Evaluating Soil Quality and Productivity of Different Clusters in Kabanon-Kapkamak Irrigation Scheme, Kenya

MuyaE. M.[*1], YegonJ.[3], MangiP. M.[1], GachiniG.N.[1], ChekA.L.[1], ThuraniraE. G.[1], GoroH.[4], OwengaP.[1], WasikeV.[2], Kirigua V.[2] and Mainuri Z.G.[5]

[1]Kenya Agricultural and Livestock Research Organization (KALRO), Food Crop Research Institute, P.O. Box 14733-00800, Nairobi; [2]KALRO Headquarters, P.O. Box 57811, Nairobi; [3]KALRO-Perkerra, P.O. 32, Marigat; [4]Small Scale Horticulture Development, Ministry of Fisheries, P.O. Box 30028, Nairobi
[5]Egerton University, P.O. Njoro 536-20115, Egerton

Corresponding: edwardmuya2011@gmail.com or edwardmuya@yahoo.com

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Abstract

This study investigated soil conditions with an objective of differentiating the area into different clusters on the basis of topographical characteristics, hydrological processes, and degree of erosion, soil surface characteristics, soil colour, depth, texture, structure and consistence across the rolling uplands into the valley bottom. Within each cluster, five composite (replicate) samples were collected at the depth of 0-20 cm and subjected to laboratory determination of soil quality attributes such as pH, soil organic carbon, macro- and micro-nutrients. The adequacy of soils for plant growth was assessed, using semi-quantitative land evaluation methods, where ranges of numerical values of the selected soil quality indicators were rated and assigned fractional values (in percentage). The functional relationships between the measured soil quality attributes and relative crop yields were applied to determine the soil quality and productivity index for describing the biophysical production potential of each of the clusters. All the soil data and land evaluation processes were subjected to analysis of variance (ANOVA) at 95% confidence level, using Genstat Computer Software. Six clusters were identified and the major differences between them were found to be the degree of erosion, stratification and compactness, with an important bearing on the planning and designing of the irrigation layout. The soil pH for all the clusters fell between 6.0 and 7.6, an appropriate pH for most crops. The variations of soil pH between different clusters were found to be insignificant ($P>0.05$). The most limiting factors were found to be nitrogen and soil organic carbon, with percentage deficiency levels ranging from 51 to 76 in

all the six clusters. These deficiencies called for blanket fertilizer recommendation across the six clusters with respect to all soil quality indicators with exception of phosphorous and potassium. Since phosphorous and potassium levels varied widely between the six clusters, the fertilizer types and levels required to enhance the availability of these nutrients to plants should be cluster-specific.

Key words: Soil quality, soil productivity and clusters

Introduction

With the advancement of agriculture, soils are being degraded at alarming rate by wind and water, desertification, acidification, salinization, adverse alteration of C:N ratio and decline in soil productivity (Sharma *et al.,* 2004). Therefore, baseline information on soil productivity and its spatial variability is not only necessary for determining the types and quantity of fertilizers to apply, but also appraising the current state of soil quality and management against which the impacts of intervention will be measured and monitored. Growing of crops one after another without giving due consideration of the status of soil quality and health as well as nutrient requirements of the crops being grown has resulted into the decline in soil fertility, especially nitrogen (Ghosh *et al.*, 2003). Assessment of baseline soil productivity, based on the analysis of soil quality index that reflects changes over various spatial and temporal scales has been suggested by Hussain *et al.,* (1999) as a tool for deciding on the corrective actions to improve soil productivity for sustainable agricultural production. In recent years, soil quality research has focused on establishing the linkages between management practices, soil processes and observable soil characteristics (soil quality indicators) that are integrally compounded into indices of their functions and productivity.

The soil quality indicators to include in an index are selected on consideration of their effects on crop yield and soil functions which are site and cluster specific and oriented to the user's focus on biophysical sustainability (Lewandowski *et al.,* 1999). The soil functions specific for Kabanon-Kapkamakare those required for improvement of soil health for enhanced organic matter and nutrient supply, especially nitrogen and phosphorous, which were found to be limiting to sustained agricultural production (Muya *et al*., 2013). In this case, soil health constitutes the biological systems, their functions as well as soil conditions that enhance or limit the desired biological activities, depending on the gap between the actual soil conditions and their critical/optimal levels. A critical or optimal level of a given soil is defined as a numerical value of a soil property where crop yield is 80% of the maximum yield. Understanding the cause-effect relationship between soil properties and yield as well as their spatial variability is essential for developing recommendations for sustainable management of soils for enhanced crop production and environmental sustainability (Aune and Lal, 1997)). Fertilizer response curves have been developed but often without consideration of the generic relationships between soil properties (soil quality indicators) and crop yield (Sanginga and Woomer, 2009). Therefore, the critical limits and functional relationships between soil properties and relative crop yields developed by Aune and Lal (1997) may be applied through quantitative and semi-quantitative land evaluation processes to derive the soil quality index for characterizing the productive capacities of different clusters as well as their spatial variability. This will provide a reasonable basis of prescribing the appropriate types and quantities of agricultural inputs for enhanced crop production and environmental sustainability. For the degraded soils, increased crop production and enhanced environmental sustainability may be achieved mainly through increased organic matter content for, not only soil aggregate formation and stabilization, but also nutrient supply through improved carbon/nitrogen ratio.

The major biological activities required for improved organic matter levels and nitrogen supply in the soil are decomposition processes which depend on the interactions between soil quality attributes and the biological systems within different agro-ecosystems (Ridder *et al.,* 1982).Management, aimed at optimization of these interactions through improved soil quality is required for enhanced supply of nutrients from soil nutrient reserves for improved nutrient use efficiency and sustainable agricultural production value chains. According to the Government of Kenya (2011), the long-term economic prospects for value chains depend on the effective stewardship of the natural resources upon which they depend. Unless care is taken the value chain development can undermine the ecosystem services through inappropriate use and management of land resources, leading to severe ecosystem degradation. This can be avoided by prescription of agricultural inputs and management strategies, based on the diagnostic analysis of the state of soils and production systems with respect to the envisaged cropping patterns and agricultural production value chains. Against this background, the objective of the study was to characterize and cluster production systems into spatial polygons or domains, based on physical, hydrological and chemical attributes with direct or indirect influence on soil quality and productivity.

