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The effects of different combinations of herbaceous and shrubs and microdose of fertilizer on bean and maize yields, soil proprieties and carbon sequestration on two degraded soils in the highland of South Kivu, Eastern of DR Congo

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ABSTRACT: Better managements of soil fertility are imperative for rehabilitating degraded soil in order to increase crop yields. Our objective was to assess the effect of improved fallow of different combinations of herbaceous-shrubs species and microdose of fertilizer on maize-bean yield, aboveground organic carbon sequestration and soil proprieties improvement. The treatments consisted of *Pennisetum purpureum, Setaria sphacelata* and *Tripsacum laxum* or *Tithonia diversifolia* combinations with 3 shrub species (*Leucaena diversifolia*, *Calliandra calothyrsus*, and *Albizzia chinens*) and microdoses of fertilizer (NPK-manure), two controls treatments without fertilizer were also included. These treatments were arranged in a split-plot design with, the main plot treatment consisting of herbaceous-shrubs fallow type subdivided into four subplots of beans ([M211], [NAMULENGA] [CURANTINO] and [VCB] cropped with three maize varieties [SamVita A and B], and [Gv664]. Application of microdose and herbaceous species combination increased bean and maize grain yield at both sites 21 months after trial initiation. No significant difference was observed between the different combinations in both sites and for the 3 planting seasons for assessed parameters. Herbaceous combinations increased significantly the number of nodules ($P < 0.01$). Highest biomass yield, C sequestration number and biomass of earthworm were found in the herbaceous-shrubs combinations treatments and lower in NPK-manure and control treatments in both sites. In addition, the number of earthworms was enhanced with application of microdose of fertilizers (546) and herbaceous-fallow grassland (725) compared to control (282) 2 years after trial initiation at Mulungu site. No significant difference was observed between the different combinations in both sites for soil temperature and moisture variation.

KEYWORDS: Biomass, Herbaceous species, Improved fallows, Organic carbon, Soil fertility.

1 INTRODUCTION

Maize, bean and cassava are the major food crops in DR Congo, especially in South Kivu. Intercropping is a common practice [1]. Beans are mainly grown in association with maize, bananas, cassava, or others root or tuber crops. About 22% of the production area is sole cropped, 43% is in association with maize, 15% with bananas, 13% with root and tuber crops, and 7 % with other crops [2] . However, production of these crops remains low and is falling farther behind other countries in Africa. The production varie from 0.8 to 3.5 t ha^{-1} and from 400 to 800 kg ha-1 respectively for maize and beans [3], [4]. Many rural families in Africa are below the poverty line and cultivate crops on land that is already degraded [5].

Soil fertility depletion on smallholder farms is the fundamental cause of declining food production in Africa including the East of DR Congo [6].). Amount of nutrients is annually taken away in the form of harvested crop. The soil nutrient mining was estimated to an average of 660 kg of nitrogen (N), 75 kg of phosphorus (P) and 450 kg of potassium (K) per hectare per year during the last 30 years from about 200 million hectares of cultivated land in 37 countries in Africa [7].

The conventional agricultural practices, especially crop residues burning and transfer out of fields use by farmers is the main cause of soil fertility diminution on smallholder in Africa beans [8]. In addition, farmers cultivate local varieties with poor nutrients, low crops yield and no resistance to biotic and abiotic stress [9], [10]. Also, Farmers cultivate food crops and bananas on sloping land in South Kivu, eastern of Democratic Republic of Congo (DRC) where appropriate soil conservation is required [5].

Better managements of soil fertility are imperative for rehabilitating degraded soil in order to increase crop yields in Africa, especially in South Kivu Province. For example, the strategies of application small doses of fertilizer and planting improved crop varieties were reported [1], [11. In the other hand, agroforestry is a sustainable land-management option because of its ecological, economic, and social attributes [12]. Woody or herbaceous species in agroforestry systems can enrich topsoil through enabling nutrient cycling from the subsoil, and through biological N2 fixation by legume species. Farmers are encouraged to enrich the soils through planting of desirable woody or herbaceous species as improved fallows for example *P. purpureum*, or simultaneously with the crops [11]. In addition, agroforestry is an appealing option for sequestering carbon on agricultural lands because it can sequester significant amounts of carbon than agricultural monocultures [13]. Carbon sequestration in agroforestry systems occurs in aboveground biomass and in belowground biomass, agroforestry systems have received increased attention for climate change adaption and mitigation [14], [15].

