The Influence of *Miraba* Soil Conservation Practices on Soil Properties and Crop Yield in the Usambara Mountains, Tanzania

ABSTRACT

Usambara Mountains in Tanzaniaare severely affected by various forms of soil erosion that has led to soil properties deterioration and reduced crop productivity. Indigenous soil erosion control measures such as *miraba* implemented in the area yielded liltle success. Field plot experiments were laid down in Majulai and Migambo villages from 2011 – 14 on *Acrisols*. The aim was to single out soil properties evolved under*miraba*soil conservation practices for improved production of Maize (*Zea mays*) and beans (*Phaseolus vulgaris*). It was found that total N, OC, available P, Ca^{2+}, Mg^{2+}, K^{+} and pHwere significantly (P = .05) powerful components that discriminated between conservation measures. The trend was *miraba* with *Tughutu*(*Vernoniamyriantha*) mulching >*miraba* with Tithonia (*Tithoniadiversifolia*)mulching >*miraba* sole > crop land with no SWC measures (control).Micro nutrients (Fe, Cu and Mn) did not differ significantly with SWC measures except for Zn which were significantly (P = .05) lower under control. Bulk density (BD) and available moisture content (AMC) were also significantly strong descriminitor between conservation measures. Maize and beans grain yields differed significantly (P = .05) in the following trend *miraba* with *Tughutu*>*miraba* with Tithonia>*miraba* sole > control in both villages. Crop yieds did not vary within parts of the studied conservation practices except for control where maize yield was significantly (P = .05) higher in lower than the upper parts.Crop yield under *miraba*was a function of AMC and pH (R^2= 0.71); AMC, available P, Ca^{2+} and K^{+} (R^2= 0.89) under *miraba* with Tithonia mulching; AMC, available P, Ca^{2+} and K^{+} (R^2= 0.90) under *miraba* with *Tughutu* mulching. These findings imply that *miraba* with *Tughutu* mulching had greater potential in improving soil properties and crop yields than *miraba* with Tithonia mulching and *miraba* sole.

Key words: Soil erosion, *miraba*, Tithonia, *Tughutu,* maize yield, beans yield

1.0 INTRODUCTION

The problem of soil erosion is global it has been reported all over the world to affect agricultural sustainability [1; 2; 3]. The TheUsambara Mountains of Tanzania for example are characterized by a high population density of about 102 persons/km^{-2}, farming on steep slopes of more than 40 % due to land scarcity, all of which causedsevere soil degradation by water erosion [4; 5]. Soil loss, nutrients depletion and reduced capacity of the soil to retain water are major forms of soil degradation in the area. These lead to soil properties deterioration and reduced crop productivity [6]. Population pressure in the area has lead to an increased land use intensity and expansion of cultivation offood and cash crops in valleys and sloping land [4; 5].

There is a growing concern that land use practices in the Usambara Mountains may not be sustainable because of their detrimental effects on soil properties[4; 7]. To address the problem of soil degradation by water erosion, Usambarafarmers developed indigenous SWC measures such *mirab*icro ridges and stone bunds as an integral part of their farming systems while introduced measures have often been rejected or minimally adopted because they were expensive interm of money and labour[9; 8]. However,indigenous soil erosion control measures implemented in the area have remained surprisingly poorly documented.Besides, the farmers' efforts to conserve the degrading landyielded very little success such that deterioration of some soil propertieshave been activein places where SWC measures are practised [9; 4; 7; 10]. This is partly due to a limited knowledge on the effectiveness of indigenous SWC practices. Moreover, indigenous SWC measures in the area have been for decade left traditional with little scientific intervension for improvement [9; 10].

Indigenous SWC measures have been documented to play a considerable role in controlling soil ersion and improving crop yield. For example,stone bunds in Ethiopia have been reported by[11]to be effective in increasing yield from 632 to 683 kg ha^{-1} for cereals, from 501 to 556 kg ha^{-1} for *Eragrostistef* and from 335 to 351 kg ha^{-1} for *Cicerarietinum* as compared to the situation without stone bunds.Likewise the study by[10] in UsambaraMoutains, Tanzania revealed *miraba* to have some contribution in controlling soil erosion and increased maize yield form 0.7 Mg ha^{-1} in crop land with no soil conservation measures to 1.1 Mg ha^{-1} in farms with *miraba*.

Although studies on the effectiveness of some introduced SWC technologies on soil erosion control and agricultural productivity have recently been carried out in Western Usambara Mountains [9; 7], the contribution of indigenous SWC measures including *miraba*which is the most preferred in the study area for sustained crop productivity have not fully been investigated [4; 10]. Even when investigated, none of them in isolation explained the linkages that exist between soil propertiesand crop productivity associated with SWC technologies. Furthermore, land use planners, agricultural managers and extension officers need sound information to guide implementation of SWC practices within the constraints of improved soil properties and maximized crop production; but, at present such information do not exist.

The study reported herein, therefore, aimed at establishing the linkages between identified soil properties associated with selected SWC practices and the productivity of maize (*Zea maize*) and beans (*Phaseolus vulgaris*) under smallholder farming conditions in Usambara Mountains. The objectives of this study were (i) to identify soil properties that discriminate between selected SWC practices (ii) to test whether the identified soil properties correlated with crop yield and (iii) to determine the relation between the identified soil properties and crop yield

2.0 MATERIAL AND METHODS

2.1 Description of the Study Sites

Migambo and Majulai villages in Western Usambara Mountains, Lushoto District, Tanzania (Fig. 1) are located between $38^0$15' to $38^0$24' E and $4^0$34' to $4^0$48' S. Migambo is humid cold with mean annual air temperature of 12 ^{0}C−17 ^{0}C and an annual precipitation is 800–2300 mm. Majulai is dry warm with mean annual air temperature between 16 ^{0}C and 21 ^{0}C and annual precipitation of 500–1700 mm.The annual evapo-transpiration (ETo) as estimated by the local climate estimator software (New_LocClim) [12] ranges from 100 mm to 145 mm. The UsambaraMountains support a large population density more than 102 persons/km^2[5].

According to World Reference Base (WRB) for soil resources[13] the soil type in Majulai site classifies as *ChromicAcrisol* (*Humic, Profondic, Clayic,Cutanic,Colluvic*) whereas in Migambo site the soil is *HaplicAcrisol*(*Humic, Profondic, Clayic,Colluvic*).

The main land uses include cultivation on slopes and valley bottoms, settlements on depressions, lower ridge summits and slopes and forest reserves on ridge summits and upper slopes. Vegetables such as carrots, onions, tomatoes, cabbages, and peas are grown as sole crops in valleys under rain fed or traditional irrigation. Beans are mainly grown during long rains while maize in short rains, round potatoes and fruits namely peaches, plums, pears, avocado, and banana are grown on ridge slopes under rain fed mixed farming. Round potatoes are also grown in valleys as sole or intercropped with maize.

