5. RESULTS AND DISCUSSION

Results and discussions of the current work deals with some important items outlined in the following sequence:

5.1. Digital image pre-processing.

5.2. Digital image post processing.

5.3. Geomorphology and associated landforms.

5.4. Pedogeomorphology and soils of the different landforms.

5.5. Spatial variability of soil characteristics of the studied area.

5.6. Soil mapping and taxonomy.

5.7. Precision farming of the current work.

5.8. Economic and environmental profitability of PF at the experimental field level.

5.9. Economic and environmental profitability of PF at the studied area level.

5.10. Precision Farming Spatial Model (PFSM).

5.1. Digital image pre-processing

The ETM+ image was first examined visually for systematic and random noise errors caused, for example, by detector malfunction. Such errors can manifest as line dropouts and bit errors (**Lillesand and Kiefer 2007**). However, visual inspection of the imagery indicated the lack of any significant degradation caused by these errors therefore, no further corrections for noise were necessary. Prior to correcting any distortion or degradation of the image data, the studied area was spatially subsetted from the original image to reduce the volume of the data and processing time required for image data analyses.

An area of Interest (AOI) was created and the subsetting process was involved.

5.1.1. Radiometric and atmospheric correction

Radiometric correction involves the process of normalizing for variations resulting from sensor system degradation, illumination source, or sensor viewing angle; while atmospheric correction is a process to cure degradation of image quality caused by the influence of atmospheric interferences (dust, haze, smoke, etc) **(Aronoff, 2005)**. The effects of the atmosphere upon remotely-sensed data are not considered errors, since they are part of the signal received by the sensing device but the resulting satellite image will addresses variations in pixels intensities (DNs). However, it is important to remove atmospheric effects, especially for subsequent analysis so atmospheric correction aims to retrieve the surface reflectance of each object by removing the impact of atmospheric effects.

To correct the variations in atmospheric transmission, the digital numbers of the ETM+ image was converted to spectral radiance in units of watts per square meter per steradian per micrometer ($W/(m^2.sr.\mu m)$) and then the resulting spectral radiance ETM+ image was converted to exoatmospheric reflectance or top of atmosphere reflectance ranging from 0 to 1. The spectral profiles at one pixel of maize cultivation of ETM+ image before and after atmospheric correction could be shown in Figures 9 and 10 as reflectance expressed as relative reflectance.

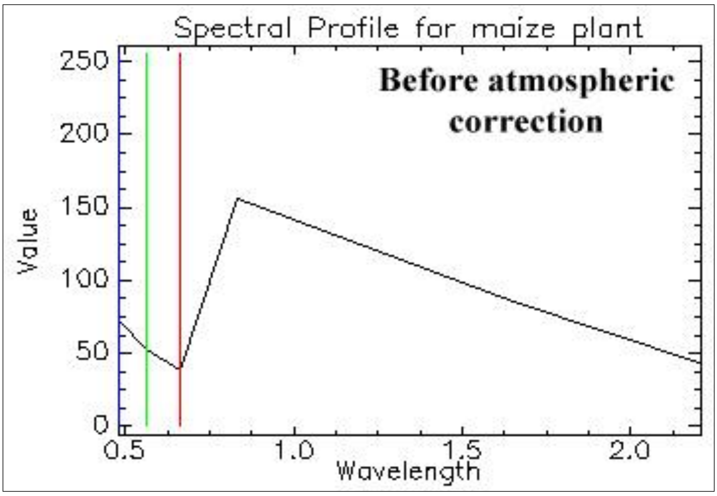


Fig. 9: spectral profiles of maize plant before atmospheric correction (wavelength in um).

