Climate change mitigation through biodiversity conservation of wild nutmeg (*Myristica spp.*) and its habitat (case study in Halmahera Forest, North Maluku)

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Abstract. Changes in the growing environment (habitat), including the habitat of wild nutmeg (*Myristica* spp.) due to deforestation, land degradation due to mining, erosion of soil fertility, reduced density of flora, fauna, and microorganisms can increase the risk of climate change. The role of the wild nutmeg plant environment is that its canopy can absorb CO_2 from the air, and its roots effectively store water and prevent erosion so that it can mitigate climate change. Vegetation analysis is used as an approach to climate change mitigation through managing wild nutmeg habitat biodiversity as a single function of the Halmahera forest against the impacts of climate change. The results of vegetation studies on the natural habitat of wild nutmeg have shown that the composition and structure of the natural habitat vegetation of wild nutmeg in the Halmahera forest have been disturbed although still in the moderate category. The composition and structure of the natural habitat vegetation of wild nutmeg (*Myristica* spp.) in the Halmahera forest, North Maluku with abundant diversity and high species richness can play a role in mitigating climate change as long as the biodiversity of vegetation in this area is maintained stable. Further studies based on this research can provide deeper insight into wild nutmeg conservation strategies and their role in mitigating climate change.

Keywords: *Mitigation, Climate Change, Wild Nutmeg, Biodiversity*

1 Introduction

Climate change impacts ecosystems through changes in average conditions and climate variability and increases in atmospheric CO2 concentrations [1], including changes in ecosystems such as degradation, deforestation, and fragmentation that have effects on biodiversity, energy networks, and nutrient cycles. At the same time, ecosystems can also play a role in mitigating climate change, namely through management to increase resilience and the ability of ecosystems to transform against the impacts of climate change [2].

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Climate change influences extreme climate variability and alters patterns of human interaction in response to rapidly changing ecosystems, including shifts in temperature, precipitation, atmospheric carbon dioxide concentrations, and water balance [1,3]. An opportunity to increase resilience to climate change is to anticipate future ecological changes with a conservation approach to protect or restore the complexity and structure of ecosystems in tropical forests. [4,5]

The diversity of plant communities can be eroded due to increasing climate warming [1], so it is necessary to conserve plant ecosystems that allow species to thrive despite the challenges of a rapidly changing growing environment. Conservation actions will increase the potential for climate change mitigation where biodiversity can play a key role in regulating biogeochemical cycles, greenhouse gases, and the long-term removal of atmospheric carbon dioxide [2,6]

The potential for carbon sequestration by forest plants is very significant in mitigating climate change because they function not only to protect and restore forests but also other native ecosystems, such as peat lands and mangrove forests, which provide the benefits of increasing biodiversity and avoiding forest conversion. Forest conversion is carried out to increase the potential for protection and recovery from the effects of climate change. Strategies for increasing vegetation cover can contribute to climate change mitigation [1]. Protection, management, and breeding strategies for climate change mitigation can be carried out through nature-based biodiversity conservation [6]

Wild nutmeg (*Myristica spp*.) is an export commodity that produces seeds and mace with high economic value. Wild nutmeg is a source of diversity among wild plants that grow naturally in the forests of Halmahera Island, North Maluku, Indonesia. Wild nutmeg has a floristic species composition [7], life forms, diversity, and community structure concerning edaphic variables [3], its population is threatened due to shifting cultivation and the development of mining areas, which cause land degradation and deforestation but the recent changes in climate variables did not impose any direct detrimental impact on biomass [8]. These activities reduce forest cover, degrade soil quality, increase greenhouse gas emissions, and affect biodiversity in the region [9]

This study was conducted to determine the composition and vegetation structure of wild nutmeg populations that are beneficial for the development of economic value and tree cover potential, as well as biological value, especially related to CO2 absorption, preventing erosion, and water absorption, as well as providing scientific reasons about the potential development of wild nutmeg germplasm conservation that plays a role in mitigating climate change in the North Maluku region. The targets of that call for the conservation and protection biodiversity, increasing nature-based solutions for climate mitigation and adaptation, and increasing investment in biodiversity conservation.