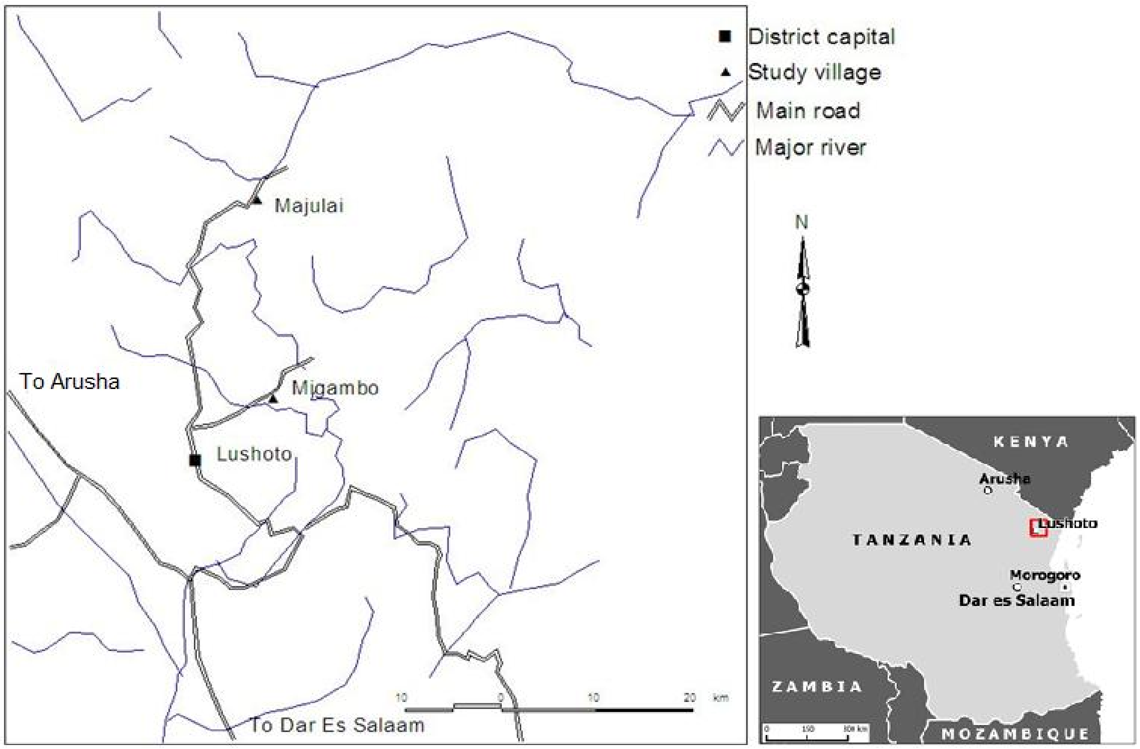

Fig.1: Location Map of Migambo and Majulai villages, Lushoto District, Tanzania

2.2 Establishment of *miraba* in field plots

Miraba were established by using Napier grass (*Pennisetumpurpureum*) barriers in field plots in April 2011 about nine months before crops were grown. Napier grass barriers forming *miraba* were established by planting tillers in a single row at 10 cm spacing perpendicular to the general slope and were maintained to about 50 cm wide strips. Napier grass barriers across the slope were spaced 5 m apart to mimic the recommended maximum effective width of hand made bench terraces[14]. It has been documented that soil conservation measures such as *FanyaJuu* and stone bunds tend to progressively form bench terraces when at a closer spacing [14; 15]. Moreover, the closer the grass strips are the more effective they become in controlling soil erosion [15]. Progressive bench terraces formation could also be possible under *miraba* when adjusted to appropriate spacing of grass strips. Natural bench terraces formations as a result of *miraba* implementation are much less expensive compared to mechanical bench terraces construction that is scared by farmers. Bench terraces are highly recommended for use in Usambara Mountains [16; 17; 9; 4]. On the other hand the spacing of Napier grass barriers forming *miraba* along the slope was set at 3 m apart.

2.3 Experimental Design

Miraba plots 22 x 3 m in a randomized complete block design (RCBD) were set in the lower ridge slopes at 50 % slope in Majulai and 45 % slope in Migambo village (Fig. 2). Maize and beans were palnted in rotation as test crops in 2012 and 2013/14 rain seasons, where maize was planted during short rains (*vuli*) while beans during long rains (*masika*). The treatments included plots with (i) *Miraba* and planted with maize or beans (***MI***) (ii) *Miraba* with Tithonia mulching and planted with maize or beans (***MITH***) (iii) *Miraba* with *Tughutu* mulching and planted with maize or beans (***MITG***) (iv) No SWC measures (***CO***) (Control) and planted with maize or beans, all replicated three times.

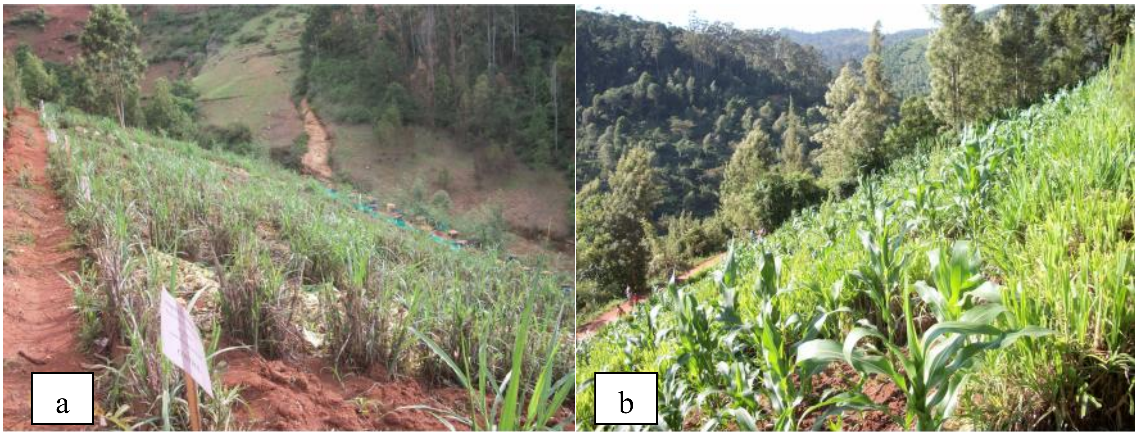

Fig.2:a) Majulai experimental plots b)Migamboexperimental plots with maize crop.