Materials and Methods

Location of the Research Site

Kabanon/Kapkamak Irrigation Scheme is located in Elgeyo Marakwet County in West Marakwet District. The project is located in Tunyo Division in Marakwet West Sub – County of Elgeiyo Marakwet County. It is situated at approximately latitude $0^{o}56'$ North and Longitude $35^{o}37'$ East at a mean altitude of 1019 metres above sea level. It utilises water from Arror River for irrigation.

Description of the Research Site

The research area is targeted by the Small Scale Horticulture Project (SHDP) for irrigation development. The project which was initiated in 2008 and is still at the implementation stage i.e. production has not yet started. The project area receives average rainfall between 850 – 1000 mm per year.

There are 853 Households, distributed into the two Kabonon and Kapkamak clans with a population of 3562 persons. The average farm size is about 0.8ha. The scheme has been in existence for over 200 years using traditional furrow irrigation over the years to discharge water from the main river into the farms. In the individual fields, the irrigation method practiced is flooding/basin. Small Scale Horticulture Project (SHDP) intends to improve the system of surface to overhead sprinkler system. Currently, the area under irrigation is approximately 200ha. It is projected that the targeted area by SHDP is 602 ha.

Field Investigation and Clustering Production Systems

Systematic auger boring was carried out on the transects across the rolling uplands into the valley bottom. At each auger observation point, topographical characteristics, hydrological processes, degree of erosion, soil surface characteristics, soil colour, depth, texture, structure and consistence were studied and applied in differentiating the area into different clusters. Within each cluster identified, five composite (replicate) samples were collected at the depth of 0-20 cm for laboratory analysis.

Laboratory Determinations

The soil samples were air dried and sieved through a 2-mm sieve. Soil pH was measured in 1:2.5 soil: water mixture, using the relevant electrodes according to Hinga *et al.*, (1980). Organic carbon was oxidized with concentrated H_2SO_4 and K_2CrO_7 and determined calorimetrically (Anderson and Ingram, 1993). Total N was determined using the method provided by Okaleb *et al.*, (2002). Cation exchange capacity (CEC) and exchangeable cations were extracted using 1N ammonium acetate at pH 7.0, followed by flame photometry for the determination Na, K, Mg and Ca, using flow analyzer (Okaleb, 2002). Soil texture was determined using hydrometer method (Hinga *et al.,* 1980).

Indexing the Soil Quality Attributes

The ability of soil to maintain or enhance crop production was measured by compounding all the relevant soil quality attributes into indices that can be applied in monitoring soil productivity under different land use systems.

Indexing of soil quality and soil productivity was done, using semiquantitative land evaluation methods (Da Lo Rose and Van Diepen, 2002; Driessen and Konijn, 1992), where ranges of numerical values of the selected soil quality indicators were rated and assigned fractions in percentage, being guided by the critical limits of the indicators (Table 1). The critical limit of an indicator is defined as the numerical value of the soil property where crop yield is 80% of the maximum yield (Aune and Lal, 1997).

Productivity index (PI) was determined using parametric methods of land suitability assessment provided by Driessen and Konijn (1992) that involved assigning ranges of numerical values and percentage fractions to each soil property selected as key soil quality indicators and ranking (Table I) and combining all the single factor valuations in one mathematical equation that produces a numerical expression of the system performance or a relative index of performance (compounding) as follows:

$$PI = (SQ1/100) \times (SQ2/100) \times (SQ3/100) \times (SQn/100)$$

Where:

PI = Productivity index in % and SQ1, SQ2, SQ3, SQn are percentage ratings of soil quality indicator number 1, 2, and number n. The numerical values of the measured soil quality attributes were obtained from the crop response functions in Figures 1 to 5.

Table 1: Ratings of soil quality indicators

Soil quality indicator	**Ranges of numerical values**	**Assigned values in %**	**Ratings**	**Remarks**
Soil pH	5.6-6.8 or 4.8-5.5	100	1	80% of the maximum yield of maize obtained from pH of 5.1 (Aune and Lal, 1997)
	4.8-5.5 or 6.9-7.5	80	2	
	4.0-4.7 or 7.6-8.7	60	3	
	3.5-4.5 or 8.7-10.0	40	4	
	<3.5 or >10.0	20	5	
Exchangeable sodium percentage	<2.0	100	1	The permissible environmental threshold is 6 where maize yield is 80% (Weeda, 1987)
	2.1-10.0	80	2	
	10.1-20.0	60	3	
	20.1-35.0	40	4	
	>35.0	20	5	
Bulk density (g/cc)	<1.2	100	1	According to PIERCE et al (1986), bulk density of 1.0-1.4 gave sufficiency of 100%
	1.3-2-1.5	100	2	
	>1.5	75	3	
Potassium (m.e./100g)	>0.5	100	1	80% of the maximum yield obtained by the value 0.7 (Aune and Lal, 1997)
	0-2-0.5	80	2	
	0.1-0.2	60	3	
	<0.1	40	4	
Phosphorous (ppm)	>60	100	1	7.6 ppm gave 80% of the maximum yield of maize (Aune and Lal, 1997); threshold value of 20 ppm to be applied for soil fertility appraisal.
	21-60	90	2	
	10-20	80	3	
	<20	70	4	
Soil organic carbon (%)	>2.5	100	1	Threshold value of 2.0 to be applied for appraising the soil fertility status (Weeda, 1987)
	1.6-2.5	90	2	
	1.0-1.5	80	3	
	<1.0	70	4	
Nitrogen (%)	>2.0	100	1	Threshold value of 2.0 to be applied for appraising the soil fertility status (Weeda, 1987)
	1.5-2.0	90	2	
	1.0-1.5	80	3	
	<1.0	70	4	