2 Research Methods

2.1 Location of Research

Vegetation research on wild nutmeg populations was conducted in forest areas in Central Halmahera and East Halmahera Regencies, North Maluku Province. detail of the geographical coordinate of the study sites is Wayamli: 1° 00' - 0° 59' South Latitude and 128° 30' - 128° 22' East Longitude and Maba Bicoli : 0° 33' - 0° 42' S and 128° 30' - 128° 31' E) in East Halmahera Regency and Patani: 0° 16' - 0° 17' S and 128° 44' - 128° 48' East in Central Halmahera Regency.

2.2 Data Collection and Data Analysis

The purposive sampling was used to identify the village woodlands in the East Halmahera and Central Halmahera Regencies, which were the locations of the wild nutmeg populations that were sampled. Snowball sampling was used to determine the number of population samples based on the informants' recommendations. A plotless sampling methodology is a sampling approach that uses no plots to analyze the vegetation of the wild nutmeg population. This method, assuming that the individual plants are distributed randomly, measures the distance between individual plants or the distance from a randomly chosen tree to the particular plants nearest to the observation site.

The Point Centered Quartered Method is one of the most effective plotless sampling techniques because it is simpler to use in the field, takes less time, and does not require a correction factor to estimate the density of individual plants. However, it has some restrictions, including the requirement that each quadrant contain at least one individual plant and that each individual cannot be counted more than once [10]. The steps for carrying out:

Placing several sampling locations at random throughout the plant population. In a neighborhood with a wild nutmeg population, a compass direction line (the pilot line) is first drawn. Along this line, several sample spots are then randomly or routinely selected. To increase sampling accuracy, the planned sample points are at least 20 sample points chosen.

Using a compass, divide the region surrounding the sample point into four equal-sized quadrants (Figure 1). Alternatively, suppose a sequence of paths is utilized. In that case, the quadrants can be created by using the pathways themselves and a line perpendicular to the pathways that pass through the example point.

For each measurement point, a fictitious ordinate line and abscissa are created, resulting in four quadrants at each measurement point. The trees in each quadrant that are closest to the measurement point are the ones that were observed, and then the distance between each tree and the measurement point was calculated. Only the four chosen trees' dimensions were measured.

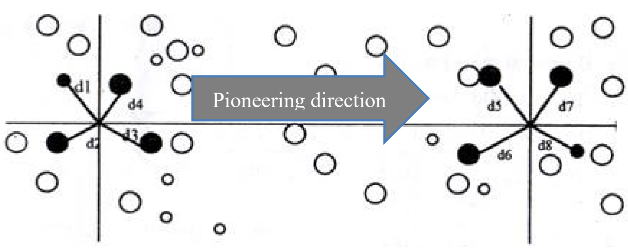

Figure 1. The design of Point-centered quarter method

Calculation of the quantitative value of vegetation parameters is as follows:
The average distance of individual trees to the measurement point

$$d' = \frac{d1+d2+\cdots+dn}{n} \quad (1)$$

a. Density (De)

$$\text{De} = \frac{Unit\ Area}{(d')^2} \quad (2)$$

$$d \approx Basal\ area = \left(\frac{1}{2}d\right)^2 \prod$$

c. Relative density (RDe)

$$\text{RDe} = \frac{Number\ of\ Individuals\ of\ a\ Type}{Number\ of\ Individuals\ of\ All\ Types} \times 100\% \quad (3)$$

d. The density of a Type (DeT)

$$\text{DeT} = \frac{RDe \times De}{100} \quad (4)$$

e. Dominance (Do)

$$Do = DeT\ \times Average\ Dominance\ Per\ Type \quad (5)$$

f. Relative dominance (RDo)

$$\text{RDo} = \frac{Do}{Dominance\ of\ all\ types} \times 100\% \quad (6)$$

g. Frequency (F)

