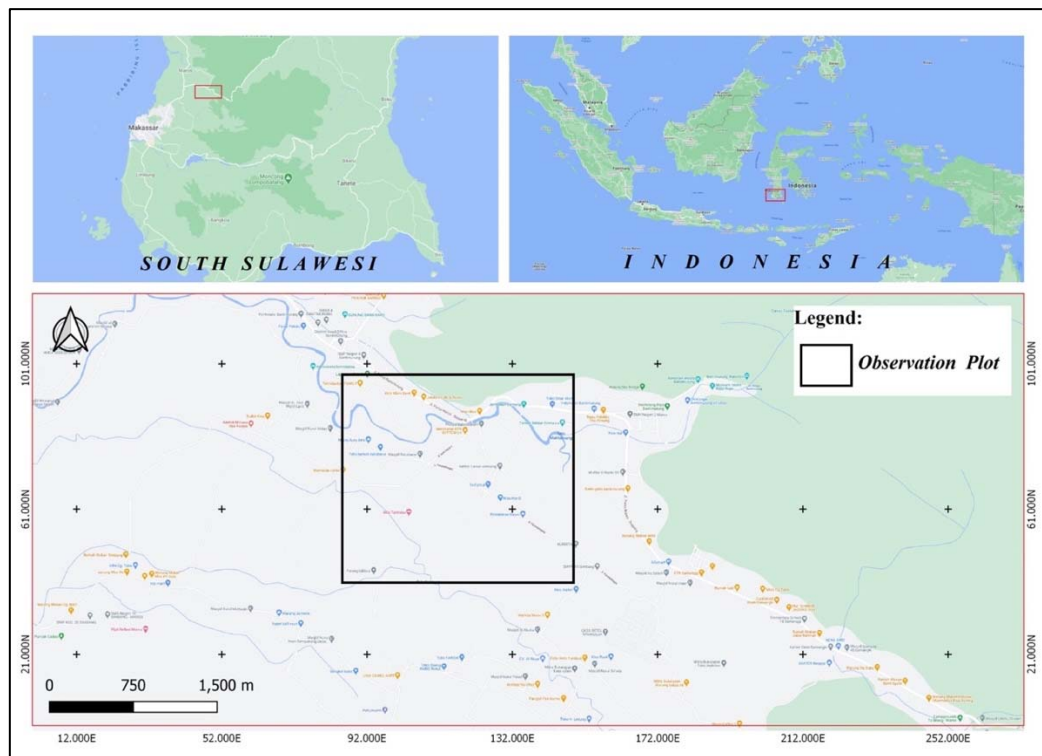
*Acerodon celebensis* is one of fruit bat species endemic in Sulawesi island and is known to live in large colonies on tree branches during the daylight. The species can be generally found roosting in areas close to human settlements. Recently, *A. celebensis* has been classified as *Vulnerable* by the IUCN (*The International Union for Conservation of Nature*) Red List due to declining populations in some areas [22] and based on CITES (*Convention of International Trade on Endangered Flora and Fauna Species*), this species is included in Appendix II. Apart from hunting and trading threats in the northern part of the island [23,24], disturbances and clearing of roosting trees have also been identified as one causes of species decline. Lack of information and data of each roosting site has impeded the conservation efforts of bats globally [25] and particularly for this endemic species.

In South Sulawesi, roosting sites are scattered in several regencies, such as Sinjai, Bone, Pangkep, Soppeng, and including Maros [26,27]. In Maros Regency, the roosting site is located nearby human settlement and agricultural areas of the village. Previous studies have indicated that there were 147 trees of 22 species utilized by *A. celebensis* to roost with inhabitants of more than 6,000 bat individuals [28,29]. However, due to its location, the roosting site might be prone towards disturbances by human activities as well as exposed to high risks of eradication in particular due to issues related with virus-transmission of current pandemic. Therefore, this study aims to determine potential roosting tree species and their regeneration in Maros Regency as one of the main roosting sites to further conserve *Acerodon celebensis* in the region.

