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Diversity, nutrient contents and production of forage plants in an integrated cattle livestock-oil palm plantation in East Kalimantan, Indonesia

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Abstract. *Daru TP, Sunaryo W, Pagoray H, Suhardi, Mayulu H, Ibrahim, Safitri A. 2023. Diversity, nutrient contents and production of forage plants in an integrated cattle livestock-oil palm plantation in East Kalimantan, Indonesia. Biodiversitas 24: 1981-1989.* The integration of cattle livestock rearing into oil palm plantations delivers various benefits. The livestock management can reduce the weeds and add organic nutrients to the plantations, while the understorey vegetation grow under the oil palm trees can be used as forage for the livestock. Several studies reported that the age of oil palm plantations affects forage production in integrated cattle livestock palm oil plantations. From an ecological standpoint, the diversity of plant species and the level of forage production varies based on the age of the oil palm trees. Therefore, this study aimed to determine the diversity, composition, nutrient contents, forage production and carrying capacity of understorey vegetation in oil palm plantations at different ages of 3, 7, and 10 years in Paser District, East Kalimantan Province, Indonesia. A total of 29 plant species from 13 families were found under oil palm plantations, of which 14 species (48.27%) are palatable to cattle livestock. The results showed that the diversity of plant species decreased along with the increasing age of oil palm trees, but they were able to meet the needs of livestock. In the 3, 7, and 10-year-old plantations, the diversity index (H') was 1.491, 1.634, and 2.099, with evenness index (E) of 0.538, 0.589 and 0.757; as well as the dominance index of 0.15, 0.30, and 0.18, respectively. Narrow-leaved forage plant species dominated the understorey vegetation and increased along with the age of oil palm plantations due to the ability to adapt to environmental conditions. The low forage production under the different ages of oil palm plantations caused a low carrying capacity to support livestock feed, namely 0.87, 0.56, and 0.36 Animal Unit (AU) ha^{-1} per year in the 3, 7, and 10-year-old plantations. Nonetheless, Crude Protein (CP) and total digestible nutrients can meet the basic life needs of livestock. The results of this study imply that oil palm plantations in Paser District can be applied as livestock rearing with different carrying capacities based on the different ages of oil palm plantations.

Keywords: Carrying capacity, cattle livestock, diversity, forage plants, oil palm plantations, Paser District

INTRODUCTION

The development of oil palm plantations has been increasing in Indonesia, especially in the large islands (i.e. Sumatera and Kalimantan). While there has been a long history of oil palm development in Sumatra which began in the Dutch colonial era, oil palm expansion in Kalimantan has been occurring in recent decades (Pahan 2008; Purba & Sipayung 2017). In East Kalimantan, oil palm plantation began at Paser District in 1982 which was initiated through the People's Nucleus Plantation Project (PIR) managed by Plantation State Company VI (PTP VI) which has continued to develop to the present (Plantation office of East Kalimantan Province 2021). East Kalimantan is among the provinces with the rapid development of oil palm plantations. In 2016, there was 1,150,078 ha of oil palm plantations and it continued to grow to 1,377,985 ha in 2021 (BPS-Statistics of East Kalimantan Province 2022).

Differing from the case of oil palm plantations, the development of beef cattle production relatively has slowly increased. For example, in 2016, the beef cattle population in East Kalimantan was 118,712 heads and it will increase slightly to 120,447 heads in 2021. The low increase in beef cattle population in East Kalimantan Province is due to the limited lands being allocated for livestock rearing and grazing as well as for producing forage plants as fodder for the livestock. The needs of fodder for livestock feeds were often supplied by utilizing forage plants around agricultural areas (Nurlaha et al. 2014), forestry (Garsetiasih et al. 2018) and various types of plantations (Kumalasari et al. 2020). In this regard, the development of oil palm plantations can be integrated with animal husbandry especially beef cattle livestock.

Oil palm plantations have potential areas to supply forage plants as cattle livestock feeds. The understorey vegetation under the oil palm plantations can be used as forages, providing double benefits to farmers for livestock and palm oil production (Bremer et al. 2022).

Forage plants in oil palm plantations are generally native species that are characterized by diverse growth characteristics, produce more seeds and are more adaptive to various environments than exotic forage plants which are higher in production but less adaptive to certain environments (Edvan et al. 2015; Scasta et al. 2015). Forage plants are often found growing in oil palm plantations such as *Paspalum conjugatum*, *Ottochloa nodosa*, *Cyperus rotundus*, *Asystasia intrusa*, *A. gangetica*, and *Ageratum conyzoides* (Daru et al. 2014; Kanny et al. 2022) and have the potentials to be used as a source of feed for ruminants (Purwantari et al. 2015).