$$\text{F} = \frac{Number\ of\ Points\ Found\ by\ a\ Type}{Sum\ of\ All\ Measurement\ Points} \quad (7)$$

h. Relative frequency (Rf)

$$\text{Rf} = \frac{F}{Frequency\ of\ all\ types} \quad (8)$$

i. Important Value Index (IVI)

$$IVI = RDe\ + RDo + Rf \quad (9)$$

j. Shanon-Wienner Diversity Index (H’)

$$\text{H}' = -\sum \left[\left(\frac{ni}{N}\right) ln \left(\frac{ni}{N}\right)\right] \quad (10)$$

k. Species richness Margaleff (R')

$$\text{R}' = \sum_{k=1}^{n} \left(\frac{S-1}{ln\ N}\right) \quad (11)$$

l. Sp.ecies evenness Pielou (E)

$$\text{E} = \frac{H\prime}{\ln S} \quad (12)$$

3 Results and Discussion

The natural habitat for wild nutmeg is described as a location where the plant grows and where the entire period of the plant's growth and development takes place. In the Halmahera Island Forest's natural habitat, 44 species of wild nutmeg were discovered. The recorded vegetation types were derived from the results of vegetation analysis on wild nutmeg habitat at 3 observation points, namely 2 points (Wayamli: 1° 00' - 0° 59' South Latitude and 128° 30' - 128° 22' East Longitude and Maba Bicoli : 0° 33' - 0° 42' S and 128° 30' - 128° 31' E) in East Halmahera Regency and 1 point (Patani: 0° 16' - 0° 17' S and 128° 44' - 128° 48' East) in Central Halmahera Regency.

The important value index (IVI) parameter provides an overview of the role of the species in question quantitatively and qualitatively in the community [4]. Differences in the composition and structure of vegetation within a community are influenced by vegetation phenology, dispersal, and natality [11–13]. Wild nutmeg vegetation (*Myristica* spp.) found

in natural habitats on Halmahera Island had the highest important value index (IVI) (54.75%), followed successively by *Euterpe edulis* (44.15%), *Agathis* spp.. (9.03 %), and *Macharang*a spp.. (8.25%), while other vegetation has an IVI ranging from 0.49% -5.94%, details in Table 1.

Table 1. The Composition of Vegetation in Natural Habitat of Wild Nutmeg (*Myristica* spp.) in Halmahera Forest, North Maluku.