## 2. Materials and methods

### 2.1. Study area

This research was conducted for 3 months in 2018 in Jenetaesa Village, Simbang District, Maros Regency, South Sulawesi (Indonesia). Geographically, the village is located between 5°01'24" S and 119°39'53" in Maros-Pangkep Karst Area. The village was located around 37.9 km from Makassar, the capital city of South Sulawesi Province with the width of 10.08 km<sup>2</sup> (figure 1). Number of people inhabited the area is around 4,019 people with density rate of 398.71 persons per km<sup>2</sup>. The area receives rainfall of 347 mm/month and it is situated at 232.68 m above the sea level with relative temperature of 29°C and humidity between 60-82%.

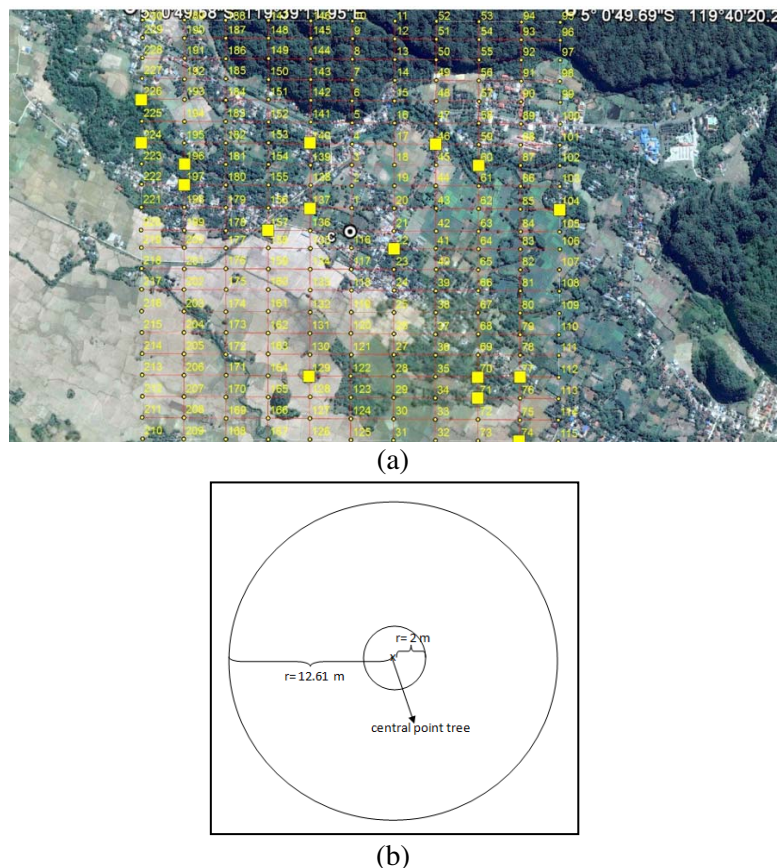


**Figure 1.** Study area located in Jenetaesa Village, Maros Regency.

## 2.2. Data collection and analysis

The data collections were divided into two stages: 1) determining species and abundance of current roosting trees of Sulawesi fruit bats *Acerodon celebensis*, and 2) examining potential and regeneration of roosting trees in Jenetaesa Village. To identify the species, the roosting habitat was determined and surveyed through direct observation. Tree species were recorded and number of all tree individuals were calculated.

Meanwhile, the potential and regeneration of roosting trees in the village were examined by establishing grids in a 2 x 2 km plot (figure 2). The grids were divided into 11 paths to both North-South and East-West directions (figure 2a) which were based on potential roosting tree species in Jenetaesa Village. The distance between each path was 100 m apart to the vertical line and 250 m to horizontal with the length of 2 km. The points made by the intersections between horizontal and vertical grids were determined as observation points. In each observation point, a circular plot with a radius of 12.61 m was constructed to further observe potential and regeneration of roosting tree species. There was a total of 230 systematic circular plots in the area. The points were processed by using *Google Earth* application to determine each plot's coordinate and were then imported to handheld GPS by using *DNR Garmin*.



**Figure 2.** Illustration of circular plot placement in the observation area of 0.05 ha (a) and determination of potential and regeneration of roosting trees in a circular plot (b) for Sulawesi Fruit Bats *Acerodon celebensis* in Jenetaesa Village, Maros Regency

Each plot was divided into two sizes: 1) a radius of 12.61 m to measure number of trees, stakes and poles, and 2) a radius of 2 m to observe number of seedlings (figure 2b). At the tree level, each individual's physical characteristics were measured, such as total tree height and branch-free tree height by using a *clinometer*. Diameter at breast height (dbh) in each tree located in the plots were also measured. For pole, sapling, and seedling level, the species and numbers of individuals per species in each sub plots were recorded.