The objectives of this study is to compare the effects of improved fallows of different combinations of herbaceous-shrubs species and microdose of fertilizer on maize-beans yield with farmer practice, (2) to study herbaceous species biomass production under intensive cutting management on above-ground organic carbon sequestration and (3) to assess the effect of herbaceous-shrubs species and microdose of fertilizer on degraded soil proprieties improvement.

2 Site, Materials And Methods

2.1 Site Description

The experiments were established in field at two sites with degraded soil in South Kivu at INERA-Mulungu research station (158 300 S, 358 150 E, altitude of 1,700 m asl) and at Mushinga (158 300 S, 358 150 E, altitude of 1029 m asl). The soil characteristics of these sites are described in detail in [16].

2.2 Materials And Methods

This agroforestry fallow was established in 2016 and since establishment the plots have been continuously cropped with bean and maize as test crop for soil fertility restoration. The treatments consisted of combinations of three different grasses species (*Pennisetum purpureum, Setaria sphacelata* and *Tripsacum laxum* or *Tithonia diversifolia depending the availability at the site.*) with 3 shrub species (*Leucaena diversifolia*, *Calliandra calothyrsus*, and *Albizzia chinens*) and microdoses of fertilizer (NPK-manure), two controls treatments were also included. This resulted in a fully factorial design with 5 treatments: T1: *Pennisetum-Leucaena-calliandra-Albizzia-NPK-manure;* T2: *Setaria–Pennisetum-Leucaena - Albizzia –Calliandra –NPK- manure* and T3: *Tripsacum or Thitonia–Pennisetum –Calliandra- Leucaena – NPK-manure*. T00: control: 0 grasses, shrubs, NPK and manure; T0: NPK-manure. These treatments were arranged in a split-plot design with, the main plot treatment consisting of agroforestry-fallow type subdivided into four subplots of beans-maize cropping maize corresponding of four bean varieties and 3 maize varieties. Each main plot was repeated five times per site and it measured 100 m²and the subplot of beans 2.5 m^2 and contained five lines of beans and three line of maize. Fours climbing bean varieties (*Phaseolus vulgaris L*) ([M211], [NAMULENGA] [CURANTINO] and [VCB]. The maize varieties were [SamVita A and B], and [Gv664]. The bean varieties were intercropped with the maize at only 9, and 21 months after trial establishment. However only beans were planted 3 months after agroforestry fallow installation because of lower soil fertility of the trial sites and only maize was planted 15 months after trial initiation because it needed a bean rotation to control beans disease. The observations were taken during three cropping seasons for each crop: (2016 B [March-June 2016], 2017 A [September 2016-January 2017] and 2018 A [September 2017-January 2018]) for beans and 2017 A [September 2016-January 2017], 2017 B [March-June 2017], 2018 A [September 2017-January 2018]) for maize. Grasses species and shrubs were planted in mixture at 1 m interval; the intra-line spacing was 25 cm for grasses and 50 cm for 100 cm for shrubs.

Beans were planted in lines 50 cm apart and maize 100 cm and the intra-line spacing was 25 cm for climbing bean and 50 cm for maize plants. Gasses cut was carried out after 2-3 weeks interval (i.e. during the bean-maize cropping season). No shrubs pruning was done because they were so small. Weeding was carried out monthly. Manure (20 t DM/ha) and micro doses of NPK (17.17.17) fertilizer (50 kg ha-1) were applied.

2.3 Data Collection

2.3.1 Beans

Beans data were collected on grain yield and rhizobium nodules in centrally located net plots, which comprised 3 lines of 60 plants beans. Five plants were selected randomly in the net plot for nodules assessment.

