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SHORT NOTE [NOTA CORTA]

NON-DELIBERATE ORGANIC INPUT IN RELATION TO LAND USE IN A SEMI-ARID AGRO-ECOSYSTEM IN NORTHERN ZIMBABWE

[APORTE NO INTENCIONAL DE MATERIA ORGANICA EN RELACIÓN AL USO DEL SUELO EN UN AGROECOSISTEMA DE LA REGIÓN SEMI ÁRIDA DEL NORTE DE ZIMBABWE]

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SUMMARY

Animals via excretory processes are important in nutrient cycling in agro- ecosystems and can supply nutrients (nitrogen and phosphorus) at rates comparable to major nutrient sources. Land use influenced nutrient levels with mixed areas (wildlife and livestock) indicating the potential of improved nutrient cycling than wildlife and livestock as stand alones. The time of application for both plant residues and faecal material may influence the nutrients available to the crops. The time of application of faecal material should be aimed to increase N and P availability which is during the early dry season. Nitrogen levels in faecal material were comparable to levels found in legume cover crops indicating the high quality of faecal material. This study reports that non-deliberate organic inputs by livestock and wildlife can be important in fertility improvement in mixed farming systems in northern Zimbabwe.

Key words: nutrient cycling; mixed farming systems; livestock; wildlife.

RESUMEN

Los animals participan en el ciclo de nutrientes de los agro- ecosistemas debido a sus productos de excresión y pueden proveer al sistema nitrógeno y fósforo en cantidades comparables a las fuentes convencionales principales de los mismos. El uso del suelo tiene influencia sobre los niveles de nutrientes en ares mixtas (fauna silvestre y ganadería) indicando el potencial de mejorar el ciclo de nutrientes en comparación a sistemas basado únicamente en ganadería o fauna silvestre. El momento de aplicación de los residuos de plantas o material fecal tiene influencia sobre los nutrientes disponibles a los cultivos. El momento de aplicación del material fecal debo estar enfocado a incrementar la disponibilidad de N y P al inicio de la estación seca. Los niveles de N en el material fecal son comparables a los encontrados en las leguminosas empleadas como cobertura. Este trabajo reporta que el aporte de material orgánico proveniente de la ganaderia y fauna silvestre puede ser importante para la mejora de la fertilidad del suelo en sistemas mixtos de la región Norte de Zimbabwe.

Key words: ciclo de nutrients; sistemas agrícolas mixtos; ganadería; fauna silvestre.

INTRODUCTION

Soils deficient in the major nutrients, nitrogen (N) and phosphorus (P), have been identified as a major problem affecting crop productivity in much of sub-Saharan Africa (Mokwunye et al., 1996; Smaling et al., 1997). Soil nutrient depletion further impacts on increased productivity and has contributed to poverty and food insecurity. Soil nutrient depletion occurs when nutrient inflows are less than outflows (Bationo et al., 2004). One possible way to improve soil fertility is a more efficient use of locally available nutrient resources such as crop residues and animal faeces. Experiments involving addition of crop residues and faecal matter have resulted in improvement in soil fertility (Matsumoto et al., 2009), crop yield and soil property (Probert et al., 1995). Such nutrient inputs from outside ecosystem boundaries, often referred to as allochthonous inputs, are important in many ecosystems (Polis et al., 1997, Carpenter et al., 1998) including agro-ecosystems. The transfer of nutrients from grazing lands to croplands through manure contributes considerably to the maintenance of soil fertility and the sustainability of the farming systems (Devendra and Thomas, 2002). Inorganic inputs to crops are minimal or non-existent in most fields in northern Zimbabwe. Similarly the deliberate additions of organic inputs in the form of manure are rare or insignificant. However, the non-deliberate organic input in the form of faeces from livestock, wild herbivores and the various weeds that colonize the fields may be significant.

