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Carbon Storage and Nutrient Capacity of Forage Native Grasses Growing in Oil Palm Plantation at Commercial and Transformation Forest Ecosystem in Jambi, Indonesia

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Abstract

Ruminant-oil palm plantation Integration is one of agricultural practices, which commonly applied in Jambi. In this production system, grasses species are potential forage source. Despite of being forage, grasses play important role in storing carbon in transformed forest ecosystem. Nevertheless, information about carbon store capacity in grass species as well as its related nutrient quality have not much been elucidated, due to lack of data, especially for those are grown under oil palm plantation coverage in the transformation forest ecosystem. Many ecological studies of carbon storage focus on timber or woody plants.

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Hence, identification of the varieties, nutrient quality and carbon storage capacity of grasses were the aim of this study. Observation was conducted in the palm plantation at Sarolangun District, Jambi Province that is a representative of lowland rain forest transformation ecosystem. Randomized samples were taken from designing plots and sub-plots. Furthermore, root, stem and leaf were separated from the grass for further examination. It was identified that Panicum brevifolium, Axonopus compressus, Centotheca longilamina Ohwi, Schleria sumatrensis Retz, were high potential grass species in storing carbon beside as primary ruminant feed. This was indicated by percentage of C organic found in the grass (37.6 % - 53.4 %) in comparison to around 1.27 % - 4.46 % of that in soil. In addition, C organic and Nitrogen content found in the leaf were higher than in the stem and in the root. However, there was still variation identified in Nitrogen content, NDF, ADF, fiber fraction and digestive value of dry and organic matters for all observed species.

Keywords: grasses; carbon storage; forest; ecosystem; nutrient quality**.**

1. Introduction

The productivity of a livestock highly depends on continuous supply and sources of animal feeds over the years. Tropical grasses are one of importance feedstocks of ruminants in Indonesia. Almost 70% of forage consumed by ruminants in Indonesia is derived from local grass species [1].

Along with progressive development in recent years, the occurrence of potential area/ fields that are covered with growing grasses. Therefore, it is necessary to seek an alternative way for the fulfilment of feedstocks. One alternative is by harnessing of Palm plantation sites. Indonesia as a world main supplier of Palm oil has a potential figure to back up the pre-mentioned idea. Up to now, in Indonesia, there are around 12 million ha of Palm plantations and that always progressively increase every year. One of spacious Palm plantation areas is located in Jambi province that has approximately 721.400 ha of Palm plantation areas [4]. These plantations are scattered on several Sub-districts including of that is located on Pauh Sub-district of Sarolangun Distric. Most of Palm plantations on those Sub-districts are forest transformation type plantation that are managed by local societies. Meanwhile, several others have been managed by commercial companies.

Various local grass species existed in Pauh Subdistric are laying under coverage of Palm plantation and has been an integrated part with the Palm plantation ecosystem [15]. This was due to tolerance of grasses of auspices of palm trees and of light interceptions in between of Palm trees that still enable it for doing decent photosynthesis process. Besides, the adaptive capability of the grasses to grow over the limited environments has been believed as a cause [30]. Moreover, some grass species have the ability to maintain its production, although in coverage conditions of other plans [29]. Grasses species diversity might influence its available nutrient capacity and store carbon into an ecosystem due to its carbon and other nutrient capacity. However, carbon storage capacity of grass species that is growing under plant coverage, especially palm tree has not been much elucidated. Therefore, the carbon storage capacity and nutrient content of local grass species grown under palm plantation area of importance criterion that needs to be investigated. This can be resulted in a new strategy in forage management that is ecologically friendly.