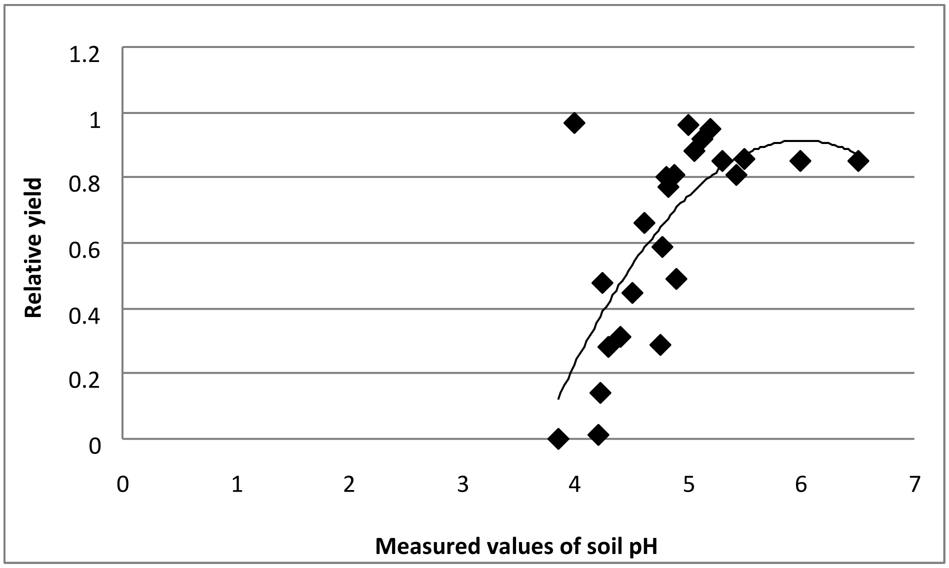

Figure 1: Functional relationships between soil pH and relative yield of maize after Aune and Lal (1997)

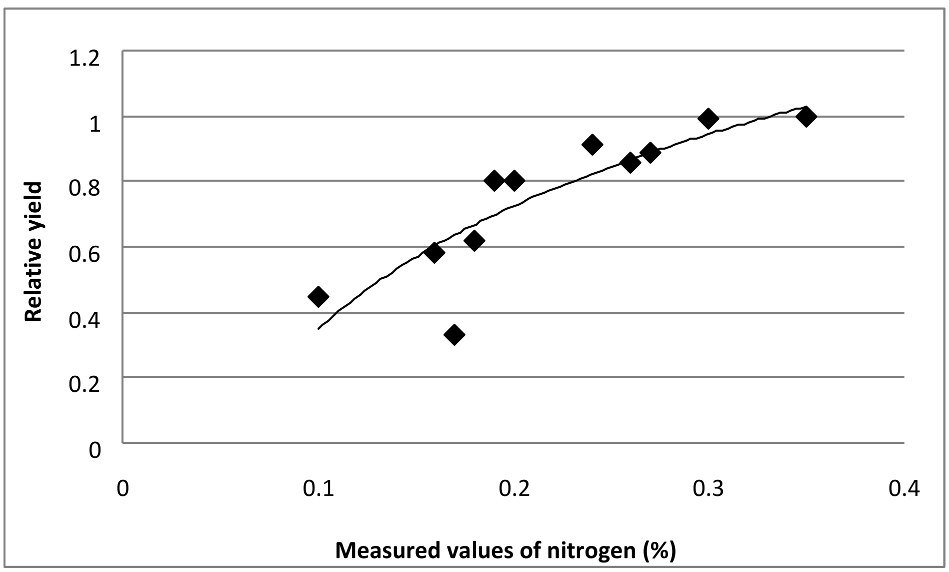

Figure 2: Functional relationships between nitrogen and relative yield of maize after Aune and Lal (1997)

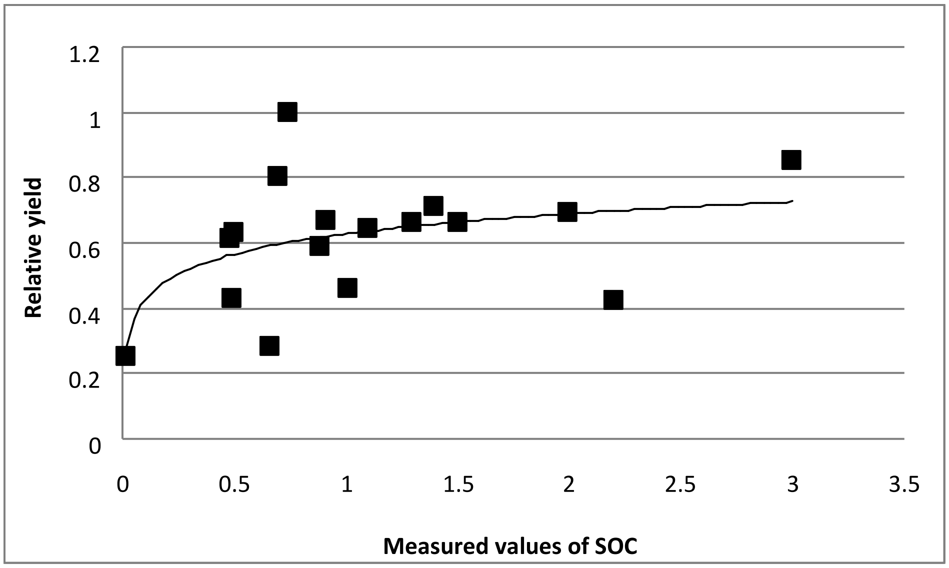

Figure 3: Functional relationships between soil organic carbon and relative yield of maize after Aune and Lal (1997)

