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Soil profile based tillage practices for wheat production in the Central Rift Valley area of Kenya

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ABSTRACT
Objective: To evaluate the influence of soil profile based tillage practices on soil properties and wheat production within the Central Rift Valley Province of Kenya
Methodology and results: The tillage systems studied were (1) Continuous No-till –NT (mulch and herbicide); (2) Continuous minimum -MT1 (1 disc harrow + chisel plow with sweeps); (3) Continuous minimum -MT2 (herbicide + chisel plow with crumblier roller); (4) Continuous conventional -CT (1 disc plow + 2 disc harrows + 1 light tine harrow); and (5) Alternating the systems above i.e. CT in 2003, NT in 2004 and MT2 in 2005. The three tillage practices compared were conventional, conservation and alternating (conventional and conservation) tillage. Treatments were laid out in a Randomized Complete Block Design (RCBD) with three replicates. In each case, soil was left undisturbed from harvesting until planting of the subsequent season. Soil physical and chemical properties were assessed for each system before the start of the experiment in 2003 and after harvest in 2005. Yield and yield components were also determined. Soil profile analyses showed that the topsoil was shallow, being immediately underlain by pumice. The subsoil had more available P, Cu and organic C than the topsoil. The subsoil had better Ca: Mg nutrient supply ratio of 2:1 and Ca: K ratio of 9.7 compared to that of topsoil of 2:7 and 7:8, respectively. Reduced tillage systems MT2 produced significantly higher grain than conventional tillage CT. Conservation tillage systems resulted in higher percentage soil organic matter (SOM) than CT and higher water stable aggregates (WSA) than conventional tillage. It took less time to prepare a seedbed in conservation tillage than conventional tillage. The order of infiltration rates was CT (12 cm/hr) > MT1 (8.6 cm/hr) > MT2 (5.2 cm/hr) > NT (3.7 cm/hr). However, the soil water infiltrating into the subsoil would be considered lost owing to the pumice layer underlying the topsoil that blocked water from rising by capillarity from subsoil. Conventional tillage also resulted in more compaction than conservation tillage.
Conclusion: To facilitate sustainable wheat production in the Central Rift region of Kenya, conservation tillage is a better option than other tillage practices.

Key words: Tillage, soil organic matter, conservation, Rift Valley

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INTRODUCTION
The most important agronomic constraints to crop production in the Central Rift Valley Province of Kenya are environmental degradation, inadequate agronomic research (Wambugu, 1999) and inadequate rainfall, neglect, misuse, mismanagement of natural resources and the resulting widespread degradation of soils (Mwangi *et al.*, 2004). Wheat

is the main crop cultivated in the region covering an estimated 140,000 hectares with a production of about 250,000T per year. Production meets 40% of local demand, which is increasing at an estimated 5% every year. The Central Rift region receives less than 800mm of rain annually. Recently, the areas have witnessed long spells of hot and dry weather and hence a short cropping season.

Soils in the region are derived from recent volcanic activities and are low in N, P and Cu. Majority of the farmers do not use adequate inorganic fertilizer due to high costs (Nkonya, 2001, Mwangi *et al*., 2004). Livestock manure is a valuable source of plant nutrients and is applied as a soil amendment but available crop nutrients are low and its application is labor intensive. After harvesting, cattle are grazed on fallow land thus reducing the soil organic matter (Okalebo & Woomer, 2003). Additionally, crop rotation is not practiced due to lack of suitable crops to rotate with, since a rotational crop should be possible to produce under mechanization, as is the practice with wheat. Rapeseed, legumes, and recently Irish potatoes have been tried with limited success.

These factors have led to declining soil fertility since cultivation without addition of nutrients depletes soil nutrient reserve, decreases soil organic matter and impairs soil-water relationships (Ahmad *et al*., 2000; Al-Ghazal, 2000).