2.3.2 Maize

Maize data were collected on grain yield in one line of 9 m centrally located in net plots and contained 36 plants.

2.3.3 Biomass Above-Ground And Carbon Above-Ground C Stock

Harvested biomass of each herbaceous species was measured to determine biomass weight using a scale. The aboveground C stock (C sequestrated) was direct derivative from aboveground biomass (AGB) measurements/estimates, assuming that 50% of the biomass is made up by C [17],

2.3.4 Number Of Earthworm And Biomass

In trial field, soil blocks of 30 x 30 x30 cm were studied by hand as proposed by **[18]**; the living earthworms were counted and weighted. The mean number of individuals in 1 m^2 of soil surface was calculated.

2.3.5 Soil Moisture Determination And Temperature Measurement

Soil moisture was measured in August during the dry season (i.e. one month after the end of rain season) during the season which crops suffer much from water stress. Soil samples were collected in all treatments from the five replicates. Soil samples were taken at 0-5, 10-15 and 15-20 cm soil depth using inox bulk density sampling ring, (5cm diameter - 5cm high) and placed in plastic bags. The soil samples fresh weight was measured using a kitchen scale weighed and then dried in an oven at 105 0C. After 72 h of drying the dry weights were recorded. The soil surface temperature (0–5 cm depth) was measured.

2.3.6 Data Analysis

The data was subjected to analysis of variance (ANOVA) using GENSTAT discovery version 11). The LSD test was used for means separation.

3 Results And Discussion

3.1 Effect Of Different Herbaceous Species Combination And Microdose Of Fertilizer On Maize And Bean Grains Yields

Herbaceous species combination with microdose of fertilizer generally did not affect maize yield in the fiertil soil of Mulungu (Table 1). Contrary, the average yield of maize produced with different herbaceous species combination and microdose of fertilizer at Mushinga was significantly higher than maize yield produiced with no herbaceous and no fertilizer (control) for the three cropping seasons. At both sites , the average yield of maize produced in the plot with microfertilzer were higher than yied produced in the plot with herbaceous for both sites for the three cropping season, in both cases the reduction of yield could be due to the competion between maize and herbaceous species used for soil fertility restoration. No significant differences (P>0.05) in the mean grains yield was observed between the herbaceous species combination and between maize varieties at both sites. In addition, the effect of fertilizer and herbaceous species combination was more pronounced on maize yield at Mushinga on relatively poor soil than on relatively fertile soil at Mulungu. Similarly, [16] and [19] observed a more pronounced effect of fertilizer on banana growth and beans yield in the poor soil than relative fertile soil in south Kivu. Herbaceous species combination enhanced maize grain yield 21 months after trial initiation at both sites and for the three varieties. Maize yield did not significantly varie between different varieties at both sites.

The results of this experience indicate that there is a build up of nutrients in the herbaceous improved fallow due to repeated application of organic mater from repeated herbaceous cut.

Table 1. Effect of different herbaceous species combination and microdose of fertilizer on maize grains yield during three cropping seasons at two sites. NPK-manure was applied in all treatment except the control (T00).

Sites	Treatment	Maize grains yield per variety (kg/ha)								
		Gv664			Sam Vita A			Sam Vita B		
		9 M	15 M	21 M	9 M	15 M	21 M	9 M	15 M	21M
Mushinga	T0*	107a#	22a	804a	91a	32a	699a	93a	29a	619a
	T1	34b	5ab	298b	35b	7b	291b	34b	7b	316b
	T2	36b	5ab	478b	32b	5b	552ab	34b	5b	525ab
	T3	43b	4b	327b	24b	5b	562ab	34b	6b	348ab
	T00	0c	1b	0c	0c	0b	0c	0c	0b	0c
	LSD	21.7	17	287	21.7	17	287	21.7	17	287
	Fpr	0.001	0.318	0.002	0.001	0.318	0.002	0.001	0.318	0.002
Mulungu	T0	1712a	470a	1719a	2328a	536a	1611a	1319a	578a	1419a
	T1	402b	37b	865b	497c	45b	876b	461c	32c	913b
	T2	191b	15b	761bc	174c	18b	855b	153c	38c	821b
	T3	280b	20b	277c	300c	16b	408b	426c	10c	770b
	T00	1350a	318a	704bc	1283b	466a	688b	783b	289b	759b
	LSD	379.4	361	497	379.4	361	497	379.4	361	497
	Fpr	0.001	0.003	0.001	0.001	0.003	0.001	0.001	0.003	0.001

#:Means in a column followed by the same letter are not significantly different from each other according to LSD at P=0.05.