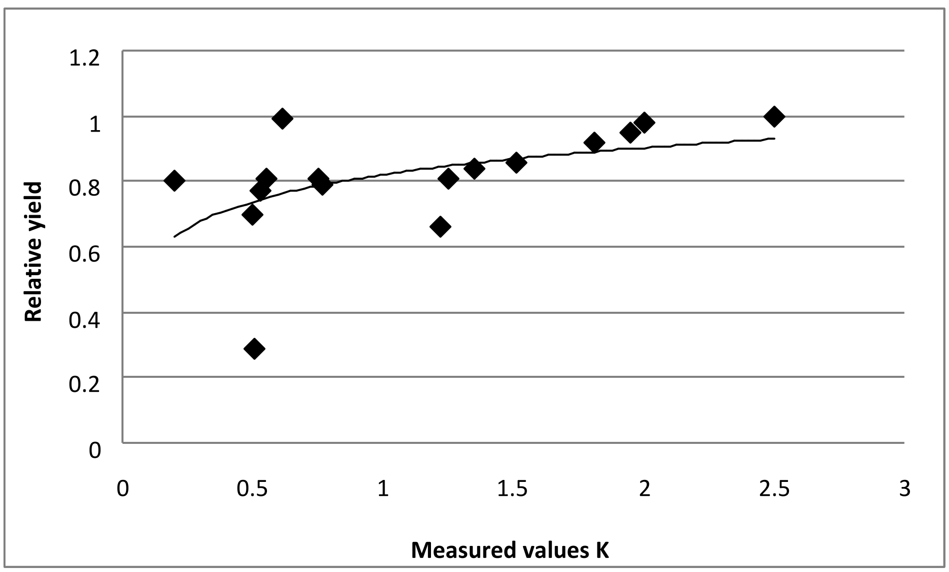

Figure 4: Functional relationships between potassium and relative yield of maize after Aune and Lal (1997)

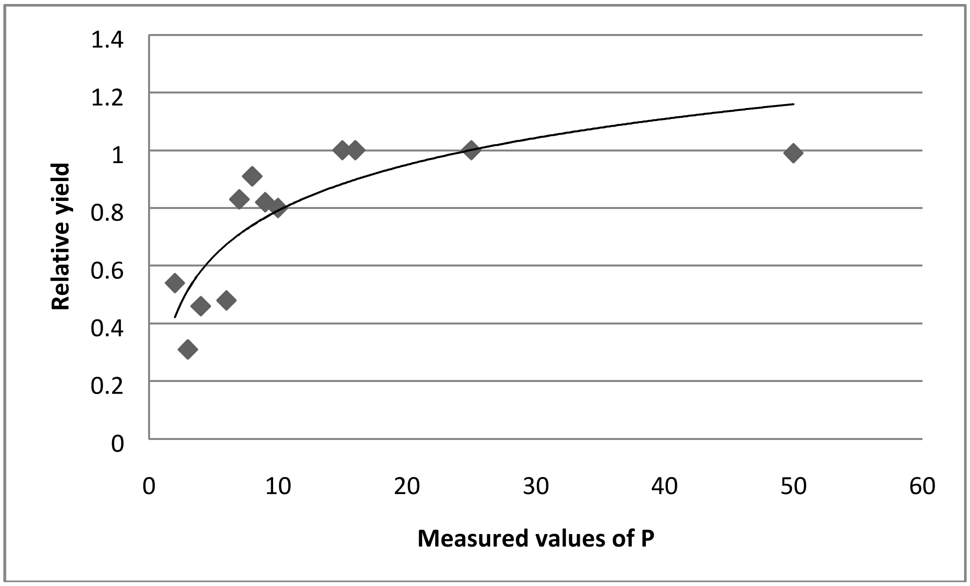

Figure 5: Functional relationhips between the measured values of phosphorous and relative yield after Aune and Lal (1997)

To assess the homogeneity of the identified clusters, the variations in the selected soil quality attributes and PI within and between the clusters were evaluated by subjecting the data obtained from laboratory determinations to analysis of variance (ANOVA) at 95% confidence level, where those soil quality indicators with significant levels were separated using Genstat Computer Software.

Results and Discussions

Identified Clusters and their Implications on Irrigation System Design

The six clusters identified are shown in Table 2 and Figure 7. Cluster 1a1 and 1a2 were found to be similar in terms of topographical and drainage conditions as well as textural characteristics. However, they varied in land use, soil surface characteristics and degree of erosion. The major difference in soil conditions between the six clusters was found to be the degree of erosion, stratification and compactness, with cluster 3 being the most severely eroded and not recommended for irrigation. Cluster 4 consisted of the most highly stratified soils, while cluster 5 was found to be extremely compact. The most loose and friable soils were found in cluster 6. The variations in these physical parameters between different clusters have an important bearing on the planning and designing of the irrigation layout since they influence the hydraulic properties of soils that determine types and capacities of water distribution structures (Muchangi *et al.,* 2005). Goulburn Broken (2004), reported that the irrigation system, water application methods and scheduling, based on the knowledge of hydraulic properties of soils yielded irrigation efficiency of more than 75%. Therefore, Muya *et al.,* (2012) recommended that the physical and hydraulic properties of soils should accompany the identified clusters to be superimposed on the preliminary layout of the design for improved irrigation efficiency of the existing schemes. In addition to the hydraulic properties of the soil, the designed water supply into individual fields through the tertiary structures should be understood and compared with the irrigation schedules designed on the basis of the actual crop water requirements and the hydraulic parameters. This is because irrigation design, based on hydraulic parameters and crop water requirements will lead to an efficient practice that will minimize loss of nutrients through leaching and run-off due to excess irrigation applications (Muya, *et al.,* 2012).

