UDC 633; DOI 10.18551/rjoas.2022-08.15

ESTIMATION OF STORED CARBON ABOVE SOIL SURFACE IN POST-ROTATIONAL CULTIVATION LAND OF DAYAK COMMUNITY

Rezekiah Arfa Agustina[1,2]*, **Ruslan Muhammad**[2], **Kadir Syarifuddin**[2], **Mahmud**[3]
[1]Doctoral Program of Agricultural Science, University of Lambung Mangkurat, South Kalimantan, Indonesia
[2]Faculty of Forestry, University of Lambung Mangkurat, South Kalimantan, Indonesia
[3]Faculty of Engineering, University of Lambung Mangkurat, South Kalimantan, Indonesia
*E-mail: aarezekiah@ulm.ac.id

ABSTRACT
The development of global warming is one of the main causes of climate change. The increase in greenhouse gasses causes global warming which affects the earth's ecosystem. The imbalance of CO_2 concentration in the atmosphere with the availability of vegetation is also one of the causes of climate change. Loksado District, which is located around the Meratus Mountains, with the majority of its people being the Meratus Dayak Tribe, still applies local wisdom owned by the local community by farming using a rotational system. This has resulted in the existence of former community cultivation lands which are divided into *balukar anum, jurungan,* and mixed gardens. The ability to store carbon is different for each land due to the variation in the types of vegetation that make up each land use. Therefore, this study was conducted to analyze and calculate the potential for carbon storage in each ex-cultivated area. Calculation of tree biomass during the research analysis used the allometric formula for estimating carbon content in natural forests. The percentage of carbon stored in a tree species in natural forest stands can be estimated at 47% of the total biomass. The mixed garden area had more species found than the other two areas. The highest average diameter and base area in the ex-cultivated area for the pole level are in the mixed garden area in Haratai Village, while the lowest value is in the B*alukar anum* area in Haratai Village. From the total biomass per hectare for each ex-cultivated area it can be seen that the biomass is greater at the tree level than at the pole level. The highest carbon estimate is in the mixed garden area in Lok Lahung Village, which is 61,097 tons/ha. Meanwhile, the lowest estimated carbon value is found in the anum balukar area in Haratai Village, which is 1,045 tons/ha.

KEY WORDS
Biomass, carbon, balukar anum, jurungan, mixed gardens.

Global warming is one of the main causes of climate change. The increase in greenhouse gasses causes global warming which affects the earth's ecosystem. The imbalance of CO_2 concentration in the atmosphere with the availability of vegetation is also one of the causes of climate change (Rahman et al. 2018). Vegetation has an important role as a CO_2 absorber so it can be an effort to overcome global warming caused by an increase in greenhouse gasses. Carbon storage is an important indicator of forest ecosystem services. One of the ways to determine carbon storage is by measuring aboveground biomass (Puspanti et al. 2021). Aboveground biomass consists of both living and dead vegetation. However, several studies have focused on measuring aboveground biomass using living components because of their superiority as the primary carbon store. Above ground, biomass accounts for 70% to 90% of the total forest biomass (Kumar & Mutanga, 2017). Accurate biomass estimates can be used to understand the impacts of deforestation and environmental degradation (Kumar & Mutanga, 2017).

Mitigation of carbon by reducing greenhouse gas emissions and increasing carbon storage has become one of the efforts to overcome climate change. Optimizing the potential for carbon sequestration in soil can be a way to mitigate climate change (Abdullah et al, 2022). Carbon emissions can be reduced through protected forest management by controlling deforestation and replacing fossil fuels with renewable fuels. There is one way to recover CO_2 from the atmosphere, namely by conservation, restoration, and sustainable forest management (Nunes et al. 2019). Land use practices related to trees, such as in forestry can make a major contribution to reducing atmospheric CO_2. Such land use has a high capacity to capture and store CO_2 on vegetation, soil, and in biomass products (Dayamba et al. 2016; Jose & Bardhan 2012).

Indonesia is a country that has forests with great potential and its existence is important for forest communities. The Meratus Dayak community living around the Meratus Mountains is one of the people who fulfill their daily needs by utilizing the land for gardening and farming. The community carries out gardening activities on their former agricultural land. The rotational system applies land clearing for cultivation activities that are rotated with annual crops in the fallow period after the cultivation period is complete to increase soil fertility and production levels (Kristian et al. 2019). In this system, people move from one land to another after being used for cultivation for approximately 2 years to rest the land. If the first land left is fertile after the fallow period, it will be re-opened for farming and this system will be sustainable (Kristian et al. 2013; Van et al. 2013). This farming system is the local wisdom of the local community in managing the land. Broadly speaking, land management with this system is related to three things, namely land clearing, planting period, and fallow period (Susanto, 2016). In a rotational system, the community utilizes annual crops in cultivated areas and annual crops such as rubber, fruits, candlenut, and cinnamon in ex-cultivated areas (Fahrianoor et al. 2014; Muhaimin et al. 2021; Siahaya et al. 2016)

