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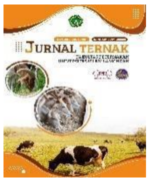

Vegetation-Based Assessment of Forage Potential in Cattle–Oil Palm Integrated Farming Systems

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ABSTRACT

Integrated cattle–oil palm farming systems (SISKA) have been widely promoted in Indonesia, yet quantitative information on the forage potential of plantation understory vegetation remains limited and site-specific. This study assessed the composition, dominance structure and dry-matter (DM) attributes of understory vegetation in smallholder oil palm plantations (<10 years old) managed under a cattle–oil palm integration scheme in Tanah Laut Regency, South Kalimantan, Indonesia. Vegetation was sampled using twenty 1 × 1 m quadrats per site. For each species, relative density (RD), relative frequency (RF) and a simplified Importance Value Index (IVI = RD + RF) were calculated. Palatability was confirmed by direct observation of cattle intake, and DM content was determined by oven-drying herbage samples to constant weight. A total of 12 species from 7 families were recorded, consisting of grasses (*Poaceae*), sedges (*Cyperaceae*), legumes (*Fabaceae*) and broad-leaved forbs. The understory was strongly dominated by grasses, with *Axonopus compressus* showing the highest RD (60.36%), RF (16.67%) and IVI (77.03), and a relatively high DM content (33.51%), making it the keystone species in the ground layer. Almost all species (11 of 12; 92%) were classified as palatable to cattle, while only *Peperomia pellucida* was rejected and contributed negligibly to DM due to its low abundance and very low DM percentage (5.78%). The coexistence of productive grasses, nitrogen-fixing legumes and various forbs indicates a moderately diverse understory community that can provide a continuous, though heterogeneous, forage supply. These findings provide a site-specific, vegetation-based baseline for estimating forage DM potential and designing grazing strategies in SISKA systems, contributing to more productive and sustainable cattle–oil palm integration in Indonesia.

Introduction

Beef cattle play a strategic role in Indonesia's food security and rural livelihoods, yet domestic beef production still supplies only around half of national demand, forcing the country to rely heavily on imports. One of the key biophysical constraints to increasing cattle productivity especially for smallholders is the year-round availability of sufficient, good-quality forage. In this context, integrated crop–livestock systems are increasingly promoted as a way to intensify production while improving resource-use efficiency and environmental performance.

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Among these systems, the cattle–oil palm integration model, widely known in Indonesia as the Sistem Integrasi Sapi–Kelapa Sawit (SISKA), has attracted strong policy and research attention. Recent studies highlight SISKA as a promising flagship program to improve land-use efficiency, support national meat self-sufficiency targets, and contribute to the Sustainable Development Goals through more circular nutrient flows and reduced pressure on natural forests [1]. Indonesia's position as the world's largest palm oil producer—with oil palm expanding from about 0.3 million ha in 1980 to roughly 14.8–16.5 million ha by 2020 (Directorate General of Estate Crops, Ministry of Agriculture, 2020) creates a vast potential forage resource if the understory vegetation beneath the palms can be effectively utilized for grazing cattle [2].

Integrating cattle grazing into oil palm plantations adds another functional dimension to understory management. Comparative work in Malaysian plantations shows that cattle grazing can effectively suppress excessive understory growth, reduce the need for chemical weed control and maintain adequate ground cover, thereby supporting both agronomic and environmental objectives [3]. Under rotational grazing regimes, understory species richness, cover and structural complexity have been reported to increase, suggesting that well-managed cattle grazing can simultaneously act as a biological weed-control strategy and a driver of biodiversity within plantations.

Recent studies in Indonesian oil palm plantations have identified 16–36 understory species, often dominated by grasses and other palatable herbs, with average fresh biomass yields exceeding 7–13 t ha^{-1} in some sites, although species composition and diversity decline as plantations age [4], [5]. Technical reviews on forage availability under oil palm emphasize that the carrying capacity for cattle varies widely between estates and is strongly influenced by vegetation composition, palm age and management practices, including the introduction of improved forages and the use of rotational grazing [6]. These findings suggest a considerable potential for the understory as a forage resource, but also highlight that this potential is far from uniform or fully quantified.

To optimize the use of plantation understory as cattle feed within SISKA systems, detailed information is needed on the botanical composition, dominance structure and biomass production of the vegetation, expressed in terms of dry-matter (DM) yield and effective carrying capacity. While several authors have described weed or understory communities and provided preliminary estimates of forage production under oil palm, comprehensive studies that explicitly link quantitative vegetation analysis with estimations of forage DM potential and grazing capacity under Indonesian cattle–oil palm integration conditions remain limited and often site-specific [5], [6].

