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Competing use of organic resources, village-level interactions between farm types and climate variability in a communal area of NE Zimbabwe

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ABSTRACT

In communal areas of NE Zimbabwe, feed resources are collectively managed, with herds grazing on grasslands during the rainy season and mainly on crop residues during the dry season, which creates interactions between farmers and competition for organic resources. Addition of crop residues or animal manure is needed to sustain agricultural production on inherently poor soils. Objectives of this study were to assess the effect of village-level interactions on carbon and nutrient flows, and to explore their impact on the long-term productivity of different farm types under climate variability. Crop and cattle management data collected in Murewa Communal area, NE Zimbabwe was used together with a dynamic farm-scale simulation model (NUANCES-FARMSIM) to simulate village-level interactions. Simulations showed that grasslands support most cattle feed intake (c. 75%), and that crop residues produced by non-cattle farmers sustain about 30% of the dry season feed intake. Removal of crop residues (0.3–0.4 t C ha^{-1} yr^{-1}) from fields of non-cattle farmers resulted in a long-term decrease in crop yields. No-access to crop residues of non-cattle farmers increased soil C modestly and improved yields in the long-term, but not enough to meet household energy requirements. Harvest of grain and removal of most crop residues by grazing cattle caused a long-term decline in soil C stocks for all farm types. The smallest decrease (−0.5 t C ha^{-1}) was observed for most fertile fields of cattle farmers, who manure their fields. Cattle farmers needed to access 4–10 ha of grassland to apply 3 t of manure ha^{-1} yr^{-1}. Rainfall variability intensifies crop–livestock interactions increasing competition for biomass to feed livestock (short-term effect) or to rehabilitate soils (long-term effect). Prolonged dry seasons and low availability of crop residues may lead to cattle losses, with negative impact in turn on availability of draught power, affecting area under cultivation in consecutive seasons until farmers re-stock. Increasing mineral fertiliser use concurrently with keeping crop residues in fertile fields and allocating manure to poor fields appears to be a promising strategy to boost crop and cattle productivity at village level. The likelihood of this scenario being implemented depends on availability of fertilisers and decision of farmers to invest in rehabilitating soils to obtain benefits in the long-term. Adaptation options cannot be blind to what occurs beyond field and farm level, because otherwise recommendations from research and development do not fit the local conditions and farmers tend to ignore them.

1. Introduction

Crops and livestock are integrated in the farming system that predominates in communal areas of northeast (NE) Zimbabwe (Kunjeku et al., 1998). Main interactions between crops and livestock are the use of draught power for ploughing, animal manure applied to crops, and the use of crop residues as feed for livestock (Steinfeld, 1988). Manure is needed to sustain crop production because soils are inherently poor and mineral fertilisers alone are insufficient to achieve crop yields required to secure household food requirements (Rodel and Hopley, 1973; Grant, 1976). Cattle are economically the most important livestock kept by farmers, although only 40% of the households own cattle (Zingore et al., 2007a). Rainfall variability represents one of the largest risks to farming in NE Zimbabwe, with a high frequency of occurrence of droughts (one out of five years) and recurrent dry spells (Matarira et al., 2004).

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Within the communal area of Murewa in NE Zimbabwe, each village has access to well-delimited communal grasslands where cattle are herded during the growing season to avoid crop damage. During the growing season the feed value of grasses is much better than during the dry season (Frost, 1996), when cattle graze preferentially maize and groundnut residues available on croplands. Most cattle owners collect part of their crop residues to feed cattle in the dry season, when feed shortages are critical (Mtambanengwe and Mapfumo, 2005). Collection of crop residues may have negative consequences for crop production because of the continuous removal of organic materials from fields, especially for farmers who have no access to other sources of carbon (C). Differential management of fields has resulted in heterogeneity in soil fertility within and across farms: farmers who own cattle concentrate manure on fields closest to their homesteads, which led to gradients of soil fertility with fertile homefields, and poor outfields (Zingore et al., 2007a). The fields from poor farmers without livestock receive small amounts of nutrients and show poor soil fertility irrespective of distance from homesteads.

