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Carbon Sequestration Potentials for Agro-forestry System and Grasslands in Bukidnon and Cagayan de Oro Landscape

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Abstract

This study aimed mainly to determine the biomass accumulation and carbon sequestration of grassland ecosystem in Barangay Pualas Bukidnon. Sample plots were established throughout the one-hectare area for data collection. The measurement of biometrics and biomass of each plant in the canopy was computed using allometric regression equation for the above ground biomass, estimated below ground biomass, necromass from the canopy, layer and carbon density, or estimated carbon content / stock of biomass of trees using (IPCC) model. Other inputs were climatic data, physiographic and soil chemical properties. General findings revealed that trees (woody vegetation) have more carbon stocks compared to grassland/ pastureland per unit area. The estimated carbon stocks for grassland was 2.78 Mg, discrete patches was 10.9 Mg and 0.4731 Mg for litter layer. Agro-forestry system using alley cropping or hedgerow intercropping are dominated by fruit trees, palm and rubber which normally do not grow are big as forest trees, thus lesser carbon stock. This study generates an essential information in the implementation relevant to the expanded. Reducing Emissions from Deforestation and Forest Degradation (REDD+) as payment for environmental services for transforming grassland into an agro-forestry system. This system design is a potential restoration of watershed quality of water devastated during flashflood from the tragic typhoon "Sendong' and typhoon "Pablo".

Keywords: carbon stock, sequestration, biomass, agro-forestry system, climate change

1. Introduction

It is a common knowledge that as long as the amount of carbon flowing into the atmosphere (as CO_2) and out (in the form of plant material and dissolved carbon) are in balance, the level of carbon in the atmosphere remains constant. The level of CO_2 in the atmosphere is determined by a continuous flow among the stores of carbon in the atmosphere, the ocean, the earth's biological systems, and its geological materials. One of the earth's biological systems is the grassland ecosystem. As grasses grow and their biomass increases, they absorb carbon from the atmosphere and store it in the plant tissues resulting in the growth of different parts. Active absorption of CO_2 from the atmosphere in photosynthetic process and its subsequent storage in the biomass of growing trees or plants is the carbon storage (Ilyas, 2013).

Many upland areas in the country nowadays were transformed into open grassland by illegal logging, shifting cultivation and grazing. Usually these are degraded and abandoned farmlands or grazing areas dominated by different species of grasses. Several studies from the World Agro-forestry Centre, Ecosystem Research and Development Services – DENR and academe have stated that this ecosystem store and sequester smaller amount of carbon from the atmosphere compared to other land-uses such as forestland, brushland and agro-forestry. For example, Boundary planting using bagras (*Eucalyptus deglupta* Blume) on corn plantation can sequester CO_2 at a rate of 26.75 Mg ha^{-1} yr^{-1} (Palma and Carandang, 2014). Nevertheless, grassland ecosystem will play a key role in mitigating the effect of climate change with increasing population and per capita consumption of wood creating tremendous pressures into the remaining forests (Cossalter and Pye-Smith, 2003).

Thus, the national government encouraged upland farmers to integrate forest trees into their farm. The practice of agro-forestry in the Philippines was reinforced with the implementation of the Integrated Social Forestry Program (ISFP) in 1982. The ISFP is one of several people-oriented forestry programs that have been integrated under the Community-based Forest Management (CBFM) strategy of the Philippine government which was promulgated in 1995 through Presidential Executive Order No. 263. Some of the agro-forestry systems adopted include woody perennials in farm forest/ tree farms, boundaries, homelots, agricultural crops in terraces and grass in fallow areas. In 2011, the Philippine government launched another national program through Executive Order No. 26, the National Greening Program (NGP) as one of the strategies to attain the priority programs of resource conservation and protection and climate change mitigation and adaptation. Thus, terms like “trees on farm” or “trees outside forests” was developed. The study of Palma (2012) on typology of upland farmers provided some insights why farmer’s in Misamis Oriental and Bukidnon introduced trees on their farm. The farmers plant trees for domestic consumption like repair or construction of their houses, commercial purposes like selling lumber to a sawmill or lumber yard, pole for banana’s and shelterbelt/ windbreak to protect the adjacent community during scheduled spraying.

