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Impact of Cattle Grazing and Fallow systems on Maize Grain Yield, Soil Chemical Properties and Daily Weight Gain in the derived savanna zone of Nigeria

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ABSTRACT

The effects of two alternative land use systems (system 1: natural fallow with and without grazing and system 2: improved fallow with and without grazing) on grain yields; soil chemical composition, fodder yield and animal weight change were compared during 1993 through 1999 planting seasons in the derived savanna zone of Nigeria. The experimental design was a split plot with three replications. Main plots were improved and natural fallow. The sub plots consisted of grazing with cattle (CG) and no grazing (NG). *Lablab pupureus* was relayed cropped with maize in the improved fallow, but the natural fallow plots were not relayed- cropped with lablab. Cattle grazed the designated plots after maize grain harvest at a stocking rate of 350 AU /ha. Data on annual grain yields, forag production, and soil chemical composition and animal weight change were recorded for the two main fallow and grazing subsystems over a period of six years. Results showed that cattle grazing natural fallow increased grain yield by 23% while grazing improved fallow increased grain yield by 21%. Grazing reduced soil organic carbon - OC (7- 18%) and increased available P (5-26%) status in both fallow systems. Total N status of soil in grazed plots was 3% higher than ungrazed plots in the improved fallow while in the improved fallow system grazing increased soil N by 13% and K by 4%. Available forage before grazing in the improved fallow system was higher than the natural fallow by 31%. Average daily weight gain of cattle grazing

Increase total land productivity in smallholder mixed crop-livestock systems through increased crop and livestock outputs and enhanced soil productivity.

Keywords: *Fallow systems, Crop-livestock, relayed cropped,*

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INTRODUCTION

Rapid population growth in West Africa is leading to agricultural intensification changing land use patterns, and closer integration of crop and livestock production (Mcintire *et al.* 1992; Winrock, 1992; Jabbar, 1993). To meet the food and feed needs of the expanding population, cropped lands have been expanded and cropping intensity increased. Consequently, the frequency and duration of fallowing needed to restore soil fertility is declining sharply leading to decreased soil fertility and increased risk of environmental degradation.

Seasonal changes in the supply of quality feed and low soil fertility have been identified as major constraints to increased livestock and crop output in the smallholder mixed crop-livestock systems in West Africa (Winrock 1992, Jabbar, 1993; Smith *et al*. 1997). Therefore, strategies and technologies that promote synergistic integration of crops and livestock while protecting the natural resource base are needed to improve total productivity of the mixed crop-livestock systems in the region. Integration of herbaceous legumes to enhance soil productivity, suppress weed growth, accelerate nutrient cycling, and to provide food and quality fodder is an attractive option to improve the sustainability of such crop-livestock systems.

Small-scale farmers in the humid and savanna zones of West Africa traditionally use fallow with natural vegetation re-growth (natural fallow) for soil regeneration (Kang *et al*. 1997). Several studies have been conducted on the use of herbaceous legume fallow (Improved fallow) to replace natural vegetation fallow for soil fertility management in the West Africa over the past 30 years (Tarawall, 1991, 1994; Sanchez, 1995; Kang *et al*. 1997; Muhr *et al.* 1999a, b, c). However, most of these studies did not consider the potential role of livestock in fallow management for sustained intensification of smallholder mixed crop-livestock systems. Researches in West Asia and North Africa show that integration of livestock into fallow

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systems could improve total land productivity of mixed crop-livestock systems (Thomson *et al*. 1992). Therefore, the International Livestock Research Institute (ILRI) conducted studies from 1993 1999 in the derived savanna zone of Nigeria to assess the impact of cattle grazing natural and improved fallow systems on crop and livestock outputs and soil chemical properties.

MATERIALS AND METHODS

Study sites

The experiment was conducted between 1993-1999 at the International Livestock Research Institute Sub humid zone, International Institute of Tropical Agriculture Ibadan, Nigeria (Latitude 7^{0} 30^{1} and Longitude 3^{0} 4^{1}) Annual rainfall averages 1250mm and occurs from April to November with a marked dry season from December to March. The wet season can be divided into major-wet (April-July) and minor-wet (September to November) seasons). *Design and Treatments* A split-plot design with three replications was adopted in this research. Main-plots were natural and improved fallow system and sup-plots were grazing or no grazing with cattle. The ungrazed plots measured 15 x 45m and the grazed 33 x 45m. The natural fallow consisted of native vegetation (2-4 month's re-growth) and maize stover while the improved fallow consisted of native vegetation re-growth, maize stover and lablab (*Lablab purpureus*), a dual-purpose legume for grain and fodder production (Wood, 1983).