Against this background, the present study, entitled "Vegetation-Based Assessment of Forage Potential in Cattle–Oil Palm Integrated Farming Systems", aims to: (1) characterize the composition and structure of understory vegetation with forage value in oil palm plantations managed under a cattle oil palm integration scheme; (2) estimate the potential dry matter yield of the available forage. The results are expected to provide a scientific basis for designing grazing strategies and improving the management of cattle–oil palm integration systems, thereby contributing to more productive and sustainable livestock development in Indonesia.

Materials and Method

Study area

This study was conducted in oil palm plantation areas located in Tanah Laut Regency, South Kalimantan Province, Indonesia. Tanah Laut is geographically situated between 3°30′33″–4°11′38″ S and 114°30′20″–115°23′31″ E, with the regency capital in Pelaihari, approximately 60 km south of Banjarmasin, the provincial capital. The region has a humid tropical climate, with an average monthly rainfall of about 166.3 mm and an average of 9–10 rainy days per month. The average elevation of the regency is around 20 m above sea level, dominated by lowland areas. Land use in Tanah Laut is characterized by agriculture, plantation crops and livestock production, with oil palm and rubber as the main plantation commodities and the regency recognized as one of the important livestock centres in South Kalimantan.

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Data collection

Field data were collected in 5 smallholder oil palm plantations younger than 10 years. At each site, twenty square plots were randomly established using 1 × 1 m quadrats. Within every quadrat, all understory plant species were identified and the number of individuals of each species was recorded, following standard quadrat-based vegetation survey procedures commonly applied in oil palm plantations. To evaluate their potential use as forage and estimate biomass production, selected understory species were first offered to cattle to confirm palatability, then harvested by cutting at ground level and weighed to obtain fresh biomass yield, in line with destructive sampling approaches used to estimate forage production under oil palm. Each plant species sample was subsequently oven-dried to constant weight following FAO guidelines for feed sampling and dry matter determination, providing standardized data for further nutritional evaluation [7].

Vegetation analysis

Vegetation composition and diversity were assessed using standard phytosociological procedures widely applied in recent vegetation studies. For the understory community, a simplified Importance Value Index (IVI) was calculated for each species as the sum of its relative density (RD) and relative frequency (RF):

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

$$RD = \frac{Density\ of\ a\ species}{Total\ density\ of\ all\ species} X100\%$$

$$RF = \frac{Frequency\ of\ a\ species}{Total\ frequency\ of\ all\ species} X100\%$$

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

$$IVI_i = RD_i + RF_i$$

Relative density (RD) was obtained by dividing the number of individuals of species i by the total number of individuals of all species in all quadrats, multiplied by 100. Relative frequency (RF) was calculated as the proportion of quadrats in which species i occurred divided by the sum of frequencies of all species, multiplied by 100. These metrics are commonly used to quantify species dominance and community structure in modern phytosociological analyses [8], [9].

Results and Discussion

Plant species diversity

The understory flora recorded in the cattle–oil palm integration area consisted of a mixture of grasses, sedges, legumes and broad-leaved forbs, a pattern that is typical for vegetation growing beneath oil palm canopies in Southeast Asia. Recent studies in oil palm plantations report that ground vegetation usually comprises *Poaceae, Cyperaceae, Fabaceae* and various herbaceous dicots, many of which function simultaneously as weeds and as a potential forage resource for grazing ruminants [6], [10], [11]. Such species assemblages are known to support not only feed availability for livestock but also soil biodiversity and ecosystem processes when the understory is managed rather than eliminated [3], [10].

In the present study, the species list *Mimosa pudica, Ocimum tenuiflorum, Grona triflora, Dichanthelium oligosanthes, Cyperus rotundus, Muhlenbergia schreberi, Axonopus compressus, Ichnanthus pallens, Panicum repens, Richardia brasiliensis* and *Peperomia pellucida* reflects this functional diversity. Several grasses, including *Axonopus compressus, Ichnanthus pallens, Dichanthelium spp., Muhlenbergia schreberi* and *Panicum repens*, are shade-tolerant species frequently reported under tree crops and are recognized as useful, though sometimes invasive, forage grasses [12]. The sedge *Cyperus rotundus* is a well-known, highly competitive weed that can contribute substantially to understory biomass in oil palm plantations, while *Mimosa pudica* and *Grona triflora (Fabaceae)* represent nitrogen-fixing legumes that can improve forage

