Integrating issues of biodiversity and climate change to achieve sustainable forest management: A case of Mbeliling landscape, Flores

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Abstract. Biodiversity and climate change are interrelated, so a coordinated approach is needed to cover it by focusing on how landscapes provide many benefits. The Mbeliling landscape, Flores is the smallest management unit in an ecological perspective, essential for the conservation and preservation of biodiversity, especially for the endemic birds of Flores. Efforts to preserve biodiversity are also expected to contribute to climate change mitigation and adaptation. The study aims to produce data and information on biodiversity and potential carbon stocks at the land cover of the Mbeliling landscape. Desk study and field survey were used to answer research questions. The Mbeliling landscape has eight types of tree vegetation land cover that can serve as carbon sinks and the habitat for four species of Flores endemic birds. Approximately 139 species of vegetation with the total carbon stocks could potentially absorb the carbon dioxide in the atmosphere of ± 103.63 Mt CO2-e. The type of land cover significantly influences carbon stocks. The land cover with forest category in the Mbeliling landscape has the most extensive carbon stock among other land cover types. This result can be used as a reference in managing the Mbeliling landscape in integrating efforts to conserve biodiversity and mitigate climate change through the REDD+ scheme.

1. Introduction
Poverty, food security, climate change, water scarcity, deforestation, and biodiversity loss are interrelated global problems. Economic needs and food security often require the development of agricultural activities that sometimes drive the loss of forests as a source of biodiversity that ultimately impacts increasing GHG emissions. These problems are interrelated, so an integrated approach is needed to address them by focusing on how landscapes provide multiple ecological, economic and social benefits.

There has been a shift in the paradigm in realizing sustainable management from "Weak Sustainability" to "Strong Sustainability." Sustainable management will be achieved if there are only
ecological, economic, and social slices but separate from a system (Weak Sustainability) but when the three aspects (environmental, economic and social) have also developed closer to the picture of sustainability, called "Strong Sustainability." "Strong Sustainability" assumes that economic, social, and environmental capital are complementary but not interchangeable: a particular function performed by the environment cannot be duplicated by humans or human-made capital [1]. This makes it a challenge to manage an area. Biodiversity and climate change are linked. Efforts to conserve biodiversity through ecosystem services can also contribute to climate change mitigation and adaptation. The climate change era that generates economic activities to mitigate and adapt to climate change must be utilized and integrated to conserve biodiversity.

The existence of the Mbeliling Forest in the Mbeliling landscape has an essential meaning for the conservation of Flores Biodiversity. Mbeliling Forest, previously known as Tanjung Karita Mese, is one of the conservation areas proposed by FAO/UNDP because it is a habitat for Flores endemic birds. Tanjung Karita Mese, currently known as the Mbeliling Forest, is a tropical forest located 12-20 km southeast of the district capital, Labuan Bajo.

Another important ecological function of the existence of Mbeliling Forest is as a “carbon sequester” (absorber and storage of carbon stocks). Its function has become essential in the era of climate change, which is the most significant environmental challenge of the twenty-first century. Furthermore, most of the surrounding Mbeliling forest community uses the Mbeliling landscape as a source of livelihood by developing agroforestry, rice cultivation, and livestock activities in the area. As the real economic value of Mbeliling forest to support various functions continues to grow, new opportunities arise to manage the forest as part of a productive landscape by integrating environmental and socio-economic interests to achieve sustainable management. The importance of biodiversity conservation and the ecological value of carbon in the Mbeliling Nature Forest is the research background to produce data and information on biodiversity and potential carbon stocks at the land cover of the Mbeliling landscape.

2. Materials and Methods
The research was conducted using desk study and field survey methods, which were then analyzed descriptively and quantitatively.

2.1. Site description
The Mbeliling landscape with an area of ± 94,000 Ha is located on the island of Flores, administratively belongs to the West Manggarai Regency, East Nusa Tenggara Province. Geographically this area is at 119°47'60"E - 120°07'48"E and 08°32'06"S - 08°52'12"S (Figure 1).

2.2. Methods
The location of the sample plots was determined based on the stratified sampling design. GPS was used to match the accuracy of the tree sampling location to the predetermined plot locations (159 plots). The distribution of sample plot locations consists of shrubs (16 plots), teak forest (9 plots), primary dryland forest (41 plots), secondary dryland forest (41 plots), secondary mangrove forest (4 plots), agriculture (16 plots), mixed agriculture (16 plots) and savana (16 plot).