Table 2: Clusters identified and their characteristics

Clusters	Description
Cluster 1a1	Well drained, dark reddish brown to red, very deep, sandy clay, in places with gravelly and rocky surfaces with gully formation through increased erosion. Land use: green grams, maize, mangoes, sorghum, on rolling and undulating uplands.
Cluster 1a2	Well drained, dark reddish brown to red, sandy clay to clay, mainly uncultivated, under trees, shrubs, herbs, and grass on very gently sloping to steep, undulating uplands.
Cluster 3	Highly susceptible to erosion in places severely degraded with huge gullies, being mainly under trees, shrubs and herbs. Not recommended for irrigation
Cluster 4	Stratified, loamy sand to clay loam developed on colluvial materials, land use being mainly maize, green grams and sorghum.
Cluster 5	A complex of extremely compact, sandy loam with strong surface sealing and stratified loamy sand to sandy clay loam/clay loam, main crops being green grams and sorghum.
Cluster 6	Sand to sandy clay loam, loose, soft to very friable on bottomlands, land use being mainly maize and green grams

Macronutrients and their Implications on Fertilizer Inputs

The mean soil pH for most clusters fell between 6.0 and 7.6, with L.S.D. and CV of 0.55 and 0.58 respectively (Table 3). The pH values between 5.5 and 7.0 are appropriate for most crops (Cornell University, 2005). Extremely high soil pH above 7.5 has indirect adverse effects on plant growth by causing induced nutritional disorders such as P, Fe, and Zn deficiencies and NH^{3-} and HCO^{3-} toxicities (Redulla *et al.,* 2002). The variations of soil pH were found to be insignificant ($P>0.05$) between clusters 1a1, 3, 4 and 5, which should, therefore, be treated as one management unit (with respect to soil pH), while clusters 1a2 and 6 should fall within a different unit. Nitrogen level ranged from 0.05 to 0.10, being highest and lowest in cluster 3 and 6 respectively, with L.S.D and CV value of 0.027 and 27.900 respectively. The variations in the level of nitrogen (0.052a - 0.066a %) for clusters 3, 4 and 5 were found to be insignificant ($P>0.05$). Clusters 1a1, 1a2 and 6 showed a similar pattern with the levels ranging from 0.07 to 0.10%. However, the mean value of nitrogen for all the six clusters was found to be lower than the optimum level of 0.2% provided by Aune and Lal (1997). This called for blanket application of fertilizers across all the six clusters as far as nitrogen is concerned. The mean value of soil organic carbon (SOC) ranged between 0.486 and 0.916, with L.S.D. and CV of 0.265 and 28.5% respectively. Although there were significant variations in SOC between some clusters, the organic inputs to be applied to raise it to optimal level should be the same since it is far much lower than the critical level for all the clusters. The mean value of phosphorous (P ppm) was found to vary widely and significantly between clusters, ranging from 2 to 131 with L.S.D. and CV of 95.5 and 158.6% respectively. Potassium (K me%) and calcium (Ca me%) assumed the same pattern, with K having values ranging from 0.52 to 1.024 me% (L.S.D. and CV being 0.43 and 46.1 respectively), while the latter had 1.64 to 2.78 me%. The lowest level of magnesium occurred in clusters 4 and 5 with values of 1.49a and 2.94b respectively, while clusters 6, 1a1, and 1a2 had values>3.00 me%, L.S.D and CV being 0.948 and 23.7% respectively.