M:months after trial initiation

** :T1: Pennisetum-Leucaena-calliandra-Albizzia-NPK-manure; T2: Setaria–Pennisetum-Leucaena - Albizzia –Calliandra –NPK- manure and T3: Tripsacum or Thitonia–Pennisetum –Calliandra- Leucaena – NPK-manure. T00: control: 0 grasses, shrubs, NPK and manure; T0: NPK-manure.*

3.2 EFFECT OF DIFFERENT HERBACEOUS SPECIES COMBINATION AND MICRODOSE OF FERTILIZER ON BEAN GRAINS YIELD

The following table present results on the effect of different herbaceous species combination and microdose of fertilize on bean grains yield.

Table 2. Effect of different herbaceous species combination and microdose of fertilizer on bean grains yield of four different varieties during three cropping seasons in two sites. NPK-manure was applied in all treatments except the control (T00)

Sites	Treatment	Bean grains yield per variety (kg/ha)											
		NAMULENGA			VCB81013			M211			CUARANTINO		
		3 M	9 M	21 M	3M	9 M	21 M	3M	9M	21M	3M	9 M	21 M
Mushinga	T0*	201a#	217a	768a	236a	84a	664a	260a	148a	704a	119a	186a	441a
	T1	143a	75bc	359b	91ab	60ab	212b	117b	47bc	325b	102a	86b	274ab
	T2	147a	80b	387b	89ab	67ab	264b	101bc	54bc	307b	97ab	83b	277ab
	T3	156a	84b	255b	102a	68ab	315b	101bc	75bc	310b	91ab	124ab	175bc
	T00	25b	0c	0c	12b	0b	0c	27c	0c	0c	20b	0c	0c
	LSD	79	77.9	185	79	77.9	185	79	77.9	185	79	77.9	185
	Fpr	0.004	0.009	0.001	0.004	0.009	0.001	0.004	0.009	0.001	0.004	0.009	0.001
Mulungu	T0	749a	245a	1156a	305a	181a	1120a	1144a	166a	671a	1021a	101a	825a
	T1	38b	118a	1010a	7b	97a	1045a	1c	110ab	476ab	1b	104a	476b
	T2	25b	139a	962a	4b	146a	957a	5c	112ab	402b	5b	114a	492b
	T3	20b	103a	912a	2b	137a	842b	2c	181a	303b	3b	163a	422b
	T00	554a	218a	386b	111ab	102a	293c	455b	50b	379b	681a	50a	616ab
	LSD	244	97.2	256	244	97.2	256	244	97.2	256	244	97.2	256
	Fpr	0.001	0.395	0.008	0.001	0.395	0.008	0.001	0.395	0.008	0.001	0.395	0.008

#Means in a column followed by the same letter are not significantly different from each other according to LSD at P=0.05.