To analyse the distribution of roosting trees, spatial GIS hardware and software were applied to portray current and potential roosting trees of *A. celebensis* in the area. Tree potential data was analysed to further calculate density, dominance, and frequency of each tree species in each path by using *Microsoft Excel*. A histogram was constructed to illustrate regeneration rate for potential tree species in the area.

### 3. Results

#### 3.1. Roosting tree species

In Jenetaesa Village (Maros), there was a total of 142 individuals consisting of 21 tree species utilized as roosting habitat for the endemic Sulawesi fruit bats *Acerodon celebensis* (table 1). The 21 species of roosting trees were mainly planted by the villagers surrounding their houses or in backyard gardens and therefore, the distribution of the roosting trees was tended to be clumped nearby the human settlement. Some of these tree species were known to be *fast-growing* species such as *Gmelina arborea*, and and

multi-purpose trees such as *Artocarpus heterophylla*, *Mangifera indica*, *Arenga pinnata* (fruit and sap-producing trees), and *Tectona grandis* (construction wood trees). Based on the information, there is no illegal hunting or trading activities in Jenetaesa Village, Maros.

**Table 1.** Species and abundance of current roosting trees used by Sulawesi fruit bats (*Acerodon celebensis*) in Jenetaesa Village, Maros.

No.	Species	Family	$\Sigma$ Individuals
1	<i>Alstonia scholaris</i>	Apocynaceae	1
2	<i>Anthocephalus cadamba</i>	Rubiaceae	2
3	<i>Arenga pinnata</i>	Araceae	5
4	<i>Artocarpus heterophylla</i>	Moraceae	4
5	<i>Baccaurea macrocarpa</i>	Euphorbiaceae	1
6	<i>Buchanania arborescens</i>	Anacardiaceae	3
7	<i>Cassia fistula</i>	Fabaceae	1
8	<i>Ceiba pentandra</i>	Malvaceae	9
9	<i>Crescentia cujete</i>	Bignoniaceae	1
10	<i>Flacourtia rukam</i>	Flacourtiaceae	1
11	<i>Gmelina arborea</i>	Lamiaceae	66
12	<i>Mangifera indica</i>	Anacardiaceae	18
13	<i>Nuclea orientalis</i>	Rubiaceae	2
14	<i>Paraserainthes falcata</i>	Fabaceae	4
15	<i>Pterocarpus indicus</i>	Fabaceae	7
16	<i>Samanea saman</i>	Fabaceae	1
17	<i>Swietenia mahagoni</i>	Meliaceae	4
18	<i>Syzygium cumini</i>	Myrtaceae	5
19	<i>Syzygium malaccensis</i>	Myrtaceae	2
20	<i>Tectona grandis</i>	Lamiaceae	4
21	<i>Vitex coffassus</i>	Lamiaceae	1
<b>Average:</b>			<b>142</b>

There were 21 species were mostly used as roosting habitat with *Gmelina arborea* as the dominant species inhabited as roost (66 individuals). Other species identified with more than 7 individuals were *Mangifera indica* (18 individuals), *Ceiba pentandra* (9 individuals), and *Pterocarpus indicus* (7 individuals) (Table 1). It was also recorded from the observation that apart from tree species, 5 clumps of bamboo plants (*Bambusa* sp.) in the area have also been spotted as roosting sites of *Acerodon celebensis*.

### 3.2. Potential of Sulawesi Fruit Bats Roosting tree

**3.2.1. Tree Level.** The results showed that at the tree level, there were 56 individuals of 9 species potentially becoming roosting trees in Jenetaesa Village (table 2). The total of 56 individuals were only located in 15 plots out of 230 plots made. At tree level, it was dominated by *Gmelina arborea*, *Tectona grandis*, and *Mangifera indica* where each species had more than 10 individuals in the plots. However, there were 3 potential tree species (*Tamarindus indicus*, *Aleurites moluccana*, and *Terminalia catapa*) which were not currently used as roosting trees by Sulawesi fruit bats *Acerodon celebensis* but might serve as potential roosting tree in the future.