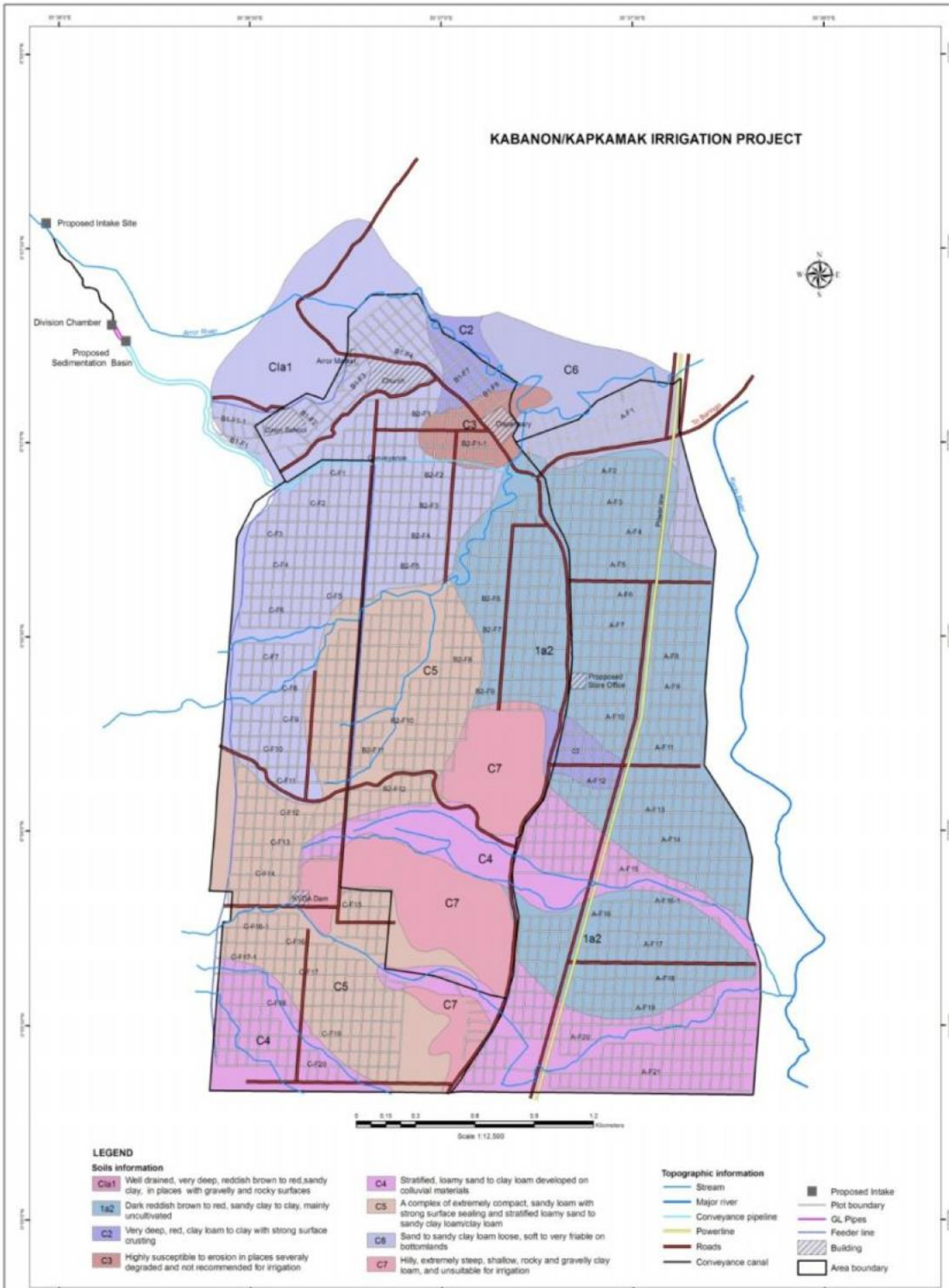

Figure 7: Cluster map

<u>Table 3:</u> Mean values of soil quality attributes

Clusters	Soil quality attributes						
	Soil pH	N%	SOC%	P ppm	K me%	Ca me%	Mg me%
1a1	7.41b	0.072ab	0.680ab	2	0.476	1.70	3.87b
1a2	6.64a	0.094b	0.916bc	39	0.872	2.62	3.26b
3	7.5b	0.052a	0.486a	3	0.708	2.78	3.46b
4	7.49b	0.06a	0.560a	48	0.520	1.64	1.49a
5	7.51b	0.066a	0.612a	51	0.660	2.42	2.94b
6	6.82a	0.098b	0.976a	131	1.024	3.06	3.15b
L.S.D	0.5493	0.02709	0.264	95.5	0.4315	1.354	0.948
CV%	0.58	27.9	28.5	158.6	46.1	43.3	23.7

Key: N=Nitrogen; SOC=Soil organic carbon; P=phosphorus, K=Potassium; Ca=Calcium; Mg=Magnesium; me=Millequivalent and ppm=Parts per million; L.S.D.=Least Standard Deviation; CV=Coefficient of variations

Most of the soil quality attributes were found to be deficient and appropriate management practices are required to bring their levels to the threshold value for sustained crop production (Table 4). The most limiting factors were found to be nitrogen and soil organic carbon, with percentage deficiency levels ranging from 51 to 76 in all the six clusters. However, the highest level of deficiency was phosphorous, occurring in cluster 1a1 and 3, with deficiency level of 90 and 85% respectively. The rest of the clusters had no deficiency of this nutrient element. Potassium was found to be least limiting. These deficiencies called for blanket fertilizer recommendation across the six clusters with respect to all soil quality indicators with exception of phosphorous and potassium. Since phosphorous and potassium levels varied widely between the clusters, the fertilizer types and levels required to enhance their availability should be cluster-specific.

Table 4: Deficiency of soil quality attributes

Soil quality level	Threshold clusters in % and C:N ratio	The magnitude of deficiency in different attributes					
		1a1	1a2	3	4	5	6
Nitrogen	0.2%	64	53	74	70	67	51
Soil organic carbon	2%	66	54	76	72	69	51
Phosphorous	20 ppm	90	ND	85	ND	ND	ND
Potassium	0.8 me%	40	ND	9.2	35	14	ND

Key: ND=Not deficient; C: N=Carbon-Nitrogen Ratio

Micronutrients and their Management Implications

The mean values for all the micronutrients (Table 5) were found to be below the critical limits given in Table 6, meaning that application of fertilizers is mandatory to supply the required micronutrients to the level required for optimal plant growth. The mean value of copper ranged from 1.946a and 3.356c ppm in cluster 3 and 1a2 respectively. The variation of the mean values of copper between cluster 3 and 1a2 was significant ($P<0.05$) hence the two clusters should be treated as two different management units as opposed to the rest, which shows insignificant difference. Mean iron value varied from 25.02a to 49.6c , while zink was in the range of 2.1 to 3.03 ppm. Since the variations of zink between different clusters were significant (L.S.D. and CV being 1.48 and 44% respectively), the quantity of zink fertilizer to be applied should be commensurate with level of zink in the soils of each cluster thereby avoiding blanket application. Manganese varied from 0.354a in cluster 1a1 to 0.588b in cluster 5 (L.S.D and CV, being 0.1421 and 24.1% respectively.