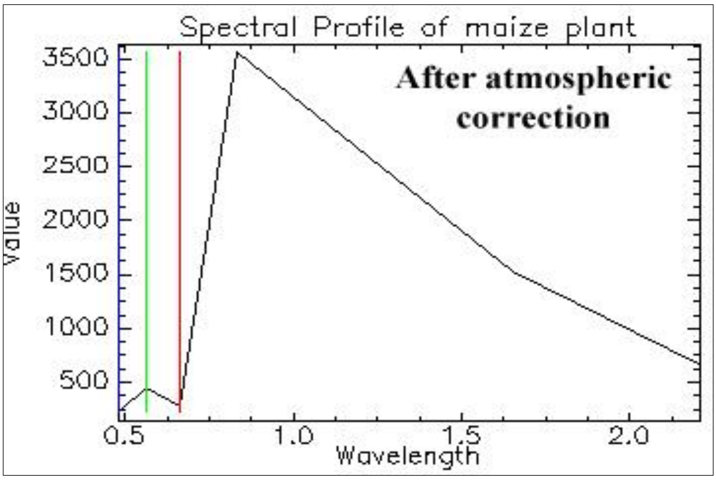


Fig. 10: spectral profiles of maize plant after atmospheric correction (wavelength in um).

It is noticed that after atmospheric correction, radiation was slightly reflected in the green band by the chlorophyll of maize plant, absorbed and reflected sharply in the red and near infrared bands representing the right spectral signature of the maize plant. As a result of atmospheric correction Visibility and Average Water Amount were calculated as 28.5340 km and 2.7848 cm respectively.

5.1.2. Image geometric correction

Geometric correction of satellite images involves modeling the relationship between the image and ground coordinate systems. There are both systematic and non-systematic geometric errors present in satellite imagery **(Jensen, 1996)**.

The systematic errors in Landsat imagery are well documented, and are primarily functions of scan skew, mirrorscan velocity, panoramic distortion, platform velocity, perspective and earth rotation **(Mather, 1999; Jenson, 1996).**

Data on sensor characteristics and ephemeris information are modeled and applied to the raw imagery as part of the systematic correction performed by the Landsat receiving stations **(Masek *et al.*, 2001)**. Assuming an accurate ephemeris based correction software model is implemented, systematic errors are corrected in commercially available Landsat imagery (e.g. ACRES Landsat-7 ETM+ Level 5 product). Non systematic errors are mainly caused by variation through time in the position and attitude angles of the satellite platform (Jenson, 1996). Without accurate sensor platform orientation parameters, these errors can only be corrected in image-to-map rectification or image-to-image registration with the use of Ground Control Points (GCPs) and a suitable precision photogrammetric or empirical model **(Mather, 1999; Jenson, 1996)**. The ETM+ image was rectified through image-to-map registration to the Universal Transverse Mercator Projection (UTM / zone 36 WGS

84) using a second-order polynomial transform. The used resembling method was the Nearest Neighbor (NN) which maintains data value integrity in the output data. More accurate geometric correction of the image is by obtaining RMS error with a value of less than one pixel. The obtained Root Mean Square Error (RMSE) for the geometric correction of the studied area image was 0.023 pixel, which means that, the error in the image dataset is 0.65 m. deviated from the location on earth.

5.1.3. Image Enhancement:

To increase the interpretation accuracy of the ETM+ image, an enhancement procedure was applied to the digital image of the studied area. The image enhancement was conducted for two reasons; the first reason is that the digital number range of pixels is narrow and this because of the design of satellite sensors which made to hold all the electromagnetic reflections of all the land features. The second reason is that because the studied area image is not covering the dynamic range of pixels that the landforms especially which are very similar in reflections such as sand dunes and sand flats are very close in electromagnetic reflection.