**3.2.2. Pole and Sapling level.** Number of individuals of potential roosting tree species found at the pole level in 0.05 ha plot was 72 individuals consisting of 13 tree species. The highest individuals (17 individuals) with the highest density value (1.48 individuals/ha) were recorded in *Gmelina arborea* and *Theobroma cacao* (table 2). While, the lowest density was *Syzygium malaccensis*, *Terminalia catapa*, and *Carica papaya* with a value of 0.09 individuals/ha. High occurrences in each plot were known to be *Gmelina arborea* and *Theobroma cacao* ( $F=0.07$  m<sup>2</sup>/ha).

At the sapling level, there were only 7 species found in all plots surveyed (table 2). The species were *Annona muricata*, *Mangifera indica*, *Tectona grandis*, *Gmelina arborea*, *Citrus maxima*, *Artocarpus heterophylla*, and *Terminalia catapa*. Only four species were known to be used as roosting tree species (*Mangifera indica*, *Tectona grandis*, *Gmelina arborea*, and *Artocarpus heterophylla*). Similar with the pole, at this level, *Gmelina arborea* had the highest number of individuals with the total of 38 individuals while other species were below 5 individuals. The highest density value was shown by *Gmelina arborea* with a density value of 3.304 individuals/ha, and the lowest with a value of 0.087 from *Annona muricata*, *Mangifera indica*, *Citrus maxima*, *Artocarpus heterophylla*, and *Terminalia catapa*. The largest frequency came from *Gmelina arborea* ( $F=0.0165 \text{ m}^2/\text{ha}$ ,  $FR=80.5\%$ ), and the lowest were shown by *Citrus maxima*, *Artocarpus heterophylla*, and *Terminalia catapa* ( $F=0.004 \text{ m}^2/\text{ha}$ ,  $FR=2.1\%$ ).