Table 5: Mean levels of micro-nutrients

	Micronutrients				
	Cu ppm	**Fe ppm**	**Zn ppm**	**Na me%**	**Mn me%**
1a1	3.356c	34.9ab	2.4	0.160	0.354a
1a2	2.31ab	31.2ab	2.53	0.236	0.462ab
3	1.946a	25.02a	2.10	0.316	0.378a
4	2.37ab	49.6c	3.03	0.164	0.408a
5	2.824bc	41.2bc	2.29	0.176	0.588b
6	2.284ab	37.5bc	3.05	0.216	0.494ab
L.S.D	0.818	13.16	1.48	0.1003	0.1421
CV%	24.7	27.3	44	36	24.1

Key: Cu=Copper; Fe=Iron; Zn=Zink; Na=Sodium; Mn=Manganese

Table 6: Critical limits of the micronutrients

Types	**Deficient**	**Marginal**	**Adequate**
Copper	0-0.4	0.5-0.6	>0.6
Iron	0.0-0.6	0.7-1.0	>1.0
Manganese	0.0-0.7	0.7-1.0	>1.0
Zink	0.0-0.5	0.6-1.0	>1.0

Source: Jason Cathcart (2013)

Soil Quality Index in Relation to the Current Practices

As indicated by the soil quality index in Figure 8, all the soil quality attributes were found to be over 50% adequate for sustainable crop production in respect to: soil pH in all the clusters; soil organic carbon (SOC) in cluster 1a2 and 6; phosphorous in clusters 1a2; potassium in clusters 1a2, 3, 4 and 6. The rest of the clusters were less than 50% adequate, hence relatively very low productivity. However, 50% adequacy indicates the potential nutrient reserves, which may only be tapped through improved mineralization processes by the soil organisms, whose functions are dictated by the soil quality and health. For example, Richard and Simpson (2011) demonstrated how a given group of microorganisms can be manipulated, through management, to enhance the availability of P, which would, otherwise remain locked up within the soil nutrient reserves. Therefore, the generally low productivity index (PI) of most clusters, indicated in Table 7 could be attributed to impeded soil's capacity to mineralize and tap the locked up nutrients from the reserves. FAO (1995) showed that the physicochemical locations and soil micro-environments in which these organisms occur are characterized by the soil quality attributes whose mutual interactions, not only determine the soil health, but are also influenced by management.

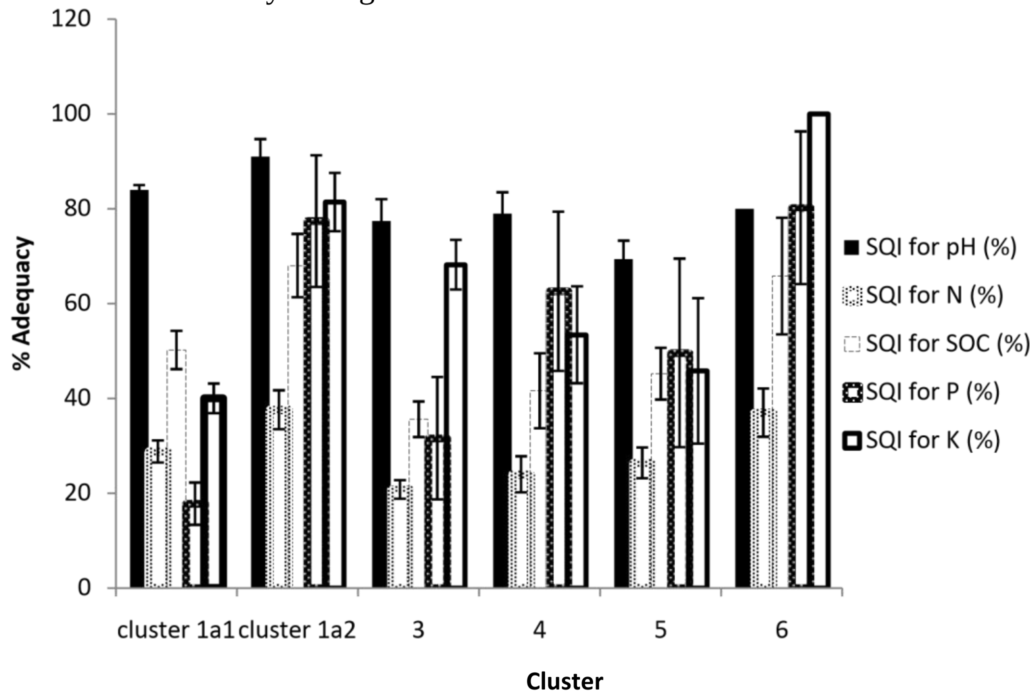

Figure 8: Adequacy levels for different soil quality indicators

The productivity index of all the clusters varied between 1.0 and 8.4%, being far much lower than the threshold value of 50% provided by Aune and Lal (1997). This was attributed to inadequate levels of all the soil quality attributes except soil pH with index of over 50% (Table 7). The low soil productivity could be the explanation of the yield gaps of the major crops grown in the project area reported by Muya *et al.,* (2013) as indicated in Table 8.

Table 7: Soil quality and productivity index for different clusters

	Soil quality and productivity index					
Clusters	**Soil pH**	**N**	**SOC**	**P**	**K**	**PI %**
1a1	0.85bc	0.15ab	0.63abc	0.2	0.73a	1.0
1a2	0.85c	0.18c	0.64c	1.0	0.80cd	7.0
3	0.65ab	0.11a	0.58a	0.28	0.78b	1.0
4	0.65ab	0.12a	0.61a	1.0	0.74ab	4.0
5	0.65a	0.12a	0.61ab	0.61	0.79ab	2.0
6	0.85b	0.19ab	0.64bc	1.0	0.81ab	8.4
LSD	10.78	11.03	22.5	47.04	25.36d	
CV%	10.2	28.7	33.4	67	29.7	

The high yield gaps indicated in Table VIII are attributed to inappropriate management practices that include: cultivation up and down the slopes using tractors without conservation structures, planting low yielding crop varieties, broadcasting seeds without thinning, hence heavy nutrient mining, little organic and inorganic fertilizer inputs, no systematic cropping sequence or rotation, no pests and disease control measures. Currently in the scheme no organic/inorganic fertilizers are used the reason being belief that the land is still fertile.