The sample plot for observing trees is a rectangular plot measuring at least 0.1 hectares with a width of 20 m and a length of 50 m which is divided into five subplots, namely: A (2 x 2 m), B (5 x 5 m), C (10 x 10 m), D (20 x 20 m), E (20 x 50 m) (Figure 2). Measurements of plant biodiversity and carbon storage in each carbon pool were carried out on a measuring plot (Figure 2). Vegetation tree life/death is classified based on the growth stage as follows:
- Seedlings/understoreys are vegetation with a height of less than 1.5 m and Ø <2cm;
- Saplings are vegetation with a minimum height of 1.5 m with Ø ranging from 2 cm to <10 cm;
- Poles are woody plants ranging with Ø ranging from 10 cm to <20 cm;
- Small trees are woody plants with Ø ranging from 20 cm to <35 cm;
- Large trees are woody plants with a minimum Ø of 35 cm.
The carbon storage value is estimated by destructive sampling, weighing or non-destructive sampling, using conversion factors, or using a relationship model with specific parameters. In summary, the method of estimating carbon stocks used in this study is shown in Table 1.
Table 1. Methods for estimating carbon stock.

| Carbon pool's                               | Sampling methods                                    |
|---------------------------------------------|------------------------------------------------------|
| Aboveground Biomass                         |                                                      |
| *Seedling, understory (herbs, shrub)*      | Destructive                                          |
| *sapling, pole, tree*                      | Non-destructive (allometric model)                  |
| *Palm, rattan*                             | Non-destructive (allometric model)                  |
| Belowground Biomass                         |                                                      |
| Deadwood                                    |                                                      |
| *Standing dead tree*                        | Non-destructive (allometric model and deadwood criteria) |
| *Dead tree fell*                            | Non-destructive (geometric volume)                  |
| *Stump*                                    | Non-destructive (geometric volume)                  |
| *Fallen parts of the tree (branches, twigs)*| Destructive                                          |
| Litter                                      | Destructive                                          |
| Soil                                        | Destructive                                          |

Species diversity based on the land cover type was analyzed using a diversity index [2] which includes: a) Shannon diversity index, b) Species richness index (Margalef index), and c) Evenness index.

**Shannon's diversity index**

\[ H' = \sum_{i=1}^{s} \left( P_i \times \ln(P_i) \right) \]

Remarks:

*H' is the diversity index, P_i is ni / N, ln is the natural logarithm, ni is the number of individuals of type i, N is the number of individuals.*

**Species richness index (Margalef Index)**

\[ D_M = \frac{S - 1}{\ln N} \]

Remarks:

*Where N is the number of individuals from all recorded species and S is the number of species.*

*H' is the diversity index, P_i is ni / N, ln is the natural logarithm, ni is the number of individuals of type i, N is the number of individuals.*

**Evenness Index**

\[ E = \frac{H'}{H'_{max}} \]

Remarks:

*E is the evenness index (values between 0-1), H' is the Shannon-Wiener diversity index, H'_{max} = \ln S and S are the number of species.*

Processing and analysis of carbon stock data include calculating biomass and carbon storage in each land typology at the plot scale. Determination of standing live and dead tree biomass on a plot scale of several tree species was carried out using the non-destructive sampling method, which is calculated using several available specific allometric equations such as AGB = 0.048*D^{2.68} for mahogany [3], AGB = 0.0579*D^{2.5596} for sengon [4], AGB = 0.281*D^{2.065}, AGB = 0.030*D^{2.13}, AGB = 0.131*D^{2.28} for coffee, banana and bamboo [5], AGB = 4.5+7.7*H_{stem} for Palm [6], \ln AGB = -1.576 + 2.179*\ln D +
0.198*(lnD)^2 – 0.0272*(lnD)^3 + 1.036*ln ρ for others tree [7]; AGB = aboveground biomass (kg), D = diameter at 1.3 m (cm), ρ = wood density (gr/cm³). Below ground biomass was determined using a root-to-shoot ratio (AGB≤125:0.323 and >125:0.246) [16]. Dead tree fell and stump were calculated using the geometric volume formula (V = [(1/4 Π D₁)+(1/4 Π D₂)]/2 x L). Carbon stocks stored in biomass can be determined by multiplying the biomass by the carbon fraction of the biomass, which is generally 0.47 (0.44-0.55) [16].