Loksado District, which is located around the Meratus Mountains, with the majority of its people being the Meratus Dayak Tribe, still applies the local wisdom of the local community. For example, in Haratai Village, Lok Lahung Village, and Loksado Village, which still apply a rotational system for farming activities. This has resulted in the discovery of former community cultivation lands. The ex-cultivated land by the community is divided into *balukar anum, jurungan,* and mixed gardens. Changes in land use by communities can affect carbon stocks in an ecosystem (Han et al. 2015). Previously, the conversion of forest land into various other land uses was believed to be the main cause of global warming (Big et al. 2020). According to Abdullah et al. (2022), knowing the availability of carbon stocks in each land use is necessary because it is related to sustainable cultivation activities and can be an effort to conserve natural resources. Research on climate change in agriculture can be used to assess more controlled mitigation and adaptation and can be used to evaluate the potential for more appropriate management (Ogle et al. 2013). The diversity of species found in ex-cultivated areas from land use by the community has the ability to absorb and store carbon. The ability to store carbon is different for each land due to the variation in the types of vegetation that make up each land use. Therefore, it is necessary to conduct this study to analyze and calculate the potential for carbon storage in each ex-cultivated area.

MATERIALS AND METHODS OF RESEARCH

The study was conducted in Loksado District, Hulu Sungai Selatan Regency, South Kalimantan. Loksado District has an area of 338.89 km^2 and geographically borders Kotabaru Regency in the east, Banjar Regency in the southeast, Padang Batung District in the west, and Telaga Langsat District and Hulu Sungai Tengah Regency in the north (BPS Kab. Hulu Sungai Selatan, 2021). Loksado District is located around the Meratus Mountains where the community is dominated by the Meratus Dayak Tribe. The Meratus Dayak tribe has local wisdom in farming activities that use a rotational system. The research was conducted on former farming areas belonging to the community which was divided into *balukar anum, jurungan,* and mixed gardens in Haratai Village, Lok Lahung Village, and Loksado Village. These three villages were chosen because the majority of the community still carry out farming activities with a rotational system so that many ex-cultivated areas are found. The research location can be seen in Figure 1.

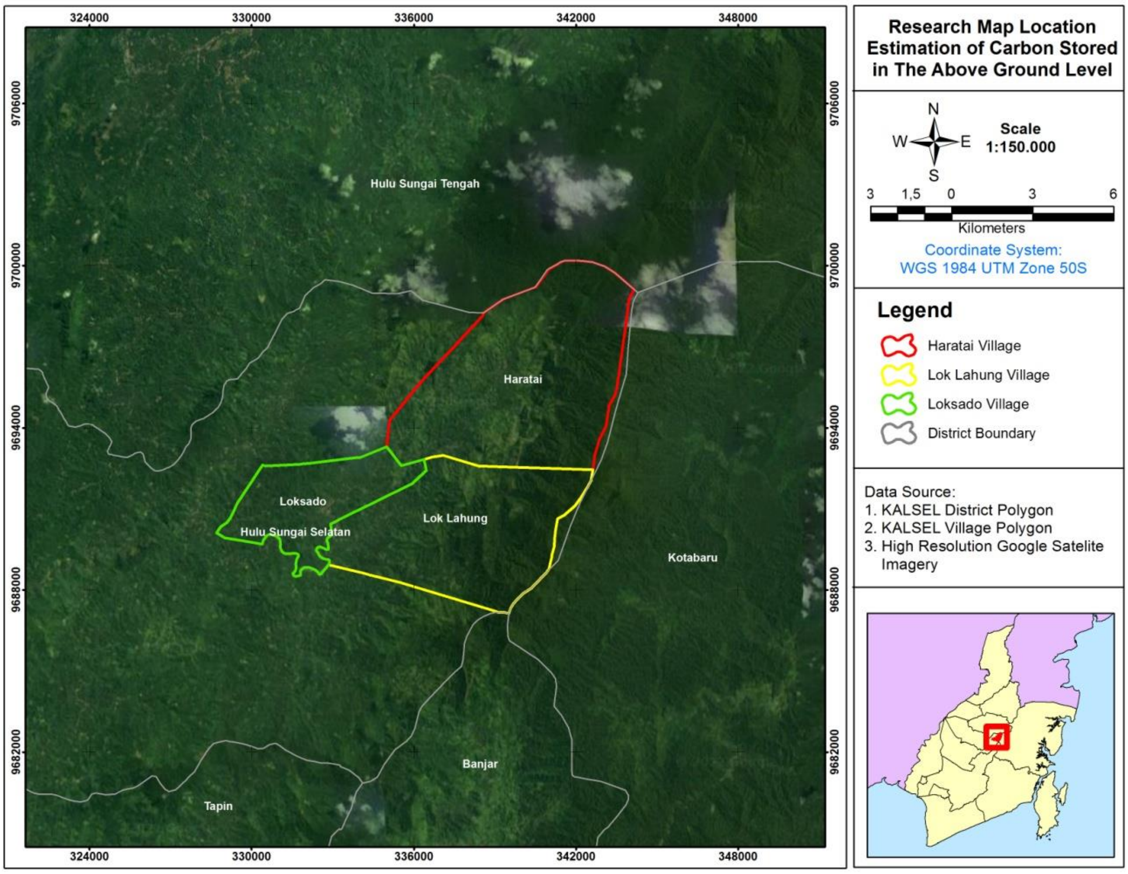

Figure 1 – The research location about the estimation of stored carbon above soil surface in Post-rotational cultivation land of dayak community