No	Vegetation	De	BA	RDe	DeT	Do	RDo	F	RF	IVI
			m2	%			%		%	%
1	*Myristica spp..*	431.4	0.1	29.4	127	19.7	25.2	1.0	0.2	**54.8**
2	*Euterpe edulis*	1876	0.0	9.3	175	27.2	34.7	0.6	0.1	**44.2**
3	*Agathis spp..*	101.2	0.1	7.5	7.6	1.2	1.5	0.4	0.1	**9.0**
4	*Macaranga sp.*	2457.9	0.0	1.4	34.5	5.4	6.8	0.1	0.0	**8.3**
5	*Dracontomelon dao*	291.8	0.1	3.7	10.9	1.7	2.2	0.3	0.0	**5.9**
6	*Palaquium obtusifolium*	272.2	0.1	3.7	10.2	1.6	2.0	0.3	0.0	**5.8**
7	*Shorea sp.*	1301.9	0.0	1.4	18.3	2.8	3.6	0.1	0.0	**5.0**
8	*Pometia pinnata*	73.3	0.1	4.2	3.1	0.5	0.6	0.4	0.1	**4.9**
9	*Cannarium hirsutum*	346.1	0.1	2.8	9.7	1.5	1.9	0.3	0.1	**4.8**
10	*Adina fogifolia*	156	0.1	3.3	5.1	0.8	1.0	0.2	0.0	**4.3**
11	*Callophylum spp..*	632.6	0.0	1.4	8.9	1.4	1.8	0.1	0.0	**3.2**
12	*Duabanga moluccana*	35.7	0.2	2.8	1	0.2	0.2	0.2	0.0	**3.0**
13	*Mangipera sp.*	285.1	0.1	1.9	5.3	0.8	1.1	0.2	0.0	**3.0**
14	*Tristania sp.*	970.3	0.0	0.9	9.1	1.4	1.8	0.1	0.0	**2.7**
15	*Anthocepalus chinensis*	75.1	0.1	2.3	1.8	0.3	0.4	0.2	0.0	**2.7**
16	*Homalium foetidum*	43.5	0.2	2.3	1	0.2	0.2	0.2	0.0	**2.6**
17	*Alstonia scholaris*	378.8	0.1	1.4	5.3	0.8	1.1	0.1	0.0	**2.5**
18	*Cinnamomum culilawan*	657	0.0	0.9	6.1	1.0	1.2	0.1	0.0	**2.2**
19	*Gnetum gnemon*	1494.4	0.0	0.5	7	1.1	1.4	0.1	0.0	**1.9**
20	*lstonia angustiloba*	155.7	0.1	1.4	2.2	0.3	0.4	0.1	0.0	**1.9**
21	*Intsia bijuga*	485.5	0.1	0.9	4.5	0.7	0.9	0.1	0.0	**1.9**
22	*Mangifera minor*	448.8	0.1	0.9	4.2	0.7	0.8	0.1	0.0	**1.8**
23	*Hibiscus tiliaceus*	1394	0.0	0.5	6.5	1.0	1.3	0.1	0.0	**1.8**
24	*Litsea angulata*	375.7	0.1	0.9	3.5	0.5	0.7	0.1	0.0	**1.6**
25	*Vitex cofassus*	42.3	0.2	1.4	0.6	0.1	0.1	0.1	0.0	**1.5**
26	*Anisopthera thrurifera*	28.5	0.2	1.4	0.4	0.1	0.1	0.1	0.0	**1.5**
27	*Ficus benyamina*	19.2	0.2	1.4	0.3	0.0	0.1	0.1	0.0	**1.5**
28	*Dillenia spp..*	1067.6	0.0	0.5	5	0.8	1.0	0.1	0.0	**1.5**
29	*Gmelina moluccana*	940.3	0.0	0.5	4.4	0.7	0.9	0.1	0.0	**1.3**
30	*Arengapinnata*	831.4	0.0	0.5	3.9	0.6	0.8	0.1	0.0	**1.2**
31	*Gluta renghas*	831.4	0.0	0.5	3.9	0.6	0.8	0.1	0.0	**1.2**
32	*Lagruceae sp.*	157.8	0.1	0.9	1.5	0.2	0.3	0.1	0.0	**1.2**
33	*Petrocarpus indica*	657	0.0	0.5	3.1	0.5	0.6	0.1	0.0	**1.1**

34	*Piper aduncum*	657	0.0	0.5	3.1	0.5	0.6	0.1	0.0	**1.1**
35	*Artocarpus elasticus*	657	0.0	0.5	3.1	0.5	0.6	0.1	0.0	**1.1**
36	*Myristica iners*	62.6	0.1	0.9	0.6	0.1	0.1	0.1	0.0	**1.1**
37	*Mimusops elengi*	38.8	0.2	0.9	0.4	0.1	0.1	0.1	0.0	**1.0**
38	*Heritera sylfalica*	555.5	0.0	0.5	2.6	0.4	0.5	0.1	0.0	**1.0**
39	*Vatica Papuana*	20.8	0.2	0.9	0.2	0.0	0.0	0.1	0.0	**1.0**
40	*Syzygium polyanthum*	332.4	0.1	0.5	1.6	0.2	0.3	0.1	0.0	**0.8**
41	*Aglaia sp.*	302.2	0.1	0.5	1.4	0.2	0.3	0.1	0.0	**0.8**
42	*Hopea novoguineensis*	145.7	0.1	0.5	0.7	0.1	0.1	0.1	0.0	**0.6**
43	*Quercus sp.*	64.6	0.1	0.5	0.3	0.1	0.1	0.1	0.0	**0.5**
44	*Paraserianthes falcataria (L.)*	21.3	0.2	0.5	0.1	0.0	0.0	0.1	0.0	**0.5**
Sum				**100**			**100**		**1**	**201**

Note: De= Density, RDe=Relative Density, BA=Basal area, DeT=Density of a tyipe Do=Dominance, RDo=Relative Dominance, F= Requency, FR=Relative Frequency, IVI=Important Value Index.

