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RESEARCH PAPER

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Effects of dairy cattle rotational grazing on soil properties in the grassland area of CSU Piat, Cagayan

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ABSTRACT

The study aimed to compare the effects of continuous grazing, rotational grazing, and exclusion of livestock on soil physical, chemical, and biological properties in a grassland area of the Dairy Cattle Center in CSU Piat, Cagayan. The treatments were non-grazed (NG), heifer rotational grazing (HRG), dairy cow rotational grazing (DCRG), and continuous grazing (CG). Soil physico-chemical and biological properties were determined and significant results were noted. The study concluded that rotational grazing can be an effective method to reverse the degradation of grazing areas for dairy cattle in the region when an area is limited. Furthermore, changes in ground cover characteristics, soil particle size distribution, bulk density, soil organic C, and total N concentrations will be good indicators for soil management and grazing management.

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INTRODUCTION

Land degradation in general is one of the most serious problems in the world. Overgrazing is one of the serious issues for degraded soils in Asian countries, not only soil erosion and overall loss of soil fertility. The effects of overgrazing on the plant community and soils are considered destructive because of the reduction of canopy cover, the destruction of topsoil structure, and the compaction of soil because of trampling. Thus, this activity increases soil crusting, reduces soil infiltration, and enhances soil erosion susceptibility, especially in hilly and mountainous areas (Khaledian *et al.*, 2013).

In recent years, intensive studies on the effects of grazing on vegetation changes and its overall impact on soils have been conducted. Results showed that slash, burn and pasture cultivation strongly impacted sediment yield (Santos *et al.*, 2017), continuous grazing is detrimental to the environment (Zhao *et al.*, 2004) and soil restoration on degraded sandy grassland is a slow process, although the vegetation can recover rapidly after the removal of livestock disturbance (Bastida *et al.*, 2006). This mean that the sediment yield was strongly affected by the land cover, continuous grazing might give rise to a decrease in ground cover and soil health, and proper fencing in a rotation grazing system must be adopted in the initial stage of grassland degradation.

The previous studies mentioned were conducted in a different set-up i.e. different climate types, soil types, topography, and vegetation. Recently, no studies concerning the effects of grazing on soil properties have been conducted in the Philippines. Information on these aspects is required for a better understanding of soil biology and appropriate management and conservation of grasslands. Thus, the study aimed to compare the effects of continuous grazing, rotational grazing, and exclusion of livestock on soil physical, chemical, and biological properties in the Dairy Cattle Center at Cagayan State University (CSU) Piat Campus. CSU grazing area, located in the agro-pastoral zone in Piat, Cagayan may be considered a critical zone that needs to be monitored for it to be a sustainable one. Overgrazing could later be a major problem for this environment if not given attention in the present, thus, a proper grazing schedule and management should be made and applied for sustainable dairy cattle production.

MATERIALS AND METHODS

Study location and site characterization

The study was conducted at the Dairy Cattle Center grazing area of Cagayan State University (CSU) Piat Campus, located in the north-central part of the campus, approximately 5 km from the national highway of Piat, Cagayan. The topography of this area is flat to undulating. The climate is Type 2 with no pronounced dry season and a maximum rainy period from November to April (this covers usually the eastern part of Cagayan Valley). The 3-year mean annual temperature is 22°C, with the coldest and warmest monthly mean temperature of 19°C in January and 33°C in May, respectively. The 3-year mean annual precipitation is 173.6 mm. The soils belong to San Manuel Series (Fluventic Eutrudept). The study site is a 10-hectare open and flat to undulating natural grassland. It was devoted to continuous cattle grazing and the soil characteristics and vegetation cover were relatively homogeneous.

Sampling design and field experiment

Eight paddocks (sites) along a gradient of grazing area were selected for sampling. One paddock was allotted for (NG) non-grazed treatment (excluded for three years), one paddock was used for continuous grazing (CG), three paddocks (each paddock represents one replicate) were used for (HRG) heifer rotational grazing and the other three paddocks were used for (DCRG) dairy cow rotational grazing. Within each site, three plots with an area of 4 m × 5 m (20 m^2) were marked as the three field replicates except for HRG and DCRG. Within each plot, nine 1 m × 1 m quadrates were established uniformly, and soil and plant samples were collected during the peak of the standing crop. The aboveground plant components were sampled by clipping 0.5 m^2 at each sampling quadrate. Plant biomass was partitioned into surface litter, standing withered and live biomass by plant species.