Calculation of tree biomass during the research analysis used the allometric estimating carbon content in natural forests by Ketterings (2001), as follows:

$$BD = \rho \, 0.11 \, D^{2.65}$$

Where: BD is the Biomass Density, then ρ is the kind density, D is the diameter at breast height (DBH), and the values 0.11 is the equation coefficients. After that, the biomass analysis was carried out using the above obtained per tree and was canceled for each land use.

Calculation of Biomass content per hectare for aboveground biomass with the following formula:

$$\text{Biomass in hectares (Kg/ha)} = \text{Biomass (in kg/m}^2\text{)} \times 10{,}000\text{m}^2$$

After knowing the value of biomass content in hectares, then the results are converted into units tons per hectare (Tons/ha). The percentage of carbon stored in a tree species in natural forest stands can be estimated at 47% of the total biomass (Indonesian National Standardization Agency number 7724, 2011).

RESULTS AND DISCUSSION

The types of vegetation found in former cultivation areas for balukar anum, jurungan and mixed gardens areas have varied results. In balukar anum area for pole level, woody plants such as balik angin (*Mallotus paniculatus*), candlenut (*Aleurites moluccana*), sungkai (*Peronema canescens*), cinnamon *(Cinnamomum verum)*, rubber (*Hevea brasiliensis)*, lua (*Ficus racemosa*), bangkal gunung (*Nauclea subdita*), and jengkol (*Archidendron *pauciflorum*) were found. In addition, plants such as banana (*Musa* sp.) and bamboo (*Bambusa* sp.) were also found. This is because balukar anum is a former field of cultivation with an age of 3-6 years, so some plants such as bananas and bamboo are still found. For the tree level, species were found such as jengkol (*Archidendron pauciflorum*), balik angin (*Mallotus paniculatus*), candlenut (*Aleurites moluccana*), sungkai (*Peronema canescens*), tarap (*Artocarpus odoratissimus*), bangkal gunung (*Nauclea subdita*), hillwood, and several other typical fruits plants of Kalimantan such as hamawang (*Mangifera foetida*) and tiwadak (*Artocarpus integer*).

The jurungan area which is a former cultivation area aged 6-12 years is dominated by woody plants. For the pole level found types of mahang (*Macaranga* sp.), candlenut (*Aleurites moluccana*), lua (*Ficus racemosa*), madang puspa (*Schima wallichii*), balik angin (*Malotus paniculatus*), candlenut (*Aleurites moluccana*), cinnamon (*Aleurites moluccana*), sungkai (*Peronema canescens*), palawan, tarap (*Artocarpus odoratissimus*), and jengkol (*Archidendron pauciflorum*). Types of fruit were found, such as hambawang (*Mangifera foetida*), durian (*Durio zibethinus*), and pampakin (*Durio kutejensis*). In addition, in this area there are still several types of bamboo (*Bambusa* sp.). The vegetation found at the tree level included tarap (*Artocarpus odoratissimus*), jengkol (*Archidendron pauciflorum*), rubber (*Hevea brasiliensis)*, sungkai (*Peronema canescens*), cinnamon *(Cinnamomum verum),* balik angin (*Malotus paniculatus*), and bangkal gunung (*Naucleasubtitle*). In this area, several fruit trees were also found, such as pampakin (*Durio kutejensis*), durian (*Durio zibethinus*), tiwadak (*Artocarpus integer*), hambawang (*Mangifera foetida*), kapul (*Baccaurea macrocarpa*) and rambai (*Baccaurea motleyana*). In the area of the *jurungan*, pioneer species such as mahang (*Macaranga* sp.) were found. Mahang is one of the pioneer species which is often found in ex-cultivated areas (Susanto, 2016; Karyati, 2013).

The vegetation found in mixed garden areas with an age of more than 12 years is dominated by fruit trees. At the pole level, fruit trees were found, namely durian (*Durio zibethinus*), langsat (*Lansium domesticum*), rambai (*Baccaurea motleyana*), mangosteen (*Garcinia parvifolia*), rambutan (*Nephelium lappaceum*), kasturi (*Mangifera casturi*), jackfruit (*Artocarpus integra*), hambawang (*Mangifera foetida*), kapul (*Baccaurea macrocarpa*), and papakin (*Durio kutejensis*). Other woody plants were also found, such as sungkai (*Peronema canescens*), rubber (*Hevea brasiliensis)*, candlenut (*Aleurites moluccana*), cinnamon *(Cinnamomum verum),* and tarap (*Artocarpus odoratissimus*). The species found at the tree level were almost the same as the vegetation found at the pole level. However, at the tree level, other vegetation was found, such as kayu kuning (*Arcangelisia flava*), kayu luing (*Ficus hispida*), sugar palm (*Arenga pinnata*) and coconut (*Cocos nucifera*). In the mixed garden area, the most typical fruit plants of Kalimantan were found compared to other areas. Examples of typical fruit plants from Kalimantan include pampakin (*Durio kutejensis*), ramania (*Bouea macrophylla*), kuini (*Mangifera odorata*), kasturi (*Mangifera casturi*), hambawang (*Mangifera foetida*), kapul (*Baccaurea macrocarpa*) and rambai (*Baccaurea motleyana*).