A contrast enhancement was applied on the digital image of the studied area by performing a linear contrast stretch to increase the pixels digital numbers range based on the pixels frequency with no clipping of both ends of image data range (Figure 11). This is particularly useful for displaying images with only a few data values, where clipping might saturate all of the values. The following Figure shows image histogram for ETM+ band 1:

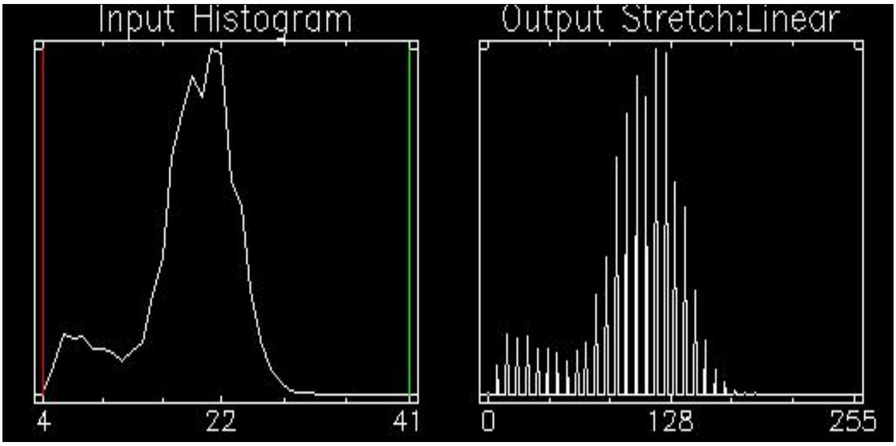


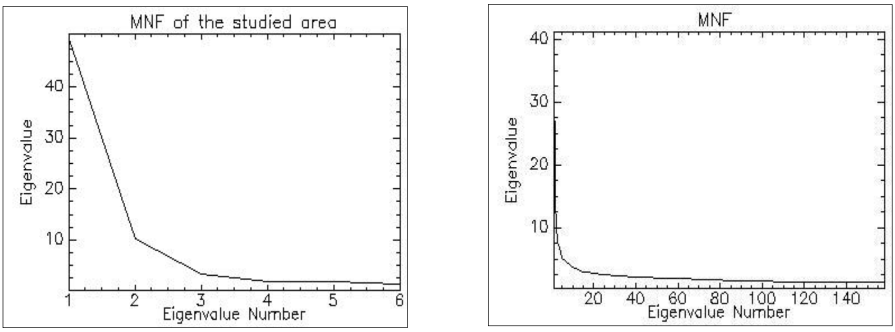
Figure 11: Image histogram for ETM+ band 1

5.2. Digital image post processing:

Digital image processing is to extract the statistical features characteristics and information.

5.2.1. Transformation of minimum noise fraction (MNF)

MNF transformation was used to determine the inherent dimensionality of image data, to segregate noise in the data, and to reduce the computational requirements for subsequent processing **(Boardman and Kruse, 1994)**. The MNF transforms as modified by **Green *et al.* (1988)**, it is a linear transformation that consists of the following separate principal component-analysis rotations: The first rotation uses the principal components of the noise covariance matrix to decorrelate and rescale the noise in the data (a process known as noise whitening), resulting in transformed data in which the noise has unit variance and no band-to-band correlations.The second rotation uses the principal components derived from the original image data after they have been noise-whitened by the first rotation and rescaled by the noise standard deviation. Since further spectral processing will occur, the inherent dimensionality of the data is determined by examining the final eigenvalues and the associated images. Data space can be divided into two parts: one part associated with large eigenvalues and coherent eigenimages, and another is a complementary part with near-unity eigenvalues and noise-dominated images. Using only the coherent portions separates the noise from the data, thus improving spectral processing results. Fig. 12 illustrates the minimum noise fraction for ETM (a) and Hyperspectral (b) images.