2.4 Mulching materials

Mulching materials used included the leaves of *Tithoniadiversifolia* (*Alizeti Pori*) and *Vernoniamyriantha* (*Tughutu*) in Migambo, while in Majulai village mulching materials were*Tithoniadiversifolia* (*Alizeti Pori*). The mulch was applied under *miraba* two weeks after crops germinated at the rate of 3.6 Mg ha^{-1} dry weight. These shrubs were chosen as mulches because the plants are readily available in the area and they have been documented to contain appreciable NPK contents [18; 6]. Samples from each mulching material were collected for the determination of total N, available P, K^+, Mg^+, Ca^{2+} and Na^+.

2.5 Determination of soil chemical and physical properties

The impact of SWC measures on soil chemical and physical properties was determined by taking composite top soil samples to 30 cm depth from each treatment for the analysis of pH, OC, total N, available P, K^+, Ca^{2+}, Mg^{2+}, Na^+, Fe, Cu, Zn, Mn and soil texture. Undisturbed core soil samples were also collected at 0 – 5 cm depth for bulk density and available moisture content determination. Soil samples were collected after every cropping season i.e. long rains and short rains from 2012 to 2013/14. At each runoff experimental site a soil profile was excavated and soil samples were collected from each horizon for characterization. Undisturbed core soil samples were taken at 0-5 cm, 45- 50 cm and 95-100 cm soil depth by Kopecky's core rings (100 cm^3) for bulk density and available moisture determination for the purpose of characterization. The soil was classified to level-2 according to WRB for Soil Resources [13].

2.6 Crop yields determination

Maize (*Zea mays*) variety PANNAR 67 and beans (*Phaseolus vulgaris*) Kilombero variety were planted in runoff plots during the 2012 and 2013 rainy seasons with maize in short rains (*vuli*) and beans during the long rains (*masika*). The spacing was 75 × 30 cm for maize and 50 × 25 cm for beans. Beans were always planted three weeks before maize were harvested in Migambo and two weeks in Majulai village. Farmyard manure with 0.6% N, 0.4% P, 0.5 % K and

15 % OC was basal and spot applied at the rate of 3.6 Mg ha^{-1} air-dry weight, DAP 18: 46: 0 NPK ratio and Urea46 % N were applied at the rate of 80 kg ha^{-1}, but Urea was not applied for beans. At maturity maize and beans grains were harvested and dried to about 13% moisture content.

2.7 Soil and plant samples analysis

Soil analysis was done following the [19] Laboratory Manual. Organic carbon (OC) was measured using the dichromate oxidation method, total nitrogen (TN) by Kjeldahl method, available phosphorus (Bray-I), exchangeable bases (Ca^{2+} and Mg^{2+}) by atomic absorption spectrophotometer, exchangeable Na^{+} and K^{+} by flame photometer and pH water by normal laboratory pH meter.The available Fe, Mn, Zn and Cu were extracted using buffered DTPA (Diethylenetriaminepentaacetic acid) the method and the DTPA extract was determined in an Atomic Absorption Spectrophotometer (AAS). Soil texture was determined by Hydrometer method. Bulk density was determined by oven dry method.Soil moisture retention characteristics were studied using sand kaolin box for low suction values and pressure plate apparatus for higher suction values [20].

2.8 Statistical analysis

Bartlett's test for homogeneity of variance was conducted to test data normality using the GenStat software [21]. All data were subjected to Analysis of Variance (ANOVA). GenStat statistical analysis software [21] was used for the analysis and significant differences were tested by the Least Significant Difference ($LSD_{0.05}$). Box and whisker plots were used to visualize soil properties that discriminated between SWC practices at 95 % confidence interval. Box covers the interquartile range with the median values dividing the boxes. The whiskers represent the minimum and maximum values. Correlationand multiple linear regressions were performed using Minitab software [22] to determine the relation between soil properties and crop yield under the studied SWC measures.

3.0 RESULTS AND DISCUSSIONS

3.1 Selected chemical properties of mulching materials

Chemical properties of mulching materials are presented in (Table 1). It can clearly be seen that *Tughutu* had the higher nutrient contents than Tithonia (Table 1). This situation is also supported by [18] who also found higher NPK contents in *Tughutu* than in Tithonia shrub.

Table1: Chemical Properties of mulching materials and farm yard manure applied in Majulai and Migambo villages

	Plant nutrients content %					
Mulching materials	N	P	K	Ca	Mg	Na
Tithonia	3.3	0.3	6.1	1.2	0.7	0.04
Tughutu	3.6	0.3	6.3	1.4	0.9	0.04
Farm yard manure	1.7	0.4	1.9	0.9	0.6	0.07

3.2 The influence of SWC measures to selected soil physico-chemical properties

Variability of soil chemical and physical properties between SWC measures are presented in (Table 2&3; Fig. 2 C, 3, 4 & 5).Considering the soil chemical properties in relation to the SWC measures, most of the properties were significantly(P = .05) different between treatments. The differences can be explained by the influences of the intervened SWC measures. It was revealed in both villages that all the studied macro nutrients contents followed the trend that:*miraba* with *Tughutu*mulching >*miraba* with Tithonia mulching>*miraba* sole > crop land with no SWC measures (Table 2 ; Fig.2C & 4) except for Na^+ which did not significantly (P = .05)differ. Similarly forpH which followed the same trend. It was therefore concluded that total N, OC, P, Ca^{2+}, Mg^{2+}, K^+ and pH were powerful components that discriminated between SWC measures. Studies by [9; 7] revealed similar observations where terracing such as bench and *FanyaJuu* terraces to effectively control runoff and soil losses, thus improving soil physical and chemical properties in Usambara Mountains. The higherpH and macro nutrients status under *miraba* with *Tughutu* mulching than under *miraba* with Tithonia mulching can be explained by the higher nutrient contents of *Tughutu* as compared with Tithonia mulching material (Table 1). The higher NPK contents in *Tughutu* than in Tithonia shrub was also reported by [18]. It is also well known thatexchangeable bases have strong positive correlation with soil pH [23; 24]. In the case of micro nutrients, it was found that there were no significant(P = .05) different between SWC measures exept for Zn which was significantly lowest under crop land with no SWC measures. Therefore Zn was spotted as the best micronutrient descriminator between SWC measures. These differences can be explained by the influences of the tested SWC measures. [7] in Usambara Mountains, also reportedbench terraces and grass strips have aninfluence of soil chemical properties such as pH, total N, OC, CEC, Ca^{2+} and $Mg^{2+}$when compared to control. Similar observations were reported by [9] and [25] in Usambara Mountains, where soil conservations measures suchas bench terraces, *FanyaJuu* terraces and grass strips were found to have a big influence to soil chemical and physical properties as compared with crop land with no SWC measures.