Figure 2 shows a comparison of the number of vegetation types in each cultivated area. It can be seen in Figure 1, the pole-level vegetation has a higher number of species found than the tree level in each ex-cultivated area. The mixed garden area had more species found than the other two areas. This can be influenced by the age of a land. The older a vegetation community, the more species found, but the lower the number of individuals in each species. In young communities, there will be fewer species with a higher number of individuals per species. Similar to the research of Oktavia et al., (2021) in Belitung Island which stated that the number of species in the *Bebak* and *Padang areas* had fewer species compared to jungle land which had an older age than the other two areas. The low number of species in the *balukar anum* can be caused by the fact that at the age of 3 to 7 years, the land has just recovered from former cultivation by the community (Aththorick, 2012).

The people of Loksado District, the majority of whom are Dayak Meratus, have local wisdom in managing land for farming. Land management using a rotational system has the main characteristic of cultivating on one land which after the cultivation period is complete the land will be left to restore soil conditions and cultivators use other land for farming. The presence of fallow period in a land can increase carbon storage in the soil. Increasing soil organic matter in the long term can reduce CO_2 in the atmosphere and increase soil fertility (Kristian et al. 2019). Therefore, in this land management system there are ex-cultivated areas which are divided based on the fallow period of the land.

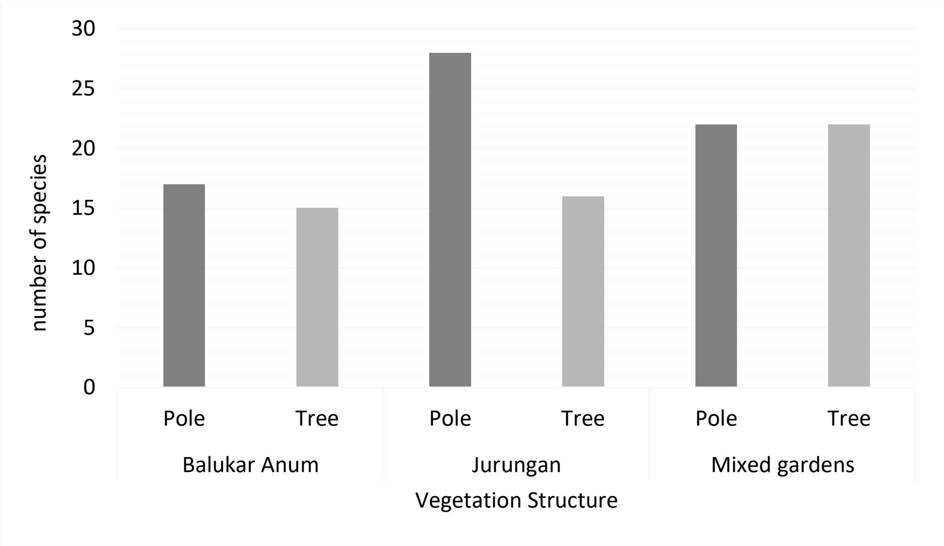

Figure 2 – Comparison of vegetation types in each area of former rotational cultivation

Vegetation diameter is one of the important parameters to assess the performance of vegetation and has a close relationship with other tree characteristics such as volume, biomass, and carbon (Setiahadi 2021). The parameter in the form of diameter is commonly used as a variable in the assessment of aboveground biomass. There are several studies which state that diameter as a variable in biomass calculations has good accuracy (Ribeiro et al. 2015; Taeroe et al. 2015; Setiahadi 2021). In areas with irregularly spaced vegetation, diameter can be a better variable in calculating carbon estimates than using tree height. This can be due to the fact that tree height measurements have a high potential for bias due to difficulty in determining the canopy of vegetation (Setiahadi 2021). The diameter and area of the base area in the ex-cultivated area can be seen in Table 1.