The integration of livestock in oil palm plantations delivers an advantage in terms of recycling the energy and nutrients between oil palm plants and livestock, so there are mutually beneficial and synergies compared to when each activity is carried out separately. The understorey plants grown under the oil palm plantations can provide feed sources for the livestock. Vice versa, the collection of the understorey plants for fodder helps to weed activities while the manure and the urine produced from the livestock provide organic nutrients which promote the growth of the oil palm plants (IACCB 2020). This relationship illustrates the mutualistic symbiotic relationships between oil palm plantations and livestock rearing.

The integration of livestock in oil palm plantations is also beneficial to the environment as there is an opportunity for the community living surrounding the plantations to establish a livestock or plantation management into a business that emphasizes aspects of profit, social responsibility, as well as environmental sustainability (Chang et al. 2020). This agroecosystem diversification is also aimed at intensifying agricultural products sustainably by reducing conventional inputs from external sources (e.g. fertilizer and livestock feed) so that both agricultural products become optimal (Isbell et al. 2017). This system is often called a circular economy.

The diversity of forage plant species is important for the growth and health of livestock because the nutritional elements of various forage plant species can complement each other to meet the ideal nutrient composition and level required by the livestock (Baumont et al. 2008; Distel et al. 2020; Zanon et al. 2022). An area used as grazing land and fodder sources should be composed of diverse plant species to provide feeds in the form of grasses, herbs, and trees needed by livestock which contain adequate primary nutrient elements, such as carbohydrates, proteins and minerals, as well as the secondary nutrients such as phenolic compounds, terpenes, and so on (Beck & Gregorini 2020). Naturally, ruminant livestock chooses and combines any food that has different nutritional content and bioactive compounds to improve the efficiency of the digestive and metabolic systems (Villalba et al. 2014; Leiber et al. 2020).

In the context of integrated oil palm plantation and livestock rearing, the diversity of forage plants grown in oil palm plantations plays an important role in meeting the physiological needs of livestock as reflected by their habit of selecting forage plant types. This is because not all plant species in oil palm plantations are preferred and consumed by livestock. In addition, the composition of understorey vegetation under oil palm plantations also changes along with the age of the plantation. However, there is limited information regarding the dynamics of understorey vegetation in oil palm plantations which can be used as the folder source for cattle livestock. Therefore, this study aimed to investigate the diversity, composition, nutritional values and production of understorey vegetation to be used as forage plants for cattle livestock that grow under oil palm plantations in varying plantation ages in Paser District, East Kalimantan Province, Indonesia. We expect the result of this study can inform the possibility and feasibility of the integration of cattle livestock rearing into oil palm plantations in Paser District.

MATERIALS AND METHODS

Study area

This study was conducted at oil palm plantations in Long Ikis Sub-district, Paser District, East Kalimantan Province, Indonesia (Figure 1). The geographical position is at 116º11'58.38" E and 1º34'58.76' S. The average monthly rainfall is 230.75 mm with an average number of rainy days in a year of 206 days. Long Ikis District is dominated by Red Yellow Podzolic soil (BPS-Statistics of Paser District 2021).

Data collection

Data was collected from smallholder oil palm plantations sites of 3, 7, and 10 years of plantation age, respectively. Twenty-five randomly square plots were observed at each site using a quadrat measuring 1x1 m for each plot. All plant species in each quadrat were identified and counted for the number of individuals of each species. To investigate the potential application or use as forage plants and their production, the selected plants were fed to cattle livestock, cut to the ground level, and weighed. Each plant species was dried as FAO guidelines (FAO, 2011).

Vegetation analysis

Analysis of vegetation composition and diversity followed Tjitrosoedirdjo et al. (1984) and Satriawan & Fuady (2019). The community composition of understorey vegetation that grows on oil palm plantations was analyzed using Important Value Index (IVI) and calculated as follow:

Important Value Index (IVI) = Relative Density (RD) + Relative Frequency (RF)

Where:

$$\text{Density (D)} = \frac{\text{Number of species individuals}}{\text{Plot area}}$$

$$\text{Relative density (RD) (\%)} = \frac{\text{Density of a species}}{\text{Total density of all species}} \times 100$$

$$\text{Frequency (F)} = \frac{\text{Number of plots found on a species}}{\text{Total of all plots}}$$

$$\text{Relative frequency (RF) (\%)} = \frac{\text{Frequency of a species}}{\text{Total frequency of all species}} \times 100$$

The Diversity Index (H') was calculated using Shannon Index equation (Magurran 2004; Razali et al. 2014) as follows:

$$H' = -\sum_{i=1}^{s} Pi \ln Pi$$

Where:
H' : Diversity index
P_i : Individual proportion in the species i^{th} = ni/N
n_i : Total individuals in the species i^{th}
N : Total of all species

The level of diversity index (H') was classified referring to Baliton et al. (2020) in which H' ≥ 3.50 = extremely high diversity; 3.00-3.49 = high diversity; 2.50-2.99 = moderate diversity, 2.00-2.49 = low diversity; and H' ≤ 1.99 = extremely low diversity.