Table 2: The influence of the studied SWC practices on soil chemical properties

Village	SWC	N	pH	OC	N	P	K^+	Ca^{2+}	Mg^+	Na^+	Fe	Mn	Zn	Cu
				%	%	Mg kg^{-1}	cmol (+) kg^{-1}				Mg kg^{-1}			
Majulai														
	Control	12	4.5	2.2	0.19	10.6	0.15	1.1	0.72	0.32	36.4	44.4	1.5	3.2
	Miraba sole	12	4.5	2.4	0.22	14.4	0.17	1.5	0.95	0.33	41.2	42.0	2.1	3.6
	Miraba with Tithonia	12	4.5	2.6	0.26	23.1	0.31	1.4	1.17	0.32	42.5	47.2	1.7	3.1
	Miraba with *Tughutu*	12	4.9	2.9	0.28	26.7	0.45	2.2	1.93	0.34	41.6	51.7	2.2	3.9
Migambo														
	Control	12	5.2	3.4	0.33	5.6	0.13	4.3	1.22	0.31	42.3	157.6	3.5	2.6
	Miraba sole	12	5.5	3.7	0.36	7.5	0.19	6.1	1.79	0.32	41.7	187.6	4.7	3.5
	Miraba with Tithonia	12	5.7	4.1	0.38	10.1	0.42	6.4	2.38	0.34	44.6	155.0	4.4	3.2
	Miraba with *Tughutu*	12	5.7	4.4	0.42	13.0	0.46	7.3	2.78	0.35	47.9	164.4	5.1	3.5
	LSD (P = .05)		0.3	0.5	0.03	4.0	0.13	1.3	0.6	0.09	6.5	30.9	1.1	1.5
	SE		0.1	0.2	0.01	1.4	0.05	0.5	0.2	0.01	2.3	11.0	0.4	0.5

LSD: least significant different; SE: standard error of means

On the other handsoil physical properties were significantly (*P* = .05) different between SWC measures except for soil texture which did not differ (Table 3). The available moisture contents (AMC) were higher under *miraba* with mulching than under *miraba* sole and crop land with no SWC measures. While bulk density (BD) values were significantly lower under *miraba* with mulching than under *miraba* sole and crop land with no SWC measures. Thus AMC and BD were powerfull soil physical properties that discriminated between SWC measures. The higher AMC and lower bulk density under *miraba* with mulching can be explained by the increased organic carbon contents due to the application of mulches (Fig. 2 C & 4). It has been established that the higher the organic carbon contents in the soil the lower the bulk density while also the higher the capacity of the soil to retain moisture available to plants [26].

The improvements of the aforementioned soil physical and chemical properties under *miraba* can also be explained by the fact that; despite the ability of grass barriers forming *miraba* in retaining soil sediments and nutrients, moreover,*miraba* were progressively forming bench terraces such that the terrace height was raised to about 1 m in Migambo and 0.7 m in Majulai village after three years of experimentation. The terraces that were formed cutoff the slope steepeness resulted into reduced runoff velocity and increased rate of infiltration which intern reduced runoff volume thus reduced soil and nutrient losses. Observations by [27] reported grass hedge to effectively reduce runoff and nutrient loads following manure application as compared with cropland with no grass hedge. A similar observation by [28] who reportedelephant grass, lemon grass, paspalum and sugarcane were effectively trapping sediments and reducing runoff from cropland in Uganda.

Table 3: The influence of the studied SWC practices on soil physical properties

Village	SWC practises	N	AMC	BD g/cc	Sand %	Silt %	Clay %
%Majulai							
	Control	12	58.2	0.98	34	9	56
	Miraba sole	12	64.2	0.97	33	9	58
	Miraba with Tithonia	12	67.9	0.93	34	9	57
	Miraba with *Tughutu*	12	67.9	0.91	33	12	55
Migambo							
	Control	12	52.6	0.95	35	13	52
	Miraba sole	12	57.7	0.89	35	15	51
	Miraba with Tithonia	12	60.9	0.88	35	16	50
	Miraba with *Tughutu*	12	64.3	0.83	35	13	52
	LSD (*P* = .05)		2.7	0.06	5.1	3.0	4.6
	SE		1.0	0.02	1.8	1.1	1.6