Classifying as C_4 plant, grasses are well known to have a high photosynthesis rate [7]. During photosynthesis, by the subservience of light intensity, carbohydrate can be produced by carbon sequestration. Carbon sequestration is defined as reservation of CO2 from the atmosphere by grasses through semi-permanent processes to organic compounds during photosynthesis or also known as Carbon Fixation [8]. Every species would have a different carbon storage capacity, depending on species, CO2 concentration in the air, light intensity and condition of its environment [12]. Grassland ecosystem in China has 17,5% - 56,4% of carbon storage capacity [6]. This variety shows that carbon storage capacity would be vary depending on the types of grassland. Ni (2002) claimed that grassland carbon storage in China contributes to 9-16% of total world sequestratable carbon of grassland [22]. Meanwhile, savanna ecosystems pose the highest potential of carbon sequestrasi in an American tropical area [16]. Introduction of some grass species to degraded grassland was believed as an alternative in improving carbon absorption capability and gaining high income in Columbia Amazonia [20]. However, there has not published evidence for potential of Indonesia's grassland as carbon storage as well as nutrient standard as forage.

This study was aimed to gather information regarding to the carbon storage potential of some tropical grass species that are grown under the coverage of palm plantation in the commercial and transformed forest. In advanced, nutrient content and digestibility of grasses as forage were also evaluated. By this study, recommendation for development of high nutrient quality of local grass species, for utilization of plantation as a source of forage and for carbon storage media that would have a direct significant contribution in controlling climate change due to green-house gas effect can be proposed.

2. Method

2.1. Research Location and Timeline

This study was conducted on November 2012 to February 2013. Samples were taken from two locations at Pauh Subdistrict of Sarolangon District Jambi Province. First location was at Palm Plantation that has been intensively managed by joint cooperation between a commercial company named PT. Eka Mitra Agro Lestari (PT. EMAL) and local community of Lubuk Kepayang Village and Baru Village. Meanwhile, the second location was at Palm Plantation of transformation forest in Conservation Forest of Bukit Dua Belas. Furthermore, Analysis of C organics of leaves, stem, root and soils and analysis of Nitrogen of leaves and stem were performed in Soil Science and Field Resource Department Laboratory of Agriculture Faculty of IPB. Meanwhile ADF, NDF and fibre fraction analysis were performed at Balai Penelitian Ternak (Balitnak) Ciawi. In advance, Ruminant Laboratory facilities of the Animal Husbandry Faculty of IPB were employed to analyze digestibility.

2.2. Sample Preparation

A modification of Sawen Method [27] was utilized in sample preparation of grasses from Palm Plantation of transformation forest by the transect method from forest outskirts toward the plantation. Meanwhile, in commercial palm plantation, randomized plot were designed. In commercial Palm Plantation and transformation forest, 3 (three) main plots were created with each having an area of 50x50 m^2. Every main plot was extended to have 3 (three) sub-plots with having an area of 5x5 m^2. Totally, the observation area would consist of 6 plots and of 18 sub plots. The distance between the plots for every location was measured to be ± 100 meters. For easy identification purpose, every sub plot would be extended to be quadrant of 1x1 m^2 that was marked with moveable raffia rope. Light intensity was measured by means of Lutron LX-1108 of Lux meter for every sub plot.

Grasses samples were obtained by taking out the grass down to root using small scope. Leaves, stem and root were separated and soil from root were collected of approximately 250 grams/ sample for C analysis purpose. Furthermore, the soil and grass samples were dried out in an oven with maximum temperature of 70^0 C for 48 hours. Afterward, grass samples were milled to get finest grain size that can be used for laboratory analysis.

2.3. Light Intensity Measurement

A Lutron LX-1108 Lux meter was utilized to measure light intensity in every sub plot.

2.4. Grasses Species Identifications

Grasses samples were given a code and recorded on observation sheets. Then, a herbarium was produced for every coded and recorded grasses sample. This was done by spraying the grasses sample with 70% of alcohol concentration, then enveloping it paper bag. Thus, specimens were taken to Agrostology Laboratory of IPB for identification of taxonomy [25,26].

2.5. Carbon and Nutrient Content Analysis

Carbon analysis of leaves, stems and root as well as the soil was performed by using the gravimetric method [3]. Meanwhile, N analysis of leaves and stems was conducted using AOAC method [3]. Van Soest method was used to analyze content of cellulose, hemi-cellulose, lignin, ADF and NDF for every grasses species [35]. Digestibility analysis was carried out using Tilley & Terry method [33].

