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# A COMPARISION FOR NUTRIENT LEVEL IN SOIL AND PLANT BETWEEN CUT AND CARRY AND GRAZING PASTURE SYSTEMS

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**ABSTRACT**

Cultivating pastures in cut and carry (CC) and grazing (GZ) systems may potentially affect nutrient availability in soil and nutrient concentration of grass vegetation. The objective of this study was to compare soil nutrient availability and grass nutrient concentration between the two pasture systems namely CC and GZ, which was conducted in Universiti Putra Malaysia Bintulu Sarawak Campus (UPMKB). Twenty-nine (29) blocks were established across the systems, sampling for CC pasture was done by systematic grid sampling method and sampling for GZ pasture was based on the location of waterways and manure deposition respectively, for CC and GZ systems. The findings reveal that the CC system had significantly higher pH, TOC, TN, AP, AFe, and AMn values (except CC1 and CC5) compared to GZ, which had very strongly acidic pH with lower TN and AP. A reason for this observation could be due to difference in fertilizer management practices, the GZ, only relied on animal excreta as source of nutrients. Consequently, the repeated application in CC system had helped higher nutrient uptake by grasses that resulted in production of high-quality Napier grass. The soil nutrient status in intensive GZ system should be monitored closely to prevent losses of fertility and fertilization programme should be implemented to supplement the organic nutrients provided by the animal excretes.

**Key words:** Bekenu series, grazing, napier grass, pasture, pH, total organic carbon

## INTRODUCTION

High quality grass derived from pasture is important to meet the livestock food demand. To achieve this, many factors need to be considered and one of it is the selection of pasture species (Capstaff & Miller, 2018). The common species that are chosen vary according to their type of cultivation and some of the recommended species are *Panicum maximum*, *Pennisetum purpureum*, *Brachiaria decumbens*, *Setaria sphacelata*, and *Centrosema pubscens*.

There are two pasture systems commonly practised by the livestock farmers cut and carry (CC) and grazing (GZ) systems. These two systems serve different purposes and different plant species are considered to be the best grown to feed the livestock. For example, in CC systems Napier grass was recommended due to the high yield and it can be harvested according to their growth cycle (Aswanimiyuni *et al.*, 2018). Meanwhile, in GZ system, grasses and legumes are commonly used to feed the livestock as recommended by Undersander *et al*. (2002). The most important characteristic is rapid rejuvenation of its shoot. Several different grazing management systems have been introduced, such as rotational and continuous grazing, to ensure adequate pasture is available to graze at all times throughout the grazing cycle.

Another important criterion for a productive pasture system is the sustainability of the soil fertility in the long run, especially in GZ systems. In intensive GZ areas, soil compaction and nutrient leaching are often reported by researchers. According to Vendramini *et al.* (2007), excessive amendment of fertilizer and increasing livestock excreta will significantly increase nutrient retention and also N leaching tendency from the soil system. Abdalla *et al.* (2018) reported decreasing amounts

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of C, N and P with increasing bulk density as an impact of grazing intensity. However, semi-intensive and rotational GZ may improve nutrient retention and fertility. This was proven in a study conducted by Garcia *et al.* (2011), it is stated that rotational grazing systems provide more time for pasture plant to re-grow and at the same time shows improvement of organic P in soil. The most significant effect of GZ systems is the deterioration of bulk density as the livestock keeps walking and trampling on soil surface (Byrnes *et al.*, 2018; Xu *et al.*, 2018). Therefore, the objective of this study is to compare soil nutrient availability and plant uptake between the two namely CC and GZ.

## MATERIALS AND METHODS

### *Location of study area and methods of sampling*

The pastures are located in the area of Universiti Putra Malaysia Bintulu Sarawak Campus (UPMKB), which belongs to Bekenu soil series. Theere were two types of pasture system, cut and carry (CC) and grazing (GZ), with an estimated total land of 13,261 $m^2$. In CC, the elephant grass (*Pennisetum purpureum*) was originally cultivated using stem cutting and harvested every 50 days for three consecutive years. Thereafter, Napier stem cutting was transplanted when the clumps became unproductive. The pastureland was fertilized with organic manure before transplanting of Napier grass and NPK green (15:15:15) was applied a week after re-cutting. Simultaneously, GZ was cultivated with *Setaria sphacelata* and naturally grown wild grass from *Axonopus* spp. However, this system depended solely on cattle excreta for nutrients fertilisation and was intensely grazed by Bali and Brahman cattle breeds with five hours grazing daily.