In order to identify the available resources, it is necessary to quantify nutrient cycles related to agricultural activities such as crop and livestock production (Matsumoto et al., 2009). This will enable the development of management practices that enhance the contribution of livestock in the moderation of nutrient flows on continuously cultivated lands (Thorne and Tanner, 2002). Thus an evaluation of nutrients of applied organic matter in crop residue and faecal material, and their effects on farmland soil fertility become significant. Most research has focused on nutrients applied by the farmers and non-deliberate inputs have received little attention. Non-deliberate organic nutrient inputs refer to nutrients applied onto arable land from other systems without direct influence from the farmers. Hence we investigated spatial variation of nutrients due to faecal deposition and crop residue return to farmland in livestock, wildlife and mixed (both livestock and wildlife) areas in a semi-arid agro-ecosystem in northern Zimbabwe. The time of application of crop residue and faecal material are important in determining the amount of nutrients available to plants after application, hence we analyze the influence of season on nutrient concentration in both plant residue and faecal material. This study is a preliminary investigation into nutrient cycling and seasonal availability on different land uses in a semi-arid agro-ecosystem with emphasis on nitrogen and phosphorous as major nutrient elements.

MATERIALS AND METHODS

Location

The study was carried out in Dande communal lands located in the Mid Zambezi valley in northern Zimbabwe. Dande (30^o 50 S, 16^o 20 E) is characterized by floodplains of the Zambezi basin drained by two rivers, Angwa and Manyame. Dande lies within agro-ecological region IV and V, averaging 400m above sea level. Annual rainfall ranges between 450-650mm and mean annual temperature is 25^oC. It has two distinct seasons, the rainy season from December to March and a long dry season from April to November. Sorghum (*Sorghum bicolor* (L.) Moench) is the most common crop farmed in this region. The local biodiversity is relatively intact, with more than 40 large mammals, 200 bird and 700 plant species (Biodiversity Project, 2002). Most of the mega-fauna are present with the exception of the black rhino (*Dicero bicornis*). Due to the expansion of agriculture there is a gradient against wildlife populations from Mushumbi, East Angwa and West Angwa. Treatments were designated following this gradient, Mushumbi (livestock), East Angwa (mixed) and West Angwa (wildlife).

Data collection and analysis

Plant biomass and faecal samples were collected in 5 randomly placed 5 m x 5 m quadrates in sorghum fields in the three treatment areas, livestock, mixed and wildlife. Sampling was carried out twice, first in April (early dry season) and September (late dry season). Early dry season defines the period soon after the main harvest while late dry season is the period just before planting or before the first effective rains. Above ground plant biomass (including crop residue) and faecal material was collected in each quadrate thoroughly mixed to obtain a composite sample ~40 g of each and air dried in a forced air oven at 60°C for 48 h. The samples were ground to pass through a 2mm sieve and analysed for nitrogen (N) content using the Kjeldahl method (AOAC, 1996) and phosphorus (P) by the ascorbic acid method (Anderson and Ingram, 1993). Nitrogen and phosphorous were compared between the seasons using the *t*-test and among the three treatments by a one-way ANOVA. We used Tukey's HSD post hoc test to examine significant differences between treatment means (Zar, 1984). The relationship between plant N and P concentration and FN (faecal nitrogen) and FP (faecal phosphorous) respectively, was established by a regression analysis. All the statistical analysis were done using SPSS version 14 (SPSS Inc., 2005, Chicago, IL U.S.A).

RESULTS AND DISCUSSION

Nitrogen ($F_{2, 27} = 0.89$, $P = 0.42$) and FP ($F_{2, 27} = 2.44$, $P = 0.11$) levels were similar across the three land use types (Table 1). Phosphorous ($F_{2, 27} = 5.86$, $P = 0.008$) was significantly higher in the wildlife area than in both livestock and mixed areas. The wildlife area, probably due to low animal densities, had significantly lower FN ($F_{2, 27} = 9.11$, $P = 0.01$) than livestock and mixed areas. Therefore, non-deliberate organic inputs from both livestock and wild ungulates could benefit poor farmers who are constrained by labour commonly in short supply and is a major determinant in choice of crops and production methods (Zingore et al, 2009). Additionally, livestock and mixed systems result in improved system productivity through the manure (and compost)–soil–crop pathway, enhancing both soil chemical and physical properties for better plant growth (Thorne and Tanner, 2002). However, although not statistically significant mixed systems had high N levels and may prove beneficial to poor farmers who lack adequate nutrient resources and labour key factors that limit the productivity of smallholder farming systems.