The Evenness index (E) describes the similarity in the number of individuals among species in a plant community and it was calculated using the formula by Magurran (2004) as follows:

$$E = \frac{H'}{\ln S}$$

Where:
E : Evenness index
H' : Diversity index
S : Total species found

The Evenness index category followed the scale of Simpson's Evenness value (Coracero & Malabrigo Jr 2020) in which the value of 0.75-1.00 = extremely high species evenness; 0.50-0.74 = high species evenness; 0.25-0.49 = moderate species evenness; 0.15-0.24 = low species evenness; and 0.05-0.14 = Extremely low species evenness.

The Dominance index was calculated using Simpson index (D) equation (Magurran 2004):

$$D = \sum_{i=1}^{s} Pi^2$$

Where:
D : Dominance index
P_i : Individual proportion in the species i^{th}

The D index value ranges from 0 - 1. The Dominance index close to 0 means no individual dominated, and vice versa.

Nutritional content analysis

The nutritional content of crude protein (CP), crude fiber (CF), crude fat (CFT), and ash was analyzed according to AOAC (2005) at the Livestock Nutrition Laboratory, Faculty of Agriculture, Universitas Mulawarman, Indonesia. While the nitrogen-free extract (NFE) was obtained from the calculation of 100 - (CP + CF + CFT + ash). The total value of digestible nutrients (TDN) was calculated referred to Sutardi equation (Indah et al. 2020) as follows:

TDN (%) = 70,6 + 0,259 CP + 1,01 CFT-0,76 CF + 0,091 NFE

Forage plant production

Production of fresh forage plants per hectare was calculated using the equation:

P = C x {10.000-(LP x JS)} (Daru et al. 2014),

Where:
P : Production of forage plants per hectare (kg)
C : Average weight of forage plants per m^2
LP : Circular area of oil palm trees with radius of 2 m (total area of the circular was 12.56 m^2)
JS : Number of oil palm individuals in 1 hectare (average of 132 trees)

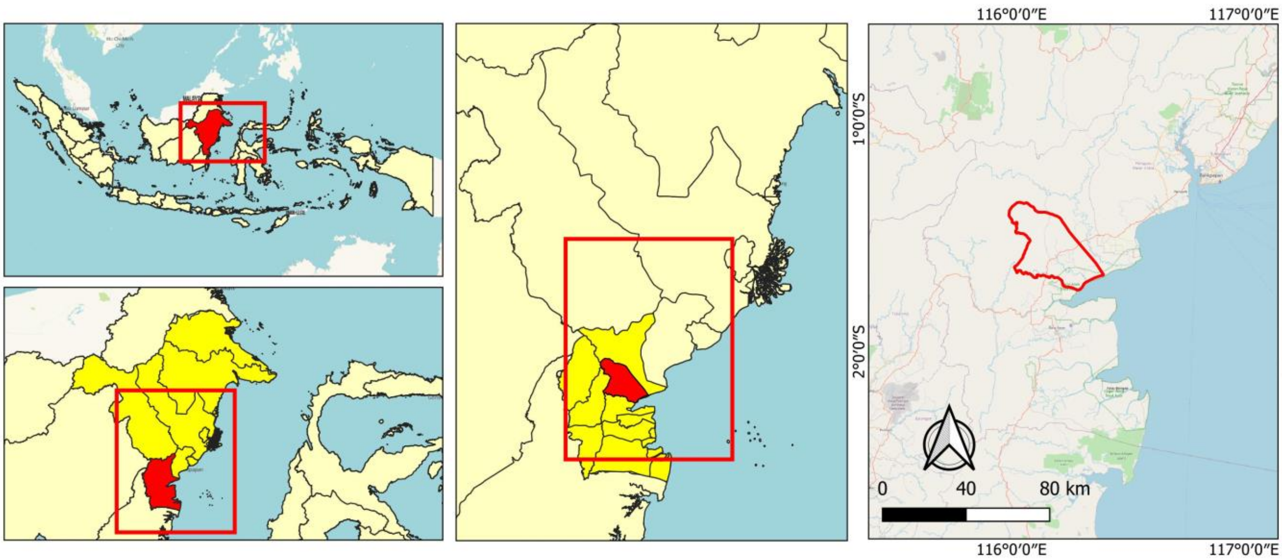

Figure 1. Map of the study area in Long Ikis Sub-district, Paser District, East Kalimantan Province, Indonesia