Five CC areas (size between 200 $m^2$ to 350 $m^2$) and one GZ area (11,868 $m^2$) were used in this study. Generally, the soil and plant tissue samplings from all areas were sampled according to systematic grid sampling techniques in CC while in GZ it was done according to the location of waterways and manure deposition. Four soil samples were augured per block (four blocks for CC and nine blocks for GZ) and mixed thoroughly as a composite sample and air-dried. The soil was then pulverised and analysed for soil pH (Tan, 2010), soil texture (Tan, 2005), total N, P, K, Fe, and Mn (Hach *et al.*, 1985), available P, K, Fe, and Mn (Bray & Kurtz, 1945; Nelson, 1953), and total organic carbon (TOC) (Sutherland, 1998). Plant tissue was sampled from the upper 15 cm of plants before blooming in each block to obtain about 300 g (fresh weight). It was then rinsed with distilled water to clean off soil and finally dried in an oven at 60°C for three days. The dry leaf was then ground into powdered form and analysed for N, P and K using wet digestion procedure (Hach *et al.*, 1985).

### *Statistical analysis*

All data were tested for significant difference using analysis of variance (ANOVA) through Tukey's test at p=0.05 using Statistical Analysis System (SAS Ver. 9.4). The strength of correlation for each value was calculated by principal component analysis (PCA) using Addinsoft™ (XLSTAT Ver. 2018).

## RESULTS AND DISCUSSION

### *Initial soil properties*

The area under Bekenu soil series of the UPMKB has been used for pasture practices since 2010. This series has been reported to be developed over mixed sedimentary rocks and is characterised by the presence of the argillic horizon and low base saturation (Paramananthan, 2000). The areas contained more than 58.3% sand and less than 23.7% clay, so they were classified as sandy clay loam according to the Textural Triangle provided by the Natural Resources Conservation Service (NRCS). The status of nutrients in soil ranged from 0.31 g $kg^{-1}$ to 0.75 g $kg^{-1}$ for N, 1.81 g $kg^{-1}$ to 3.08 g $kg^{-1}$ for P, 3.37 g $kg^{-1}$ to 11.71 g $kg^{-1}$ for K, 16.97 g $kg^{-1}$ to 28.61 g $kg^{-1}$ for Fe, and 1.94 g $kg^{-1}$ to 3.13 g $kg^{-1}$ for Mn.

**Table 1.** Initial soil characteristic

| Systems | Sand | Silt | Clay | N | P | K | Fe | Mn |
|---|---|---|---|---|---|---|---|---|
| | % | | | g $kg^{-1}$ | | | | |
| CC1 | 64.3 | 12.1 | 23.6 | 0.75 | 2.09 | 6.39 | 19.61 | 3.13 |
| CC2 | 58.3 | 19.1 | 22.6 | 0.51 | 1.81 | 3.37 | 19.22 | 3.05 |
| CC3 | 65.0 | 13.2 | 21.8 | 0.31 | 1.86 | 5.77 | 20.53 | 3.12 |
| CC4 | 75.1 | 11.7 | 13.2 | 0.46 | 2.34 | 9.29 | 28.61 | 2.93 |
| CC5 | 77.6 | 11.2 | 11.2 | 0.48 | 3.08 | 11.71 | 23.16 | 2.73 |
| GZ | 61.2 | 15.2 | 23.7 | 0.41 | 2.15 | 6.44 | 16.97 | 1.94 |