Table 1. Mean % (± SE) concentration of N, P, FN and FP in the Livestock, Mixed and Wildlife area. (n = 10)

	Livestock	Mixed	Wildlife	F	P
N	8.59 ± 1.34	11.08 ± 0.74	10.35 ± 1.79	0.89	0.423
P	1.58 ± 0.55 [a]	1.56 ± 0.25 [a]	3.97 ±0.78[b]	5.86	0.008
FN	6.82 ± 0.87 [a]	6.67 ± 0.46 [a]	3.64 ± 0.28[b]	9.11	0.001
FP	0.55 ± 0.35	1.01 ± 0.25	0.24 ± 0.04	2.44	0.106

Different superscript letters (a and b) in the same row indicate significant differences between means.

In the wildlife area N levels were significantly higher in the early dry than the late dry season (t_8 = -5.84, P < 0.001) (Fig 1a). Seasonal decline in FN in all areas was also observed. This may suggest that nutrient inputs during the early dry season could improve N available to plants since nitrate-N concentration is normally highest at the start of the season (Wong and Nortcliff, 1995) and also the time of fertility improvement is of particular relevance in agroecosystems (Kihanda et al., 2004). Furthermore application of manure in the early dry season avoids the soggy anaerobic conditions which may result in denitrification (Kimani and Lekasi, 2004) in the wet season. However, N levels were similar between seasons in the livestock area (t_8 = -0.83, P > 0.05) and mixed area (t_8 = -0.09, P > 0.05) (Fig 1a). This could indicate that season may not influence the N available to plants although other factors such as mineralisation rates of N may differ with season. Phosphorous was significantly higher in the late dry season than in the early dry season in both wildlife (t_8 = 0.47, P < 0.001) and mixed (t_8 = 6.08, P < 0.001). In contrast phosphorous was similar between seasons in the livestock area (t_8 = 1.13, P > 0.05) (Fig 1b). This could indicate that in the wildlife and mixed areas P available to plants may be highest during the late dry season.

FN was significantly higher during the early dry season than the late dry season in all three areas (Fig 2a). Agroecosystems rely on inputs of nitrogen (N) to sustain productivity therefore FN inputs during the early dry season could enhance available N for plants. The level of nitrogen in the faecal material was similar to most legume cover crops with over 3% N (Palm et al., 2001) which could indicate high quality manure. Liquid manure has high content of water-soluble N and a high N/P ratio (Schroder, 2003) which could improve N and P availability in these agroecosystems although this may increase N leaks into adjacent environments affecting the health of other ecosystems (Janzen et al., 2003). FN from non-deliberate inputs were higher (Table 1) compared to the dry season N values found in stored manure from smallholder farmers which ranged from 0.4 to 1.2% (Nhamo et al. 2004; Kimani and Lekasi, 2004). The significant increase in FP (t_8 = 22.34, P < 0.01) in the mixed area may have resulted from the aggregation of livestock closer to fields in preparation for the farming season. Increase in human activity on arable lands could have resulted in low wildlife densities consequently reduced faecal deposits on to the fields.

Agro-ecosystems that combine wildlife and livestock have the potential to improve nutrient cycling and availability to plants although some of the trends shown do not achieve statistical significance (Table 1). In this type of systems, nutrient status of the arable land may hardly change over time, and systematic mining, leading to reductions in soil nutrient stocks, only occurs on the rangelands (de Ridder et al., 2004). Thus, integrated wildlife-livestock-cropping systems can be beneficial to communal farmers in improving soil fertility and hence crop yields. Other studies have shown that addition of organic residues significantly increase faunal biomass indicating a likelihood that soil invertebrate functions can be manipulated by external inputs of organic residues (Ayuke, et al., 2002). The relationship between N and FN was not significant (r = 0.23, n = 30, p = 0.23). Similarly, there was no significant relationship between P and FP (r = 0.05, n = 30, p = 0.81), maybe because the N/P ratio in animal manners is usually much lower than the N/P ratio of the plant residue (Schroder, 2003).