Soil samples (0-15 cm) were collected using a soil auger after all the plant litter was removed from the soil surface. Separate cores (7.5 cm diameter) at 0-15 cm were collected at each sampling quadrate to assess root biomass and soil litter mass. Duplicate soil cores were also taken at each sampling quadrate for bulk density determination. In addition, three random 5-point transects in each plot were used to determine percent bare ground, live vegetation, and dead vegetation. Standing litter heights of each major plant species or group were measured at 15 random points in each plot.

Laboratory analyses

Soil samples were passed through a 2-mm screen. At the time of sieving, roots and other debris were removed from the soil and discarded. The moisture content of the sieved soil was determined gravimetrically. Particle size distribution was determined through the hydrometer method. Soil pH and electrical conductivity (EC) were determined using 1:1 soil: water slurry and 1:5 soil: aqueous extract. Part of each sample within each plot was composited for enzyme activity and basal soil respiration (BSR) determination. Another part of the sample was air-dried and finely ground to pass a 0.1 mm sieve and was analyzed for organic C and total N by the Walkley-Black dichromate oxidation procedure and by the Kjeldahl procedure, respectively. For soil enzyme activities, samples were submitted to the University of the Philippines Los Baños – National Institute of Molecular Biology and Biotechnology (UPLB-BIOTECH) to determine catalase and urease activities. BSR was estimated through CO_2-C evolution at 28°C in samples that were incubated for 7 days. Measurements were made in the laboratory under standardized soil moisture conditions at 60% field capacity. Through the hand-washing method, soil litter and roots were separated. Each plant component was air-dried at 50°C and weighed and ground.

Then, plant samples taken from three adjacent sample quadrants were mixed thoroughly within each category and analyzed for organic C content with the same method as soil samples (nine per treatment within each category).

Data analyses

The study was conducted in one location and was not replicated, approach in statistics wherein each of the three plots was considered as a replication in the summary statistics was used. Values from all the sampling quadrates within each plot were averaged. One-way analysis of variance (ANOVA) procedures was used to detect the differences between means of parameters examined of the seven sites (three treatments). The least significant difference (LSD) was performed to determine the significance of the treatment means at $p<0.05$.

RESULTS

Ground characteristics

Live vegetation and litter were highest in NG, followed by sites under HRG, DCGR, and CG, respectively (Table 1). After three years of livestock exclusion, bare ground was decreased by 61% and 39% compared with the continuously-grazed and rotationally-grazed, respectively. There was also an increase in standing litter percentage with increased refurbishment time.

Standing litter was 54% and 22% higher in NG compared with CG and rotationally-grazed (HRG and DCRG), respectively. Plant species composition was also observed to be different under the different treatments (Table 2). Dominant species in NG sites were *Ficus ulmifolia* and *Cynodon nlemfuensis*. In CG, the common species found was *Panicum maximum*. In rotational grazing sites (HRG and DCRG), the dominant species were *Ficus ulmifolia* and *Brachiaria humidicola*, respectively. Non-grazed treatment (3-year livestock exclusion) resulted in a higher total amount of above- and below-ground biomass (Fig. 1). Total biomass in NG sites increased by 59%, 46%, and 43% compared with CG, HRG, and DCRG, respectively.

Soil physical characteristics

The particle size distribution of the top 15 cm of the soils under the different treatments is shown in Table 3. It showed more silt and less sand in NG compared with continuously- and rotationally-grazed sites. In terms of silt percent distribution, however, HRG showed more clay compared with the other treatments. Soil bulk density was highest in the CG site and lowest in the NG site (Table 3). A significant difference was observed between the treatments.

Table 1. Ground cover characteristics at the study sites

Percent ground cover (%)	NG	CG	HRG	DCRG
Bare ground	21.9 c	56.0 a	36.0 b	35.4 b
Live vegetation	39.2 a	26.3 b	33.5 b	33.6 b
Standing Litter	38.9 a	17.7 c	30.5 b	31.0 b

Means with the same letters are not significantly different (p<0.05).