2.6. Data Analysis

The Identification data of grass species were discussed descriptively. Grass species that always reveal from 2 observation locations were treated as dominant species. Average values of Carbon and Nutrient content, C/N ratio, ADF, NDF, fibre fractions and digestibility of commercial and transformation forest palm plantation were statistically analysis using *t-student* test [31].

3. Result and Discussion

3.1. Light Intensity

Light intensity magnitudes were averaged from the measured value of each subplot. From the results, it reveals that the average light intensity of 28.27 Lux/fc was provided by grasses species from Commercial Palm

Plantation (CPP). Meanwhile, grass species from Transformation Forest Palm Plantation (TFPP) shows a remarkable light intensity magnitude of 258 Lux/fc. Therefore, it is plausible that TFPP posses the highest light intensity value in comparison to that of CPP.

3.2. Grasses Species Identifications

Identification was conducted by comparing the data gathered from herbarium with data existed in literatures. After comparison, it was identified 5 (fives) grasses species that are commonly grown in CPP at Pauh Sub district of Sarolangun Distric of Jambi Province which are:

1. Scleria sumatrensis Retz
2. Axonopus compressus
3. Centotheca longilamina
4. Centotheca longilamina Ohwi
5. Panicum brevifolium

In advanced, there are 8 (eight) grasses species grown in TFPP that are:

1. Axonopus compressus
2. Panicum brevifolium
3. Kylinga brevifolia Rohb
4. Scleria sumatrensis Retz
5. Centotheca longilamina Ohwi
6. Paspalum sp
7. Leptochloa chinensis L
8. Cyperus multispicatus Boeks

Among those species either grown in CPP or TFPP, there are 4 (four) grass species that predominant for both types of Palm Plantation (Figure 1).

Axonopus compressus | Scleria sumatrensis | Centotheca longilamina Ohwi | Panicum brevifolium

Figure 1: Predominant grasses species that are grown in both Commercial Palm Plantation and Palm Plantation

of Transformation Forest.

3.3. C organic, Nitrogen Content and C/N Ratio

Results as depicted in Table 1 shows C organic content of leaves, stems and root and soil and Nitrogen content of leaves and stems as well as C/N ratios. Separation of leaves, stems, roots and soils from its mother grasses was regarded to observe the carbon storage capacity distribution during grasses growth. In general, from Table 1, it can be conceivable that different locations can affect C organic and Nitrogen content in most leaves except for Axonopus compressus species. Leaves of Axonopus compressus grown in TFPP ecosystem poses higher magnitude of N contents. This is owing to higher light intensity emitted to the grasses grown in TFPP hence providing an optimum photoshyntesis process. Equilibrium between CO_2 sources, nutrient contents, water and light intensity play a significant role in maintaining the physiological function of the grass including photosynthesis process (Agren, 2008). C organic generated during photosynthesis is being absorbed by Axonopus compressus effectively for assimilation of N due to having C frame that is in forms of 2-oxoglutarat, ATP and reductant [13]. Furthermore, Sirait (2006) indentified that degradation of N content inline with increasing in coverage area [29].

For both ecosystems (e.g. CPP and TFPP), the magnitude of N content of the stems reveal insignificant differences, but it is inversely proportional to magnitude of C organic. However, growing area has a significant contribution to C organic contents, especially on the stems that are appearing from C organic magnitude of Axonopus compressus, Centotheca longilamina Ohwi and Panicum brevifolium. These three species were grown in TFPP ecosystem. This is conceivable as sufficient light intensity emitted to this ecosystem comparing to that of are growing in CPP ecosystem. A decent quality and quantity of light would influence on the growth of plans in regards to plan etiolation, pigmen production, width of leaves, the growth of branches and prolongation of the stems [19].