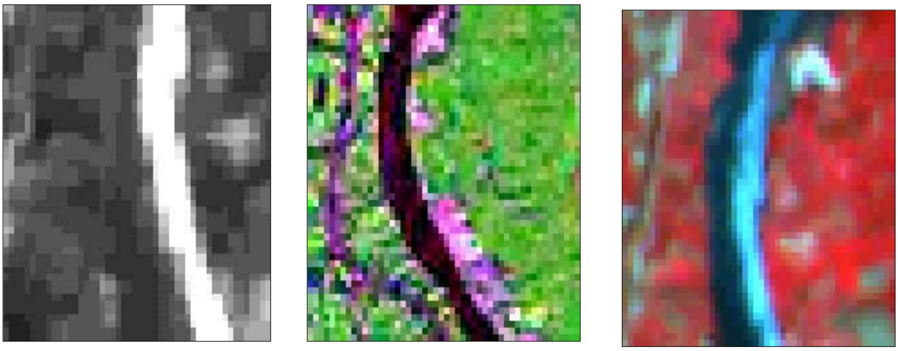


(a) ETM **(b) Hyperspectral**

Fig. 12: Minimum Noise Fraction for ETM (a) and Hyperspectral (b) images.

<u>5.2.2 Data merge (Fusion) of satellite images:</u>

Data merge was used to enhance the ground resolution of the low resolution image by merging the low-resolution multi-spectral image (ETM+) with a high-resolution gray scale image (MS SPOT5) (with resembling to the high-resolution pixel size).Color normalized was used to apply a merging technique that uses a mathematical combination of the color image and high resolution data. Each band in the color image is multiplied by a ratio of the high resolution data divided by the sum of the color bands. The function automatically resembled the three color bands to the high-resolution pixel size using nearest neighbor convolution. The output RGB images have the pixel size of 10 m high-resolution data. Figures (13 a, b and c) shows data merge for a part of the studied area. Fusion methodology was applied according to (**Ranchin and Wald, 2000).**



(a) SPOT5 pan before merge (b) ETM+ before merge (c) ETM+ after merge

Fig. 13: Data merge.

5.2.3. Image classification:

Image classification is producing meaningful material distribution maps by identification of individual pixels or groups of pixels with similar spectral responses (spectral signatures) to incoming radiation. These pixels or groups represent different materials or classes. The actual values associated with each pixel (digital numbers from 0-255 or reflectance percentage given as the ratio of reflected radiation to incoming radiation) are analyzed mathematically using computer driven algorithms. These algorithms attempt to determine the uniqueness of classes and to cluster similar pixels and groups of pixels into classes. Such algorithms are contained within several commercially and governmentally available software programs.

5.2.3.1.Unsupervised classification:

Unsupervised classification algorithms compare pixel spectral signatures to the signatures of computer determined clusters and assign each pixel to one of these clusters. Knowledge of the materials contained within the scene is not needed beforehand as the computer assesses the inherent variability and determines cluster identification. Classified distribution maps then require knowledge of the scene area in order to determine what each class (i.e. cluster) may represent in the real world.

In general, supervised classifications are more accurate than unsupervised. Figures 14 and 16 show the two kinds of classification.

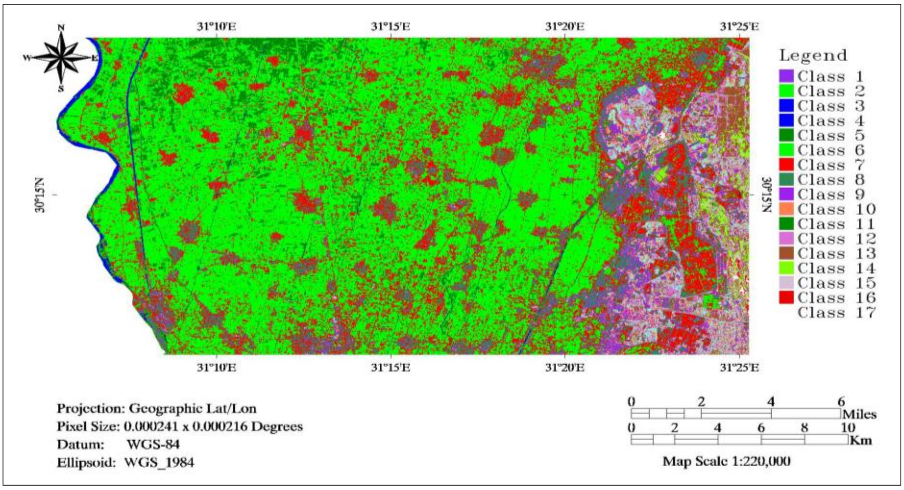


Fig 14: Unsupervised classification.