Table 2. Plant species composition at the study sites

Plant local name	Scientific name	Treatments							
		NG		CG		HRG		DCRG	
		N	p%	N	p%	N	p%	N	p%
Amorseco	*Chrysopogon aciculatus*	28.1	79	9.0	10	1.6	5	2.1	5
As-is	*Ficus ulmifolia*	67.0	49	0	0	26.0	49	0	0
Carabao grass	*Paspalum conjugatum*	2.6	6	9.3	10	0	0	23.4	45
Cogon grass	*Imperata cylindrica*	7.0	69	0	0	0	0	0	0
Common setaria	*Setaria sphacelate*	42.6	19	0	0	4.0	49	6.5	50
Goosegrass	*Eleusine indica*	12.3	23	0	0	1.6	5	0	0
Guinea grass	*Panicum maximum*	1.3	5	23	30	4.5	5	0	0
Humidicola grass	*Brachiaria humidicola*	1.8	5	10.1	10	0	0	34.0	40
Itchgrass	*Rottboellia cochinchinensis*	11.2	27	0	0	3.0	21	23.0	22
Napier grass	*Pennisetum purpureum*	1.3	5	10.1	10	3.4	22	4.0	21
Red oat grass	*Themeda triandra*	5.6	38	0	0	3.1	9	3.4	10
Paragrass	*Brachiaria mutica*	14.6	19	10.1	10	0	0	0	0
Stargrass	*Cynodon nlemfuensis*	51.0	70	10.5	20	4.0	5	12.0	10
Total number of species recorded		13		7		9		8	
Above-ground biomass (g/m²)		72		14.0		54.2		58.3	

N, mean number of individuals per quadrate; p% frequency.

Table 3. Particle size distribution and bulk density of soils under different treatments

Parameter	NG	CG	HRG	DCRG
Particle size distribution (%)				
Sand (2-0.05 mm)	78.6 b	83.7 a	80.5 ab	79.9 ab
Silt (0.05-0.002 mm)	6.3 a	2.1 c	4.6 b	4.5 b
Clay (<0.002 mm)	15.1 b	14.2 b	24.1 a	15.6 b
Bulk density (g/cm3)	1.34 c	1.58 a	1.44 b	1.43 b

Within rows, means with the same letters are not significantly different (p<0.05).

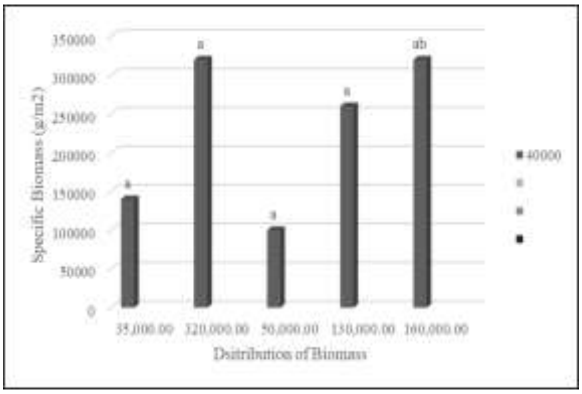

Fig. 1. Biomass in plant components on grazed, rotationally-grazed, and non-grazed sites

Soil chemical properties

Soil EC showed no significant difference among the treatments (Table 4). Soil pH, although highest in CG, was statistically and numerically similar under the four treatments. Soil organic C concentration was highest in NG followed by rotationally-grazed sites (HRG and DCRG). A significant difference was recorded between NG and CG (p=0.01), but there was no significant difference observed between NG, HRG, and DCRG. Total N concentration showed no significant difference among the non-grazed and rotationally-grazed sites, but these sites were statistically different from CG. The

C/N ratio showed significant differences between the treatments with a wider average value in NG, followed by HRG and DCRG, and the narrowest value in the CG soils (Table 4).

Soil enzyme and basal soil respiration

The two enzymes assayed had very low activity but showed significant differences among the treatments (Table 5). Catalase and urease activities were higher in non- and rotationally-grazed sites than in CG. A significant difference in urease activity was also observed between NG and rotationally-grazed sites (HRG and DCRG), unlike in catalase activity. In terms of BSR (Table 5), a significant difference was also observed among the treatments. The highest value was in NG and the lowest was in CG.

Table 4. Soil chemical properties under different treatments

Parameters	Treatment			
	NG	CG	HRG	DCRG
EC (µs/cm)	45 a	49 a	50 a	51 a
pH	7.6 a	7.9 a	7.6 a	7.82 a
Organic C (g/kg)	2.69 a	2.10 b	2.43 ab	2.42 ab
Total N (g/kg)	0.259 a	0.239 b	0.252 a	0.251 a
C/N ratio	10.38 a	8.79 c	9.64 b	9.64 b

Within rows, means with the same letters are not significantly different ($p<0.05$).