3. Results and Discussion
Mbeliling landscape is one example of integrating biodiversity conservation and climate change in one management unit with a landscape approach.

3.1. Integrating environmental issues on landscape management
A landscape is defined as a socio-ecological system consisting of a mosaic of natural and human-modified ecosystems, with a configuration of topographic, vegetation, land use, and settlement characteristics influenced by ecological, historical, economic and cultural processes and activities [8]. With landscape-based management, it is hoped that there will be a balance between forest products and services (forest functions) or the balance between ecological integrity and community livelihood interests so that the various needs of the parties can be met at present and in the future [9]. The landscapescale is used as the basis for the scope, mainly related to the heterogeneity of the land unit characteristics and functions. Different types of land use have different amounts of carbon stored in biomass. Changing the type of land use to other types of land use can cause an increase or decrease in the amount of carbon in biomass. In this regard, it is essential to integrate a landscape approach into climate change mitigation and adaptation programs. The interaction between forests and other land units (agriculture, plantations, shrubs) in a landscape is necessary because forests play an essential role as environmental services providers. Landscapes are generally recognized as basic units for the conservation and preservation of biodiversity. Conservation of biodiversity at a landscape scale can sometimes be pursued due to climate change. Efforts to conserve biodiversity through the ecosystem services it supports also contribute to climate change mitigation and adaptation.

3.2. Biodiversity
Mbeliling landscape, Flores Island is located in the Wallacea region between the Oriental and Australian regions. In the western part, this area is bounded by the imaginary line of the Wallacea Line, while in the eastern part, it is bounded by the Leydekker Line. The Wallacea region is home to a beautiful mix of Oriental and Australian fauna elements. In addition, the isolated Wallacea region in the oceans has become an arena for the evolution of a large number of endemic bird species [10].

In the Mbeliling landscape area, there is a forest area, namely the Mbeliling Forest, located in the southwest of the island of Flores. The existence of the Mbeliling Forest has an essential meaning for the conservation of Flores Biodiversity, which has become a shelter for endemic/typical plants and bird species [11]. At least five types of Flores endemic birds can be found in the Mbeliling Forest, namely kehicap flores (Monarcha sacerdotum), celepuk flores (Otus alfredi), serindit flores (Loriculus flosculus), gagak flores (Corvus florensis), and perkici flores (Trichoglossus weberi). In addition, Seventeen birds that are important for conservation were also found in the study location, some of which have a "Critically Endangered" status, namely kakatua-kecil jambul-kuning (Cacatua sulphurea) [12].
Figure 3. Birds in the Mbeliling landscape: a) Kehicap Flores (Monarcha sacerdotum), b) Kakatua-kecil jambul-kuning (Cacatua sulphurea).

In the Mbeliling landscape area, approximately 139 species belonged to 123 genera and 59 families, and 41 species were not recognized/identified by the community. Several types of vegetation found in the Mbeliling landscape include Rhus taitensis Guill., Tectona grandis L.f., Canarium asperum Benth., Aleurites moluccanus (L.) Willd., Elaeocarpus floribundus Blume, Gliricidia sepium (Jacq.) Walp., Ficus variegata Blume, Arenga pinnata (Wurmb) Merr., Lagerstroemia flos-reginae Retz., Swietenia mahagoni (L.) Jacq., Dillenia pentagyna Roxb, and Pagiantha sphaerocarpa (Blume) Markgr.

Biodiversity includes two main parameters, namely: species richness and evenness [13]. Species richness is related to the number of different species present in the area being analyzed, while evenness describes the homogeneity (and heterogeneity) of species abundance [14]. This level of biodiversity can be determined quantitatively based on the Shannon-Wiener Diversity Index, the Margalef Species Richness Index, and the Magurran Evenness Index. The analysis of the level of biodiversity in the Mbeliling landscape can be seen in (Table 2).