LSD: least significant different; SE: standard error of means

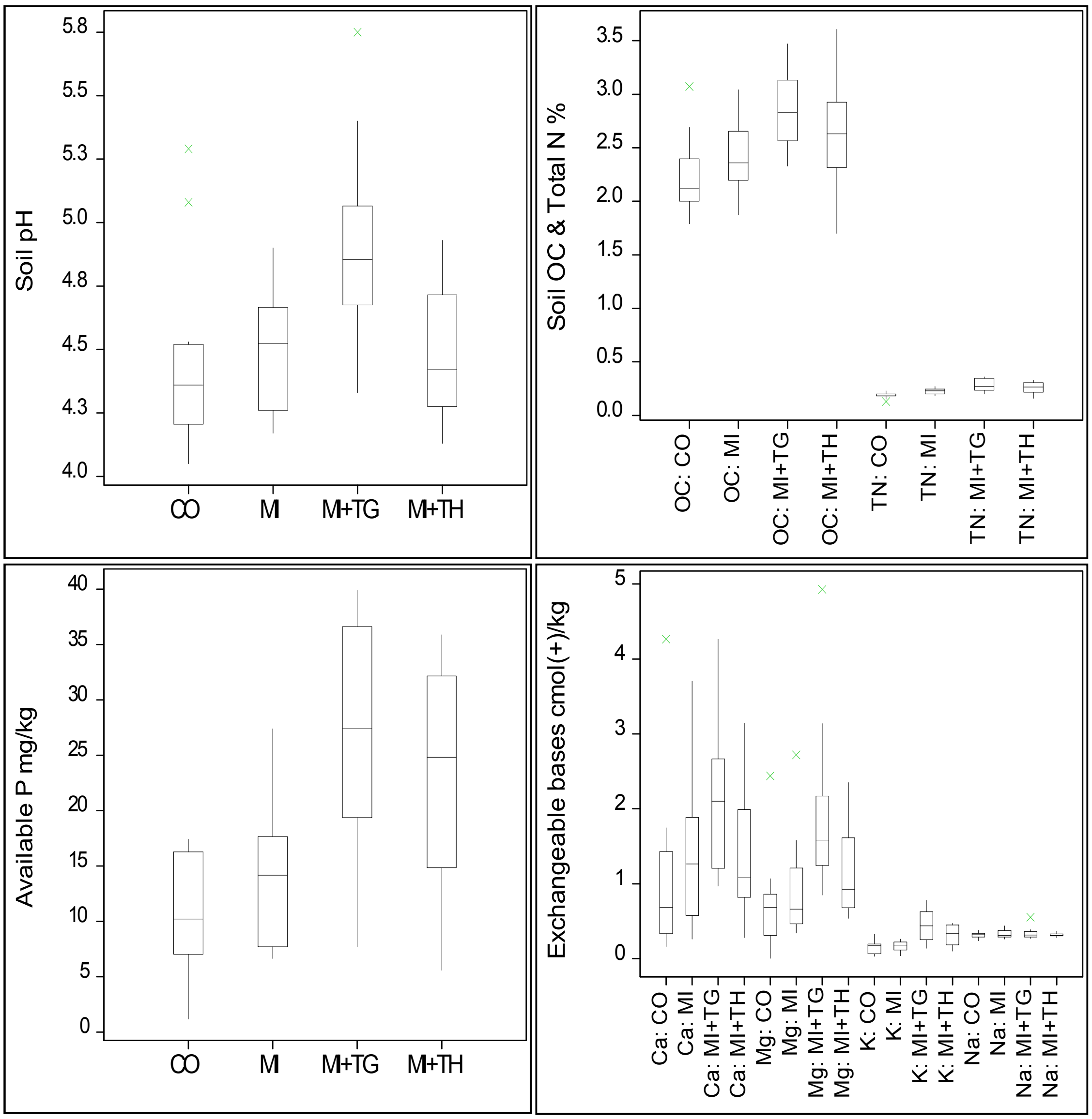

Figure 2 C : Influence of SWC measures on pH, available P, total N, OC and exchangeable bases in Majulai village. (Key: CO=Control, MI=*Miraba*, MI+TG= *Miraba* with *Tughutu* mulching and MI+TH=Miraba with Tithonia mulching.

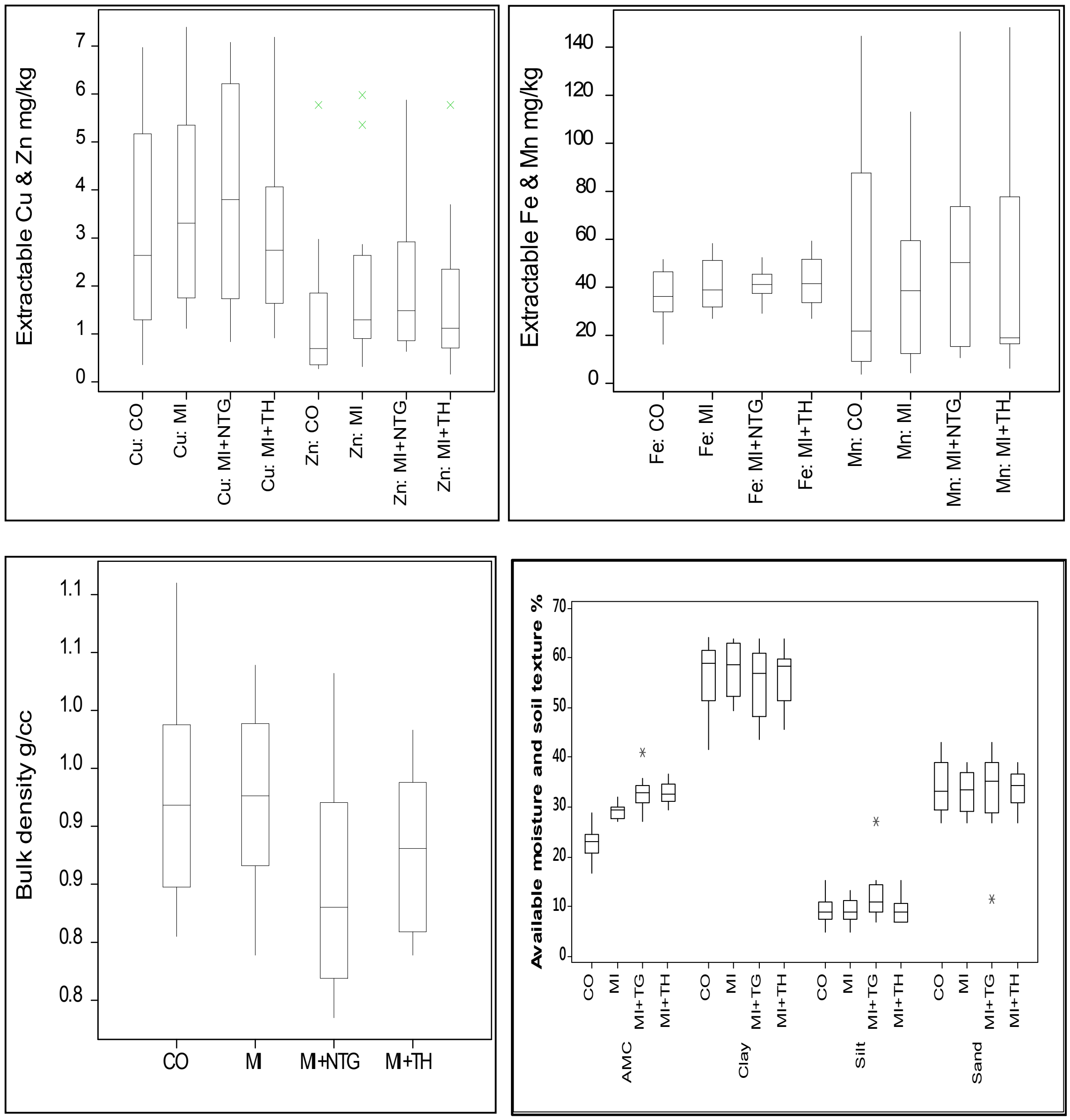

Figure 3: Influence of SWC measures onmicro nutrients, and selected soil physical properties in Majualai village. (Key: CO=Control, MI=*Miraba*, MI+TG= *Miraba* with *Tughutu* mulching and MI+TH=*Miraba* with Tithonia mulching