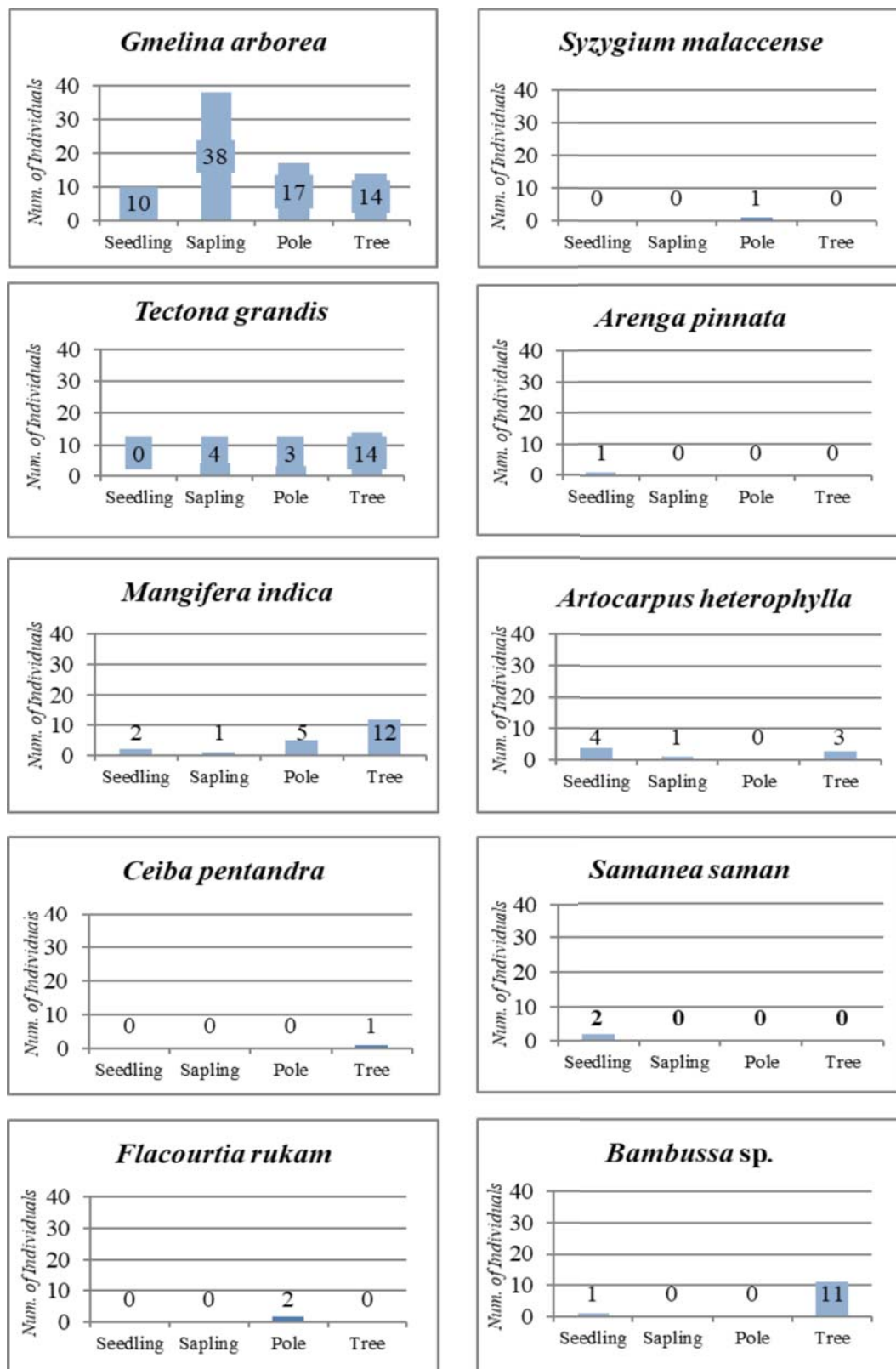


**Table 2.** Potential of roosting tree found in the plots at different growth level (\*= tree species found at the *roosting site* ; LT=canopy area; TBC=free-branch pole height; TTot=total height; LBDS=width of tree basal area; K=density; KR=relative density; F=frequency; FR=relative frequency; D=dominance; DR= relative dominance)

No.	Type	$\Sigma$ Ind	D (Min-Max) (m)	LT (m <sup>2</sup> ) (Min-Max)	TBC (Min-Max) (m)	TTOT (Min-Max)	LBDS (cm <sup>2</sup> )	K (ind./ha)	KR (%)	F (m <sup>2</sup> /ha)	FR (%)	D (m <sup>2</sup> /ha)	DR (%)
<i>Tree Level</i>													
1	<i>Mangifera indica</i> *	12	0.6 (0.27-1.05)	149.3 (43.57-311.65)	4.6 (2.55-7.75)	14.17 (9.89-30.54)	428904.5	1.043	21.43	0.03	26.67	1072.26	58.7
2	<i>Gmelina arborea</i> *	14	0.28 (0.21-0.47)	88.8 (17.34-571.21)	6.7 (3.26-8.9)	14.28 (11.3-19.54)	113886.6	1.217	25	0.03	20.00	298.69	16.4
3	<i>Tectona grandis</i> *	14	0.27 (0.23-0.39)	53.31 (22.89-92.41)	4.99 (2.7-7.27)	12.1 (8.5-16.33)	113886.6	1.217	25	0.01	10.00	284.72	15.6
4	<i>Pterocarpus indicus</i> *	7	0.33 (0.23-0.47)	43.6 (17.34-72.35)	7.1 (4.17-12.6)	14.24 (9.31-22.95)	34997.5	0.609	12.5	0.02	16.67	87.49	4.8
5	<i>Tamarindus indicus</i>	3	0.37 (0.24-0.57)	105.3 (15.72-275.98)	5.3 (3.81-7.27)	10.95 (7.75-15.78)	9808.9	0.261	5.36	0.01	6.67	24.52	1.34
6	<i>Artocarpus heterophylla</i>	3	0.47 (0.27-0.72)	60.89 (13.85-152.22)	2.82 (2.37-8.26)	8.78 (5.1-13)	15484.2	0.261	5.36	0.01	10.00	38.71	2.12
7	<i>Terminalia catapa</i>	1	0.28	51.50	8.8	17.1	602.6	0.087	1.79	0.004	3.33	1.51	0.08
8	<i>Aleurites moluccana</i>	1	0.62	115.88	4.74	12.22	3027.5	0.087	1.79	0.004	3.33	7.57	0.41
9	<i>Ceiba pentandra</i> *	1	0.77	110.23	6.81	13	4701.4	0.087	1.79	0.004	3.33	11.75	0.64
<i>Pole Level</i>													
1	<i>Mangifera indica</i> *	5						0.43	6.94	0.02	6.94		
2	<i>Gliricidia sepium</i>	4						0.35	5.56	0.02	5.56		
3	<i>Coffea sp.</i>	2						0.17	2.78	0.01	2.78		
4	<i>Flacourtia rukam</i> *	2						0.17	2.78	0.01	2.78		
5	<i>Arthrophyllum diversifolium</i>	12						1.04	16.67	0.05	16.67		
6	<i>Gmelina arborea</i> *	17						1.48	23.61	0.07	23.61		
7	<i>Lannea coromandelica</i>	2						0.17	2.78	0.01	2.78		
8	<i>Tectona grandis</i> *	3						0.26	4.17	0.01	4.17		
9	<i>Kleinhovia hospita</i>	5						0.43	6.94	0.02	6.94		
10	<i>Syzgium malaccense</i> *	1						0.09	1.389	0.004	1.39		
11	<i>Carica papaya</i>	1						0.09	1.389	0.004	1.39		
12	<i>Theobroma cacao</i>	17						1.48	23.61	0.07	23.61		