5.2.3.2. Supervised classification:

In supervised classification, spectral signatures are developed from specified locations in the image. These specified locations are given the generic name 'training sites' and are defined by the user. Supervised classification was performed through two steps 1- deriving endmembers for the satellite image and 2- using SAM classifier

1-Extracting Endmembers with SMACC:

The Sequential Maximum Angle Convex Cone (SMACC) spectral tool finds spectral endmembers and their abundances throughout an image. Endmembers are spectra that are chosen to represent pure surface materials in a spectral image. Endmembers that represent radiance or reflectance spectra must satisfy a positivity constraint (containing no values less than zero). Other pHysically-based constraints may be imposed, such as a sum-to-unity constraint (the pixels are weighted mixtures of the endmembers) or a sum-to-unity or less constraint (the pixels are weighted mixtures of the endmembers plus black). SMACC uses a convex cone model (also known as Residual Minimization) with these constraints to identify image endmember spectra. Extreme points are used to determine a convex cone, which defines the first endmember. A constrained oblique projection is then applied to the existing cone to derive the next endmember. The cone is increased to include the new endmember. The process is repeated until a projection derives an endmember that already exists within the convex cone (to a specified tolerance) or until the specified number of endmembers are found.

In other words, SMACC first finds the brightest pixel in the image, then it finds the pixel most different from the brightest. Then, it finds the pixel most different from the first two. The process is repeated until SMACC finds a pixel already accounted for in the group of the previously found pixels, or until it finds a specified number of endmembers. The spectra of pixels that SMACC finds become the endmembers of the resulting spectral library.

Unlike convex methods that rely on a simplex analysis, the number of endmembers is not restricted by the number of spectral channels. Although endmembers derived from SMACC are unique, a one-to-one correspondence does not exist between the number of materials in an image and the number of endmembers. SMACC derives endmembers from pixels in an image. Each pixel may contain only one material or it may contain a high percentage of a single material with unique combinations of other materials. Each material identified in an image is described by a subset spanning its spectral variability. SMACC provides an endmember basis that defines each of these material subsets. SMACC also provides abundance images to determine the fractions of the total spectrally integrated radiance or reflectance of a pixel contributed by each resulting endmember.

Mathematically, SMACC uses the following convex cone expansion for each pixel spectrum (endmember), defined as *H*:

$$H(c,i) = \sum_{k}^{N} R(c,k)\,A(k,j)$$

where:

- *i* is the pixel index
- *j* and *k* are the endmember indices from 1 to the expansion length, *N*
- *R* is a matrix that contains the endmember spectra as columns
- *c* is the spectral channel index
- *A* is a matrix that contains the fractional contribution (abundance) of each endmember *j* in each endmember *k* for each pixel

The 2D matrix representation of a spectral image is factored into a convex 2D basis (a span of a vector space) times a matrix of positive coefficients. In the image matrix (*R*), the row elements represent individual pixels, and each column represents the spectrum of that pixel. The coefficients in *A* are the fractional contributions or abundances of the basis members of the original matrix. The basis forms an *n*-D convex cone within its subset. The convex cone of the data is the set of all positive linear combinations of the data vectors, while the convex hull is the set of all weighted averages of the data. The factor matrices are then determined sequentially. At each step, a new convex cone is formed by adding the selected vector from the original matrix that lies furthest from the cone defined by the existing basis. **(Gruninger *et al.,* 2004)**. Figure 15 shows the extracted enmembers in the investigated area.

