Effects of improved pigeonpea fallows on biological and physical soil properties and their relationship with maize yield

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INTRODUCTION

Land degradation and declining soil properties, have affected agricultural productivity in Sub Saharan Africa**.** All forms of land and soil degradation can be reversed through adoption of agroforestry systems for soil conservation and rehabilitation (Mafongoya et al., 2006). Through agroforestry systems nutrient cycling can be improved, soil physical properties can be improved and soil biodiversity as well as soil organic matter can be enhanced (Sileshi et al., 2014). Use of leguminous trees such as pigeonpea improved fallows, is one of the agroforestry system that can restore degraded soils. Maize (*Zea mays* L) is the dominant staple food crop grown by most smallholder farmers in South Africa (Mashingaidze, 2006). Many studies have looked at mechanisms of chemical and biological soil properties on increasing maize yield under improved fallows. Little attention has been given to the relationship of physical and biological soil properties and maize yields. However, these studies did not study the relationship of physical and biological soil properties and maize yields. The objective of the study was to relate maize grain yield after two-year pigeonpea improved fallow to biological and physical soil properties

MATERIALS AND METHODS

The experiment was established at Fountainhill Estate, Wartburg (latitude 29°27'2" S; longitude 30°32'42" E and altitude 853 m above sea level) The site has an annual precipitation of 805 mm .The minimum temperature is 3.3 °C and the maximum is 37. 4°C. The soils are classified as ferralisols (FAO-Classification). A randomized complete block design replicated three times was used with 5 treatments, continuous unfertilized maize (T1), natural fallow-then maize (T2), pigeonpea intercropped with grass in (1st year) - then pigeonpea (2nd year) – then maize (3rd year) (T3), maize intercropped with pigeonpea (1st year) – then pigeonpea fallows (2nd year) – then maize 3rd year (T4). Two-year pigeonpea fallow then maize on 3rd year (T5). Pigeonpea fallows were planted as pure stands at a spacing of 1 m by 1m, direct seeded in 2015/2016 season. Four 1 m × 1 m quadrats were randomly taken from each plot after 7 months of establishment to estimate the amount of dry leaf litter fall accumulation on the soil surface. The fallows were terminated in November 2017, and then maize was planted in all plots. Soil macrofauna was sampled using steel monoliths measuring 25 × 25 × 25 cm driven into the soil using a steel hammer on all plots of each treatment replicated three times on the randomly selected positions. Infiltration rate was measured using double rings. Aggregate stability was measured using a modified wet-sieving technique. In November 2017 all the pigeonpea plants were removed and the natural fallow cleared using a hoe. The pigeonpea biomass (leaves) was incorporated into the soil while preparing to plant maize crop.

Photo credit: Misheck Musokwa

DATA ANALYSIS

Data was analyzed using ANOVA using a two computer software packages Estimate S and GENSTAT C.

RESULTS

There were significant difference (P<0.05) on soil macrofauna species richness and diversity, aggregate stability, infiltration rate and bulk density (Table 1)

Table 1: Effects of pigeonpea fallows on biological and physical soil properties

Treatments	Soil macrofauna species diversity (H`)	Soil macrofauna species richness (H`)	Aggregate stability (mm)	Infiltration rate (cm/hr)	Bulk density (g/cm^{-3})
Continuous maize without fertilizer (T1)	0.98a	6.00a	5.02a	12.44a	1.46b
Natural fallow - maize (T2)	1.66b	9.67b	8.99b	19.11ab	1.43b
Pigeonpea + grass - Pigeonpea - maize (T3)	0.78a	10.56bc	10.13bc	20.99b	1.26a
Pigeonpea + maize - Pigeonpea - maize (T4)	1.62b	13.33c	11.20c	15.97ab	1.36ab
2-year pigeonpea fallow - maize (T5)	1.66b	17.44d	11.45c	29.81c	1.22a
LSD $_{(0.05)}$	0.33	3.49	1.604	7.47	0.15
P-value	<.001	<.001	<.001	0.006	0.015
CV	13.0	16.3	14.4	20.2	9.4

Numbers followed by same letters are not significantly different at P<0.05 according to Fisher`s Protected Lsd

Pigeonpea leaf litter fall accumulation was significantly different (P < 0.05). Two-year pigeonpea fallow (T5) had the highest leaf litter as compared to both intercrops (T3 and T4). There was no significant different on T4 and T3. (See Table2). Significant difference (P < 0.05) was observed in both maize grain and stover yield. Maize and stover yields were significantly higher in two-year pigeonpea fallow plots (T5) and lowest in continuous maize without fertilizer plots (T1). (See Table 2)