Table 1 – Diameter and area of the base area of vegetation in each ex-cultivated area

Land Covering/Use	Pole		Tree	
	Diameter (cm)	LBD (m^2)	Diameter (cm)	LBD (m^2)
1. Haratai Village				
Balukar Anum	10.333	83.995	-	-
Jurungan	10.625	90.766	-	-
Mixed Garden	14.773	178.017	26.684	572.802
2. Lok Lahung Village				
Balukar Anum	10.500	86.743	-	-
Jurungan	12.200	119.163	-	-
Mixed Garden	14.000	159.983	28.714	668.035
3. Loksado Village				
Balukar Anum	13.617	148.651	27.026	579.821
Jurungan	13.565	147.451	27.109	583.498
Mixed Garden	13.527	146.656	27.033	580.431

The highest average diameter and base area in the ex-cultivated area for pole level were found in the mixed garden area in Haratai Village of 14.773 cm and 178.017 m2, respectively. Meanwhile, the lowest value is found in the balukar anum area in Haratai Village with a diameter of 10.333 cm and a base area of 83.995 m2. The diameter at the tree level which has the highest value is found in the mixed garden area in Lok Lahung Village, which is 28.714 cm with a base area of 668.035 m2. Compared to Haratai Village and Lok

Lahung Village, in Loksado Village the values of diameter and base area for pole and tree levels in each ex-cultivated area did not have a significant difference. Mixed gardens are the areas with a higher average diameter than other areas in Haratai Village and Lok Lahung Village. In addition, Haratai Village and Loksado Village have an increasing average diameter in each ex-cultivated area that has an older age. This is different from Loksado Village, where at the pole level the highest average diameter is found in the balukar anum area and at the tree level the highest average diameter is found in the jurungan area.

Table 2 – Calculation of estimated above ground carbon land

Land Covering/Use	Total Pole Biomass (tonnes/ha)	Total Tree Biomass (tonnes/ha)	Total Biomass (tonnes/ha)	Total Carbon (tonnes/ha)
1. Haratai Village				
Balukar Anum	2.271	-	2.271	1.045
Jurungan	15.349	-	15.349	21.181
Mixed Garden	51.588	81.232	132.819	61.097
2. Lok Lahung Village				
Balukar Anum	7.121	-	7.121	3.276
Jurungan	13.685	-	13.685	6.295
Mixed Garden	40.872	138.595	179.467	82.555
3. Loksado Village				
Balukar Anum	28.699	42.331	71.030	32.674
Jurungan	26.940	40.074	67.014	30.826
Mixed Garden	26.218	39.810	66.028	30.373

Table 2 showed the calculation of the estimated carbon in the ex-cultivated area in each village. From Table 2, it can be seen that at the pole level the highest amount of biomass was found in the mixed garden area of Haratai Village at 51.588 tons/ha. The lowest amount of biomass was found in the balukar anum area in Haratai Village at 2.271 tons/ha. The highest amount of biomass at the tree level was found in the mixed garden area in Lok Lahung Village of 138.595 tons/ha. Meanwhile, the lowest amount of biomass was found in the mixed garden area in Loksado Village, which was 39.810 tons/ha. The mixed garden area has a low value when compared to other use areas found in Loksado Village. Balukar anum area has the highest amount of biomass at 42.332 tons/ha among the jurungan and mixed garden areas in Loksado Village. Same as at the pole level, the amount of biomass at the tree level in Loksado Village has a value that the difference is not too significant. This is compared to the amount of biomass for the pole level in Haratai Village and Lok Lahung Village which increases with the aging of the land.

The highest total biomass was found in the mixed garden area in Lok Lahung Village with a value of 179.467 tons/ha and the lowest was found in the balukar anum area of 2.271 tons/ha. In Haratai Village and Lok Lahung Village, mixed gardens have the highest total biomass value when compared to other ex-cultivated areas, namely the balukar anum area and the jurungan area. However, different results were found in Loksado Village, where the highest amount of biomass was found in the *balukar anum* and mixed gardens became the area with the lowest biomass value. Although the *balukar anum* has a higher value, the biomass value in the three ex-cultivated areas in Loksado Village does not have a significant difference. Differences in Haratai Village and Lok Lahung Village with Loksado Village can be influenced by different environmental conditions. This is similar to the statement of Dayamba et al. (2016), which states that there are differences in the total biomass value which can be caused by environmental conditions that can affect vegetation productivity. In addition to environmental conditions, biomass production in vegetation can be influenced by soil type, as well as the length of the planting period (Big et al. 2020).

Data on total biomass per hectare for each ex-cultivated area can be seen that the biomass is greater at the tree level than at the pole level. This is because trees have a larger diameter compared to pole-level vegetation. In general, the larger the size of the vegetation, the higher the biomass and carbon stock in the vegetation will be (Karyati et al. 2021). Diameter is an important parameter in the calculation of biomass and carbon. The larger the diameter of the tree can indicate good growth where the vegetation can absorb nutrients and water well, so it can have a high biomass value (Setiahadi et al. 2021; Wang et al. 2019). As can be seen in Table 1 and Table 2, the mixed garden area in Lok Lahung Village has the largest average diameter so that it has high biomass and total stored carbon as well. Most of the results of biomass and carbon calculations in ex-cultivated areas increase in proportion to the larger the diameter. However, there are some results where the average diameter of vegetation in an area does not match the amount of biomass. This could be due to the greater number of individuals found in the area so that it can produce greater biomass as well. Similar to the study of Besar et al. (2020) which states that the carbon storage in palm oil is greater than that of gaharu because it has a greater number of individuals.