Table 5. Soil enzyme activities and basal soil respiration (BSR) at 0-15 cm

Parameters	Treatment			
	NG	CG	HRG	DCRG
Catalase activity	1.56 a	1.29 b	1.54 a	1.55 a
Urease activity	10.3 a	6.3 c	8.7 b	7.8 bc
BSR	3.6 a	2.3 b	2.7 b	2.8 b

Within rows, means with the same letters are not significantly different ($p<0.05$).

DISCUSSION

Effects of rotational grazing

In terms of ground cover characteristics and soil physico-chemical properties, rotational grazing was significantly better than continuous grazing. Also, a higher total number of plant species was recorded in rotational grazing than in CG. This could be because of the time allowance of the plant community to recover between grazing periods. Moreover, there was no significant difference observed between NG and rotationally-grazed sites (HRG and DCRG) for organic C and total N concentrations. It could be because of the slightly degraded status of the site before the conduct of the study. Since the degradation is in its initial stage, through rotational grazing, it could be relatively easy to reverse. But if the degradation continues and becomes severe, the reversion would be very slow (Dong *et al.*, 2022).

Effects of continuous grazing

The results indicate that continuous grazing and frequent trampling by dairy cattle made the ground surface bare and exposed to wind erosion. Decreased vegetation cover and litter accumulation resulted in accelerated wind erosion thereby promoting soil coarseness and soil organic matter losses (Wu *et al.*, 2020). Loss of clay particles in the soil will result in decreases in water holding capacity of the soil, soil consistency, and organic C and soil nutrient availability. The changes will then affect the kind and amount of plant species the site will support. The results indicated that *Panicum maximum* became the major species at the continuously grazed site and other species were less than that in the non-grazed site. While *Panicum maximum* is considered a good source of feed for dairy cattle (Paciullo *et al.*, 2016), it also indicates that the land is being restored or needs restoration (Ghosh *et al.*, 2021).

Effects of livestock exclusion

The results showed that the exclusion of livestock for three years resulted in a significant increase in ground cover through vegetation recovery and litter accumulation compared with continuous grazing. The resulting increase in ground cover protected the soil from wind erosion losses and the elimination of livestock resulted in a significant increase in OM thus significant decrease in bulk density was also noted. Soil organic C and total N concentrations following three years of livestock exclusion showed a significant increase compared with continuous grazing sites. This was the same result as that of Piñeiro *et al.* (2010) who reported that the continuous grazing sites contained less organic C and total N than in non-grazed sites. The increase in organic C and total N concentrations is mostly due to the increase in organic matter that was returned to the soil and reduced wind erosion because of vegetation recovery and litter accumulation. The species composition could have also possibly affected the soil OM and nutrient contents. The NG soil had a lower pH than that of the CG soil, although not significant, this could be attributed to root systems, SOC content, and plant coverage. Too much organic acid secretion from the roots and the amount of CO_2 released from the roots and microorganisms could make the soil acidic (Sindhu *et al.*, 2022). The EC of the soils showed that the soils are non-saline. In terms of biological properties, the exclusion of livestock for three years positively affects enzyme activity and BSR, although the measured responses were low, indicative of the slightly degraded status of the grassland. Low enzyme activity does not favor the decomposition of plant litter and residues thus nutrient release is also limited (Ji *et al.*, 2022). This means that the continuous exclusion of livestock could improve biological activity in the soil which could contribute to increased organic matter and improved soil environment.

CONCLUSION

The study site is slightly degraded and needs to be introduced to sustainable grazing management. Non-grazing considerably increases ground cover, significantly improves soil physical and chemical properties, and slightly progresses soil biological activities. Continuous grazing, however, continuously degrades vegetation cover thus decreasing litter accumulation and slowing down the development of annual and perennial grasses. When area is limited, rotational grazing instead, can be an effective method to reverse the degradation of grazing areas for dairy cattle in the region. Changes in ground cover characteristics (based on treatments), soil particle size distribution, bulk density, soil organic C, and total N concentrations will be good indicators for grazing and soil management. It is recommended that further study on erosion and grassland restoration be conducted in the area.

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