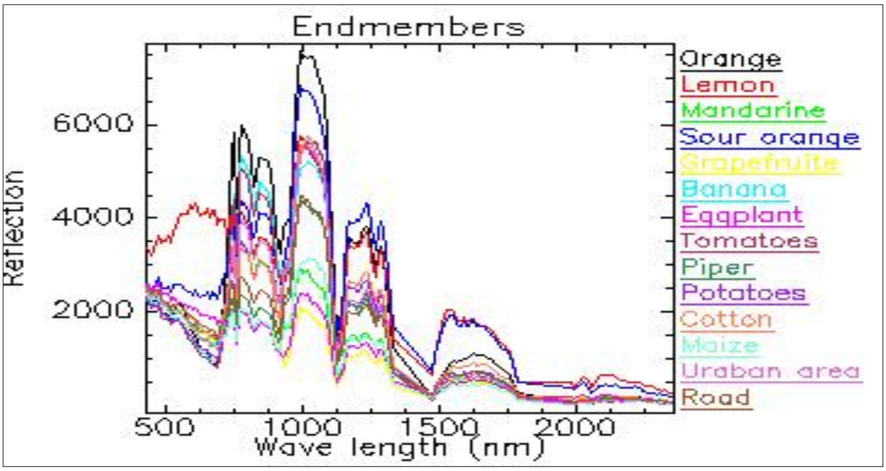


Figure 15: enmembers in the investigated area

2- Using Spectral Angle Mapper (SAM) classifier:

SAM was used as supervised ckassifier.It is a pHysically-based spectral classification that uses an *n*-D angle to match pixels to reference spectra. The algorithm determines the spectral similarity between two spectra by calculating the angle between the spectra and treating them as vectors in a space with dimensionality equal to the number of bands. This technique, when used on calibrated reflectance data, is relatively insensitive to illumination and albedo effects. Endmember spectra used by SAM was extracted directly from the hyperspectral image (as ROI average spectra). SAM compares the angle between the endmember spectrum vector and each pixel vector in *n*-D space. Smaller angles represent closer matches to the reference spectrum. Pixels further away than the specified maximum angle threshold in radians are not classified.. Supervised classification was performed on hyper spectral image using spectral Angle Mapper Classifier (AMC) resulting 14 classes as shown in Fig 16.

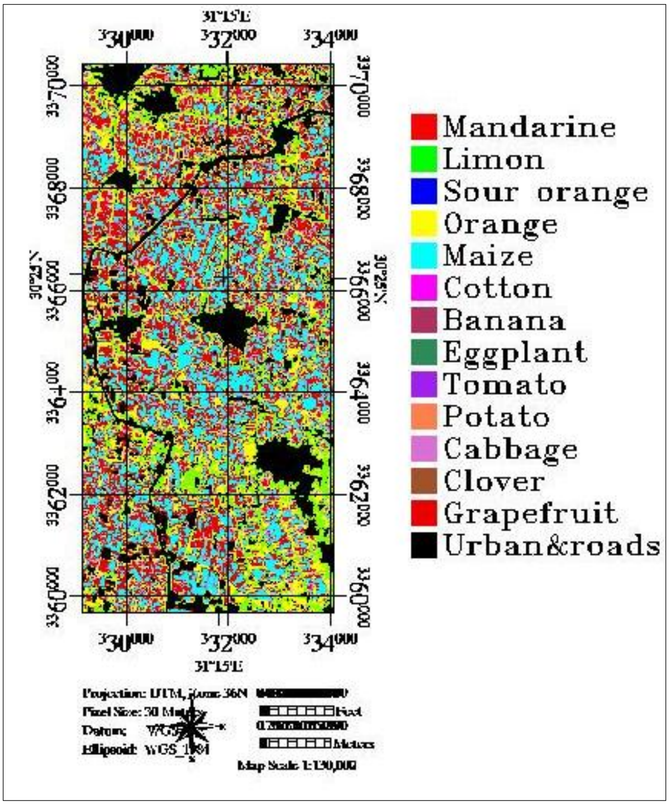


Figure 16: Supervised classification in a portion of the studied area

5.2.3.3. Normalized Difference Vegetation Index (NDVI):

NDVI is an effective indicator to show the surface coverage condition of vegetation and also to show the stage of growth of crop canopy. The temporal growing pattern of vegetation coverage expressed by NDVI is a factor to discriminate crop types, even though it induces some variation of values in certain types. The NDVI is computed as:

NDVI = NIR – RED /NIR +RED

Where,

NIR = near infrared band (band 3 in SPOT 5)

RED = red band (band 2 in SPOT 5). Fig. 17 shows the NDVI of the investigated area as follows.