Conventional tillage (CT) composed of at least a combination of 1 disc plow + 2 disc harrows + 1 light tine is the main practice in the region. Tractors used are usually very powerful and this tillage system tends to emphasize on a fine consolidated seedbed, which enhances soil moisture loss and accelerates soil erosion (Rahman *et al*., 2004). Further, in the area covered in this study, the effects of destruction of the Mau forest complex (one of the few remaining indigenous tropical rain forest) on the environment and agriculture are being felt. Impacts of logging, charcoal burning and other human activities are evident as noted in weather change (increased temperatures), prolonged drought, infrequent torrential rain, and accelerated soil erosion (Ananda & Gamini, 2003). Rivers Njoro and Molo that originate from the Mau complex have experienced a drastic reduction in water levels and consequently caused a decrease in the levels of Lakes Nakuru and Baringo, respectively, where the rivers traditionally discharged their waters.

The aim of this study was to evaluate tillage practices and recommend on a sustainable practice for this fragile environment so as to increase yields, mitigate declining soil fertility, soil erosion, loss of moisture, vegetative cover and biodiversity.

MATERIALS AND METHODS

The study was carried out in Nakuru (35°15'E; 0°15'S), adjacent to the Menengai Crater in the Rift Valley Province of Kenya during the rainy seasons between 2003 and 2005. The area lies within Rongai / Njoro plain that marks the beginning of the slopes of Mau Hills. Except for the scarps formed by the banks of Rivers Njoro and the Molo, the land is flat with undulations of 0-5% slope (Jaetzold & Schmidt, 1983). The soils have been described as mollic Andosols (FAO/UNESCO, 1990). The topsoil samples (0 - 20 cm) were collected and analyzed as described by Okalebo and Gathua (1993). Five tillage practices were assessed: (1) NT= Continuous No-till; weed control by mulch herbicide; (2) CT= Continuous conventional; 1 disc plow + 2 disc harrows + 1 light tine; (3) MT1=Continuous minimum (1disc harrow + chisel plow with sweeps); (4) MT2=Continuous minimum (Round up + chisel plow with crumblier roller); (5) CT+NT+MT = year 2003 conventional till done on the plots, in year 2004 no – till was done on the plots, in year 2005 minimum till MT2 was done.

Seven days after tillage, soil samples for bulk density were collected using soil cores 7cm x 7.5 cm. Soil moisture retention was assessed using pressure plate (Kirchoff & Basnet, 1989). The available water was taken as that held between pF 2.0 (field capacity) and pF 4.0. Infiltration rates were measured using double ring infiltrometers with outer and inner rings 60 and 20 cm, respectively, and height 20 cm. Soil samples for mean weight diameters (MWD) of water stable aggregates (WSA) for topsoil were taken for each treatment using a spade. Samples were gently shaken to separate them into their natural aggregates, screened through 8mm sieve and allowed to air dry. WSA were then determined by the wet sieving procedure (Kemper &

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Chepil, 1965). Tillage treatments were located in the same plots for the duration of the experiment.

The experiment was laid out in a RCBD with three replicates; in plots of size 20 m x 6 m. Planting of wheat variety NJBWII was done using a seed drill. Weeding was done using a herbicide. Except for tillage treatments, soil was not subjected to any other disturbance. Soil data collected included physical and chemical characteristics while for wheat, yield and yield components were determined.

The data was subjected to ANOVA and means were separated using the Least Significant Difference (LSD) method (Steel & Torrie, 1980).

RESULTS AND DISCUSSION

Soil profile data (Table 1) showed that the parent material is composed of black volcanic tuffs ashes and pumice material ejected from adjacent Menengai caldera during the quaternary and recent times, with the topsoil being 30cm deep. The second layer under the topsoil is made of very coarse granular, light material (pumice), also 30cm deep. The presence of the pumice layer in this position of the profile influences the soil water content and soil water potential and is crucial to the hydrological behavior of this soil. It is therefore important to understand the profile before recommending soil management practices. Under the pumice layer was fine textured yellowish - brown subsoil.

Soil analysis (Table 2) showed that the subsoil was better supplied with P at 25ppm and Cu at 1.02ppm, O.C. at 4.8% and also better nutrient supply ratios of Ca: Mg and Ca: K, suggesting that the subsoil may have once been topsoil but upon volcanic activity was inverted into the present lower soil layer.