Carrying capacity

The calculation of the carrying capacity of palm oil plantations was conducted using the Voisin equation (Reksohadiprodjo 1994) as follows:

(y-1) s = r,

Where:
y : Total area of land needed by an animal unit (i.e. cow)
s : Grazing period on each land area (30 days)
r : Rest period for plants to grow again (70 days)

The Proper Use Factor (PUF) was determined to be 45%, assuming that the grazing is moderate. Each animal unit (AU) was calculated as equivalent to an adult cow weighing 325 kg (Suhubdy et al. 2018). The consumption of fresh forage was assumed to be 10% of livestock body weight.

RESULTS AND DISCUSSION

Plant species diversity

The number of plant species at three different ages of plantation (i.e., 3,7 and 10 years old) was similar (Table 1) with consumable plant species being much higher at the 3 years old oil palm plantations. The number of broad-leaved plant species also much higher at the 3 years old oil palm plantations compared to other age groups which were dominated by the narrow-leaved plant groups (Figure 2). The decrease in broad-leaved plant species number is likely related to the increasing degrees of shade (Sims et al. 2018) which suppress plant growth under the shade (Pala et al. 2020).

Based on the age of oil palm plantations (3 years, 7 years and 10 years), it appears that *Ottochloa nodosa* (Poaceae) was always present and was the dominant species with high IVI. This indicates that *O. nodosa* is adaptive to growing in varying ages of oil palm plantation. Broad-leaved plants such as *A. conyzoides* and *Asystasia gangetica* were also found at every age of the oil palm plantations, although the IVI decreased as the age increased (Table 1). The dominant forage plant species in the 3 years-palm oil palm plantations based on the importance value index was *O. nodosa*, followed by *A. gangetica*, *Pueraria phaseoloides*, *Imperata cylindrica*, and *Chromolaena odorata*. This condition was also reflected by the individual densities of 33.36 m^{-2}, 24.80 m^{-2}, 22.60 m^{-2}, 18.88 m^{-2}, and 14.80 m^{-2}, respectively. The 7-year-old oil palm plantations were dominated by *Paspalum urvillei* and *O. nodosa*, which had individual densities of 45.44 m^{-2} and 31.16 m^{-2}. In addition, in the 10-years-old oil palm plantations, *O. nodosa*, *Melastoma malabatrichum, Mikania micrantha, Axonopus compressus*, and *Borreria laevicaulis* dominated the area with individual densities of 29.52 m^{-2}, 13.28 m^{-2}, 8.64 m^{-2}, 11.36 m^{-2}, and 4.76 m^{-2}. Almost all of the dominant plants under the oil palm trees are commonly consumed by livestock, except *M. malabatrichum* which grew under the 10- years-old oil palm plantations. The high importance value index of a species in a community indicates that this species suppresses the growth of other species which share similar space. Changes in plant composition under palm oil trees at different ages and locations could be caused by edaphic and climatic factors (Rao 2020).

Previous research showed that in 2- and 4-years oil palm plantations, *Eleusine indica*, *Cyperus killngia*. and *Cynodon dactylon* were the most common species compared to the other species, while *Asystasia intrusa*, *A. gangetica*, *Hyptis brevipes*, *Mikania micrantha* and *C. odorata* were very dominant in 6 years of oil palm plantations (Satriawan & Fuady 2019). Other study by Kanny et al. (2022) showed that in 2 years oil palm plantations, the dominant plant species were *O. nodosa* and *A. gangetica*, while at 7 years old plantation, *Acroceras munroanum, Paspalum scrobiculatum, Axonopus compressus, M. malabatrichum, Killianga brevifolia* dominated the area (Firison et al. 2019). However, in old oil palm plantations, the understorey vegetation is generally dominated by *Nephrolepis biserrata*, *A. gangetica*, and *Paspalum conjugatum* (Asbur et al. 2020). The strong ability of plant species from the Poaceae family to dominate oil palm plantations area is due to the presence of stolon and rhizomes, so they can compete with broad-leaved plant species.