13	<i>Terminalia catapa</i>	1	<i>Sapling Level</i>			
			0.09	1,389	0.004	1.39
1	<i>Annona muricata</i>	2	0.174	4.167	0.004	2.1
2	<i>Mangifera indica</i> *	2	0.174	4.167	0.004	2.1
3	<i>Gmelina arborea</i> *	38	3.304	80.8	0.165	80.9
4	<i>Tectona grandis</i> *	4	0.348	8.511	0.017	8.5
5	<i>Citrus maxima</i>	1	0.087	2.128	0.004	2.1
6	<i>Artocarpus heterophylla</i> *	1	0.087	2.128	0.004	2.1
7	<i>Terminalia catapa</i>	1	0.087	2.128	0.004	2.1



**Figure 3.** Regeneration of 10 potential roosting tree species in Jenetaesa Village, Maros

#### 4. Discussion

The roosting tree species used by *Acerodon celebensis* in Jenetaesa Village, Maros Regency had experienced changes in both number of species and individuals per species over the years. The current study has found that the bats have been identified to roost in 142 individuals of 21 tree species and also inhabited 5 clumps of bamboos. A slight decrease in number of individuals of roosting tree was reported in earlier study where 147 individuals were used as roost in less than a year period [28]. Compared to the previous report in 2015, number of roosting tree species have increased where previously reported only 15 species with 68 individual trees and bats were mostly found in bamboos (28 clumps of bamboo) [30]. At present, more than 50% of the bats have used *Gmelina arborea* as roosting tree (66 individuals). *Gmelina arborea* has been widely planted by the villagers in the area. The species is known as *multi-purpose tree* species with short harvest-rotation and is widely used as major species in agroforestry practices in Indonesia to generate additional income for smallholder farmers [31]. Some villagers also combined gmelina with other timber, fruit, and other MPTS tree species such as, *Mangifera indica*, *Pterocarpus indicus*, *Ceiba pentandra*, and *Syzigium cumini*. These species were generally planted nearby the settlement including in the yards/gardens and surrounding the rice fields. Those trees were also commonly utilized by the bats to roost. From direct observations, the changes in roost tree species and number of individuals could be related with tree clearing by the villagers or could be occurred due to other disturbances towards the bat's colonies which was related with human activities in surrounding the roosting site. The fact that the roosting trees are in close proximity with human settlement and agricultural activities, has emerged concerns on the existence of the roosting trees in the future.

Apart from disturbances by human, roost fidelity is also related with the distance and stability of foraging sites as food resources and predator pressures [19]. In the study area, permanent movement of all colonies of *Acerodon celebensis* to other roost site did not occur. This has indicated that the current roosting site had provided secure permanent foraging sites with less or no predation. The bats only showed frequent switching roost tree behaviour to other trees within the area. Bats that are using tree as roosting habitat tended to have low fidelity compares with those used permanent sites such as caves, tree hollows, and man-made structures [19,32]. Movement between different roost trees or even changes to other roosts within the site could be due to group size, environmental factors and the stage of reproduction [33]. In 2015, the majority of the bats have inhabited bamboos [30] and during the research the bats have mostly moved to gmelina trees.