In Conventional Till (1 disc plow + 2 disc harrows + 1 light tine) the disc-plow slices into the pumice layer and mixes it with the topsoil, interfering with the texture which increases the percent sand content and the infiltration to the observed order with CT (12 cm/hr) > MT1 (8.6 cm/hr) > MT2 (5.2 cm/hr) > NT (3.7 cm/hr). The presence of pumice layer impeded movement of water by capillarity from lower soil layers to the topsoil for utilization by wheat. Therefore the infiltration order can be interpreted as water loss from the topsoil to the subsoil. The observation indicates the contribution of tillage system to moisture conservation for the area and underscores the importance of soil profile studies when choosing tillage system for a given area (Arif *et al*., 2001).

Table 1: Soil Profile at the Menengai trial site in central Rift valley, Kenya (Parent material is volcanic ashes and tuff; Elevation 2000 meters above sea level)

Soil layer	Depth	Description
A	0 - 30 cm:	Dark Brown (10 YR 3 / 3, moist) clay loam; coarse granular; friable to Slightly firm; clear irregular boundary to:
A	30 - 60 cm	Dark Brown (10 YR 3.5 / 3, moist) pumice layer; Coarse granular; friable to slightly firm; clear smooth boundary to:
IIA	60 - 75 cm	Yellowish - Brown (10 YR 4.5 / 3, moist) clay loam; fine granular clear Smooth boundary to:
IIB	75 - 90 cm	Brown (10 YR 4.5 / 4, moist) fine granular medium sub angular blocky; clear smooth boundary to:
IIC	90 - 100+ cm	Brown (10 YR 4.5 / 4, moist) clay loam with yellow pumice fine sub angular blocky; friable.

Table 2: Chemical analysis of soil from Central Rift Valley, Kenya, before tillage in 2003 season.

Parameter	pH	Na m.e%	K m.e.%	Ca m.e.%	Mg m.e %	Mn m.e %	P ppm	N %	C %	Fe ppm	Cu ppm	Zn ppm
Topsoil	6.1	1.90	1.42	11.0	4.15	0.43	10.0*	0.3	4.43	82.08	0.32	43.32
Subsoil	5.8	1.08	0.72	7.00	3.30	+*	25	0.3	4.43	85.2	1.02	43.10

*Deficiencies underlined, *+ Not determined

There were significant differences between grain yield, straw yield and tillage systems (Table 3). The yield advantage in both MT1 and MT2 was attributed to increased soil fertility and increased availability of soil moisture (Table 4). These observations agree with those of other workers in similar environments (Mugwe *et al.,* 2004). High yields in MT2 were attributed to the chisel plow slicing through the 30cm pumice layer, blending the top and subsoil. This improved the soil fertility and water movement by capillarity to the topsoil (Al-Ghazal, 2000). Conservation tillage systems resulted in the highest

%OC and hence %OM in the topsoil and also the highest soil water availability (Table 4).

This was explained by the fact that bulk density BD of mineral particles is 2.65g/cm^3 while that of SOM is 1.30 g/cm^3 Increasing SOM with biomass resulted in improved average BD of the soil to 1.5g / cm^3 and improved water retention in the soil. Other effects of the biomass contributing to water retention could have been reducing evaporation from soil surface, soaking up incoming moisture, increasing stabilization resistance to soil erosivity and increasing soil fertility. There were significant (P<0.05) differences between effects of tillage practices on soil porosity (Table 4). Conventional based tillage systems i.e. CT and CT+ NT+ MT significantly increased the soil porosity.

Table 3: Wheat grain yields as affected by tillage systems at the end of 2005 season.

Tillage	NT	CT	MT1	CT+NT+MT1	MT2	LSD
Grain yield t/ha	6.233ab*	5.041a	6.630ab	6.021ab	7.082b	2.041
Straw yield t/ha	5.245ab	4.940a	5.767ab	5.109ab	6.104b	1.322

* Means followed by same letter in the same row are not significantly different (p≤ 0.05).

Table 4: Effect of tillage on physical properties of topsoil after 2005 season at Menengai, Nakuru, Kenya in central Rift Valley.