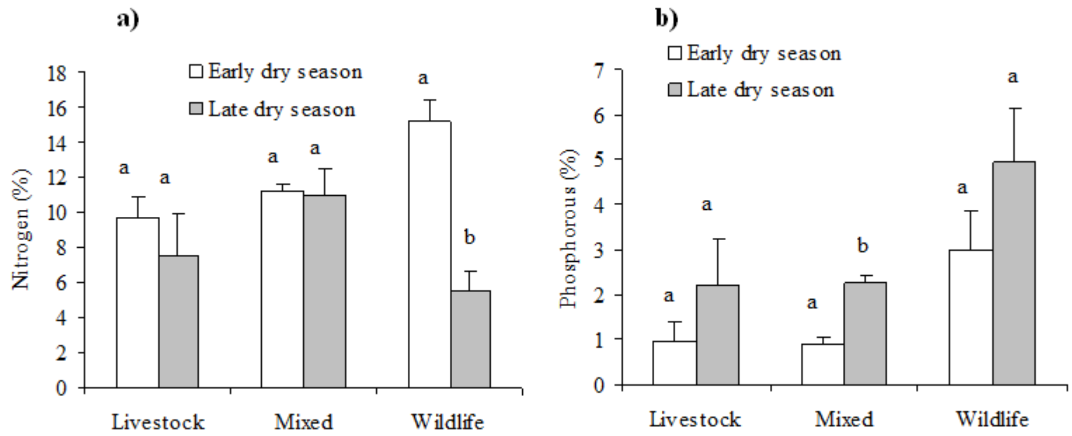

Fig 1. a) Nitrogen and b) phosphorous concentration in plant biomass in livestock, mixed and wildlife areas. Bars with different letters differ significantly (P < 0.05, Tukey HSD).

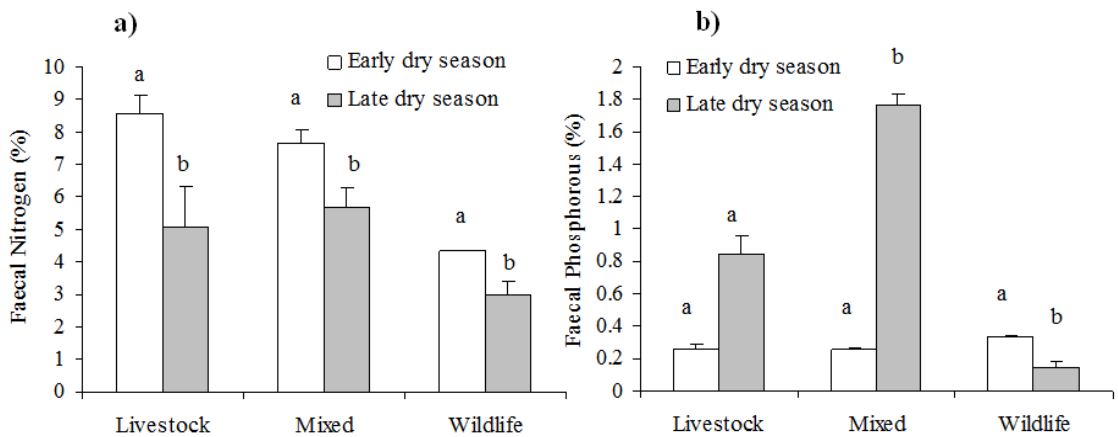

Figure 2. a) Faecal nitrogen and b) faecal phosphorous concentration in livestock, mixed and wildlife areas. Bars with different letters differ significantly (P< 0.05, Tukey HSD).

CONCLUSIONS

This study illustrates that non-deliberate organic inputs can be significant as nutrient input onto arable land because crop residues have considerable scarcity value in semi-arid rainfed areas (Erenstein, 2003) and their return to farmlands is limited. Additionally, due to the competing use of crop residues in sub-Saharan Africa (Giller et al., 2009) non-deliberate organic inputs may provide an important source of nutrients. The benefits of the integration of livestock and wildlife into farming systems could enhance the non-deliberate transfer of nutrients from rangelands to croplands to the benefit of poor farmers especially in arid areas of Zimbabwe, were manure a potential resource for nutrient recycling is hardly used (Mapfumo and Giller, 2001). Finally because non-deliberate inputs are directly deposited onto the field this has potential to enhance nutrients available to plants since N availability for crops is largely influenced by the time between excretion and application to fields (Rufino et al., 2006)

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