**:see table one.*

The application of microdose and herbaceous species combination increased bean grain yield at both sites, although this effect was more pronounced in the poor soil of Mushinga due to repeated application of mineral fertilizer and organic matter from repeated herbaceous cut. In general, there were no significant differences (P>0.05) in the mean grains yield across the sites and irrespective of the bean varieties between the different herbaceous species combination evaluated. However, the the means bean grain yields of of beans obtained in the plot where only NPK-manure (T0) was aplyed was higher than yieds of beans produced in the plot with herbaceous combination used for soil fertility restoration at both sites for the three cropping season and for all beans varieties. The average bean grain yield for all beans varieties 21 moths after trial initiation for T0 treatment were 644 kg ha-1 and 943 kg ha-1 for Mushinga and Mulungu sites respectively. In addition, bean grain yield average from treatment with herbaceous fallow 21 months after trial initiation could be ranged as following, firstly in site with relatively poor soil at Mushinga site: Pennisetum-setaria (T2) (309 kg ha-1) > Pennisetum (T1) (293 kg ha-1) > and Pennisetum-Tripsacum (T3) (264 kg ha-1) > control (T00) (0 kg ha-1). Contrary, in the site with relative relatively fertile soil of Mulungu, the average bean grain yields calcification could be ranged as following according the different treatment: Pennisetum (T1) (752 kg ha-1) > Pennisetum-Setaria (T2) (7003 kg ha-1) > Pennisetum-Tripsacum (T3) (620 kg ha-1) > control (T00) (419 kg ha-1). The reduction of yield from the treatments with herbaceous combinations could be due to the competion between beans and herbaceous species used for soil fertility restoration.

Bean grain yield was higher in more fertile soil at Mulungu compared to Mushinga during the three bean cropping seasons (Table 2). Low soybean grain yield below potential yield of SB24 variety at Mushinga site compared with yield at others sites with relative fertile soils in South Kivu was also reported by [20].

NAMULENGAvariety produced the highest bean grain yields with NPK-manure (T0) treatment at the both sites during the third cropping season, 1156 kg ha-1 for site with fertile soil and 768 kg ha-1 in poor soil. The control (T00) treatment gave the lowest bean grain yields (386 and 0 kg ha-1) respectively in the poor and fertile soils for the same variety and cropping season. The average bean yield produced in the plot with herbaceous species combination for the same variety and cropping season varied from 912 to 1010 kg ha-1 and from 255 to 359 kg ha-1 respectively in the fertile (Mulungu) and poor soils (Mushinga).

3.3 Effect Of Different Herbaceous Species Combination And Microdose Of Fertilizer On Soil Biological And Physique Proprieties

3.3.1 Effect Of Different Herbaceous Species Combination And Microdose Of Fertilizer On Beans Rhizobium Fixation

The table 3 present obtained results on beans nodule evaluation in the two experimental sites.

Table 3. Effect of different herbaceous species combination and microdose of fertilizer on beans rhizobium nodules during three cropping seasons in two sites. NPK-manure was applied in all treatment except the control (T00)

Sites	Treatment	Number of nodules per bean plant according bean varieties											
		M211			NAMULENGA			CUARANTINO			VCB81013		
		3M	9 M	21 M	3 M	12 M	21 M	3 M	12 M	21M	3M	12 M	21 M
Mushinga	T0*	49a	14a	65a	53a	10ab	94a	71b	22a	71a	93b	24a	74a
	T1	65a	16a	67a	73a	19a	74a	96ab	25a	72a	102b	14a	52a
	T2	63a	14a	57a	84a	13ab	88a	110ab	19a	74a	126ab	16a	54a
	T3	60a	10ab	49a	58a	19a	79a	120a	14a	56a	163a	13a	60a
	T00	0b	0b	0b	0b	0b	0b	3c	0b	0b	0c	0bb	0b
	LSD	47.3	13	38.8	47.3	13	38.8	47.3	13	38.8	47.3	13	38.8
	Fpr	0.001	0.022	0.008	0.001	0.022	0.008	0.001	0.022	0.008	0.001	0.022	0.008
Mulungu	T0	90a	12ab	131a	174a	22a	106b	44a	13ab	47ab	102a	14ab	82a
	T1	60ab	24a	68b	69b	27a	105b	57a	16ab	55a	64a	35a	65a
	T2	45ab	22a	87b	64b	19a	113b	53a	18a	51a	56ab	24a	76a
	T3	69ab	15ab	106a	50bc	20a	166a	76a	16ab	55a	45ab	22a	55a
	T00	21b	6b	17c	8c	6c	8c	22a	6b	6b	7b	5b	5b
	LSD	50.3	11	42.1	50.3	11	42.1	50.3	11	42.1	50.3	11	42.1
	Fpr	0.034	0.003	0.003	0.034	0.003	0.003	0.034	0.003	0.003	0.034	0.003	0.003

#Means in a column followed by the same letter are not significantly different from each other according to LSD at P=0.05.