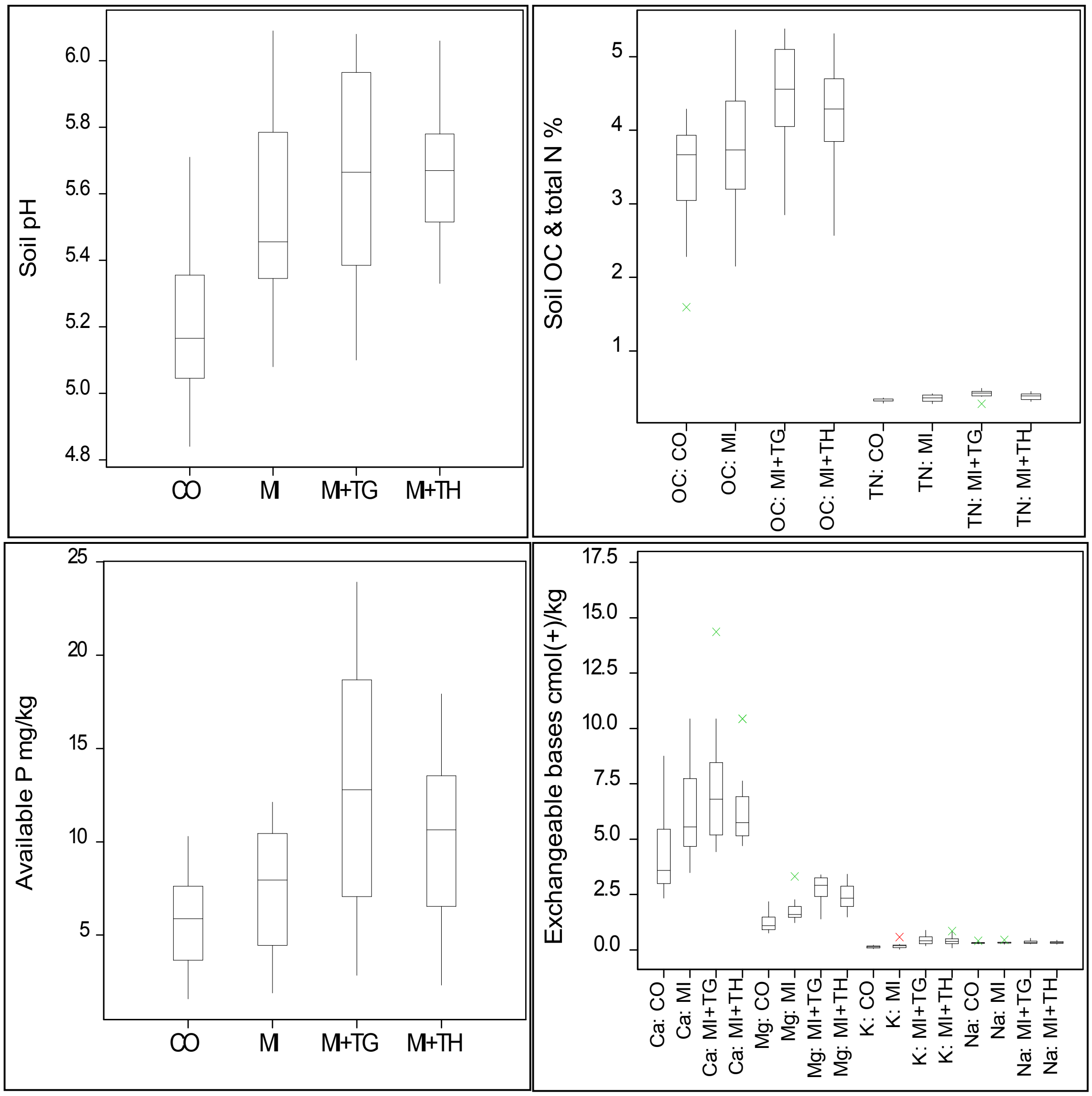

Figure 4: Influence of SWC measures on pH, available P, total N, OC and exchangeable bases in Migambo village. (Key: CO=Control, MI=*Miraba*, MI+TG= *Miraba* with *Tughutu* mulching and MI+TH=*Miraba* with Tithonia mulching

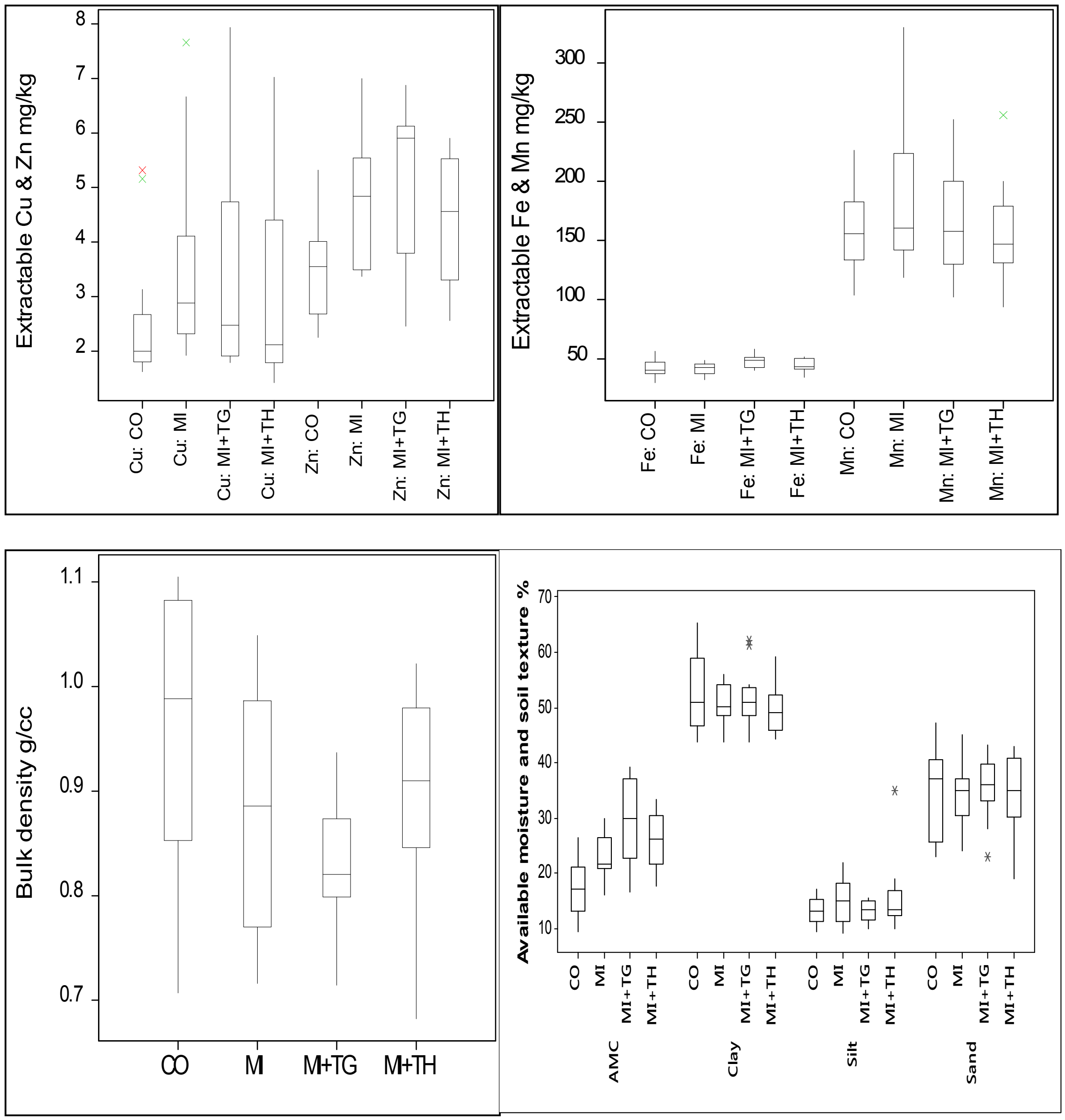

Figure 5: Influence of SWC measures on micro nutrients, and selected soil physical properties in Migambo village. (Key: CO=Control, MI=*Miraba*, MI+TG= *Miraba* with *Tughutu* mulching and MI+TH=*Miraba* with Tithonia mulching