Transforming grassland ecosystem into an agroforestry system is a difficult endeavor because of many interlacing factors. Generally, increase in productivity and reduced soil degradation or erosionare the major factors affecting the proliferation of agroforestry systems and technologies in northern Mindanao. However, with the aid of international organizations and national government, adoption is deliberately increasing (Ninang, 2015; Catacutan and Duque, 2006). Adaptation and mitigation to climate change such as agroforestry or curbing of deforestation need to be planned. Agroforestry holds great potential in channeling benefits of both adaptation and mitigation to upland people in northern Mindanao. Agroforestry enhances diversification, reduce risks and helps stabilize livelihood. Considering the increasing private tree planting by smallholder farmers in the upland where thousands of hectares of plantations are located mostly on either abandoned farm or marginal areas and thousands more are targeted for development, a measurement of biomass and carbon sequestration from the systems is imperative. The study aimed to determine the biomass and carbon sequestration of grassland ecosystem in Barangay Pualas, Baungon, Bukidnon, Philippines. Also, determine the biomass and carbon sequestration of grassland transformed into agroforestry systems. Lastly, compare the potential between grassland and agroforestry system in terms of the biomass accumulated and carbon sequestration.

Objectives of the Study

1. To determine and compare the carbon sequestration potentials of existing grasslands and hedgerow intercropping or alley cropping (planted with coconut, fruit trees and rubber); and,

2. To determine the potentials considering other ecosystem services of transforming the existing grasslands into agroforestry systems.

2. Methodology

2.1 Study Area

The study was located in Barangay Pualas, Baungon, Bukidnon (7^0 50' 00" N to 8^0 30' 00" N and 124^0 15' 00" E to 124^0 25' 00' E). Several possible sites were considered at the planning stage of the study particularly those sites adjacent to the Cagayan de Oro River. With the identified sites, the team conducted consultation with the personnel of the Community Environment and Natural Resources Office (CENRO) of Talakag who has jurisdiction over the identified sites. Each identified sites were evaluated in terms of peace and order situation, available land area for the project, presence of people's organization (PO) and active members and accessibility. The study site was part of the Municipality of Baungon in the Province of Bukidnon but it is also near to Cagayan de Oro City which is part of the Province of Misamis Oriental. Before the project, the site was utilized as grazing area for livestock by the community. Some part of the site has thin soil caused by soil erosion.

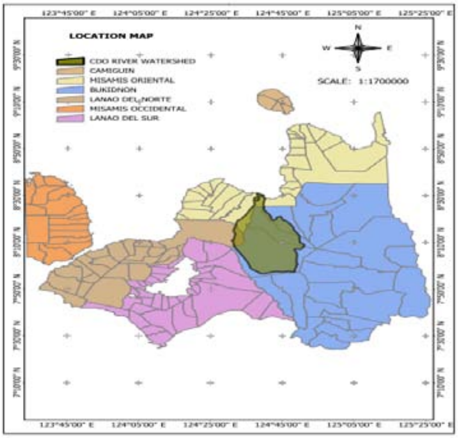

Figure 1. Location map of the study site (Osio, 2012)

2.2 Sample Plot Establishment

Four square temporary sample plots (Figure 2) were established in a one hectare (1 ha) study area. The plots were identified such that various brushes and prevailing environmental conditions are represented. Each individual plots had an approximate size of 100 m^2. A 1 m^2 temporary plot was established inside to sample the area for necromas.

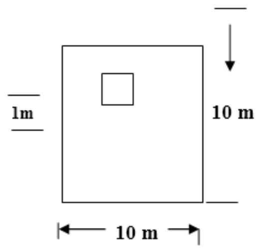

Figure 2. Lay-out of temporary sample plot

2.3. Data Collection

2.3.1 Climatic data

The historical and observed monthly normal weather data for rainfall and temperature of Barangay Pualas, Baungon, Bukidnon were obtained from the recorded data of the Philippine Atmospheric, Geophysical and Astronomical Services Administration (PAGASA) weather station at Lumbia Airport from the Climatology and Agrometeorology Division, PAGASA located at Agham Road, Diliman, Quezon City.

2.3.2 Topographic data

Elevation of each sample plot was determined using the geographic positioning system (GPS, GARMIN). The GPS was placed at the center of the plot for the elevation reading. Slope gradient was measured using a Clinometer (M5, SUUNTO). The observation was made right at the center of the plot. Aspect or exposure was determined using GPS (GPS, GARMIN).