Table 8: Production levels and yield gaps of major crops in Kabanon-Kapkamak Irrigation Scheme

Crop	Baseline level of production without agricultural inputs under rainfed agriculture	Production under optimal conditions	Yield gap (%)
Rice	4 tons/ha	8 tons/ha	50.0
Green grams	10 bags/ha	60 bags/ha	83.3
Cassava	2.5 tons/ha	20 tons/ha	87.5
Onions	5 tons/ha	45 tons/ha	88.9
Banana	20 tons/ha	60 tons/ha	66.7
Water melon	5 tons/ha	35 tons/ha	85.7
Millet	12.5 bags/ha	200 bags/ha	93.8
Sorghum	15 bags/ha	55 bags/ha	72.8
Maize	15 bags/ha	90 bags/ha	83.3

Source: Muya *et al.*, (2013)

Conclusions and Recommendations

The study established the existence of six clusters in Kabanon-Kapkamak scheme. On the basis of the physical parameters applied in their characterization and delineation, each cluster was found to differ from any other adjoining clusters to an extent that it would respond differently to irrigation water management. The major differences between these clusters were found to be the degree of erosion, stratification and compactness, with an important bearing on the planning and designing of the irrigation layout. This is because these physical parameters influence the hydraulic properties of soils that determine the types and capacities of water distribution structures. The identified clusters were described as follows: cluster 1a1 – well drained, sandy clay, in places, rocky with gully formation through increased erosion; cluster 1a2 - gently sloping to steep, undulating uplands, mainly uncultivated and comprising sandy clay to clay; cluster 3 – highly vulnerable to erosion, severely degraded with deep gullies and not recommended for irrigation; cluster 4 – stratified loamy sand to clay loam, being developed on colluvial materials with the main crops being maize, green grams, and sorghum; cluster 5 – a complex of extremely compact, sandy loam, with strong surface sealing and stratified loamy sand to sandy clay loam/clay loam with the main crops being green grams and sorghum; cluster 6 - sand to sandy clay loam, loose, soft to very friable on bottomlands, land use being mainly maize and green grams.

The mean value of soil pH for all the clusters fell between 6.0 and 7.6, the level being appropriate for most crops. The variations of soil pH between different clusters were found to be insignificant ($P>0.05$), hence the recommendation that all the six clusters be aggregated into one management unit with respect to soil pH. The mean values of nitrogen, soil organic carbon and micro-nutrients fell below the threshold levels for all the clusters. Most of the soil quality attributes were found to be deficient and appropriate management practices are required to bring their levels to the threshold value for sustained crop production. The most limiting factors were found to be nitrogen and soil organic carbon, with percentage deficiency levels ranging from 51 to 76 in all the six clusters. However, the highest level of deficiency was phosphorous, occurring in cluster 1a1 and 3, with deficiency level of 90 and 85% respectively. The rest of the clusters had no deficiency of this nutrient element. Potassium was found to be least limiting. This called for blanket fertilizer recommendation across the six clusters with respect to all soil quality indicators except phosphorous and potassium. Since phosphorous and potassium levels varied widely between the clusters, the fertilizer types and levels required to enhance the availability of these nutrients to plants should be cluster-specific.

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References

Aune, J. B. and Lal, R. (1997). Agricultural productivity in the tropics and critical limits of properties of Oxisols, Ultisols and Alfisols. *Trop. Agric. (Trinidad)* Vol. 74. No 2, pp 96-102.

Cornell University. (2005). Soil pH for field crops: Nutrient Management Spear Program – *Agronomy Facts Sheet*.

Driessen, P.M. and Konijn, N.T. (1992). Land use systems analysis. Lecture Notes, Wageningen Agricultural University.

Ghosh, P.K., Dayal, D., Wanjari, K.G. and Hati, K.M. (2003). Optimization of fertilizer schedules in fallow and ground nut-based cropping systems and an assessment of system sustainability. Field crop Research, 83-98.

Hussain, I., Olson, K.R., Wander, M.M., and Karlen, D.I. (1999). Adaptation of soil quality indices and application to three tillage systems in Southern Illinois. *Soil Tillage Research*, 50, 237-249.

Hurni, H. (1997). Concepts of sustainable land management. *ITC Journal*, pp 210-214.

Hinga, G., Muchena, F.N. and Njihia, C.M. (1980). Physical and chemical methods of soil analysis.

Muya, E.M., Nafula, L.S., Macharia, E. and Owenga, P. (2013). Land suitability assessment for improved crop production and environmental sustainability in Mosiro Irrigation Scheme, Narok County: A Technical Report.

Muya, E.M., Yegon, P., Violet, V., Otipa, M., Macharia, J., and Owenga, P. (2013). Irrigation suitability assessment for sustainable land management in Kabanon-Kapkamak Scheme, Elgeyo Marakwet County: A Technical Report.

Muya, E. M., Njeru, E., Maingi, P. M., Chek, A. L. and Otipa, M. (2012). Irrigation suitability assessment for improved soil quality and water use efficiency. A Technical Report.

Muchangi, P., Sijali, I., Wendot, H. and Lempeierre, P. (2005). Improving the performance of irrigation in Africa: Irrigation systems and their operations. IPIA Training Source Book.

Redulla, C. A., Devenport, J. R., Evans, R. J., Hattendorf, M. J., Alva, A. K. and Boydston, R. A. (2002). Relating potato yield and quality to field scale variability in soil characteristics. *American Journal of Potato Research*, Vol. 79, Issue 5, pp 317-323.

Ridder, N. D., Stroosnijder, L., Cisse, A. M. and Keulen, H. V. (1981). Productivity of Sahelian rangeland: A study of soils, the vegetations and exploitation natural resources. Wageningen Agricultural University, The Netherlands.

Sanginga, N. and Woomer, P. L. (eds). (2009). Integrated Soil Fertility Management in Africa: Principles, Practices and Development Process. Tropical Soil Biology and Fertility Institute of the International Centre for Tropical Agriculture.

Sharma, K.L., Mandal, U.K., Srinivas, K., Vittal, K.P.R., Mandal, B., Grace, J.K., and Ramesh, V. (2004). Long-term sol management effects on crop yields and soil quality in a dryland Alfisol