Plant species composition is a measure of the number of individuals in a particular community at a certain time [4]. The composition and structure of vegetation are mainly influenced by factors related to habitat, such as climate and taiga activity [14]. The type of composition is a variable that can be used to determine the current state of the process of successfully disrupted communities [15]). Therefore, if the composition of the habitat has returned to its original state, it can be said that the habitat in question has recovered significantly [16].

The results of the analysis of vegetation in the natural habitat of wild Nutmeg in Halmahera Island Forest (Table 1.), showed that wild Nutmeg (*Myristica* spp.) had the highest important value index (IVI) (54.75%), followed successively by *Euterpe edulis* (44.15%), *Agathis* spp.. (9.03%), and *Macharanga* spp. (8.25%), while other vegetation has an IVI ranging from 0.49% -5.94%. This illustrates the vegetation composition of the wild Nutmeg natural habitat, relatively dominated by *Myristica spp., Euterpe edulis*, *Agathis* spp., and *Macharanga* spp. In addition, it provides an overview of the role of these vegetation types as identifiers of vegetation structure in the wild Nutmeg natural habitat community in the Halmahera forest.

The implications of a highly important value index (IVI) parameter for *Myristica* spp., *Euterpe edulis, Agathis spp.*, and *Macharanga* spp. provide an overview of the role of the species concerned quantitatively and qualitatively in their communities [4]. The IVI range of 0.49%-5.94% in other vegetation indicates that there are differences in the composition and structure of the vegetation in the natural habitat of wild Nutmeg based on vegetation phenology. Differences in the composition and structure of vegetation within a community are influenced by vegetation phenology, dispersal, and natality [13][11][12]

High density but with a narrow basal area in *Macaranga* sp., reflecting the small canopy cover area of *Macaranga* sp. even in a large number of stands. Conversely, *Ficus benjamina* has the lowest density but has the highest basal area value. This means that the presence of *Ficus benjamina* and several other individuals with large basal areas, such as *Vatica Papuana*, *Paraserianthes falcataria (L.), Vitex cofassus*, and *Mimusops elengi* can expand the surface area of wild nutmeg in a wider habitat compared to other types of vegetation. The cover area is the proportion of the area covered through canopy cover or basal area by plant sp.ecies to the total area of the habitat[17][18][19].

High cover area but with low dominance and IVI in vegetation types *Ficus benjamina, Vatica Papuana, Paraserianthes falcataria (L.), Vitex cofassus*, and *Mimusops elengi*

illustrates the distribution of basalt vegetation in large areas in wild Nutmeg natural habitat communities, not limiting growth and development of wild Nutmeg. In the field, wild Nutmeg can adapt optimally to physical, biotic, and chemical environmental factors even though it grows and develops in evacuated areas. Several types of vegetation in tropical forests are adapted to conditions under the canopy, in the middle, and above the canopy with different light intensities [20][4][21].