**Table 2.** Soil pH and nutrient availability in cut and carry (CC) and grazing systems (GZ)

| System | pH | TOC | TN | AP | AK | AFe | AMn |
|---|---|---|---|---|---|---|---|
| | | % | mg kg$^{-1}$ | | | | |
| CC1 | 4.73$^{c}$ ± 0.17 | 4.00$^{a}$ ± 0.18 | 749.92$^{a}$ ± 160.58 | 2.13$^{b}$ ± 0.45 | 14.24$^{b}$ ± 2.82 | 358.07$^{ab}$ ± 98.97 | 4.50$^{a}$ ± 0.51 |
| CC2 | 5.10$^{abc}$ ± 0.09 | 3.37$^{a}$ ± 0.31 | 506.30$^{a}$ ± 68.29 | 4.68$^{ab}$ ± 1.13 | 20.03$^{b}$ ± 2.78 | 511.38$^{a}$ ± 133.28 | 4.63$^{a}$ ± 0.75 |
| CC3 | 5.64$^{ab}$ ± 0.06 | 3.10$^{ab}$ ± 0.13 | 314.91$^{a}$ ± 67.06 | 8.74$^{a}$ ± 3.77 | 20.68$^{b}$ ± 2.54 | 250.41$^{abc}$ ± 28.50 | 3.31$^{a}$ ± 0.13 |
| CC4 | 5.71$^{a}$ ± 0.39 | 1.82$^{c}$ ± 0.20 | 460.44$^{a}$ ± 102.63 | 2.30$^{b}$ ± 1.19 | 4.12$^{b}$ ± 1.31 | 55.21$^{c}$ ± 12.75 | 2.53$^{ab}$ ± 0.51 |
| CC5 | 4.76$^{bc}$ ± 0.08 | 2.19$^{bc}$ ± 0.23 | 476.25$^{a}$ ± 53.98 | 2.04$^{b}$ ± 0.87 | 5.43$^{b}$ ± 1.72 | 68.35$^{bc}$ ± 18.41 | 4.98$^{a}$ ± 1.39 |
| GZ | 4.56$^{c}$ ± 0.15 | 2.98$^{ab}$ ± 0.20 | 413.28$^{a}$ ± 105.00 | 1.39$^{b}$ ± 0.37 | 49.75$^{a}$ ± 5.16 | 173.71$^{bc}$ ± 39.82 | 1.79$^{b}$ ± 0.17 |

* Means with different letters were significantly different at p=0.05; ± indicates standard error.

***Comparison of nutrient availability in soil between cut and carry and grazing systems***

Soil pH varied with the pasture systems and could be grouped in three classes: very strongly acidic (CC1, CC5 and GZ), strongly acidic (CC2), and moderately acidic (CC3 and CC4) according to NRCS. Total organic carbon (TOC) was the highest in CC1 (4.00%) followed by CC2 (3.37%) and CC3 (3.10%). On the other hand, other pasture systems including GZ, recorded TOC availability below 3.00%. The total N (TN) in all pasture systems exhibited comparable concentrations, ranging from 314.91 mg kg$^{-1}$ to 749.92 mg kg$^{-1}$. For available phosphorus (AP) content, CC3 exhibited the greatest AP concentration (8.74 mg kg$^{-1}$) and the other pastures contained two to six fold less compared to CC3, showing a range of 1.39 mg kg$^{-1}$ to 4.68 mg kg$^{-1}$. The highest availability of K (AK) was observed in GZ (49.75 mg kg$^{-1}$) when compared to all CC areas. Among the CC areas themselves, the CC4 exhibited the lowest AK concentration, only 4.12 mg kg$^{-1}$, while CC3 had the highest concentration of AK, 20.68 mg kg$^{-1}$.

Soil pH in CC systems was significantly higher than in GZ (except CC1 and CC5). Lowering pH as observed in CC1 and CC5 is a side effect of N fertilizer that was applied ten days before initiation of this experiment (Tian & Niu, 2015). In CC1 and CC5, the application of 15:15:15 NPK green led to decrease in pH value (4.73 to 4.76), which indicated the accumulation of TN during soil sampling. The other CC systems showed greater pH despite having comparable TN concentrations (314.91 mg kg$^{-1}$ to 506.30 mg kg$^{-1}$). Greater TOC in CC systems compared to the GZ system can be attributed to the continuous addition of plant parts onto soil for three consecutive years before replanting. Concentration of AP (2.04 mg kg$^{-1}$ to 8.74 mg kg$^{-1}$) in CC systems was higher than that in GZ system as the soil texture (sandy clay loam) was not favourable to hold P (Martins *et al.*, 2018).

Availability of K (AK) in CC systems was two to 12 folds lower than that in GZ system, which could be due to leaching for presence of high percentage of sand (Table 1). The availability of Fe (AFe) in different CC systems followed the order: CC2 > CC1 > CC3 > CC5 > CC4. However, the solubility of this nutrient ion was unaffected by soil acidity (pH 4.73 to 5.71). The increased AFe can be attributed to the total Fe level in soil (19.22 g kg$^{-1}$ to 28.61 g kg$^{-1}$) (Mielki *et al.*, 2016; Moreno-Jiménez *et al.*, 2019). In case of Mn availability (AMn), all areas seem to contain a comparable amount of Mn with concentrations ranging between 1.79 mg kg$^{-1}$ and 3.68 mg kg$^{-1}$.