Table 2:Maize yields as affected by pigeonpea fallows and leaf litter * no leaf litter

Treatments	(kg/ha)		
	Grain	Stover	Pigeonpea leaf litter
Continuous maize without fertilizer (T1)	993a	1021a	*
Natural fallow - maize (T2)	2294b	1578b	*
Pigeonpea + grass - Pigeonpea - maize (T3)	2852c	2264c	4766a
Pigeonpea + maize -Pigeonpea - maize (T4)	2922c	2125c	5445a
2-year pigeonpea fallow -maize (T5)	3787d	3104d	7323b
LSD $_{(0.05)}$	514	451.6	1282
P-value	<.001	<.001	0.012
CV	10.6	11.9	9.7

Aggregate stability, bulk density, infiltration rate, soil macrofauna species richness and diversity were significantly (P<0.05) positively correlated to maize grain yield and stover. (Table 3). Grain and stover were significantly positively correlated to pigeonpea leaf litter with R^2 = 0.72 and R^2 = 0.84 respectively

Table 3: Relationships of maize yields to biological, physical soil properties and pigeonpea leaf litter

Correlations	r^2	n-value	P-value
Maize grain yield against aggregate stability, bulk density, infiltration rate, soil macrofauna species richness and diversity	0.83	15	0.001
Maize stover yield against aggregate stability, bulk density, infiltration rate, soil macrofauna species richness	0.72	15	0.006
Maize grain yield against pigeonpea leaf litter	0.72	9	0.002
Maize stover yield against pigeonpea leaf litter	0.84	9	<.001

n = number of data points on each variable

DISCUSSIONS

Higher species diversity and richness index of macrofauna under two-year pigeonpea fallow (T5) is probably due to the practice that maintains a year-round canopy, leaf litter, amelioration of the surface soil temperature and moisture by tree leaf biomass. The lower diversity in continuously maize cropping systems without fertilizer (T1) could be due to lack of habitat heterogeneity and food resources. Rahman et al., (2012) reported lower soil macrofauna diversity on annual continuous monocropping systems as compared to agroforestry systems. Microclimate factors which include lower soil temperature and higher soil water content, probably promotes the soil macro fauna to thrive under maize grown in legume fallows as compared to continuous maize without fertilizer. The two-year pigeonpea fallow plots had greater diversity of soil macrofauna because they had a well-developed leaf litter layer besides experiencing less human interference. This is further supported by the positive correlation between cumulative tree-leaf biomass and species diversity and species richness among pigeonpea plots. Two-year pigeonpea fallow produced 3.2 times higher maize grain yield than the continuous maize without fertilizer. These results corroborate with findings of Abunyewa & Karbo, (2005) where they found that maize yields increased after two-years of pigeonpea fallows as compared to continuous monocropping without fertilizer. Nyamadzawo et al., (2012) found that improved fallowing increased yields as compared to natural fallow which agreed with our findings both pigeonpea fallows out yielded a natural fallow. The differences in maize response to the different treatments could also be attributed to the differences in both biological (soil macrofauna species diversity and richness) and physical (aggregate stability, bulk density and infiltration rate) soil properties. This is supported by a significant positive correlation (R^2= 0.83 and 0.72) between leaf litter against maize grain and stover yields. However, the lack of significant difference between maize performance under pigeonpea intercropped with grass (T3) and pigeonpea intercropped with maize (T4) could have been caused by lower leaf litter. During decomposition process, soil macro fauna facilitates the mineralization of organic forms of nutrients in the pigeonpea leaf litter that can be absorbed by the maize crop thereby increasing yields.

CONCLUSIONS AND RECOMMENDATIONS

Agroforestry system reversed land degradation through improvement of biological and physical soil properties. Pigeonpea improved fallows increased maize yields by three times as compared to continuous maize without fertilizer. Pigeonpea improved fallows increased maize yields through improvement in aggregate stability, bulk density, infiltration, soil macrofauna species richness and diversity. Smallholders who have limited access to fertilizers can sustainably use improved pigeonpea fallows to achieve higher yields. There is a need to institute a policy to scale up agroforestry to solve the challenges of degraded soils and reduce the burden of smallholder farmers of purchasing expensive inorganic fertilizers. This will ultimately increase the yields of a staple food crop grown by most smallholder farmers thereby ensuring food security in South Africa

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