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quality but may also behave as invasive weeds under intensive grazing [4]. Broad-leaved herbs such as *Richardia brasiliensis, Peperomia pellucida* and *Ocimum tenuiflorum* further increase structural and taxonomic diversity; *P. pellucida* in particular is frequently cited as a common weed in Indonesian oil palm plantations and has emerging value as a medicinal herb [13]. The coexistence of these functional groups indicates a moderately diverse understory community with the potential to provide a continuous, though heterogeneous, forage supply for cattle within the integration system.

Figure 1. Representative plant species found in the study area: (A) *Mimosa pudica*; (B) *Ocimum tenuiflorum*; (C) *Grona triflora*; (D) *Dichanthelium oligosanthes*; (E) *Kyllinga brevifolia*; (F) *Muhlenbergia schreberi*; (G) *Axonopus compressus*; (H) *Ichnanthus pallens*; (I) *Panicum repens*; (J) *Richardia brasiliensis*; (K) *Peperomia pellucida*; (L) *Torenia crustacea*.

Vegetation composition

Vegetation composition in the understory is a critical attribute in SISKA systems because it simultaneously determines forage supply for cattle and mediates key ecosystem processes such as competition with palms, soil protection and biodiversity support. Studies from Indonesia and Malaysia show that the relative abundance of grasses, sedges, legumes and broad-leaved forbs in oil palm plantations shifts markedly with palm age, herbicide use and the presence of livestock, leading to large differences in understory biomass and grazing capacity [3], [10]. Against this regional background, the

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species composition documented in the present study provides an informative snapshot of how understory vegetation is structured under a cattle–oil palm integration scheme.

Table 1. Vegetation Characteristics: Palatability, RD, RF, IVI, and Dry Matter Percentage

Species	Family	Palatable	RD%	RF%	IVI	DM%
Mimosa pudica	*Fabaceae*	+	0.17	3.33	3.50	27.48
Ocimum tenuiflorum	*Lamiaceae*	+	0.53	3.33	3.86	15.43
Grona triflora	*Fabaceae*	+	15.55	3.33	18.88	24.35
Dichanthelium oligosanthes	*Poaceae*	+	7.33	3.33	10.67	31.89
Kyllinga brevifolia	*Cyperaceae*	+	1.13	6.67	7.79	23.20
Muhlenbergia schreberi	*Poaceae*	+	4.64	16.67	21.31	29.06
Axonopus compressus	*Poaceae*	+	60.36	16.67	77.03	33.51
Ichnanthus pallens	*Poaceae*	+	0.71	3.33	4.05	33.35
Panicum repens	*Poaceae*	+	2.76	6.67	9.43	27.66
Richardia brasiliensis	*Rubiaceae*	+	5.30	16.67	21.97	15.82
Peperomia pellucida	*Piperaceae*	-	0.32	6.67	6.99	5.78
Torenia crustacea	*Linderniaceae*	+	1.18	13.33	14.52	19.78

Note: RD%: Relative Density; RF%: Relative Frequency; IVI: Important Value Index; DM%: Dry Matter
+ : palatable by cattle; - : not palatable by cattle

The plantation understory in this study was composed of 12 plant species from 7 families (Table 1), and notably grasses (*Poaceae*) overwhelmingly dominated. The broadleaf carpet grass *Axonopus compressus* accounted for the highest relative density (60.36%) and importance value index (77.03), making it the keystone groundcover species. This dominance is ecologically significant, as *A. compressus* is well-known to form dense mats under tree *crops* and can tolerate the shaded conditions of mature oil palm stands. Nearly all recorded species (92%) were palatable to cattle, including the dominant grasses and minor herbs, indicating that the bulk of the understory biomass is actually usable forage. This aligns with observations that virtually all grass species growing under oil palm are readily grazed by cattle [14]. In contrast, only one encountered species (*Peperomia pellucida*, a succulent herb) was unpalatable; its very low abundance (RD 0.32%) and tiny dry matter content (5.78% DM) mean it contributes negligible feed value. Overall, the floristic composition points to a favorable forage resource – a grass-rich sward under the palms that can substantially contribute to cattle diets.