Tillage	MWD WSA mm	Bulk density g/cm3	Organic carbon%	Clay %	Porosity (%)	pF2	pF3	pF4	Infiltratio n. cm / hr
NT	3.2a	1.46a	4.8a	7.5	46.4a*	0.38	0.33	0.23	3.7
CT	1.6b	1.56b	3.6b	7.4	54.6b	0.36	0.32	0.22	12
MT1	3.0a	1.50c	4.6a	7.5	47.3a	0.39	0.34	0.24	8.6
CT+NT+MT1	1.7b	1.50c	3.8b	7.3	54.0b	0.35	0.34	0.22	9.0
MT2	3.1a	1.50c	4.6a	7.4	46.9a	0.36	0.31	0.25	5.2
LSD	1.3	0.04	0.8	NS	5.3	NS	NS	NS	NS

Means followed by same letter in the same column are not significantly different (p≤ 0.05). NT= Continuous No-till and weed control by mulch herbicide. CT= Continuous conventional i.e. 1 disc plow + *2 disc harrows + 1 light tine harrow. MT1=Continuous minimum (1disc harrow + chisel plow with sweeps); (4) MT2=Continuous minimum (Round up + chisel plow with crumblier roller); (5) CT+NT+MT = year 2003 conventional till done on the plots, in year 2004 no – till was done on the plots, in year 2005 minimum till MT2 was done. *The + sign is to be interpreted as 'followed by' i.e. The disc plow was first done, then followed by 2 disc harrows etc.

Due to a number of tractor passes made and the weight of tillage equipment used (> 4000kgs), Conventional Till (CT) resulted in more compaction i.e. higher (P<0.05) bulk density and less (P<0.05) water stable aggregates than conservation tillage (Table 4). This may suggest that Conventional till CT operations pulverized the fragile soil, affecting its aggregate structure, hydraulic conductivity, and moisture retention. Conservation tillage (MT1, MT2 and NT) took less time. Both MT1 and MT2 took 2.5 hrs/ha; NT took 1.5hrs/ha saving time for farmers, compared to CT which took 5.2 hrs/ha. Lagat and Maritim (2003) reported decreased fuel consumption, planting and harvesting flexibility and reduced labor requirements in conservation tillage.

In general the study showed that adoption of conservation tillage would enable the soil to maintain nutrients, water and energy flows, micronutrients build up, and to recover from degradation or depletion after intensive exploitation, by enhancing root geometry, nutrient accessibility to crops, crops establishment and sustaining yields (Pretty *et al*., 1995). In addition, conservation tillage would save the farmer up to 35% of total farming costs in terms of real costs, the time and effort put in from reduced power needs, sizeable decreases in capital investments i.e. less machinery and less powerful tractors are needed and significant reduction in labor requirements (Ithinji *et al*., 2002).

Based on soil type, soil profile, labor and economic considerations, increased soil fertility and wheat yields, conservation tillage systems MT1, MT2 and NT would be preferable as a way of conserving moisture and fertility under similar conditions to those of the area studied. These systems have an important component in that crop residues are left on the surface. Farmers should be encouraged to increase biomass accumulation in their farms by growing green manures and mulching to increase organic matter in soil.

Choice of any of the reduced tillage systems MT2, MT1 or their combination for a particular farm would be guided by soil profile and previous tillage practices. Shallow topsoil may require NT or in some cases MT1 where grass weeds dominate. Where there is broad leaf, a chopper may first be used to cut the weeds and flatten the stubble, thus bringing the residue in contact with the soil surface, which hastens decomposition, and therefore increased soil organic matter. Soil organic matter serves as a slow release nutrient store and also regulates soil temperature and moisture. Where there is hardpan, e.g. after 30 cm depth, MT2 may be used to improve permeability and improve nutrient, water and energy flows.

An appropriate policy should be formulated to spur adoption of conservation tillage in central Rift Valley. This should include local manufacture of conservation tillage implements especially the seed drill. Availability and affordability of herbicides should be put into considerations under all practices. Another incentive to the farmers could be linking adoption of conservation tillage to eligibility criterion for access to Agricultural Finance Credit from banks.

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