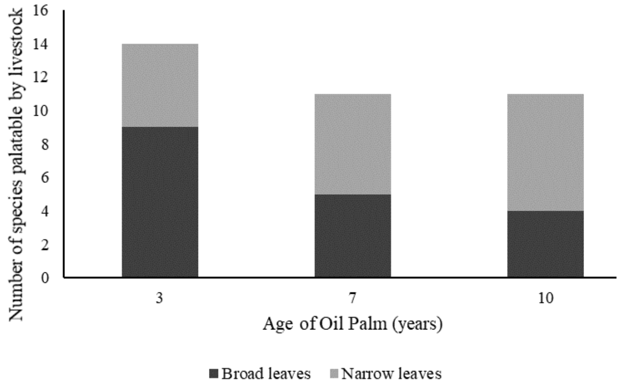

Figure 2. Number of broad and narrow-leaved plant species palatable by cattle livestock in varying ages of oil palm plantations in Long Ikis Sub-district, Paser District, East Kalimantan Province

Table 1. Plant species composition under oil palm plantations in varying ages in Long Ikis Sub-district, Paser District, East Kalimantan Province, Indonesia

Species	Family	Palatable by cattle	Number of individuals	RD (%)	RF (%)	IVI
Oil palm plantations age 3 years						
Ageratum conyzoides)*	Asteraceae	+	251	6.93	5.71	12.64
Asystasia gangetica)*	Acanthaceae	+	620	17.12	14.29	31.41
*Axonopus compressus**)*	Poaceae	+	49	1.35	7.14	8.49
Borreria laevicaulis)*	Rubiaceae	+	15	0.41	2.86	3.27
Borreria latifolia)*	Rubiaceae	+	86	2.37	7.14	9.51
Chromolaena odorata	Asteraceae	-	370	10.22	7.14	17.36
*Cyperus brevifolius**)*	Cyperaceae	+	6	0.17	1.43	1.6
Emilia sonchifolia)*	Asteraceae	+	4	0.11	1.43	1.54
*Imperata cylindrica**)*	Poaceae	+	472	13.03	14.29	27.32
Mikania micrantha)*	Anacardiaceae	+	2	0.06	2.86	2.92
Mimosa pudica)*	Fabaceae	+	38	1.05	2.86	3.91
*Ottochloa nodosa**)*	Poaceae	+	834	23.03	14.29	37.32
Passiflora foetida)*	Passifloraceae	+	11	0.30	2.86	3.16
Pueraria phaseoloides)*	Fabaceae	+	565	15.60	7.14	22.74
*Scleria sumatrensis**)*	Cyperaceae	+	283	7.81	7.14	14.95
Spermacoce densiflora	Rubiaceae	-	16	0.44	1.43	1.87
H’ = 1.491; D = 0.15; E = 0.538		87.50%				
Oil palm plantation age 7 years						
Ageratum conyzoides)*	Asteraceae	+	18	0.70	0.87	1.57
Asystasia gangetica)*	Acanthaceae	+	215	8.34	4.35	12.69
Borreria laevis)*	Rubiaceae	+	32	1.24	1.74	2.98
*Centotheca lappacea**)*	Poaceae	+	13	0.50	1.74	2.24
Chromolaena odorata	Asteraceae	-	85	3.30	8.70	12.00
Clidemia hirta	Melastomataceae	-	15	0.58	4.35	4.93
*Cyperus brevifolius**)*	Cyperaceae	+	38	1.47	1.74	3.21
Hyptis rhomboidei	Lamiaceae	-	74	2.87	4.35	7.22
*Leptochloa chinensis**)*	Poaceae	+	9	0.35	1.74	2.09
Melastoma malabatrichum	Melastomataceae	-	19	0.74	13.04	13.78
*Mikania micrantha *)*	Anacardiaceae	+	3	0.12	0.87	0.99
Nephrolepis biserrata	Lomariopsidacee	-	28	1.09	1.74	2.83
*Ottochloa nodosa**)*	Poaceae	+	779	30.23	21.74	51.97
*Panicum sarmentosum**)*	Poaceae	+	1	0.04	0.87	0.91
*Paspalum urvillei**)*	Poaceae	+	1136	44.08	17.39	61.47
Pueraria phaseoloides)*	Fabaceae	+	43	1.67	1.74	3.41
Solanum violaceum	Solanaceae	-	69	2.68	13.04	15.72
H’ = 1.634; D = 0.30; E = 0.589		64.71%				
Oil palm plantations age 10 years						
Ageratum conyzoides)*	Asteraceae	+	23	1.06	5.68	6.74
Asystasia gangetica)*	Acanthaceae	+	25	1.15	3.98	5.13
*Axonopus compressus**)*	Poaceae	+	284	13.05	2.84	15.89
Borreria laevicaulis)*	Rubiaceae	+	119	5.47	11.36	16.83
Chromolaena odorata	Asteraceae	-	22	1.01	9.09	10.1
Clidemia hirta	Melastomataceae	-	25	1.15	8.52	9.67
*Cyperus brevifolius**)*	Cyperaceae	+	3	0.14	0.57	0.71
*Cyperus rotundus**)*	Cyperaceae	+	25	1.15	1.70	2.85
*Leptochloa chinensis**)*	Poaceae	+	21	0.96	3.41	4.37
Melastoma malabatrichum	Melastomataceae	-	332	15.25	14.20	29.45
Mikania micrantha)*	Anacardiaceae	+	216	9.92	14.20	24.12
Nephrolepis biserrata	Lomariopsidaceae	-	38	1.75	0.57	2.32
*Ottochloa nodosa***	Poaceae	+	738	33.90	8.52	42.42
*Paspalum conjugatum**)*	Poaceae	+	75	3.45	2.84	6.29
*Paspalum urvilei**)*	Poaceae	+	161	7.40	3.41	10.81
Solanum violaceum	Solanaceae	-	70	3.22	9.09	12.31
H’ = 2.099; D = 0.18; E = 0.757		68.75%				