In general, as revealed from its distribution, percentage of C organic content for all parts of the grasses are shown almost the same magnitude. This indicates that all observed grasses have capability in distributing carbon to all parts of the grasses properly. Thus, it can be concluded that bigger grasses are more preferable to deposit of C organic. On the contrary, Panicum brevifolium shows an opposite figure where C organic are deposited much in stems rather in leaves. This difference is assumed to be caused by distinct compositions of grasses formation where for this species, the stems are more dominant rather than other parts.

Percentage of C organic for all the grasses observed in this study either that are grown in CPP or TFPP ecosystem are ranging from 45-50% of dried matters of the observed grasses. Those percentages are in the same agreement with what had been found by Brown in1997 [5]. Furthermore, it also reported that the ranges would indicate better carbon storage capability of the plants. Thus, it can be clarified that all observed grasses species pose better carbon storage capacity. Whereas, soil under grass roots have low C organic values that of 1.27-4.22%. This implies that C organic of the root would not affect C organic magnitude of the soils. Johnston *et al.*, (2009) stated that carbon storage capacity would be influenced by the source C organic, decomposition magnitude of microorganism, soil textures and climate [10].

Table 1: Averages of C Organics and Nitrogens content and C/N ratios of local grasses species grown dominantly in Commercial Palm Plantations (CPP) and Transformation Forest Palm Plantations (TFPP) at Pauh Subdistric of Sarolangun Districts of Jambi Province.

Peubah		Spesies			
		Axonopus compressus	***Scleria sumatrensis* Retz**	***Centotheca longilamina* Ohwi**	***Panicum brevifolium***
C organic (%)					
Leaves	CPP	53.12 ± 2.41	51.27 ± 2.11	49.75 ± 1.39	49.81 ± 0.68
	TFPP	51.43 ± 1.02	49.20 ± 1.89	50.09 ± 1.20	49.14 ± 1.04
Stems	CPP	38.39 ± 0.76^{B}	40.19 ± 1.37	45.27 ± 1.06^{B}	44.57 ± 1.53^{B}
	TFPP	45.27 ± 0.29^{A}	43.17 ± 1.28	50.22 ± 0.95^{A}	53.42 ± 1.95^{A}
Roots	CPP	43.03 ± 3.13	43.50 ± 1.72	41.43 ± 1.21^{A}	44.62 ± 2.32^{a}
	TFPP	42.60 ± 1.07	43.75 ± 1.19	36.25 ± 0.50^{B}	37.61 ± 1.63^{b}
Soil	CPP	1.27 ± 0.16^{B}	3.59 ± 0.45^{A}	1.75 ± 0.35^{B}	4.22 ± 0.44^{A}
	TFPP	4.00 ± 0.75^{A}	2.55 ± 0.46^{B}	4.46 ± 0.72^{A}	2.63 ± 0.37^{B}
Nitrogen (%)					
Leaves	CPP	1.36 ± 0.08^{b}	1.22 ± 0.08	1.78 ± 0.13	2.58 ± 0.53
	TFPP	2.05 ± 0.32^{a}	1.04 ± 0.11	2.31 ± 0.33	1.78 ± 0.23
Stems	CPP	1.04 ± 0.19	0.58 ± 0.13	1.25 ± 0.33	0.77 ± 0.16
	TFPP	1.08 ± 0.28	1.01 ± 0.25	1.18 ± 0.25	1.04 ± 0.12
C/N Ratios					
Leaves	CPP	39.08 ± 0.67^{A}	42.07 ± 1.15	27.96 ± 1.30^{a}	19.80 ± 3.85^{b}
	TFPP	25.47 ± 4.07^{B}	47.80 ± 7.04	21.95 ± 3.18^{b}	27.90 ± 2.88^{a}
Stems	CPP	37.71 ± 6.52	70.83 ± 13.39	38.54 ± 12.75	59.91 ± 12.86
	TFPP	43.95 ± 11.24	44.89 ± 13.02	43.64 ± 8.75	51.74 ± 5.30

Remarks : Magnitude with capital superscripts are exhibited very significant variables ($P \leq 0.01$). Meanwhile, magnitude with small superscripts are exhibited significant variables ($P \leq 0.05$).