2.3.3 Soil chemical properties

Soil chemical and physical properties were analyzed to determine the changes in fertility levels from grassland to agroforestry system. Soil samples were gathered from different locations within the upper, middle and lower portion of the sampling plot at 0-30 cm using soil auger. All the soil that attached to the auger was removed and placed in a plastic bag and labeled properly. The soil was mixed together to form the composite soil sample. About 1 kg was segregated for analysis. The samples were air dried, pulverized, screened and analyzed for pH, OM, N, P, K, Ca,Mg, cation exchange capacity and bulk density at F.A.S.T Laboratory, Lapasan, Cagayan de Oro City.

2.3.4 Measurement of Biometrics and Biomass

For the trees and shrubs that occurred in discrete clumps of one or more woody species, four transects measuring 10 m x 10 m were established. The total height and basal stem diameter of all woody plants 5 cm and above ground were measured and recorded . Data were collated for proper encoding in an MS Excel spreadsheet.

Inside the same sampling frame that was used for measuring trees and shrubs, a 1 m x 1 m transect was established for litter collection. Coarse litter (any tree necromass< 5 cm diameter and/or < 50 cm length, undecomposed plant materials or crop residues, all unburned leaf or branches) was collected in 1 m x 1 m quadrat on a randomly chosen location within the canopy sample. Samples and sub-samples of coarse litter were weighed (Digital Scale – ADAM-WBW 5a) and dried using oven drier (Contherm Designer Series, New Zealand) at 80^0 C for conversion to dry weight.

$$\text{Total dry weight (kg/ m}^2\text{)} = \frac{\text{Total Fresh Weight (kg) x subsample dry weight (g)}}{\text{Subsample Fresh Weight (g) x Sample area (m}^2\text{)}} \quad \text{(Eqn 1)}$$

The biomass of each plant in the canopy, together with leaf litter, was computed using the following:

a. Allometric regression equation for aboveground biomass of all trees greater than 5.0 cm diameter at 0.50 m using the equation prepared by Ketterings *et al*., (2001):

$$y = 0.11pD^{2.62}$$
(Eqn. 2)

Where:

y = above ground tree biomass
p = average wood density equivalent to 0.9035 g cc^2
D = tree dbh

b. Estimated belowground biomass in trees was equivalent to 15% of the aboveground tree biomass as proposed by Delany (1999).
c. Actual sampling of litter fall to represent necromass from the canopy layer.
d. Carbon density (Mg ha) values can be derived by multiplying the predicted biomass values (Mg ha) from yield prediction equation with the carbon content default value of 0.45 based on the overall estimate of carbon content of biomass of trees as proposed by IPCC (1996).

C = 0.454 x Biomass
(Eqn. 3)

3. Results and Discussion

3.1 Characteristics of Study Site

3.1.1 Climate

The area where the research site was established is classified as Type 2 of the Coronas Climatic Classification System which is characterized by wet (5 to 6) and dry (2 to 3) months. Mean annual rainfall within the span of growing years as recorded (8^0 26' Latitude 124^0 37' Longitude) was 1727 mm. The mean annual temperature was 26.89 ^{0}C in Misamis Oriental. Rainfall and temperature are two important parameters that need to be assessed.

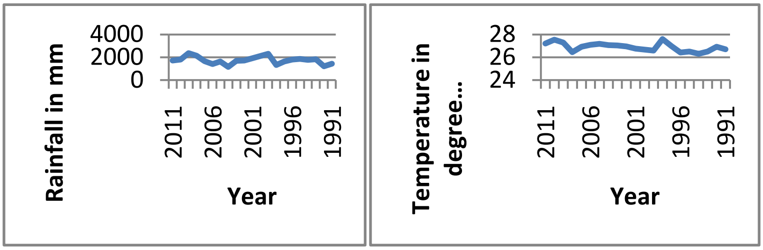

Figure 4. Average annual rainfall and temperature in Lumbia, CDOC, 1991 – 2011 (Source: PAGASA)

3.1.2 Topography

The study site has a north-east facing slope ranging from 10^o to 40^o. Elevation was 320 meters above sea level (masl). Aspect is an important indicator in boundary planting that influenced the growth of bagras. One of the possible influences of aspect is on the length of photosynthetic period (Tandug *et al.*, 2003). Exposure to sunlight allows tree to produce carbohydrates through photosynthesis. Vendiola (1996) stated that best sites are on the northwest slopes while poorest sites are on the southwest slope, and that aspect is usually a very important site feature in hilly and mountainous areas. Exposuredisruptsmountaintemperature zones (Auslander *et al.*, 2003). Since the maximum effectiveness of insolation comes only when solar radiation is at right angle to the surface, thereby variation in exposures the radiation is modified.