The existence of *Pometia pinnata and Duabanga moluccana* species which have a large diameter and high IVI can affect environmental factors in the natural habitat of wild Nutmeg, even in a limited number of tree stands. The effect is in the form of the ability to peel a wider area, inhibiting irradiation, and increasing humidity in the area being evacuated [22]. Wild nutmeg can adapt under the cover of *Pometia pinnata* and *Duabanga moluccana* vegetation so that it can grow and develop properly. The success of each type of vegetation in occupying an area is influenced by its ability to adapt optimally to all physical environmental factors (temperature, light, soil structure, humidity), biotic factors (interactions between species, competition, parasitism), and chemical factors which include water availability, evapotranspration and water efficiency [23], oxygen, pH, nutrients in the soil that interact [24–26]

The vegetation types *Myristica spp.., Euterpe edulis, and Macaranga sp.* have high dominance values as well as IVI. This describes two conditions, namely 1). the phenological similarity between *Myristica spp.. and Euterpe edulis* [27], and 2) natural habitat ecosystems for wild Nutmeg which have undergone changes and disturbances due to human intervention. The phenology similarity indicates the need for the same growth factors, so it can be stated that land grown by *Euterpe edulis* is good land for growing wild Nutmeg. On the other hand, the natural habitat of wild Nutmeg which has experienced a change in vegetation composition due to disturbance is marked by the presence of secondary vegetation, such as *Macaranga* sp.

Table 2. Biodiversity of Vegetation in the Natural Habitat of Wild Nutmeg in Halmahera

Parameter of Diversity	Category
Shanon-Wienner Diversity Index (H')	**2.96** (H' 1 ≤ H ≤ 3)
Sp.ecies richness Margaleff (R')	**31.68** (R' > 5)
Sp.ecies evenness Pielou (E)	**0.55** (0.3 < E < 0.6)

Population structure of wild Nutmeg natural habitat based on species density and dominance parameters, the highest were *Myristica spp., Palmae spp., Agathis spp., Macaranga sp., Dracontomelon dao, Palaquium obtusifolium, Shorea sp., Cannarium hirsutum,* and *Adina fogifolia*. Thus, these types of vegetation are vegetation that utilizes most of the resources in the wild nutmeg habitat ecosystem. The distribution of species, density, and dominance of a plant has a very real correlation with the place where it grows or its habitat. The dominance level of each species is determined by the density and diameter of the trees which correlate with the area of land cover (basal area) [21,28]

Biodiversity of vegetation in the natural habitat of wild nutmeg in Halmahera forest, North Maluku, which has moderately abundant species diversity (H'), high species richness (R), and moderate evenness of species. Moderate abundant diversity and evenness in ecosystems can enhance the resilience and stability of wild nutmeg populations, ensuring their conservation and sustainable use [5,29]. The biodiversity component is influenced by the condition of the natural community, in the form of biodiversity both plants, animals, and microorganisms [30], soil type, geology, climate, variations in altitude, and rainfall [31], but also influenced by human involvement, such as discourse between economic and ecological interests [32] and forest change into agroforestry [33], e.g. the application of a combination of crops planting based on silvicultural, hydro-orological, and economic aspects [34].

Changes in the composition and structure of forest vegetation are strongly influenced by both natural and anthropogenic disturbances [35].

4 Conclusion

The composition and structure of the vegetation in the natural habitat of Wild Nutmeg (*Myristica* spp.) in the forests of Halmahera, North Maluku, with its abundant diversity and high species richness can play a role in mitigating climate change as long as the biodiversity of the vegetation in this area is maintained instability. Tree vegetation from the *types Ficus benjamina, Vatica papuana, Paraserianthes falcataria, Vitex cofassus, and Mimusops elengi,* followed by tree vegetation from the types *Pometia pinnata and Duabanga moluccana*, plays an important role and influences environmental factors in the natural habitat of wild nutmeg (*Myristica spp.*), so that the existence of vegetation. This limits the level of stability of forest ecosystems in mitigating climate change. The presence of *Macaranga sp.* as secondary vegetation is a predictor of ecosystem change toward the stability of the natural habitat of wild Nutmeg (*Myristica spp.*) in the Halmahera forest. Moderate abundant diversity and evenness in ecosystems can enhance the resilience and stability of wild nutmeg populations, ensuring their conservation and sustainable use. Further studies based on this research could provide deeper insights into wild nutmeg conservation strategies and their role in climate change mitigation.

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