Carbon estimates were calculated using 47% of the biomass value. Based on Table 1, it can be seen that the highest estimated carbon value is in the mixed garden area in Lok Lahung Village, which is 61.097 tons/ha. Meanwhile, the lowest estimated carbon value is found in the anum balukar area in Haratai Village, which is 1,045 tons/ha. Loksado Village is the village with the highest total estimated carbon value compared to Haratai Village and Lok Lahung Village. There is a significant difference between the carbon estimates in the mixed garden area and other ex-cultivated areas in Haratai Village and Lok Lahung Village. This could be because mixed gardens have a longer fallow period than other areas, so the soil in mixed gardens in Haratai Village has a higher value. In addition, carbon accumulation can be affected by the age of the vegetation (Dayamba et al. 2016). Mixed gardens are ex-cultivated areas that have an age of more than 15 years, so that in mixed garden areas there will be more vegetation that is older than the balukar anum and bridge areas. This is in accordance with the statement of Besar et al. (2020), which states that differences in carbon sequestration from various land uses can be caused by differences in land age.

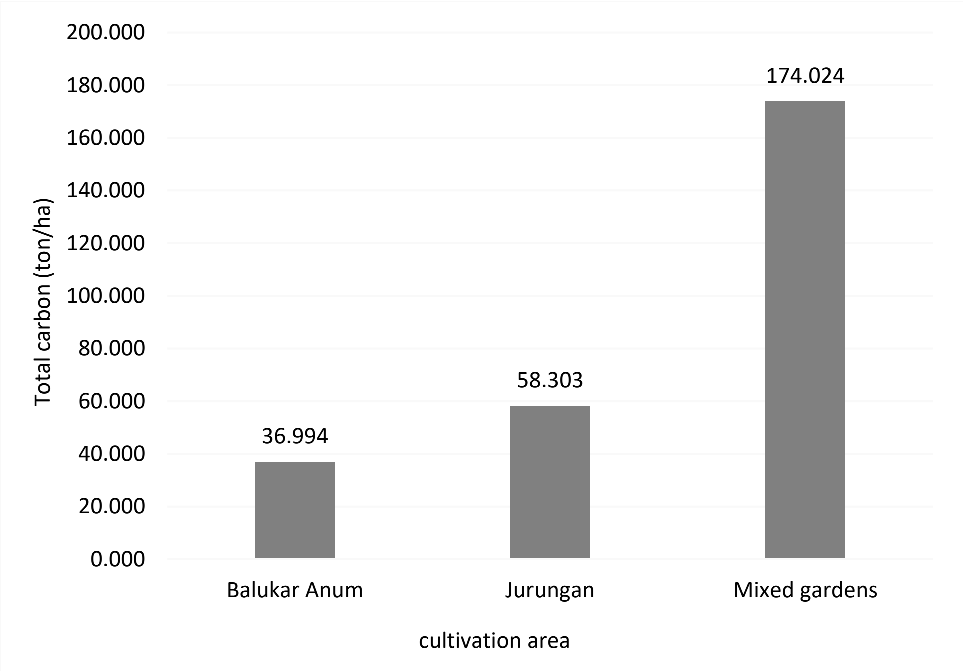

Figure 3 – Total carbon storage in the former rotational cultivation area

Figure 3 shows the total carbon storage in the former cultivation area. Based on Figure 2, it can be seen that mixed gardens have the highest total carbon storage of 174.024 tons/ha compared to the other two areas. Jurungan is in second place with a total of 58.303 tons/ha and balukar anum has the smallest carbon storage value of 36.994 tons/ha. The results of carbon storage in mixed garden areas have values that are not much different from stored carbon in natural forests in Sabah according to Asner et al. (2018) which ranged from 200 – 500 tons/ha and in the study of Besar et al. (2020) which has a yield of 249.90 tons/ha.

In addition, the total carbon stored in the balukar anum and jurungan areas that have an age of 3-15 years has a higher yield compared to agroforestry between oil palm and gaharu and oil palm monoculture in a study conducted by Besar et al. (2020).

The difference in the yield of each ex-cultivated area is influenced by the age of the mixed garden land which is somewhat older than the balukar anum and the jurungan so that there is a lot of vegetation that is older as well. Most of the older trees have a larger diameter so they can store more carbon. In addition, in mixed garden areas, more species were found compared to other ex-cultivated areas. According to Karyati et al. (2020), the amount of carbon absorbed by vegetation can be affected by species composition. This allows areas with a more diverse number of species to have greater estimates of carbon sequestration. This is similar to the study of Besar et al. (2020) on agroforestry land in Sabah, Malaysia which stated that tropical rain forest areas with more diverse species had higher estimates of above-ground carbon sequestration compared to oil palm agroforestry areas with agarwood.