The C/N ratio of the grasses grown in CPP ecosystem indicates optimal comparing with those grown in TFPP ecosystem. In addition, C/N ratios of the leaves and stems from CPP ecosystem are also in optimal magnitude compared with those from TFPP ecosystem. This is due to higher magnitude of N existed in the leaves from CPP ecosystem that balances the C organic magnitude.

3.4. ADF and NDF Content and Fiber Fractions

Most plants store carbon in forms of carbohydrate [14]. Carbohydrate consists of rough fibre and fibre fraction [35]. In advance, Van Soest (1991) classified forage into two factions; cell contains and cell wall. Cell contain comprises of protein fraction, non-structural carbohydrate, mineral and saturated fatty acid that is soluble in neutral detergent fibre (NDF). Meanwhile, cell wall that is insoluble in the NDF is grouped into several fractions according to its solution in acid detergent fibre (ADF). The soluble fractions contain of hemi-cellulose and wall cell protein (N wall cell), while insoluble fractions are cellulose, lignin, lignocellulose, and silica or commonly known as Acid Detergent Fibre (ADF).

Table 2 shows ADF and NDF content as well as fibre fraction (i.e. cellulose, hemi-cellulose and lignin) of local grass species at CPP and TFPP.

Tabel 2: Average values of NDF, ADF and fiber fraction of local grasses species predominantly grown at CPP and TFPP of Pauh Subdistric of Sarolangun Distric, Jambi Province.

Variables		**Species**			
		Axonopus compressus	***Scleria sumatrensis* Retz**	***Centotheca longilamina* Ohwi**	***Panicum brevifolium***
NDF (%)	**CPP**	72.13 ± 4.90	71.74 ± 2.98	68.64 ± 3.11	72.13 ± 3.78
	TFPP	72.03 ± 1.60	69.23 ± 3.69	70.58 ± 0.94	71.61 ± 2.64
ADF (%)	**CPP**	46.60 ± 3.30	52.26 ± 4.06	48.14 ± 3.17	48.79 ± 2.68^{a}
	TFPP	42.23 ± 1.80	49.93 ± 1.44	49.95 ± 2.41	42.72 ± 1.32^{b}
Sellulosa (%)	**CPP**	35.43 ± 0.66	35.83 ± 2.36	24.83 ± 0.48^{B}	34.85 ± 0.94^{a}
	TFPP	33.66 ± 1.82	34.68 ± 0.75	38.52 ± 0.57^{A}	32.48 ± 1.05^{b}
Hemisellulosa (%)	**CPP**	25.53 ± 0.86^{b}	19.48 ± 0.56	20.50 ± 1.82	23.34 ± 3.02^{b}
	TFPP	28.80 ± 0.44^{a}	19.30 ± 0.31	20.63 ± 2.54	28.89 ± 0.61^{a}
Lignin (%)	**CPP**	5.19 ± 0.63	8.25 ± 0.38^{b}	5.28 ± 0.20^{A}	7.29 ± 0.80
	TFPP	5.67 ± 0.61	9.99 ± 0.62^{a}	8.44 ± 0.38^{B}	6.66 ± 0.27

Remark: CPP=Commercial Palm Plantation, TFPP=Transformation Forest Palm Plantation. Magnitude with capital superscripts are exhibited very significant variables ($P \leq 0.01$). Meanwhile, magnitude with small superscripts are exhibited significant variables ($P \leq 0.05$).

Table 2 exhibits that NDF content of all observed species for all ecosystems are ranging from 68.64%-72.13%. Ecosystems have insignificant influences to NDF content. However, ecosystems affect much on ADF content as spotted by *Panicum brevifolium*. CPP provides much influence on species in terms of ADF content comparing to TFPP. In general, ADF content is in the ranges of 42.23% - 52.26%. Those values are in line with data reported by Minson (2012). Minson (2012) reported that tropical grasses would have NDF content and ADF content ranging from 45 - 85% and 21% - 55% respectively. Furthermore, Mlay *et al* (2006) found that the NDF content of tropical grasses ranges from 59.6% - 78.4% [18]. Thus, from observed data, it is conceivable that there is no significant difference regarding to NDF and ADF values for all observed species that are grown in both ecosystems.