The causes of the movement were suspected due to human activities including disturbances from domesticated animals nearby the roost. The pressures from the surrounding community were considered high as shown during the observations where the local community were caught to cut down trees for woods and building materials. There was also a possibility that the *Acerodon celebensis* switched the roosts and moved to other nearby roosts due inadequate conditions of the roosts which were no longer fulfilling their needs.

To measure potential roosting tree within a total area of 11.5 ha, 230 plots were established (with a total area of 11.5 ha), there were total of 234 individual potential trees of 30 tree species from seedling to tree levels. However, the largest number of individuals were at pile level with 72 individuals and tree level with 56 individuals. Both seedlings and saplings were below 50 individuals. In addition, not all potential tree species had individuals at each growth level. There were only two species (*Gmelina arborea* and *Mangifera indica*) had representative individuals per growth level. The success of regeneration of different species is generally influenced by several factors such as availability of dispersal agents, conditions of surrounding environment, including the ability of regeneration and species defence against competition [34]. *Tectona grandis* showed a "J" curve of its population structure which described the absence of individuals of seedlings of this plant species. Considering the conditions where the seedlings of the potential tree species found on the plots were located close to settlements, including plantations, rice fields, and the presence of community domesticated livestock, it can be assumed that the low survivability of plants at various growth level could be caused by human activities for example, weeding treatment conducted by the land owner or due to predation by animals. Other thing that may affect the rate of tree species regeneration was the characters of the seedlings themselves,

which might be difficult to grow and develop without special assistance or treatment, as well as influences of seasonal changes and weather conditions, nutrients possessed by the planting medium, and the size of the seedlings [35].

Besides the low regeneration of the potential roosting trees at various growth level in the area, potential roosting tree individuals for *Acerodon celebensis* in Jenetaesa Village were only 234 individuals at the area of 11.5 ha. This means that the density of the potential trees was also low or in other words number of trees that can potentially be used as roosting was limited and to the fact that most potential tree individuals were found only in 15 plots out of 230. In addition, in terms of roosting tree colonization, fruit bats also consider several things related with the physical characteristics of trees. Kunz [19] explains roosting tree selection, bats exclusively choose trees that can be used as a shelter from predators and human, served as camouflage for the bats while hanging, provided protection from the weather (sun and wind exposure), including offered protection for young bats from predators, the possibility of multiplying colonies, and the stability of available foraging area nearby [36,37]. The physical aspects of the trees required by fruit bats in nesting were tall tree with large trunk, dense leaves, umbrella-like canopy, and branches located far from the ground to avoid risks from predators [37,38].

As explained above, the current potential trees in Jenetaesa Village could not always guarantee to serve as future roosting sites for the bats as bats might select the most suitable ones to be inhabited. Meanwhile, bat populations as shown by the increase of trees used in 2015, have also indicated an increase. Current trees might not provide sufficient support for the bats. And therefore, there should be some efforts not only to maintain the existence of the current and potential roosting tree species but also to enrich the area by planting more potential roosting tree species. Other thing that can be done to increase the number of roosting tree species is to monitor the growth of certain important tree species to the fact that certain tree species might require optimal conditions for growth and development. To better conserve the endemic species, local government in particular at the village level should enact a regulation to prohibit roosting tree clearing and there should be a clear procedure and plan for timber cutting in the area. Education and outreach on bats, their habitats and conservation to the villagers are important to minimise impact towards the habitat and bat populations.

## 5. Conclusion

*Acerodon celebensis* have inhabited various tree species as roosting tree in Jenetaesa by occupying around 142 individuals of 21 tree species. Meanwhile, potential roosting trees within the area was limited with only 234 individuals at different growth levels found in an area of 11.5 ha. In the other sides, the regeneration of potential trees was also low as more than 60% of the individuals were at mature state with less young individuals survived. Conservation efforts need to focus on habitat enrichment followed by tree growth monitoring and maintenance to ensure the growth and development of potential tree species. This has to be accompanied with the establishment of local regulation for habitat management as well as education and outreach for the villagers on Sulawesi endemic bats (*Acerodon celebensis*) and its conservation.

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