Among all pasture system; GZ was more acidic compared CC, which may be attributed to the system itself (Table 2). About 20 cows were allowed to stay and move around the paddock fence throughout the study and eventually released patches of urine and manure. This led to a reduction of soil pH to 4.56 due to an increase in $NH_4$-N from faeces and urine (Mapfumo *et al.*, 2000). Grazing activity significantly reduced the TOC, TN, and AP in GZ compared to CC system. This was closely related to excessive defoliation and decreased vegetation cover and may further affect soil chemical properties as continuous cattle grazing in the area (Zarekia *et al.*, 2012). A similar finding had also been reported in GZ area elsewhere where a decrease of TN (3.95%) and total P (9.41%) occurred at high soil acidity (2.34) (Hao & He, 2019). Presence of patchy grass seamless ground around the paddock and soil texture enriched with sandy particles can explain the pastures' inability to retain nutrients that are supposed to accumulate after urine and manure deposition (Abdalla *et al.*, 2018; Chirinda *et al.*, 2019). Moreover, high bulk density (1.761 g cm$^{3}$) recorded in GZ earlier may provide significance on incapability of nutrients to be store in soil as subjected to compact soil structure and restricted growth of new grass.

Research by Zarekia *et al.* (2012) reported increased AP in soil under active grazing system due to the influence of animal excreta. This is also supported by Whittemore (1995), who emphasised significant amount of nutrient reported in cattle excreta such as N, P and K with 6 g kg$^{-1}$, 1 g kg$^{-1}$ and 5 g kg$^{-1}$ respectively and become another source of fertilizer to crop. However, our study

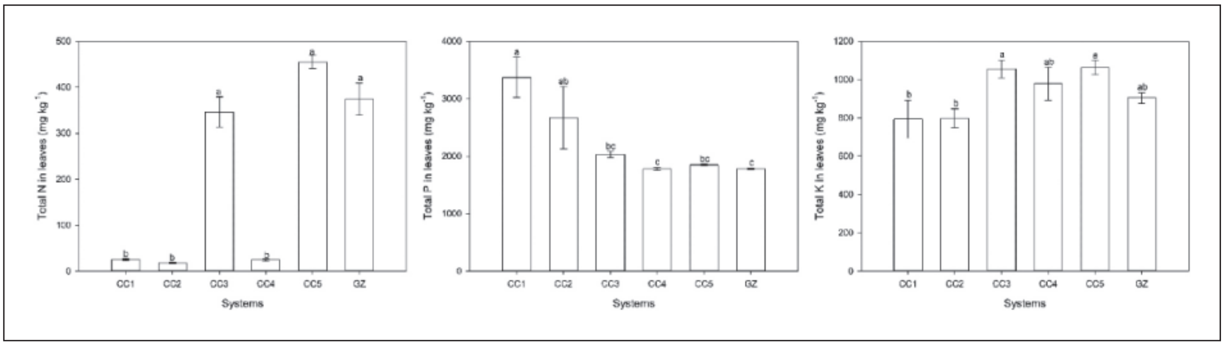


**Fig. 1.** Total N, P, and K concentration of leaves in different pasture systems. Means with different letters are significantly different at p=0.05; error bar indicates standard error.

produced contrasting results even though the area was actively grazed and had comparable soil conditions. One reason, which could support the decreased AP in the GZ area in this study, is a greater sand particle proportion (60.69%) which shows incapability of ion retention and promotion of leaching. Interestingly, our results also showed an elevated concentration of AK (49.75 mg $kg^{-1}$) in GZ compared to the CC system. Movement of cattle around the paddock and resting activities at the same shaded spots had primarily caused uneven distribution of nutrients and pasture density that could lead to overgrazing later. This is evident by comparable availability of Fe (AFe) and Mn (AMn), throughout the GZ, but the amounts were lower when compared with the CC area. Contrarily, accumulation of both metal ions has been reported elsewhere (Matsi *et al.*, 2015; Chu *et al.*, 2017; Provolo *et al.*, 2018). Thus, regular soil monitoring and conservation should be planned for any metal toxicity.

***Concentration of N, P and K in leaves***

Nutrient concentrations of leaves from all pasture systems are shown in Figure 1. Generally, CC3 and CC5 exhibited a greater concentration of N and K in leaves. Higher N concentration was noted in GZ system compared to CC system. The concentrations of P in all pasture systems showed greater concentration significant difference existed between the two systems. The K concentration showed significant differences between the systems.