3.1.3 Soils

The values of the various soil chemical properties observed in the site were shown in Table 2.

Table 2. Soil chemical and physical properties of the study site

Soil Properties	Top Soil	Sub Soil	Standard
pH (soil)	7.50	7.30	5.6-6.5
Organic Matter (%)	1.50	0.90	2.1-4.1
Nitrogen (%)	0.13	0.07	>0.20
Phosphorus (ppm)	27.80	22.20	7-30
Potassium (ppm)	52.40	48.70	
Magnesium (ppm)	2922.00	3075.00	
Calcium (ppm)	20207.00	18478.00	
CationExchange Capacity	68.80	58.50	
Bulk Density (g/cc)	0.67	0.66	< 1.60

3.2 Plant Diversity and Density

3.2.1 Shrubland

There were 15 species of trees and shrubs growing in the selected plots within the study site (Table 3). The most common tree species found in the area is Pag-oringon comprising 59 individual trees (35%). Other common trees and shrubs that appeared in all plots include Balinghasai (18%), Kamiring (9%) and Tala-tala (9%). The presence of these pioneering species indicated that the area is undergoing transition from open grassland to secondary forest. The transition process begins with the germination of individual trees scattered along the area. As the tree grows, it creates a conducive microclimate condition that allows germination of other pioneering tree species. The area covered by these patches of trees will increase and become a corridor for wildlife.

Table 3. Plant diversity and characteristics of trees in the study site.

Local Name	Plot 1	Plot 2	Plot 3	Plot 4	TOTAL	%
Guava *(Psidiumguajava* L.)	4	1			5	3
Binayuyu *(Antidesmaghasembilla*Gaertn)	11	3		2	16	10
Pagu-oringon *(Cratoxyllumcelebicum*Blume)	27	6	22	4	59	35
Malapapaya *(Polysciasnodosa*(Blume)Seem.)	2				2	1
Balinghasai*(Buchananiaarborescens*Blume)	12	2	10	7	31	18
Kamiring*(Anacardiumlongifolium*Engl.)	2	7	4	2	15	9
Cashew nut *(Anacardium occidental* L.)	1				1	1
Salagongbundok*(Wikstroemiapolyantha* Merr.)	3		3		6	4
Tala-tala*	1	2	6	6	15	9
Bagabuyo*			1		1	1
Hambabalud*(Neonaucleaformicaria*(Elm) Merr.)			5		5	3
Kampoy*			4		4	2
Unknown X	1				1	1
Unknown Y	2				2	1
Unknown Z	2			3	5	3
TOTAL	68	21	55	24	168	

*Species identified only by its local name

In turn, the droppings from these wildlife will add to the diversity of species. Through time, these patches will be formed into a forest. Based on the carbon content study conducted at Baggao, Philippines, above ground biomass (t C ha^{-1}) from grassland (50.8 t C ha^{-1}) is slightly higher than that of the secondary forest (46.3 t C ha^{-1}).

3.2.2 Agroforestry System

The pioneering species of trees and shrubs inside the research area were kept intact to serve as buffer for the Cagayan de Oro River and a corridor for the remaining wildlife. These trees and shrubs are growing in patches. Greater part of the research site was dominated by grasses. To enhance the ecological, economic and social benefits of the research site, this grassland area was transformed into an alley cropping or hedgerow intercropping system on May 2014.

Alley cropping is an agroforestry system which involves planting of hedgerows along the contours and growing agricultural crops in the "alleys" formed between two hedgerows or the planting of rows of trees and/or shrubs (single or multiple) at wide spacing, creating alleyways within which agricultural crops or horticultural crops are produced. (Lasco and Visco, 2003 as cited by Palma, 2012).

Table 4. Plant diversity and characteristics agroforestry species planted along the contour lines.