Crop and Fallow Establishment

Maize was sown at a spacing of 0.75m between rows and 0.25m within rows with two plants per hill in all plots. In the improved fallow systems, lablab were sown between the maize rows at a spacing of 0.25m within row four weeks after planting the maize, with a row of lablab alternating with every three rows of maize. Plots were hand weeded and fertilizer applied (15-15-15 NPK) in two splits in the first year only.

Grazing Management

The natural and improved fallow plots were grazed with cattle between Decembers March each year when availability of quality feed was low. The primary purpose of the grazing was to recycle the fallow vegetation into manure and urine to enhance nutrient cycling, and secondly to measure cattle weight changes when possible. Animals were treated against external and internal parasites before grazing and had free access to clean water and mineral salt licks during the grazing period.

Measurements
Maize grain yield and forage on offer. Maize grain (13-15% moisture) yield was estimated using four 2 x 2m quadrants taken from each sub-plot. Herbage dry matter yields were estimated before grazing started using four randomly placed 1 x 1-m quadrants per sub-plot cut at ground level and dried at 60^0C for 48 h.

Cattle live weight changes: Live weight of individual steers was measured before grazing, at 7 14 days intervals during the grazing period and at the end of the grazing period.

Soil sampling: Surface composite (0-15-cm depth) soil samples were collected each year before planting. ach composite sample consisted of 20 sampling points in each sub-plot. The soil samples were air-dried, ground, and sieved to determine pH (H_2O), organic carbon (OC), total nitrogen (N), available phosphorus (P) and extractable potassium (K) using procedures described by Juo (1979).

Data analyses
Data for each site were analyzed separately. A split-plot analysis of variance was used to assess the effects of fallow system and grazing on maize grain yield and soil chemical properties using the General Linear Model (Gomez and Gomez, 1984; SAS, 1996). A two-way analysis of variance was used to determine the effects of fallow system on forage available before grazing and daily live weight gain.

RESULTS AND DISCUSSION

Maize grain yield
Year, fallow system, grazing method as well as their interactions were significant on maize grain yield (Table 1). The maize grain yield ranges from 1.2t/ha under improved fallow grazed plots in 1993 to 3.9t/ha under improved grazed plots in 1995. On the average, grain yield from improved fallow was 21% higher than what was obtained under natural fallow. There was a significant variability of grain yield across the year. Irrespective of fallow or grazing methods, the best grain yield was obtained in 1995, and this was significantly higher than those of 1993, 1994, 1996 and 1997 by 68%, 57% , 5.4% and 27% respectively.

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Table 1: Influence of fallow system and cattle grazing on maize grain yield (t ha^{-1}) in the derived savanna zone of Nigeria

	NF		IF	
Year	NG	G	NG	G
1	$1.29^b \pm 0.10$	$1.46^c \pm 0.20$	$1.26^c \pm 0.01$	$1.26^c \pm 0.01$
2	$1.38^b \pm 0.20$	$1.68^c \pm 0.20$	$1.27^c \pm 0.02$	$1.68^c \pm 0.04$
3	$2.44^a \pm 0.02$	$3.37^a \pm 1.79$	$3.54^a \pm 0.04$	$3.92^a \pm 0.02$
4	$2.29^a \pm 0.10$	$3.07^a \pm 0.02$	$2.06^b \pm 0.01$	$3.71^a \pm 0.02$
5	$2.21^a \pm 0.01$	$2.86^b \pm 0.01$	$2.52^b \pm 0.02$	$2.86^b \pm 0.01$

Means in the same column with different superscripts differs ($p < 0.05$)
NF= natural fallow; IF= improved fallow
NG= not grazed; G= grazed by cattle

Table 2: Effects of cattle grazing natural and improved fallow on organic C, total N, available P and K constant in 0 -10cm of soil in the derived savanna zone of Nigeria.