3.3The influence of selected SWC practices on crops yield in Majulai and Migambo villages

Maize and beans yields for the studied SWC practices in the Majulai and Migambo villages are presented in (Table 4). Significant (P = .05) differences in crop yields between SWC practices were observed. The maize and beans grain yields followed the trend that *Tughutu*>*miraba* with Tithonia>*miraba* sole > control in both villages (Table 4). Maize grain yields were significantly (P = .05) higher in 2013 than in 2012, but there were no significant (P = .05) difference in beans grain yields between two years of study, however, the higher p values in 2013 than in 2012 indicates higher beans grain yields in 2013 than in 2012. It is clearly observed that the crop yield differences between treatments are highly influenced by the SWC practices intervention (Table 4), while the higher crop yields under*miraba* with Tithonia and *miraba* with *Tughutu* mulches can be explained by the improved soil properties especially of AMC, OC, N, P, K, Ca^{2+}, Mg^{2+}, pH and BD (Fig. 2, 3, 4 &5). Similar observations were reported by [9] where *FanyaJuu* terraces had significantly higher maize and beans yields than under bench terraces and grass strips while control was the least, likewise for the study by [10] found *miraba* with farm yard manure and mulching had higher maize and beans yields than under *miraba* sole and control was the least, the higher yields were associted with improved soil fertility. The observed crop yields under the studied SWC practices (Table 4) were higher than the average yields according to [29]of 1.5 Mg ha^{-1} for maize and of 0.7 Mg ha^{-1} for beans in Tanzania.

When considering variability of crop yields within parts of the studied SWC practices, it can be seen from (Table 4) that, maize grains yield differed significantly(P = .05) between parts in crop land with no SWC measures with lower parts having higher maize yields than the upper parts. Whereas the variation of maize grains yield between parts under all studied SWC practices did not differ significantly (P = .05). Similarly for bean grains yield were not significantly (P = .05) different between parts under all SWC practices and under crop land with no SWC measures. It can easily be noted that maize crop is more sensitive to the effect of gradients than bean crop, this can probably due to the ability of bean to fix nitrogen for its conception as opposed to maize crop. [9]reported similar observation where bean crop performance was found not sensitive to slope gradients as opposed to maize. The evenly distributed crop yields within the studied SWC practices can partly be explained by the act of reducing spacing of grass barriers tha form *miraba* from traditionally very wide to 5 m apart. This spacing was close enough to limit runoff velocity and thus reduced soil nutrients that could move with it down the slope at the lower part. Besides, at this spacing *miraba* were progressively forming bench terraces which cutoff the slope and thus reduced translocation of soil nutrients by runoff. On the other hand mulching was also contributed to the reduced soil nutrients movement from the upper to the lower parts thus crops responded evenly within the studied SWC practices.

Table 4: Crop yields under selected SWC practices in Majulai and Migambo villages

Village SWC measures	Parts within plots	N	Mean crop grains yield Mg ha^{-1} in 2012		Mean crop grains yield Mg ha^{-1} in 2013	
			Maize	Beans	Maize	Beans
Majulai						
Plots with no SWC	Upper		0.51	0.56		0.57
	Lower		0.91	0.62		0.61
	Mean	**3**	**0.71**	**0.59**	0.0	**0.59**
Miraba sole	Upper		1.24	0.80		0.85
	Lower		1.28	0.82		0.85
	Mean	**3**	**1.26**	**0.81**	0.0	**0.85**
Miraba with Tithonia	Upper		1.61	0.89		1.04
	Lower		1.63	0.89		1.04
	Mean	**3**	**1.62**	**0.89**	0.0	**1.04**
Miraba with *Tughutu*	Upper		1.96	0.93		1.09
	Lower		1.98	0.93		1.09
	Mean	**3**	**1.97**	**0.93**	0.0	**1.09**
LSD (*P* = .05)			0.15	0.15	0.0	0.15
SE.			0.05	0.05		0.05
Migambo						
Plots with no SWC	Upper		1.07	0.62	1.33	0.65
	Lower		1.97	0.66	1.95	0.69
	Mean	**3**	**1.57**	**0.64**	**1.64**	**0.67**
Miraba sole	Upper		2.53	0.81	3.10	0.92
	Lower		2.63	0.81	3.14	0.92
	Mean	**3**	**2.58**	**0.81**	**3.12**	**0.92**
Miraba with Tithonia	Upper		3.14	0.90	4.00	1.06
	Lower		3.22	0.90	4.10	1.06
	Mean	**3**	**3.18**	**0.90**	**4.05**	**1.06**
Miraba with *Tughutu*	Upper		3.75	0.95	4.82	1.14
	Lower		3.83	0.95	4.84	1.14
	Mean	**3**	**3.79**	**0.95**	**4.83**	**1.14**
LSD (*P* = .05)			0.41	0.41	0.41	0.41
SE.			0.14	0.14	0.14	0.14