CONCLUSION

The number of species found at the pole level was higher than the tree level in each ex-cultivated area. The mixed garden area had more species found than the other two areas. The older a vegetation community, the more species found, but the lower the number of individuals in each species. The highest average diameter and base area in the ex-cultivated area for pole level were found in the mixed garden area in Haratai Village of 14,773 cm and 178.017 m^2. Meanwhile, the lowest value is found in the balukar anum area in Haratai Village with a diameter of 10.333 cm and a base area of 83.995 m^2. The total biomass per hectare for each ex-cultivated area can be seen that the biomass is greater at the tree level than at the pole level. This is because trees have a larger diameter compared to pole-level vegetation. At the pole level, the highest amount of biomass was found in the mixed garden area of Haratai Village at 51.588 tons/ha. The lowest amount of biomass was found in the anum balukar area in Haratai Village at 2.271 tons/ha. The highest amount of biomass at the tree level was found in the mixed garden area in Lok Lahung Village of 138,595 tons/ha. Meanwhile, the lowest amount of biomass was found in the mixed garden area in Loksado Village, which was 39.810 tons/ha. The highest carbon estimate is in the mixed garden area in Lok Lahung Village, which is 61.097 tons/ha. Meanwhile, the lowest estimated carbon value is found in the anum balukar area in Haratai Village, which is 1.045 tons/ha. Loksado Village is the village with the highest total estimated carbon value compared to Haratai Village and Lok Lahung Village. The difference in the value of biomass and carbon in each ex-cultivated area can be influenced by the diameter of the vegetation, the number of individuals, the number of species, and the age of the land.

ACKNOWLEDGMENTS

This research was carried out properly thanks to the assistance of various parties, for that the researcher would like to thank the Heads of Haratai Village, Lok Lahung Village, and Loksado Village, as well as the Heads of RT and Staff of Haratai Village Hall, Lok Lahung Village, and Loksado Village. In addition, the authors also thank all the people of Haratai Village, Lok Lahung Village, and Loksado Village who have participated and assisted in the implementation of this research.

REFERENCES

1. Abdullah UH, Sufardi S, Syafruddin S, Arabia T. 2022. Soil organic carbon of grassland and bush forest on dryland in Aceh Besar District, Indonesia. Biodiversitas 23(5): 2594-2600. DOI: 10.13057/biodiv/d230541
2. Asner TA, Setiadi D, Purwanto Y, Guhardja E. 2012. Vegetation stands for structure and aboveground biomass after the shifting cultivation practices of Karo people in the leuser ecosystem, north Sumatra. Biodiversitas 13(2): 92-97 DOI: 10.13057/biodiv/d130207

3. Asner GP, Brodrick PG, Philipson C, Vaughn NR, Martin RE, Knapp DE, Heckler J, Evans LJ, Jucker T, Goossens B, et al. 2018. Mapped aboveground carbon stocks to advance forest conservation and recovery in Malaysian Borneo. Biol. Conserv 217: 289–310. DOI:10.1016/j.biocon.2017.10.020
4. Badan Standardisasi Nasional. 2011. Pengukuran dan penghitungan cadangan karbon pengukuran lapangan untuk penaksiran cadangan karbon hutan (ground based forest carbon accounting) Nomor 7724. Jakarta.
5. Besar NA, Suardi H, Phua MH, James D, Mokhtar M, Ahmed MF. 2020. The carbon stock and sequestration potential of an agroforestry system are in Sabah, Malaysia. Forest 11(2): 210. DOI: 10.3390/f11020210
6. BPS Kabupaten Hulu Sungai Selatan. 2021. Kecamatan Loksado Dalam Angka 2021. Kalimantan Selatan
7. Dayamba SD, Djoudi H, Zida M, Sawadogo L, Verchot L. 2016. Biodiversity and carbon stocks in different land-use types in the Sudanian Zone of Burkina Faso, West Africa. Agriculture, Ecosystem, and Environment 216: 61-72. DOI: 10.1016/j.agee.2015.09.023
8. Fahrianoor, Windari T, Taharuddin, Ruslimar'i, Maryono. 2013. The practice of local wisdom of Dayak people in forest conservation in South Kalimantan. Indonesian Journal of Wetlands Environmental Management 1(1): 33-41. DOI: 10.20527/jwem.01.01.01
9. Han G, Li F, Tang Y. 2015. Variations in soil organic carbon contents and isotopic compositions under different land use in a typical karst area in Southwest China. GeochemJ 49(1): 63-71. DOI: 10.2343/geochemj.2.0331
10. Jose S, Bardhan S. 2012. Agroforestry for biomass production and carbon sequestration: an overview. Agroforest Syst 86 105–111. DOI: 10.1007/s10457-012-9573-x
11. Karyati, Ipor IB, Jusoh I, Wasli ME, Seman IA. 2013. Composition and diversity of plant seedlings and saplings at an early secondary succession of fallow lands in Sabal, Sarawak. Acta Biologica Malaysiana, 2(3): 85-94 DOI: 10.7593/ABM/2.3.85
12. Karyati, Widiati KY, Karmini, Mulyadi R. 2021. The allometric relationships for estimating aboveground biomass and carbon stock in an abandoned traditional garden in East Kalimantan, Indonesia. Biodiversitas 22(2): 751-762. DOI: 10.13057/biodiv/d220228
13. Ketterings M Quirine, Coe Richard, Noordwijk Meine Van, Ambagau Yakub, Palm Cheryl A. 2001. Reducing uncertainty in the use of allometric biomass equation for predicting above-ground tree biomass in mixed secondary forest. Forest Ecology and Management 146: 199 – 209 DOI: 10.1016/S0378-1127(00)00460-6
14. Kristian K, Harahab, N., Hakim, A., & batoro, jati. (2019). Shifting cultivation model: an environmental and sustainable agricultural management practice. Archives of Business Research, 7(4), 1–10 DOI: 10.14738/abr.74.6353
15. Kumar L, Mutanga O. 2017. Remote Sensing of Above-Ground Biomass" Remote Sensing 9, no. 9: 935. DOI: 10.3390/rs9090935
16. Muhaimin M, Saputra AN, Angriani P, Sidharta A, Arisanty D. 2021. Mapping of shifting cultivation (gilir balik) patterns in Dayak Meratus Tribe. Paper presented at The 2nd International Conference on Social Sciences Education (ICSSE 2020). DOI: 10.2991/assehr.k.210222.080
17. Nunes LJR, Meireles CIR, Pinto Gomes CJ, Almeida Ribeiro NMC. 2019. Forest Management and Climate Change Mitigation: A Review on Carbon Cycle Flow Models for the Sustainability of Resources. Sustainability 11(19): 5276. DOI: 10.3390/su11195276
18. Ogle SM, Olander L, Wollenberg L, Rosenstock T, Tubiello F, Paustian K, Buendia L, Nihart A, Smith P. 2014. Reducing greenhouse gas emissions and adapting agricultural management for climate change in developing countries: providing the basis for action. Glob. Change Biol. 20, 1–6. DOI: 10.1111/gcb.12361.
19. Oktavia D, Pratiwi SD, Munawaroh S, Hikmat A, Hilwan I. 2021. Floristic composition and species diversity in three habitat types of heath forest in Belitung Island, Indonesia. Biodiversitas 22(12): 5555-5563. DOI: 10.13057/biodiv/d221240