Our findings both mirror and extend prior research on oil palm understory communities in integrated systems. The prominence of shade-tolerant creeping grasses like *Axonopus compressus* is consistent with reports from other regions[14]. For instance, *A. compressus* (along with similar stoloniferous grasses such as *Otochloa nodosa* and *Paspalum conjugatum*) is frequently cited as a dominant natural cover beneath palms, owing to its ability to persist under partial light and heavy grazing [15], [16]. This grass tends to colonize plantation floors and was even deliberately introduced as a cover crop in some cases due to its hardiness. The high grass cover observed here is encouraging, since grasses generally provide the bulk of nutrition in grazed systems and have higher palatability than many broadleaf weeds [14], [17]. In contrast, less favorable species compositions have been documented in older or unmanaged plantations. Under long-term shading without grazing, understories often become dominated by ferns and woody herbs that cattle largely avoid. For example, in older (>20 year) oil palm stands, unpalatable shade-loving species like *Asystasia micrantha* (Chinese violet), ferns (*Nephrolepis biserrata*), and *Peperomia* were found to be most abundant [14]. Such a shift drastically reduces the forage value of the understory. Even at intermediate ages (13–15 years), some studies noted proliferation of non-grass weeds in certain sites. The absence of those noxious weeds and ferns in our study plot suggests that the SISKA management (integrated cattle grazing) may be suppressing them, thereby maintaining a grass-dominated flora. This is corroborated by findings that grazed plantations tend to have a higher cover of low herbaceous vegetation (20% more undergrowth) compared to ungrazed ones [3]. In effect, the cattle act as biological weed control, keeping aggressive broadleaf weeds in check and favoring the persistence of palatable grasses. This highlights an important ecological synergy of integration: the cattle benefit from and simultaneously reinforce a desirable plant community structure.

Despite the palatable species richness, the forage productivity of the understory ultimately determines how many cattle can be sustained. In our study, the dominant grass *A. compressus* had a dry-matter content of about 33%, typical for tropical forages, whereas succulent forbs were much more water-rich (~80–95% moisture). This means that grasses not only cover most of the ground but also contribute disproportionately to dry matter (DM) yield. Although our site's total forage DM yield was not explicitly given above, literature values provide context for what can be expected. Under favorable light conditions (younger palms or open canopy), oil palm undergrowth can produce on the order of 2–7 tonnes of dry matter per hectare annually [14], [18], [19]. For example, a recent study in South Sumatra measured about 2.9 t DM ha^{-1} of edible forage under 5-year-old palms, which declined to only 0.7 t ha^{-1} by 15 years of age [14]. In contrast, heavily shaded mature plantations (with no grazing or understory management) might generate as little as 0.5 t DM ha^{-1} year^{-1} of understory biomass [3]. These comparisons indicate that our study plantation with its grass-rich, grazed understory likely falls toward the higher end of the productivity spectrum for its maturity stage. Indeed, the prevalence of productive grasses suggests that a significant fraction of potential biomass is being realized as forage. It is worth noting, however, that site-specific factors (soil fertility, rainfall, past cover crop use, etc.) can cause substantial variation.

Given the evidence from this study and others, it is clear that optimizing understory forage in oil palm is both an ecological necessity and an economic opportunity. The high palatable biomass we observed provides a scientific basis for designing improved grazing strategies (e.g. matching stocking rates to forage supply, selecting shade-tolerant forage species) to maximize these dual benefits. Going forward, continued research and on-farm trials will be crucial to refine such strategies, but the present results make an important step toward more productive and sustainable cattle–oil palm integration in Indonesia.

Conclusion

This study shows that the understory of smallholder oil palm plantations managed under a cattle–oil palm integration scheme is not merely a weed layer but a structurally simple yet functionally important forage resource, dominated by the shade-tolerant grass *A. compressus* and complemented by a suite of palatable grasses, legumes and forbs. The very high importance value and substantial dry-matter content of *A. compressus*, together with the finding that 92% of recorded species are palatable, indicate that the current vegetation composition is highly favourable for grazing and can contribute meaningfully to on-farm feed supply while simultaneously supporting soil cover and biological weed control. At the same time, the clear dominance of a single grass species and the lack of explicit data on annual DM yield and carrying capacity underline the need for follow-up studies that quantify seasonal biomass production and translate vegetation metrics into stocking rate recommendations across palm age classes. Taken together, these results provide a critical, vegetation-based baseline for designing more precise and sustainable grazing strategies in SISKA systems, and highlight the strategic role of understory management in unlocking the forage potential of Indonesia's extensive oil palm landscapes.

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