	NF		IF	
Year	NG	G	NG	G
		Organic carbon C (g kg^{-1})		
1	$1.70^a \pm 0.01$	$1.93^a \pm 0.02$	$1.81^a \pm 0.02$	$1.63^a \pm 0.30$
2	$1.58^a \pm 0.10$	$1.40^b \pm 0.10$	$1.36^b \pm 0.02$	$0.98^c \pm 0.02$
3	$1.27^b \pm 0.10$	$1.30^c \pm 0.10$	$1.18^c \pm 0.10$	$1.16^b \pm 0.10$
4	$1.30^b \pm 0.10$	$1.06^d \pm 0.10$	$1.45^b \pm 0.10$	$0.87^c \pm 0.02$
5	$1.09^c \pm 0.01$	$1.13^c \pm 0.10$	$1.23^c \pm 0.10$	$1.16^b \pm 0.01$
		Total N (g kg^{-1})		
1	$1.38^b \pm 0.10$	$1.41^b \pm 0.10$	$1.23^c \pm 0.02$	$0.81^d \pm 0.01$
2	$1.42^a \pm 0.10$	$1.58^a \pm 0.10$	$1.87^a \pm 0.10$	$1.63^a \pm 0.03$
3	$1.43^a \pm 0.03$	$1.34^c \pm 0.04$	$1.24^c \pm 0.03$	$1.18^c \pm 0.01$
4	$1.43^a \pm 0.03$	$1.40^b \pm 0.01$	$1.57^b \pm 0.01$	$1.40^b \pm 0.10$
5	$0.91^c \pm 0.10$	$1.03^d \pm 0.03$	$1.15^c \pm 0.10$	$1.07^d \pm 0.10$
		Available P (mg kg^{-1})		
1	$19.5^c \pm 0.50$	$30.7^b \pm 0.70$	$29.7^b \pm 0.30$	$25.6^c \pm 0.10$
2	$24.1^b \pm 0.17$	$38.8^a \pm 1.00$	$32.4^a \pm 0.40$	$40.0^a \pm 1.00$
3	$13.2^c \pm 0.35$	$15.8^c \pm 0.10$	$19.6^e \pm 0.01$	$17.0^d \pm 1.00$
4	$13.9^c \pm 0.10$	$15.8^c \pm 0.06$	$20.6^d \pm 0.01$	$23.2^e \pm 0.35$
5	$25.5^a \pm 0.87$	$29.6^b \pm 10.00$	$25.1^c \pm 0.17$	$27.0^b \pm 1.00$

	Potassium (mg kg^{-1})			
1	$0.640^{a}\pm0.01$	$0.310^{d}\pm0.001$	$0.410^{b}\pm0.001$	$0.443^{b}\pm0.02$
2	$0.373^{c}\pm0.01$	$0.537^{a}\pm0.001$	$0.330^{c}\pm0.001$	$0.430^{b}\pm0.06$
3	$0.453^{b}\pm0.01$	$0.507^{b}\pm0.001$	$0.527^{a}\pm0.001$	$0.503^{a}\pm0.01$
4	$0.447^{b}\pm0.01$	$0.443^{c}\pm0.001$	$0.517^{a}\pm0.001$	$0.420^{c}\pm0.01$
5	$0.233^{d}\pm0.01$	$0.317^{d}\pm0.001$	$0.333^{c}\pm0.001$	$0.333^{d}\pm0.01$

Means in the same column with different superscripts differs (p<0.05)
NF= natural fallow; IF= improved fallow
NG= not grazed; G= grazed by cattle

Table 3: Influence of fallow system and cattle grazing on forage-on-offer (t/ha^{-1}) and daily weight gain (g) of cattle grazing natural and improved fallow in the derived savannah zone of Nigeria

	Forage on-offer		Daily weight gain	
Year	NF	IF	NF	IF
1	$4.50^{b}\pm1.00$	$7.37^{c}\pm0.01$	$150^{b}\pm10.00$	$167^{c}\pm0.90$
2	$4.84^{b}\pm0.04$	$6.62^{d}\pm0.02$	$123^{c}\pm10.00$	$140^{d}\pm10.00$
3	$5.97^{a}\pm0.10$	$8.36^{b}\pm0.01$	$170^{a}\pm10.00$	$183^{a}\pm3.00$
4	$5.92^{a}\pm0.02$	$9.10^{a}\pm0.10$	$173^{a}\pm3.00$	$176^{b}\pm10.00$
5	$4.77^{b}\pm0.01$	$6.35^{d}\pm0.01$	$123^{c}\pm10.00$	$183^{a}\pm3.00$

Means in the same column with different superscripts differs (p<0.05)

NF= natural fallow; IF= improved fallow

Soil chemical properties

Grazing by cattle reduced the soil OC (7-18%) and increased P (5-26%) status in both fallow systems (Table 2). Animal grazing reduced soil N status by 3% and 13% in the natural and improved fallow systems respectively. Increase of K content in the improved and natural fallow was by 4% and 2% respectively. When viewed across the year, K varied from 0.640mg kg^{-1} in 1993 under natural fallow no grazing system to 0.233 under the same system combination but in 1997. On the average, the best K was obtained under ungrazed natural fallow. This was not statistically significant from what were obtained under grazed natural fallow in 1994 and 1995 as well as ungrazed plots under improved fallow system in 1995 and 1996.