All pasture systems in this study recorded lower availability of N compared to well-established pastures (Utamy *et al.*, 2018) which can be attributed to the fewer sources of N, especially in CC systems. This is because pastures in CC systems were harvested periodically every 50 days, which leads to more frequent removal of N. However, CC3 and CC5 showed greater amounts of N in the soil compared to the others. Interestingly, GZ showed greater concentration of N as the system solely was dependant on animal excreta as source of nutrients. Sufficient sources of N for pastures can incredibly increase yield (Delevatti *et al.*, 2019). Comparable concentrations of soil P was reported by Rambau *et al.* (2016), showing a range from 1.08 g $kg^{-1}$ to 1.34 g $kg^{-1}$. Our study however, discovered lower availability of N and K, which indicates insufficient nutrient availability for pasture growth. This is also supported by Delevatti *et al.* (2019) who emphasised on the importance of nutrients for pasture growth, especially vegetation height and root development.

***Soil and plant interaction in pasture systems***

Principal Component Analysis (PCA) of all pasture systems contributed to 57.02% with F1 = 32.18% and F2 = 24.85% (Figure 2). The first component (F1) indicated positive plant N, soil, and plant K, while soil N, soil and plant P, and pH were negative. Meanwhile, the second component (F2) showed positive plant N, soil P, plant K, and pH, and negative soil N, plant P, and soil K. Accordingly, two groups were identified and represented by G1 (CC2 and CC4) and G2 (CC5 and GZ).

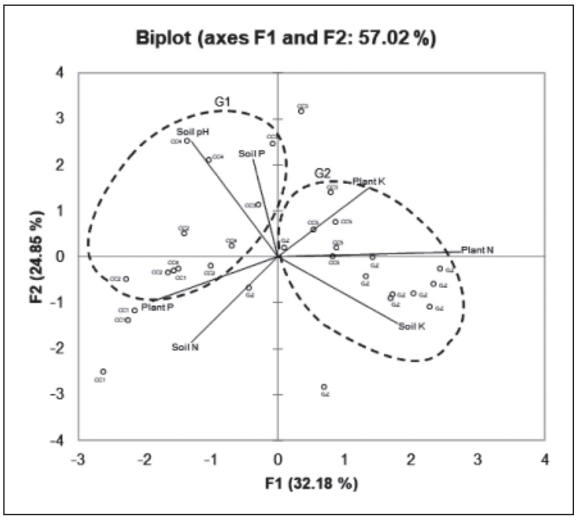


**Fig. 2.** Nutrient availability in soil (principal components analysis).

In G1, only soil pH and P availability were unaffected with the established years of the pasture system (more than 10 years). From the PCA analysis, it was determined that N and K were insufficient in plant tissues, whereas soil K was limited and only able to supply enough nutrients to fulfil the pasture requirement. It is well known that acidity causes insolubility of P, which is tightly held by Fe/Al (von Tucher *et al.*, 2018; Penn & Camberato, 2019). However, low N and K found in these pasture systems can be improved by supplying fertilizer more frequently to support growth. On the other hand in G2, soil exhibited poor acidity which had a significant effect on P compared to N and K, which was proven by greater N and K uptake in pasture tissues. Pradhan *et al.* (2018) described the benefits of cattle excreta to the increasing concentration of N and K, which ultimately benefits pasture herbage and dry matter. However, supplying sufficient amount of fertilizers in CC5 after cutting the pasture significantly improved N and K.

## CONCLUSION

Cultivating pastures in different systems significantly affects the nutrient availability in soil and plant. Grazing (GZ) system produced the most acidic soil due to the deposition of urine and manure that eventually decreased TN and AP availability. Cattle movement and excessive grazing in GZ led to lower nutrient values in soil and plant tissues. However, CC systems have recorded greater soil conditions and nutrient values with regards to TOC, TN, AP, AFe, and AMn. As the Napier grass was cut continuously for three years, build-up of TOC was recorded in most CC systems except when land clearing was performed for replanting, which lowered TOC, AP, and AK. Thus, intensive GZ system in this study provides considerable accumulation of nutrients in soil through cattle excreta; however, CC system exhibited better nutrient accumulation due to frequent use of chemical fertilizers. Therefore, it is suggested to regularly monitor soil nutrient status in intensive GZ system to prevent losses of fertility and fertilization programme should be implemented to supplement the organic nutrients provided by the animal excretes.

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