20. Puspanti A, Kusumandari A, Faida LRW, Sudaryatno. 2021. Impact of rehabilitation and status area change on land cover and carbon storage in Paliyan Wildlife Reserve, Gunung Kidul, Indonesia. Biodiversitas 22(9): 3964-3971. DOI: 10.13057/biodiv/d220944
21. Rahman FA, Qayim I, Wardiatno Y.2018. Carbon storage variability in seagrass meadows of Marine Poton Bako, East Lombok, West Nusa Tenggara, Indonesia. Biodiversitas 19: 1626-1631.99 DOI : 10.13057/biodiv/d190505
22. Ribeiro SC, Soares CPB, Fehrmann L, Jacovine LAG, von Gadow K. 2015. Aboveground and belowground biomass and carbon estimates for clonal Eucalyptus trees in Southeast Brazil. Rev Árvore 39: 353- 363. DOI: 10.1590/0100-67622015000200015.
23. Setiahadi R. 2021. Comparison of individual tree aboveground biomass estimation in community forests using allometric equation and expansion factor in Magetan, East Java, Indonesia. Biodiversitas 22(9): 3899-3909. DOI: 10.13057/biodiv/d220936
24. Siahaya ME, Hutauruk TR, Aponno HSES, Hatulesila JW, Mardhanie AB. 2016. Traditional ecological knowledge on shifting cultivation and forest management in East Borneo, Indonesia, International Journal of Biodiversity Science, Ecosystem Services & Management, 12:1-2, 14-23, DOI: 10.1080/21513732.2016.1169559
25. Susanto D, Ruchiyat D, Sutisna M, Amirta R. 2016. Soil and leaf nutrient status on the growth of Macaranga gigantea in the secondary forest after shifting cultivation in East Kalimantan, Indonesia. Biodiversitas, 17: 409-416 DOI: 10.13057/biodiv/d170202
26. Taeroe A, Nord-Larsen T, Stupak I, Raulund-Rasmussen K. 2015. Allometric biomass, biomass expansion factor, and wood density models for the OP42 hybrid poplar in Southern Scandinavia. Bioenergy Res 8(3): 1332-1343. DOI: 10.1007/s12155-015-9592-3.
27. Van VN, Adams C, Vieira ICG, Mertz O. 2013. "Slash and Burn" and "Shifting" cultivation systems in forest-agriculture frontiers from the Brazilian Amazon. Society & Natural Resources 26: 1454-1467. DOI: 10.1080/08941920.2013.820813.
28. Wang Z, Du A, Xu Y, Zhu W, Zhang J. 2019. Factors limiting the growth of eucalyptus and the characteristics of growth and water use underwater and fertilizer management in the dry season of Leizhou Peninsula, China. Agronomy 9 (10): 1-17. DOI: 10.3390/agronomy9100590.