Note: RD: Relative Density; RF: Relative Frequency; IVI: Important Value Index; *): broad leaved; **): narrow leaved; +: palatable by cattle livestock; -: not palatable by cattle livestock

Plant diversity

The diversity index tends to increase in line with the age of oil palm plantations (Figure 3). The continuous increase in plant diversity is in line with the increase in the evenness index (Figure 3A), but not in the case of the dominance index (Figure 3B). The diversity index indicates biological variability in space or time (Heip et al. 1998). The low diversity of species in the oil palm plantations indicates that only a few species grow and dominate the area under oil palm plantations. Plant diversity in oil palm plantations is strongly influenced by environmental conditions, especially soil, water, and climate. In a stable environment, plant diversity will be higher, and this reflects the environment's ability to deal with disturbances (Oksari 2014). The high or low diversity of a species in a vegetation community depends on the number of individuals of each species present (Susanti et al. 2021). The similar indication of the increase of diversity index and the age of oil palm plantations shows that the more similar the number of individuals between species or the more evenly distributed they are, the greater the balance which is indicated by the increasing diversity index (Reed & Morrissey 2022).

However, the relationship between the diversity index and the dominance index shows the opposite pattern (Figure 3B). The same pattern also occurs in the relationship between the dominance and evenness indexes (Figure 3C). The dominance index is the opposite of the evenness index, where the smaller the diversity reflects the total number of a species against other species in the community (Magurran 2004). The smaller the evenness index, the smaller the population uniformity. This shows that the distribution of the number of individuals of each species was not the same, so there was a tendency for one species to dominate. The greater the evenness index, the more balanced the distribution of the number of individuals of each species (Baliton et al. 2020).

The dominance index is a measure of species abundance in a community. High dominance could have a consequence on the low diversity, suggesting that one or a few species are very abundant. On the other hand, low dominance could mean that the distribution of species is quite homogeneous (Beisel 1997). As the age of oil palm plantations increased, plant height and canopy cover also increased, affecting the understorey vegetation community. Canopy cover plays an important role in ecosystem function since it affects the level of sunlight which is used in the photosynthesis process and also affects soil moisture due to changes in the amount of radiation that reach the soil surface (Deng et al. 2021). In particular, sunlight is the determining factor of the speed of photosynthesis, especially in broad-leaved plants (Kaligis et al. 2017). Young oil palm plantations have a greater level of resources for plants to grow, including space, nutrients, water, and sunlight. In contrast, the older oil palm plantations will produce a wider and denser canopy cover which reduces sunlight intensity that suppresses the growth of understorey vegetation, especially plants requiring high light intensity.