**:see table one.*

The results presented in the below table show that, the application of microdose and herbaceous species combination enhanced the number of nodules per bean plant at both sites. Significant differences ($P < 0.01$) were observed in the mean number of nodules per plant produced in herbaceous combination and NPK-Munure treatment (T0) in comparison with control treatment (T00) at both sites during the three cropping seasons (Table 3). Few nodules were produced in the plot with naturel fallow (T00) (0.4) and 10 nodules per plants) while most were produced by the Pennissetum treatment (T1) (56 and 54), Pennisetum-setaria (T2) (60 and 52), pennissetum-tithonia/Tripsacum (T3) (59 and 58) nodules and NPK-Manure (T0) (54 and 70); nodules per plant) at Mushinga and Mulungu sites respectively (Table 3). Simmulary, [19] observed a high number of nodules per bean plant at Mushinga and Mulungu sites. Although the number of nodules per bean plant varied across beans varieties, herbaceous species combinaison and sites, they generally vary from 0 to 76 in less favorable environments of Mushinga and from 6 to 101 nodules per bean plant in more favorable environments at Mulungu site.

3.3.2 Effect Of Different Herbaceous Specious Combination And Microdose Of Fertilizer On Biomass Yield And Aboveground Organic Carbon Sequestration In Two Different Sites

The results of different herbaceous species combination and microdose of fertilizer effect on biomass yield and aboveground organic carbon sequestration in experimental sites are summarized in table 4.

Table 4. Effect of different herbaceous species combinatison and microdose of fertilizer on biomass yield and aboveground organic carbon sequestration in two different sites.

	Mulungu				Mushinga			
	year 1		year 2		year 1		year 2	
Treatment	Biomass (t/ha)	Carbon (t/ha)	Biomass (t/ha)	Carbon (t/ha)	Biomass (t/ha)	Carbon (t/ha)	Biomass (t/ha)	Carbon (t/ha)
T2*	17.20a#	8.62a	21.4a	10.9a	7.32a	3.66a	13.6a	6.8a
T3	12.30ab	6.15a	19.8a	9.9a	7.13a	3.56a	14.5a	7.2a
T1	13.10a	6.53a	17.8a	8.9a	5.61a	2.81a	8.7ab	4.4ab
T0	1.10bc	0.56b	2.9b	1.4b	0.04b	0.02b	3.3bc	1.6bc
T00	0.80c	0.41b	2.8b	1.4b	0.02b	0.01b	1.8c	0.9c
LSD	10.20	5.10	7.36	4.2	2.57	1.29	5.8	2.8
Fpr	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001

#Means in a column followed by the same letter are not significantly different from each other according to LSD at P=0.05.

**:see table one.*

Table 4 shows the yield of aboveground biomass of herbaceous species combination and amounts of recycled organic carbon calculated from the herbaceous biomass from repeated cut and used as mulch. The aboveground biomass and C accumulation varied significantly between the land use systems ($P= 0.001$). Highest biomass average yield (21.4 t ha–1 year–1) and C sequestration were found in the herbaceous species with pennisetum-setaria combinaison (10 t ha–1 year–1) and the lowest (0.9 t/ha per year) were obtenaid in traditional system with natural fallow at Mulungu and Mushinga respectly. No significant difference was found between the different agroforestry systems and between the natural fallow (T00) and the plot where a microdose of NPK-manure (T0) was applied. These results show that total biomass and C accumulation in the aboveground in herbaceous improved fallow is generally much higher than that in land use without herbaceous specious under comparable conditions [21]. Bean yield for the second cropping season was lower than the first for all varieties; this could be due to the completion between annual crops and herbaceous species used for soil fertility restoration. This could be explains with the reduction of the number of herbaceous lines per plot 9 months after trial establishment. Instead of 0ne line of herbaceous at 0ne line at each meter, we kept one line at each two meters to reduce the competition with them and bean plants because at this period, the herbaceous developed enough roots that could compete with bean for nutrients.