Local Name	Scientific Name	Number of hills	Contour Number
Dwarf Coconut	*Cocosnucifera*	63	1-5
Rambutan	*Nepheliumlappacium*L	28	6; 12
Lanzones	*Lansiumdomesticum*Corr.	9	7
Durian	*Duriozibethinus*Murr.	11	8
Rubber	*Heveabrasiliensis*(HBK) Muell.-Arg.	36	9; 11
Mangosteen	*Garcinia mangostana* (L.)	16	10
TOTAL		163	

The woody perennials may include valuable hardwood or softwood species (for veneer, lumber or pulpwood), shrubs for fodder or fruit trees. Alley cropping is an agroforestry practice intended to place trees within agricultural cropland systems. The purpose is to enhance or add income diversity (both long and short range), reduce wind and water erosion, improve crop production, improve utilization of nutrients, improve wildlife habitat or aesthetics, and/or convert cropland to forest (Lasco and Visco, 2003 as cited by Palma, 2012). Many places in northern Mindanao had experienced rapid transformation from natural forest to grassland to a mosaic of intensive cash and food cropping and perennial-based systems (Garrity and Agustin, 1995). This practice is also the base for the incorporation of fruit and timber trees (Stark, 2000). The coconut, fruit trees and rubber were introduced in the area as hedgerow species (Table 4).

3.3 Carbon Stock

3.3.1 Grassland

Studies conducted in Bukidnon and Misamis Oriental on grassland carbon stock and carbon sequestration potential showed that it can stock and sequester in its biomass small amount of carbon dioxide ranging from 2.7 Mg ha^{-1} (Decipulo *et al.*, 2009) to 2.9 Mg ha^{-1} (Brakas and Aune, 2011). The average of the above mentioned studies will be used as the adopted value for this study. On the other hand, newly recorded data from Nueva Vizcaya showed higher carbon density at 4.1 Mg ha^{-1} for grassland (Villamor *et al.*, 2010) and far smaller compared to the values recorded by Lasco and Pulhin (2003) at 12.1 Mg ha^{-1}. The above-mentioned studies clearly stipulated that grassland does not stock or sequester that much carbon dioxide compared to other land uses. The total biomass (kg m^2), above ground and below ground carbon stock per plot is shown in Table 5. The total biomass of patches of trees and shrubs was only 24.35 kg m^2.

Using the IPCC default of 45% (0.45) for the carbon content of tree, the above ground carbon stock in trees and shrubs are determined. The result showed that the above ground biomass of the research site was only 10.9 Mg. For the below ground biomass, the value was computed using the Delaney (1999) default of 15% (0.15) for the belowground biomass for trees was 1.64 Mg ha^{-1}. These smaller values are expected because the trees and brushes which is supposed to provide bigger values are still in its sapling and early mature stage. At this stage, the trees and shrubs are growing rapidly, hence, we can assume that they also sequester high amount of carbon dioxide from the atmosphere. Combining all these possible carbon sinks, the total carbon that is stock in the trees, shrubs, grasses and litter is only 15.81 Mg ha^{-1}. This is higher than the earlier reported carbon stock by Villamor *et al*., (2010) and Lasco and Pulhin (2003).

Table 5. Above ground and below ground carbon stock of trees and shrubs patches of Pualas, Baungon, Bukidnon.

Plot	No. of Trees	Mean DBH (cm)	Biomass (kg/ m^2)	IPCC Default	Above Ground Carbon Stock (Mg C)	Below Ground Carbon Stock (Delany 1999)	Carbon Stock (Mg C)
1	19	7.01	10.25	0.45	4.61	0.15	0.69
2	10	6.00	2.91	0.45	1.31	0.15	0.20
3	12	7.48	6.61	0.45	2.97	0.15	0.45
4	7	7.71	4.58	0.45	2.01	0.15	0.30
TOTAL	48		24.35		10.9		1.64

Table 6. Carbon density in litter of discrete patches in Pualas, Baungon, Bukidnon.

Type of Litter	Total Fresh Weight (kg)	Sample Fresh Weight (g)	Sample Oven Dry Weight (g)	Sample Area (m^2)	Total Dry Weight (kg m^2)	IPCC Default	Carbon Stock (Mg ha^{-1})
CL - Leaves	0.55	39.20	38.60	1	0.55	0.45	0.25
CL – Branch	0.45	82.20	78.80	1	0.43	0.45	0.19
CL–Leaf Stalk	0.07	32.00	31.40	1	0.07	0.45	0.03
CL – Seed/Flower	0.01	8.40	8.20	1	0.01	0.45	0.00
TOTAL					1.05		0.47

3.3.2 Agroforestry Systems

Table 7 shows the potential of different agroforestry systems in stocking carbon.