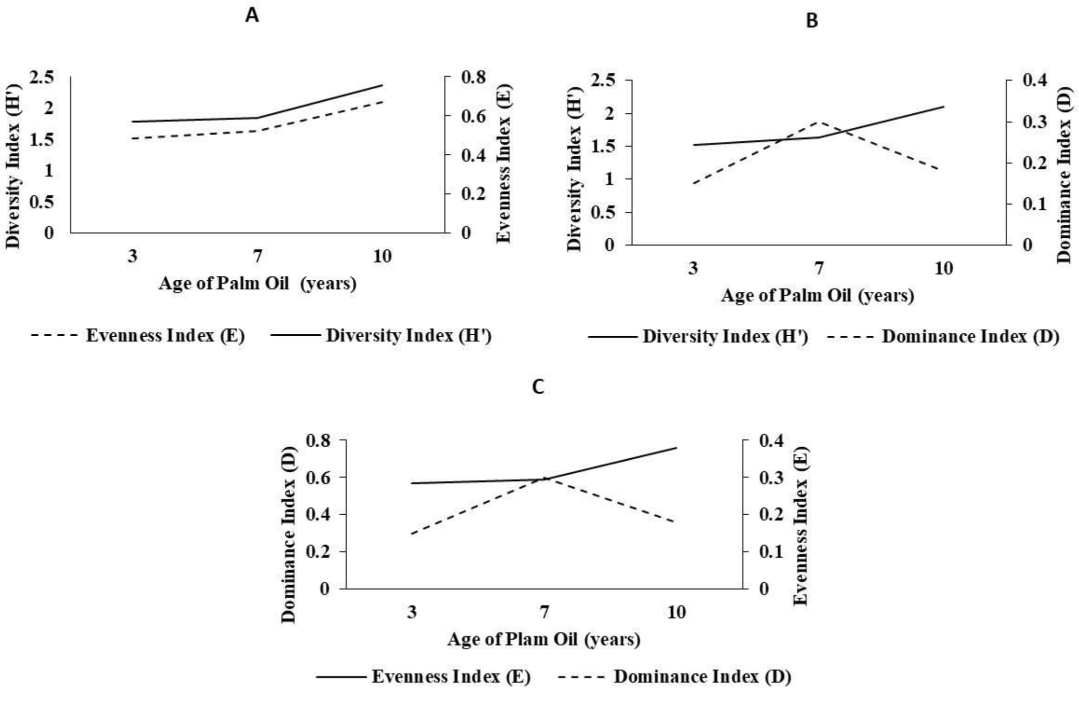

Figure 3. The relationship between the diversity index and the evenness index (A), the diversity index and the dominance index (B), and the dominance index and the evenness index (C) of understorey vegetation in oil palm plantations at different ages in Long Ikis Sub-district, Paser District, East Kalimantan

Table 2. Production and nutrient content of forage plants grown under oil palm plantations of different ages in Long Ikis Sub-district, Paser District, East Kalimantan Province, Indonesia

Measured component	Oil palm plantations age		
	3 years	7 years	10 years
Production			
Fresh matter production (kg ha^{-1} yr^{-1})	6,209.39	3,981.41	2,550.20
Dry matter production (kg ha^{-1} yr^{-1})	1,690.63	1,063.54	725.74
Nutrient content			
Crude protein (%)	7.82	10.33	10.55
Crude fiber (%)	34.4	30.60	24.40
Crude fat (%)	3.20	2.20	2.30
NFE (%)	51.08	53.07	59.55
Ash (%)	3.50	3.80	3.20
TDN (%)	54.36	57.07	62.53
Carrying capacity (AU ha^{-1} yr^{-1})	0.87	0.56	0.36

Note: TDN: Total Digestible Nutrients; NFE: Nitrogen Free Extract

Forage plant production

The production of forage plants grown under oil palm plantations in this study was analyzed from fresh and dry matter production. Furthermore, the nutrient analysis contained in forage plants as feeding sources of cattle livestock is also presented (Table 2).

The production of fresh matter from forage plants grown under oil palm plantations varied depending on the age of the plantations (Table 2). In the 3-year-old plantation, forage plants yielded fresh matter of 6,209.39 kg ha^{-1} per year. It decreased to 3,981.41 kg ha^{-1} per year in the 7-year-old plantation and 2,550.20 kg ha^{-1} per year in the 10-year-old plantation. Other research reported that 3-year-old smallholder oil palm plantations produced forage plants of 5,775.63 kg ha^{-1} per year (Ramdani et al. 2017) and 7-year-old plantations produced 5,445.1 kg ha^{-1} per year. Meanwhile, at 9-year-old oil palm plantations, the fresh matter of forage plants produced was about 2,299 kg ha^{-1} per year (Firison et al. 2019; Martono et al. 2019). Based on several studies, it appears that each research resulted in different forage production depending on the conditions of the local area. Nonetheless, the production of fresh matter from forage plants is consistently decreasing along with the increase of the oil palm plantation age.

This study showed a decrease in the production of the weight of fresh and dry matter of forage plants in line with the increasing age of oil palm trees. The reduction of sunlight intensity due to the increasing oil palm canopy influenced the growth of understorey vegetation. The higher sunlight intensity in younger oil palm plantations increases the process of photosynthesis and will results in the optimal growth of understorey vegetation (Akbar et al. 2021). In shaded conditions, the growth rate is lower than in non-shaded areas because the light compensation point becomes very low, so plant growth is inhibited (Muhtarudin et al. 2020). This process also correlates with leaf area index (LAI), plant height, light interception, and distribution of plant morphological components, especially leaf/stem balance (Lista et al. 2019). Sunlight intensity of 40-60% which penetrates through the canopy of the oil palm tree, is deemed sufficient for the growth of understorey vegetation, so it could be used for livestock grazing (Nur et al. 2021). Therefore, the intensity of sunlight strongly influences the production of forage plants. However, there are several species of forage plants that are tolerant to shade without reducing the quantity and quality of fresh and dry matter production.