Furthermore, the ecosystem would provide significant contribution to content of cellulose and lignin for Centotheca longilamina Ohwi, while in panicum brevifolium reveals significant content of cellulose and hemi-cellulose. In addition, the ecosystem would affect the content of hemi-cellulose and lignin of both Axonopus compressus and scleria sumatrensis. Furthermore, this study identifies that there are no same responses of species to their ecosystems. Herdiawan et al (2014) defined that fibre fraction a plant would be influenced by water supplies, temperature and defoliation periods [9].

3.4. Digestibility of Dry and Organic Matters

Digestibility of Dry Matters Magnitude (DDMM) and Organic Matters (DOMM) for all observed species grown either in CPP or in TFPP are depicted in Table 3.

Table 3: Average values of DDMM and DOMM of all observe species predominantly grown in CPP and TFPP of Pauh Sub-district of Sarolangun District of Jambi Province

Variables		**Species**			
		Axonopus compressus	***Scleria sumatrensis* Retz**	***Centotheca longilamina* Ohwi**	***Panicum brevifolium***
DDMM (%)	**CPP**	44.70 ± 4.32	30.48 ± 1.09^{B}	44.82 ± 1.97	37.11 ± 4.06
	TFPP	48.55 ± 3.40	47.55 ± 2.42^{A}	38.70 ± 4.38	41.58 ± 2.09
DOMM (%)	**CPP**	43.41 ± 5.82	28.42 ± 2.20^{B}	39.24 ± 0.95	34.55 ± 1.16^{B}
	TFPP	46.39 ± 2.45	46.37 ± 2.81^{A}	37.72 ± 2.22	41.01 ± 0.70^{A}

Remark: CPP=Commercial Palm Plantation, TFPP=Transformation Forest Palm Plantation. Magnitude with capital superscripts are exhibited very significant variables ($P \leq 0.01$). Meanwhile, magnitude with small superscripts are exhibited significant variables ($P \leq 0.05$).

Table 3 shows that ecosystems have no significant influences on the digestibility magnitude of either dry matters or organic matters for Axonopus compressus and Centotheca longilamina Ohwi. However, for Scleria sumatrensis Retz, the ecosystem would provide a significant contribution on digestibility values of both dry and organic matters. Meanwhile, for Panicum brevifolium, ecosystems only influence its digestibility magnitude of organic matters. These variations are caused by distinctive ways in formation of structural carbohydrate that can reveal from the formation of its fibre fraction. In general, the digestibility magnitude of all observed species are relatively low that of ≤ 50%. This is considered as high structural carbohydrate content revealed from its fibre fraction values. Besides, high lignin content also contributes to a indigestible of cellulose. Peterson (2005) stated that several factors would affect digestibility of feedstock including chemical compositions of feedstock sources, chemical compositions of feedstock, and physical appearances of feedstock, consumption volume and types of the ruminant [23]. In addition, low digestibility of organic matters is a consequence of low digestibility of dry matters. Muhtarudin and Liman (2006) defined that higher DDMM would increase DOMM thus higher the possibility of nutrient to be absorbed by ruminant for production [21].

4. Conclusion

This observation deduces that Transformation Forest Palm Plantation (TFPP) of Pauh District of Sarolangun District of Jambi Province was exposed with higher light intensity than that of emitted onto TFPP. The variation in light intensity would influence the carbon storage capacity of some grass species that are grown in both ecosystems. Distribution of reserved carbon in leaves, stems and roots of grasses that are grown under the coverage of palm plantations were considered uniform. Thus, it would have potential as carbon storage. Meanwhile, nutrient of observed species predominantly found in palm plantations were relatively low, hence necessary to be improved.

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