Table 2. Level of biodiversity.

| Land Cover             | Shannon's diversity index (H') | Species richness index (D_Mg) | Evenness Index (E) |
|------------------------|-------------------------------|-------------------------------|--------------------|
| Shrub                  | 2.69                          | 7.10                          | 0.72               |
| Teak forest            | 1.12                          | 2.37                          | 0.44               |
| Primary dryland forest | 3.86                          | 13.54                         | 0.84               |
| Secondary dryland forest | 3.70                      | 12.27                         | 0.86               |
| Secondary mangrove forest | 1.63                    | 1.76                          | 0.91               |
| Dryland agriculture    | 2.73                          | 4.79                          | 0.88               |
| Mixed dryland agriculture | 3.21                     | 7.85                          | 0.85               |
| Savanna                | 2.03                          | 3.18                          | 0.77               |

Primary dryland forest has the highest Diversity Index (H') at various growth stages, followed by secondary dryland forest. Mixed dry land agriculture has a high level of diversity close to that of the forest. The level of diversity is identical to the stability of an ecosystem; if the diversity of an ecosystem is relatively high, the condition of the ecosystem tends to be stable [15]. These three vegetation communities have very stable environmental conditions (H'>3) with high diversity. In general, land cover in the Mbeliling landscape has stable environmental conditions because it has an H'>1.

Primary dryland forest has the highest Margalef species richness index value, followed by secondary dryland forest. Based on the category of species richness determination from the Margalef Wealth Index, which is <3.5 = low, 3.5-5 = medium and >5 is high, the mixed dry land agriculture and shrub can be
categorized as high species richness, apart from primary dry land forest and secondary dry land forest. Teak forest and secondary mangrove forest have land cover types with a low species richness category, while dryland agriculture is classified into the medium category. The Margalef species wealth index value is strongly influenced by the total number of individuals found in a particular area.

According to [15], the level of evenness of species abundance can be categorized into several classes, i.e., the evenness value ≥ 0.75 = evenly distributed species, the evenness value ≥ 0.50 to close to ≤ 0.75 = relatively even distribution of species, while the evenness value ≤ 0.50 types uneven distribution. In general, the type of land cover in the Mbeliling landscape has an even distribution of species, except for Teak Forest land cover, which is in the uneven distribution category with an index value of 0.44.

The analysis of various indexes shows that forests, mainly primary dryland forest, are the most valuable cover from a biodiversity perspective, considering species richness and evenness. Forest stands have the highest score on the Shannon, Margalef, Magurran index.

3.3. Carbon stock

The carbon stock stored in ecosystems varies greatly between vegetation types and conditions. Therefore, a comprehensive accounting of carbon stocks in a landscape requires accounting for all pools where carbon is stored. According to [16], five carbon pools must be considered in order to carry out a comprehensive carbon stock calculation, namely 1) aboveground biomass pools, 2) belowground biomass pools, 3) litter pools, 4) deadwood pools and soil pools.

Total carbon stock is based on a terrestrial analysis of the Mbeliling landscape, which is stratified based on land cover, shrub, teak forest, primary dryland forest, secondary dryland forest, secondary mangrove forest, and dryland agriculture, mixed dryland agriculture and savannas, is 28.26 Mt C. It can be said that the equivalent of carbon dioxide in the atmosphere of 103.63 Mt CO2-e. ± 29% of the total carbon stock of the Mbeliling landscape is stored in living vegetation. Almost 69% is stored in the soil, while the rest is in the necromass. Soil is the largest source of carbon storage, which is almost 2.5 times the carbon stock in living vegetation. The total carbon stock in the soil could reach 3 to 4 times the carbon stock in vegetation, especially on peat soils [17]. The average carbon stock in each land cover of the Mbeliling landscape in each carbon pool can be seen in Figure 4.

Aboveground Biomass pools in the Mbeliling landscape represent the most significant proportion of the total carbon stock of the four-carbon pools excluding soil, which is between 73% to 75%. Carbon stocks in the aboveground biomass pool are essential in the carbon inventory and the mitigation project in the Kyoto Protocol scheme [18]. Trees (DBH ≥10 cm) are the components that contribute the most extensive carbon stock to the ecosystem, which is 89% on average. However, several plots on the savanna cover contribute 0% to the total carbon stock, which means that there is no trees diameter>10 cm. This variation in proportions may be due to differences in species composition and structure of stands that make up the ecosystem, and species composition is closely correlated with wood density, particularly wood density for large trees with large wood volumes [19].