Table 7. Carbon stock of different agroforestry systems in Southeast Asia

Type of Agro-forestry System	Amount of Carbon Stock ($MgC\ ha^{-1}$)	Forest trees/ Crops	Author/s	Location
Taungya Agroforestry System	174		Labata et al. (2013)	Bukidnon
Mixed Multistorey System	162		Labata et al. (2013)	Bukidnon
Falcata-Coffee-Multistorey System	92	*Paraserianth esfalcataria Coffea spp.*	Labata et al. (2013)	Bukidnon
Hedgerow Intercropping	92.78 (12 yrs)	*Eucalyptus deglupta Zea mays*	Palma (2012)	Misamis Oriental & Bukidnon
Boundary Planting	73.07 (10 yrs)	*Eucalyptus deglupta Zea mays*	Palma (2014)	Misamis Oriental & Bukidnon
Woodlot	425 (10 yrs)	*Eucalyptus deglupta Zea mays*	Palma (2012)	Misamis Oriental & Bukidnon
Boundary Planting		*Eucalyptus deglupta Musa spp.*	Palma (2014)	Misamis Oriental & Bukidnon

Trees along riparian strips are an effective sequestering system to remove excess nutrients and carbon dioxide and store them on-site in the form of wood. Thus, different species of economically valuable tree, fruit trees and palm were planted into the open grassland to transform this less productive site into a more productive land use that could sequester more carbon dioxide from the atmosphere.

Table 8. Carbon sequestration potential of agroforestry systems and grassland ecosystem.

Ecosystem Services	Agroforestry	Grassland/ Cropland
Carbon Stock	73.07 Mg ha^{-1} (boundary planting – Palma and Carandang, 2014)	1.7 to 13.1 Mg ha^{-1} (grassland – Lasco and Pulhin, 2009) 3.1 to 12.5 Mg ha^{-1} (cropland – Lasco and Pulhin, 2009) 2.7 Mg ha^{-1} (Decipulo et al. 2009)
Soil Erosion Control	15.66 t ha^{-1} (Vegetable terraces – Bugayong and Carandang, 2003) 15.40 t ha^{-1} (Grass fallows – Bugayong and Carandang, 2003)	More than 400 t ha^{-1} yr^{-1} (cropland – Delgado and Canters, 2012) 267.8 t ha^{-1} yr^{-1} (grassland/ pastureland – Francisco and delos Angeles, 1994)

4. Conclusion and Recommendations

4.1 Conclusions

Land-use and landcover types (agroforest and grassland) in the study site were assessed and their carbon stocks were calculated. Fifteen pioneering tree species growing inside the patches were identified and assessed. The addition of tree and palm species in the area, as component of the alley cropping, enhances plant diversity.

Carbon stock can be computed using combined allometric equation and direct measurement for the trees, shrubs and litters of different crops (perennial and annual). In this study, the estimated carbon stock for grassland was 2.78 Mg, discrete patches was 10.90 Mg and 0.47 Mg for litter.

Leaving the site to regenerate into a forest takes time. Exposing the area to severe erosion especially on sloping part of the site. Thus, there is a need to promote agroforestry system in critical watershed to be able to alleviate both the demand for food security at the same time address the issue on carbon sequestration.

The people's organization (POs) can use this study as longterm biomass monitoring plots to support carbon offset trading and developed skills to monitor carbon stocks within the organization, thus, reduce coaches.

Discrete patches of trees and shrubs can stock carbon higher of above ground biomass.

Necromass in patches is negligible.

Alley cropping or hedgerow intercropping are dominated by fruit trees, palm and rubber which normally do not grow as big as forest trees, thus, lesser carbon stock.

4.2 Recommendations

The result of the study in Pualas, Baungon, Bukidnon can serve as baseline data in estimating the amount of carbon stock in grasses, tree, shrubs and litter layer. Hedgerow intercropping or alley cropping can be considered as one of the options in developing grassland/ pasture areas around the Cagayan de Oro river into carbon sink. The study could be replicated in other areas having similar site characteristics and along critical watersheds. The use of mixed tree species and palm as components of the hedgerow intercropping agroforestry system has the potential to enhance biological diversity of the area and carbon sequestration, since carbon can also be stored in the soil, assessment should also be done for below ground biomass and soil to determine what land use system can best maintain carbon stock.

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