Forage-on-offer and daily weight changes

Variation in the available forage yields in the natural or improved fallow were significant (p<0.05) while there was cattle graze no difference on the amount of forage on offer in the plots and those plots not grazed at all. Available forage before grazing in the improved fallow system was higher than the natural fallow by 31% (Table 3). Average daily weight gain of cattle grazing improved fallow was greater than the natural fallow by 13% (Table 3).

The higher grain yield in grazed than the ungrazed plots could be partly attributed to higher soil fertility from manure and urine deposited (Powell *et al*. 1994; 1998). Similarly, grazing by sheep increased maize grain yield in alley farming (Atta-Krah, 1990) and maize-cowpea inter-cropping (Larbi unpublished data) systems.

The improvement of soil nutrient composition brought about by manure and urine probably stimulates bioactivities and enables the soil microbes to serve as a biological " plough" (Henderson, 1992). In general, maize grain yield in the improved fallow was relatively higher than the natural fallow and may probably due to improved soil physical and chemical properties brought about by the lablab. Intercropping cereals with legumes provides the opportunity for the cereals to utilize nitrogen fixed by rhizobia in the root nodules of the legumes (Tothill, 1986). Higher grain yield attributed to improved soil fertility status in improved than natural fallow has been reported in other studies (Muhr *et al*. 1999b; Tian *et al*. 1999, 2000).

Removal of organic matter by the grazing cattle could be partly responsible for the decline in soils OC and N (Mwendera et al., 1997a, b, c, d). The increase in soil P status with grazing could be attributed to deposition of manure and urine (Powell & Williams, 1993; Powell *et al*. 1998). In addition, nutrient losses through volatilization in urine and faces could be partly responsible for the decline in soil N in the grazing pots (Powell *et al*. 1994). Grazing has been shown to increase soil OC and decrease K status of soil in alley farming (Atta-Krah, 1990), which partly agrees with our results. Forage yield of cereal-legume inter-crops has been shown to be relatively higher than cereals alone (Tedla *et al*. 1992; Umunna *et al*. 1995).The higher weight gain of cattle grazing improved fallow than those on the natural fallow was partly due to higher intake of quality feed by cattle grazing the improved fallow with lablab. Powell and Mohammad, 1987 observed that fallow lands sown to Stylosanthes provided a high protein diet to cattle. West Africa Dwarf goat grazing Stylosanthes fodder bank has been shown to grow faster than those grazing natural pastures (Ikwuegbu *et al*. 1995). Furthermore, herbage available from cereal-legume inter-crops systems has been shown to support higher intake of dry matter and milk yield than cereal alone when fed to crossbreed cows (Khalili *et al*. 1992; Umunna *et al*. 1995).

The higher grain yield and soil P status in the grazing than the ungrazed plots in both fallow systems, coupled with the appreciable daily weight gain of cattle grazing both improved and natural fallow indicate that integration of livestock into fallow systems could increase the total productivity of small-scale mixed crop- livestock systems in the derived savanna zone. However, inappropriate grazing management could decrease soil productivity through removal of surface cover, trampling and overgrazing (Mwendera & Mohamed Saleem, 1997; Asadu *et al*. 1999). In addition, nutrient losses through volatilization in urine and faces and nutrient transfer out of the system in the form of livestock products could deplete the natural resource base (Powell *et al*. 1994). Further studies are therefore needed to quantify long-term effects of grazing and trampling on vegetation, soil hydrology and nutrient budgets in herbaceous legume short-fallow systems. For the integrated crop-livestock fallow system to be attractive to farmers, problems associated with the introduction of forage legumes into small-scale farming systems such as the shortage of land to devote to forages, the high cost of fencing in area where livestock are free-range, the management needed to ensure pre dominance of the legume, soil trampling by livestock, and legume diseases need to be addressed.

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