Primary dryland forest in the Mbeliling landscape is the type of land cover that has the most extensive average carbon stock (144.11 tonne C ha⁻¹), followed by teak forest (105.16 tonne C ha⁻¹) and secondary dryland forest (92.08 tonne C ha⁻¹). Meanwhile, the lowest was found in several plots with savanna/pasture cover (31.37 tonne C ha⁻¹). Thus, the average carbon stock in the forest ecosystem in the Mbeliling landscape is slightly lower when compared to the forest ecosystem in Kalimantan. Kalimantan’s primary dryland forest ecosystem has carbon reserves in the aboveground pools of 149 tonne C ha⁻¹ and 109 tonne C ha⁻¹ in the Secondary dryland forest [19].

The belowground biomass pool is closely related to the aboveground biomass pool. Belowground biomass pools are essential in forests’ carbon and nutrient cycling, comprising 20-26% of total biomass [20]. Root production accounts for about half of the carbon cycled annually in various forest types and 33% of global annual primary production [21]. Carbon stocks in the belowground biomass pool in the Mbeliling landscape in all land cover types determined by the Tier 1 approach, using the default root-to-shoot ratio value in the [22] (0.323 for AGB ≤125; 0.246 for AGB >125) is in the range of 9.37-34.22 tonne C ha⁻¹.
Litter carbon in forests is a relatively small but essential part of the carbon stream. Changes in litter carbon pools (C) have important implications for carbon accounting and negotiations for reducing global carbon emissions. The average carbon stock in the carbon litter pool in the Mbeliling landscape is 0.59 tonne C ha\(^{-1}\) or ranges from 0.33-1.35 tonne C ha\(^{-1}\) on various land cover types. Litter accounts for approximately 5% of all forest ecosystem carbon stocks worldwide [23]. The amount of litter is dynamically related to forest productivity and disturbance history. In climaetic forests, annual productivity levels tend to be offset by decomposition processes with minor accumulation [24, 25].

![Figure 4. The average carbon stock in each of the Mbeliling landscape land cover.](image)

Comprehensive carbon stock estimation requires measurement of all carbon pools, including deadwood / coarse woody debris (CWD). Deadwood (including dead and fallen trees) is a component of the carbon pool that plays a significant role in several forest types, particularly in secondary forests (disturbed forests). The average carbon stock in the Deadwood pool in the Mbeliling landscape is 8.06 tonne C ha\(^{-1}\) or ranges from 1.35-16.58 tonne C ha\(^{-1}\) on various land cover types. The amount of deadwood varies widely across continents [26]. Deadwood masses of 10% to 40% of aboveground biomass have also been reported by several previous studies [27]. Any disturbance in an ecosystem will affect the potential of its carbon stock, where there will be a flow of carbon stock from a carbon pool in aboveground biomass to a pool of deadwood carbon as residue or waste generated after the disturbance. This irregular distribution and frequency of disturbances, together with the mosaic of forest succession across the landscape, contributed to the high diversity of CWD within and across ecosystems [28]. The carbon pool in deadwood will provide a long-term carbon pool [24].

Soil types in the Mbeliling landscape are classified as lithosols/entisol, andosols/andisol (ochric andosols, mollic andosols). The average carbon stock value in the soil to a depth of 30 cm in the Mbeliling landscape is 207.15 tonnes C ha\(^{-1}\) ranging from 106.84 - 415.85 tonne C ha\(^{-1}\). Based on the Indonesian Soil Data Base [29], entisol soils have carbon stock values ranging from 2.90-319.40 tonne C ha\(^{-1}\).
4. Conclusion

The Mbeliling landscape is the smallest management unit from an ecological point of view which is essential for the conservation and preservation of biodiversity, especially for Flores endemic birds. In the Mbeliling landscape, there is forest cover having the largest carbon stock among other land cover types as well as at the level of biodiversity. Therefore, conservation efforts of biodiversity in the Mbeliling landscape also provide an important contribution to climate change mitigation and adaptation. The data and information generated from this research can be used as a reference for the Mbeliling landscape management by integrating efforts to conserve biodiversity and mitigate climate change through the REDD+ scheme.

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