Collective management of cattle at village level, and tolerance of non-cattle farmers to the grazing of their crop residues may contribute to the concentration of C and nutrients in the fields of the cattle owners. While the intensity of such interactions regulates the degree of inequity between farmers (Ramisch, 2005), rainfall variability may have a large effect on the extent of the interactions: in years of poor rainfall or occurrence of drought the competition for plant biomass to meet alternative uses increase. There is little quantitative information for southern Africa on the effects of communal management of feed resources on the size of nutrient and C flows and on the long-term consequences for the productivity of croplands. Objectives of this study were to assess the effect of village-level interactions on C and nutrient flows, and to explore their impact on the long-term productivity of different farm types under climate variability. Focus was placed on the interactions under current and alternative management practices, and the comparisons between cattle farmers and non-cattle farmers. We combined information available for study area collected through interviews, field measurements, observations, experiments and literature. We used the NUANCES-FARMSIM modelling framework (Giller et al., 2006; Van Wijk et al., 2009), which consists of relatively simple crop, cattle, manure management and grassland models, developed and tested for the conditions of smallholder farming in NE Zimbabwe. The specific research questions were: (i) What is the size and dynamics of nutrient and C flows mediated by cattle at farm and village level? (ii) How do nutrient and C flows change according to alternative management practices? (iii) What is the effect of climate variability on farm- and village-level interactions? (iv) When does competition for organic resources become most critical for cattle and for crop production? (v) What are the options for intensification of communal farming under climate variability?

2. Methodology

2.1. Study area

The study took place in the Murewa smallholder area located 80 km E of Harare in Zimbabwe, between 17 and 18°S and 31 and 32°E, which belongs to Natural Region II, an agro-ecological zone of relatively high potential for agriculture (Vincent and Thomas, 1960). Maize is the main staple crop in Murewa, with groundnuts, sweet potatoes, sunflower and vegetables also grown. Cattle usually graze during the day and are tethered in the kraal close to homesteads overnight. Crop residues are fed to cattle during the dry season and manure is used to fertilise maize crops and vegetable gardens.

2.1.1. Climate, soils and natural vegetation

Murewa has a sub-tropical climate receiving 750–1000 mm rainfall annually, distributed in a unimodal pattern (November–April), with an annual coefficient of variation of 30% (Kunjeku et al., 1998). Soils in Murewa are predominantly granitic sandy soils (Lixisols) with low inherent fertility (Nyamapfene, 1991). A small proportion of the area has relatively fertile dolerite-derived clay soils (Luvisols) considered the best agricultural soils in Zimbabwe. The natural vegetation at Murewa is Miombo woodland dominated by *Brachystegia* spp. and *Julbernardia* spp. trees. The grass cover in the woodland is dominated by species of the genus *Hyparrhenia*, and is therefore termed Hyparrhenia-veld type (Rattray, 1957). *Andropogon, Digitaria*, and *Heteropogon* spp. are also common species especially where tree density is high. *Sporobolus pyramidalis* dominates where grazing intensity is relatively high, and in the wet 'vlei' area.

2.1.2. Farmers and farm typology

A common approach when modelling agro-pastoral communities is to stratify farm households using typologies (Thornton et al., 2007). A simplified village that resembles the Majonjo village of Murewa was constructed using a farm typology developed by Zingore et al. (2007a). The typology distinguishes four farmer resource groups (RG) based on livestock ownership, farm size, production orientation, labour hired, and food self-sufficiency (Table 1). Feeding strategies, herding patterns, crop residues, and manure management were studied during the dry season of 2006 (June–September) and the rainy season of 2006–2007 (February–May). Cattle owners (RG1 and RG2), non-cattle farmers (RG3 and RG4) and other key informants such as the kraal head and herders were interviewed. Biomass production and species composition of the communal grassland were measured. Grain yields, amount of crop residues and their management were estimated through interviews and field measurements.

Table 1
Characteristics of farm types and resource groups classified according to the typology for the communal area of Murewa. Source: Zingore et al. (2007a).

	Farm type			
	Wealthier	Medium-wealthier	Medium-poor	Poor
Resource group	RG1	RG2	RG3	RG4
Proportion in the village (%)	6	35	26	33
Livestock owned	c. 10 cattle	<10 cattle	No cattle	No cattle
Resource exchanges	Hire labour and share draught power	Do not sell or hire labour, share draught power	Sometimes sell labour or exchange it for draught power	Sell labour and/or exchange it for draught power
Land holding (ha)	>3	2–3	<2	<1
Food self-sufficiency	Self-sufficient, able to sell grain and vegetables	Self-sufficient, able to sell grain and vegetables	Purchase grain and sell vegetables	Purchase food or receive food aid