3.3.3 EFFECT OF DIFFERENT HERBACEOUS SPECIES COMBINATION AND MICRODOSE OF FERTILIZER ON EARTHWORM NUMBER AND BIOMASS

Table 5. Effect of different herbaceous species combination and microdose of fertilize on earthworm number and biomass per 1 m²of soil in two different soils

Treatment	Mushinga				Mulungu			
Treatment	Year 1		Year 2		Year 1		Year 2	
	Number	Biomass (g)	Number	Biomass (g)	Number	Biomass (g)	Number	Biomass (g)
T1*	7a	1.22	NE	NE	110a	18.3a	887a	85a
T2	2a	0.02	NE	NE	75a	8.0a	1028a	85a
T3	0a	0.0	NE	NE	5a	0.1a	261a	24a
Average	3	0.3	NE	NE	63.3	8.8	725.3	64.7
T0	0a	0.1	NE	NE	28a	0.9a	546a	51a
T00	0a	0.0	NE	NE	22a	5.2a	282a	17a
LSD	7.97	2.1	NE	NE	146	27	1349	112
Fpr	0.580	0.782	NE	NE	0.243	0.244	0.307	0.258

#Means in a column followed by the same letter are not significantly different from each other according to LSD at P=0.05.

**:see table one.*

Herbaceous and tree species combination with microdose of fertilizer had a significant effect on total earthworm density and biomass. The mean number and biomass of earthworm were the highest in plots with herbaceous species combination and lower in control plots with farmer's practices in both sites. In other hand, the number and biomass of earthworm was high at mulungu site with relative fertile soil in comparison with Mushinga with poor soil. This number varied from o to 7 at Mushinga and from 5 earthworms per m^2 to 110 earthworm s at Mulungu 1 year after trial initiation, this difference could be due to the high soil temperature at Mushinga and less organic matter in comparison of Mulungu site. However, not significant difference was observed in number and biomass of earthworm between different herbaceous combinations within the same site. [22] Report that microbial diversity and activity were higher under no-till than conventional tillage, also, fertilizer seems to play a minor role in determining microbial diversity and activity, whereas the cropping systems played a more important role in determining the activity of soil microbial communities. Soil moisture influences the abundance of earthworm communities more than soil type [23]. The high number of earthworm is an indicator of soil fertility.

3.3.4 EFFECT OF DIFFERENT HERBACEOUS SPECIES COMBINATION AND MICRODOSE OF FERTILIZER ON SOIL TEMPERATURE

The figure below shows soil temperature recorded in the trial plots in the two experimental sites.