Analysis of nutrient contents in forage plants grown under the oil palm plantations at different ages showed that crude protein content increased and the crude fiber content decreased as the age of oil palm increased. In the 3-year-old oil palm plantations, the crude protein and crude fiber content were 7.82% and 34.4%, respectively. On the other hand, at the 7- and 10-year-old plantations, the crude protein content increased to 10.33% and 10.55%, while the crude fiber decreased to 30.60% and 24.40%, respectively. A study conducted by Ramdani et al. (2017) reported that the crude protein and fiber content in smallholder plantations aged 3 years was 6.8% and 25.6%. The increase in crude protein content due to the increasing age of the oil palm tree was also followed by an increase in the nitrogen free extract (NFE) content and total digestible nutrients (TDN).

Forage quality is often indicated by the amount of nutrients contained in forage as nutrition sources for livestock. The quality of forage can also be inferred from forage production and the digestibility of the food substances consumed by livestock. The chemical composition of food substances contained in forage plants can also be used to indicate the quality of animal feeds. In this study, shade influenced the chemical composition of nutrients contained in forage plants that grew under oil palm plantations. Under shaded conditions, the crude protein content was higher than that of non-shaded forage plants. Grasses absorb nitrogen more sufficiently in shaded conditions than in open conditions (Muhtarudin et al. 2020). On the other hand, the crude fiber content of shaded plants was lower than that of exposed ones. Shade affects cell wall content, lignin composition, and dry matter digestibility of forage feed (Norton et al. 1991). Shade causes the lignification process to slow down due to limited sunlight intensity (Muhtarudin et al. 2020).

Based on the crude protein need and total digestible nutrients for the basic needs of a 325 kg cow, it requires a crude protein of 7.66% and 46.73% (Kearl 1982). Based on this figure, the nutrient content of forage plants grown under oil palm plantations at the age of 3, 7 and 10 years old in Long Ikis Sub-district, Paser district is sufficient for the basic needs, even able to meet the full needs for better growth of livestock.

Carrying capacity

The carrying capacity of the land for livestock rearing (either through grazing or fodder collection) is defined as the ability of the land to produce feed sources for a number of livestock. The carrying capacity differs among lands which are strongly influenced by soil productivity, rainfall, topography, shade, and other growth factors. The calculation of the carrying capacity in this study was based on the fresh weight of the forage plants that are usually consumed by livestock. The carrying capacity of the 3-year-old oil palm plantations can accommodate 0.87 AU ha^{-1} $year^{-1}$ and decreases with the increasing age of palm oil plantations, i.e., 0.56 AU ha^{-1} $year^{-1}$ at 7-year-old and 0.36 AU ha^{-1} $year^{-1}$ at the 10-year-old plantations. This carrying capacity is lower than as reported by Daru et al. (2014) which can accommodate 1.44 AU ha^{-1} $year^{-1}$ at a 3-year-old plantation and 0.71 AU ha^{-1} $year^{-1}$ at a 7-year-old plantation. Another study reported that 7-year-old oil palm plantations could accommodate 1.35 AU ha^{-1} $year^{-1}$ (Sandiah et al. 2022) and without herbicide spraying treatment, 10-year-palm oil plantations could accommodate 0.51 AU ha^{-1} $year^{-1}$, while oil palm plantations treated by herbicide spraying can accommodate 0.42 AU ha^{-1} $year^{-1}$ (Endrawati et al. 2019). Not all oil palm plantations have forage plants consumable by livestock. If the composition of the forage plants in a vegetation community is low, the production will be less. Livestock, in general, can be grazed in areas that have grass with around 60-70% coverage (Nur et al. 2021).

In conclusion, as many as 29 plant species from 13 families were found under oil palm plantations across three different plantation ages, of which 14 species (48.27%) of those are palatable by cattle livestock. Furthermore, the diversity of plant species decreased along with the increasing age of the plantation. The dominant forage plants under the trees were narrow-leaved species. In the older oil palm plantation, the narrow-leaved dominated the understorey vegetation which is due to the ability to adapt to environmental conditions. This resulted in decreased forage production as the age of the plantation increased which reduced the carrying capacity of the area to support livestock feed since it produced a lower crude protein and total digestible nutrients to meet the basic needs of livestock. Based on the results of the study, it can be concluded that oil palm plantations in Paser District can be integrated with livestock rearing with different carrying capacities based on the different ages of oil palm plantations.

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