LSD: least significant different; SE: standard error of means

3.4Relation between soil properties and crop yield under SWC measures

Correlation between soil properties (that descriminated between SWC measures)and crop yield are presented in (Table5). It can be seen that all the descriminator soil properties were positively correlated to crop yield except for bulk density which was negatively correlated. The negative effect of bulk density to crop yield can be explained by the relation that high the bulk density low the OC contents of the soils (Fig. 2 C, 3, 4 & 5), similar relation was also reported by [26]. Soil OC has been acknowledged to be an important cushion for many soil nutrients thus higher the OC content higher the soil nutrients in the soil [23; 24].A multiple linear regression models was fitted through the descriminatorsoil properties that were correlated with crop yield under SWC measures (Table 6).It was found that maize grain yieldunder *miraba*was significantly (*P* = .05) a function of $Ca^{2+}$and Mg^{2+} with (R^2= 0.85)for crop land with no soil and water conservation practices and (R^2= 0.79) forcrop land with *miraba*. While under *miraba* with Tithonia mulching maize grain yield wasmainly a function of K^+ and Mg^{2+}(R^2= 0.89) whereas under *miraba* with *Tughutu* mulching maize grain yield was greatly a function of AMC, K^+ and Mg^{2+} (R^2= 0.97). On the other hand beans grain yield was significantly (p <0.05) function of Mg^{2+} and Mn(R^2= 0.68) under control; AMC and pH (R^2= 0.71) under *miraba*; AMC, available P, Ca^{2+} and K^+ (R^2= 0.89) under *miraba* with Tithonia mulching; while under *miraba* with *Tughutu* mulching beans grain yield was stronglya function of AMC, available P, Ca^{2+} and K^+(R^2= 0.90). These observations imply that AMC and pHhad the greater potential in monitoring maize and beans grain yields under *miraba*, while AMC, available Pand K^+ had the greater potential for monitoring maize and beans grain yields under*miraba* with Tithoniaand*miraba* with *Tughutumulching*. The enhanced ability of *miraba* to availability of soil water to plants and increased soil pH can be explained by the improved soil OC and exchangeable bases under *miraba* (Fig. 2, 3, 4 &5). Similarly the positive correlations of exchangeable bases with pH and AMC with OC were also reported by [23; 24]; 30].On the other hand the improved P and K^+were greatly due to the influences of mulching materials applied which have high contents of available P and K^+ (Table 1).This is strongly supported by the findings that applications of organic materials in soils reduce P sorption capacities and increase P availability [31], while also application of high quality organic materials with P content equal to or greater than 3.0 g P kg^{-1} in the soil decreases P adsorption[32] the tendence that improves P availability in the soil.

Table 5: Soil properties that correlated with crop yield under the studied SWC measures

Crop	SWC measure	Soil properties										n
Maize												
	Control	Ca*	Mg**	Zn*								24
	Miraba	Ca***	Mg***	TN***	OC**	pH***	Zn***	Mn***				24
	Miraba with Tithonia	Ca***	Mg***	TN***	OC***	K***	pH***	Zn*	Mn*			24
	*Miraba*with *Tughutu*	Ca***	Mg***	TN***	OC***	K***	pH***	Zn*	Mn*	AMC**		24
Beans												
	Control	Ca*	Mg*	Mn*								24
	Miraba	Ca*	Mg*	pH*	K*	AMC**						24
	Miraba with Tithonia	Ca*	Mg***	K***	P*	pH*	AMC***	-BD*				24
	Miraba with Tughutu	Ca**	Mg***	K***	P*	pH***	TN**	OC*	Zn**	AMC**	-BD*	24

Key: *** =significant at p<0.001, ** =significant at p<0.01 and * =significant at p<0.05

Table 6: Relation betweensoil properties and crop yield (Mg ha^{-1}) (Y) under the studied SWC measures

Crop	SWC measure	Regression equations	R^2	P	n
Maize	Control	Y = 0.152 + 0.104 Ca^{2+}cmol/kg+ 0.793 Mg^{2+}cmol/kg^{-1}	0.85	0.003	24
	Miraba				
		Y = 0.314 + 0.139 Ca^{2+}cmol/kg + 0.038 OC% + 0.716 Mg^{2+} cmol/kg	0.80	0.000	24
		Y = 0.376 + 0.03 TN% + 0.141 Ca^{2+}cmol/kg + 0.752 Mg^{2+}cmol/kg	0.80	0.000	24
		Y = 0.381 + 0.142 Ca^{2+}cmol/kg + 0.754 Mg^{2+}cmol/kg	0.79	0.000	24
	Miraba with Tithonia				
		Y = - 0.70 + 5.67 K^{+}cmol/kg + 0.703 Mg^{2+}cmol/kg+ 0.191 pH	0.90	0.000	24
		Y = - 0.040 + 5.62 K^{+}cmol/kg + 0.732 Mg^{2+}cmol/kg + 0.85 TN%	0.90	0.000	24
		Y = 0.004 + 5.71 K^{+}cmol/kg + 0.714 Mg^{2+}cmol/kg + 0.069 OC%	0.90	0.000	24
		Y = 0.134 + 5.96 K^{+}cmol/kg + 0.762 Mg^{2+}cmol/kg	0.89	0.000	24
	Miraba with Tughutu				
		Y = - 1.98 + 0.0319 AMC% vol + 0.848 Mg^{2+}cmol/kg + 3.04 K^{+} cmol/kg + 1.63 TN%	0.98	0.000	24
		Y = - 2.70 + 0.0238 AMC % vol + 0.313 pH + 0.886 Mg^{2+} cmol/kg + 3.35 K^{+}cmol/kg	0.98	0.000	24
		Y = - 1.37 + 0.0259 AMC% vol + 0.970 Mg^{2+}cmol/kg+ 3.51 K^{+} cmol/kg	0.97	0.000	24
Beans	Control	Y = 0.456 + 0.000629 Mn mg/kg + 0.0872 Mg^{2+}cmol/kg	0.68	0.006	24
	Miraba				
		Y = - 1.18 + 0.0197 AMC% vol + 0.156 pH	0.71	0.000	24
	Miraba with Tithonia				
		Y = - 0.496 + 0.0175 AMC% vol + 0.00569 P mg/kg+ 0.0470 Ca^{2+}cmol/kg + 0.242 K^{+}cmol/kg	0.89	0.000	24
	Miraba with Tughutu				
		Y = - 0.224 + 0.0123 AMC% vol + 0.00839 P mg/kg + 0.0474 Ca^{2+}Cmol/kg + 0.219 K^{+}cmol/kg	0.90	0.000	24

4.0 CONCLUSIONS AND RECOMMENDATIONS

Most of the studied chemical and physical soil properties were significantly (P = .05)influenced by the Studied SWC measures. The trend for total N, OC, available P, Ca^{2+}, Mg^{2+}, K^{+} and pH *miraba* with *Tughutu*>*miraba* with Tithonia>*miraba* sole > crop land with no SWC measures (Control), while Na^{+} did not differ. Micro nutrients Fe and Cu did not differ between SWC measures except for Zn and Mn which were significantly(P = .05) lowest in crop land with no SWC measures. Likewise,*miraba* with *Tughutu* mulching had the highest AMC and lowest BD whereas crop land with no SWC measures had the lowest AMC and highest BD. The maize and beans grain yields differed significantly(P = .05)in the following trend*miraba* with*Tughutu*>*miraba* with Tithonia>*miraba* sole > control in both villages.

AMC and pH had the greatest potential in monitoring maize and beans grain yields under miraba, while AMC, available P and K^{+} had the greatest potential for monitoring maize and beans grain yields under *miraba* with Tithonia or *miraba* with *Tughutu* mulching.Futher researches are recommended to investigate the potentials of these mulching materials to the productivity of vegetables such as cabbage, tomatoes, onions and carrots which are widely cultivated in the Usambara Mountains.

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