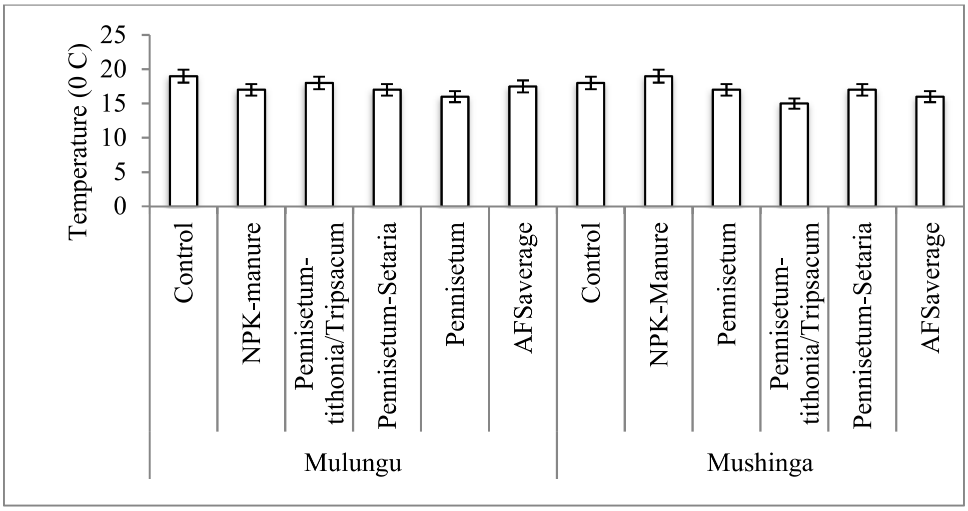

Fig. 1. Effect of agroforestry system on soil temperature

ASF average: average of Agroforestry treatments

Soil temperature recorded in August, 6 weeks after rain had stopped was higher in controls with natural fallow without fertilizer and in plot where NPK-manure were applied for both sites (Fig.1) this could be due the shade created with herbaceous combination that could reduce light penetration to soil in the plots with this treatments.

3.3.5 Effect Of Different Herbaceous Species Combination And Microdose Of Fertilizer On Soil Moisture Determination

Soil moisture results are presented in the figure 2 below.

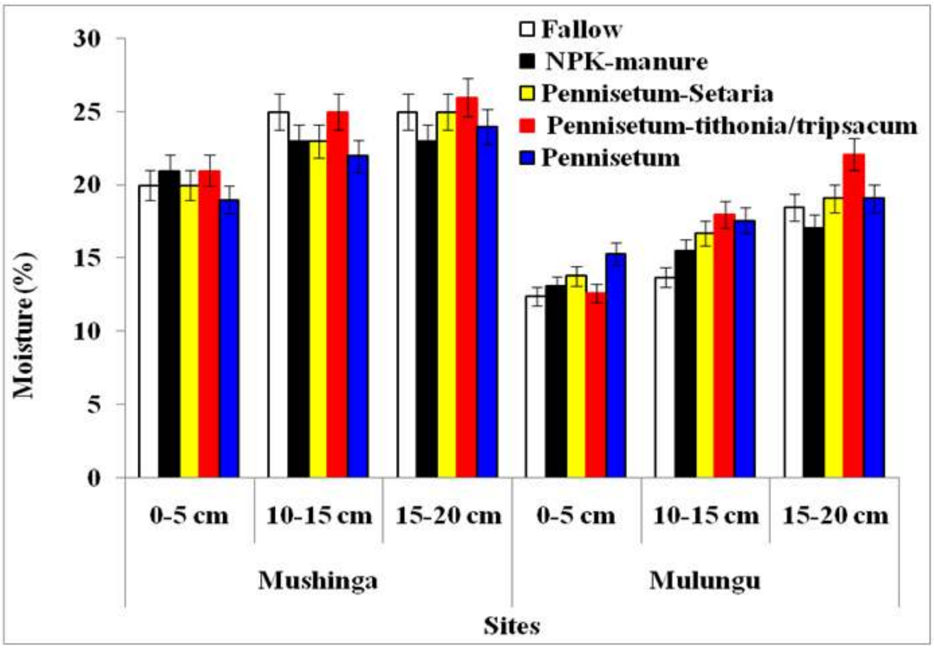

Fig. 2. Effect of different herbaceous species combination and microdose of fertilizer on soil moisture (%) per soil depth from 0 to 20 cm)

Soil moisture continent in August, 6 weeks after rain had stopped was higher in herbaceous-shrubs fallow than in controls plot with natural fallow without fertilizer and with NPK-manure in the three soil layers for both at Mulungu site and in 15-20 cm soil layers at Mushinga site. Contrary, in 0-50 and 5-10 soil layers, soil moisture content in the treatments of land use did not differ at Mushinga site (Fig.2). At both sites the soil moisture increased down the soil profile. These results are similary of those obtained by [24].

4 Conclusion And Recommendations

The results of this study show that growing herbaceous-shrubs combination simultaneous with maize and beans enhance their yield and aboveground carbon sequestration 2 years after trial establishment. Also, Maize and beans yield are highest with microdose of mineral and organic fertilizer application in degraded soil. In addition, rhizobium fixation is increased with herbaceous-shrubs species fallow and microdose of fertilize application on degraded. Evidently, for improving soil proprieties, sufficient time is needed. The soil organic carbon and mineral N improvement will be determined in December 2019, four years after initiation.

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