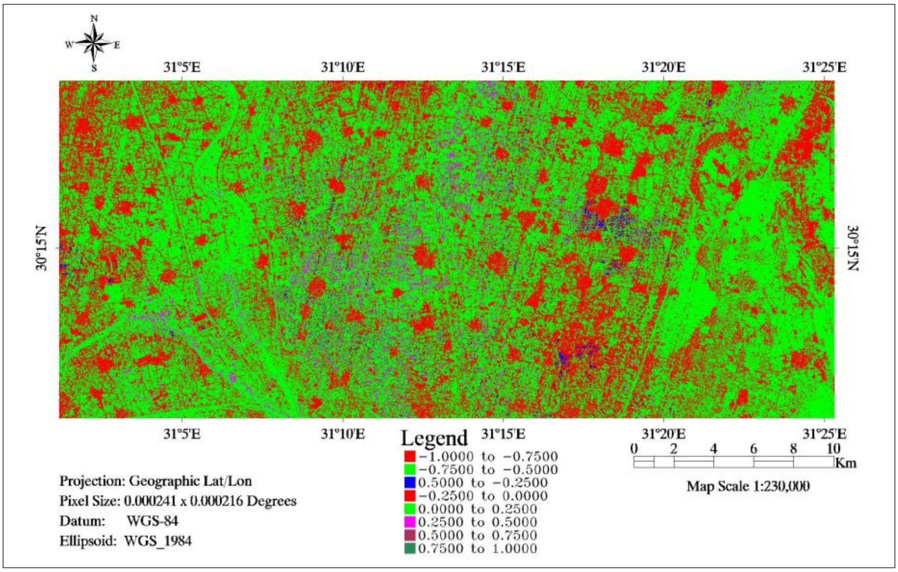


Fig. 17: NDVI of the investigated area.

5.3. Geomorphology and associated landforms:

Geomorphology is the scientific study of landforms and the processes that shape them. Geomorphologists seek to understand why landscapes look the way they do: to understand landform history and dynamics, and predict future changes through a combination of field observation, physical experiment, and numerical modeling. Geomorphology is practiced within geography, geology, geodesy, engineering geology, archaeology, and geotechnical engineering. Early studies in geomorphology are the foundation for pedology, one of two main branches of soil science **(Free encyclopedia, 2010).**

Geomorphic units could be identified throughout draping satellite image over digital elevation model (DEM). The geomorphic units of the studied area were extracted from satellite image by analyzing the main landscape **(Zahra, 2007)** recognized four main landforms 1-Flood plain, 2-Hummocky area, 3-Hilly area and 4- Turtle back. In the current work these units were reconfirmed performing confusion matrix analyses to make sure that, there is no any changes belong to geomorphic units.

Based on the satellite imagery interpretation and field observation as well, the following workable legend has been equationted by **Zahra (2007)** and reconfirmed in the current work. Total areas supported by percentages of their mapping units are illustrated in Table 9.

The obtained data revealed that, the decantation basins cover areas of 22755.27 feddan and form about 25.43 % of the total area, overflow basins cover areas of 34653.56 feddan and form 38.72 % of the total area , recent river terraces covers area of 27899.84 feddan representing about 31.15 % of the investigated area , levees cover areas of 401 feddan and form 0.45 % of the total area, swales cover areas of 556.64 feddan that form 0.63 % of the total area hummocky areas cover areas of 2023.4 feddan and form 2.26 % of the total area , hilly area cover areas of 1064.79 feddan and form 1.19 % of the total area and turtle backs cover area of 158.36 feddan and form of 0.17 % of the total area .Geomorphologic units are represented by Figure No.18.

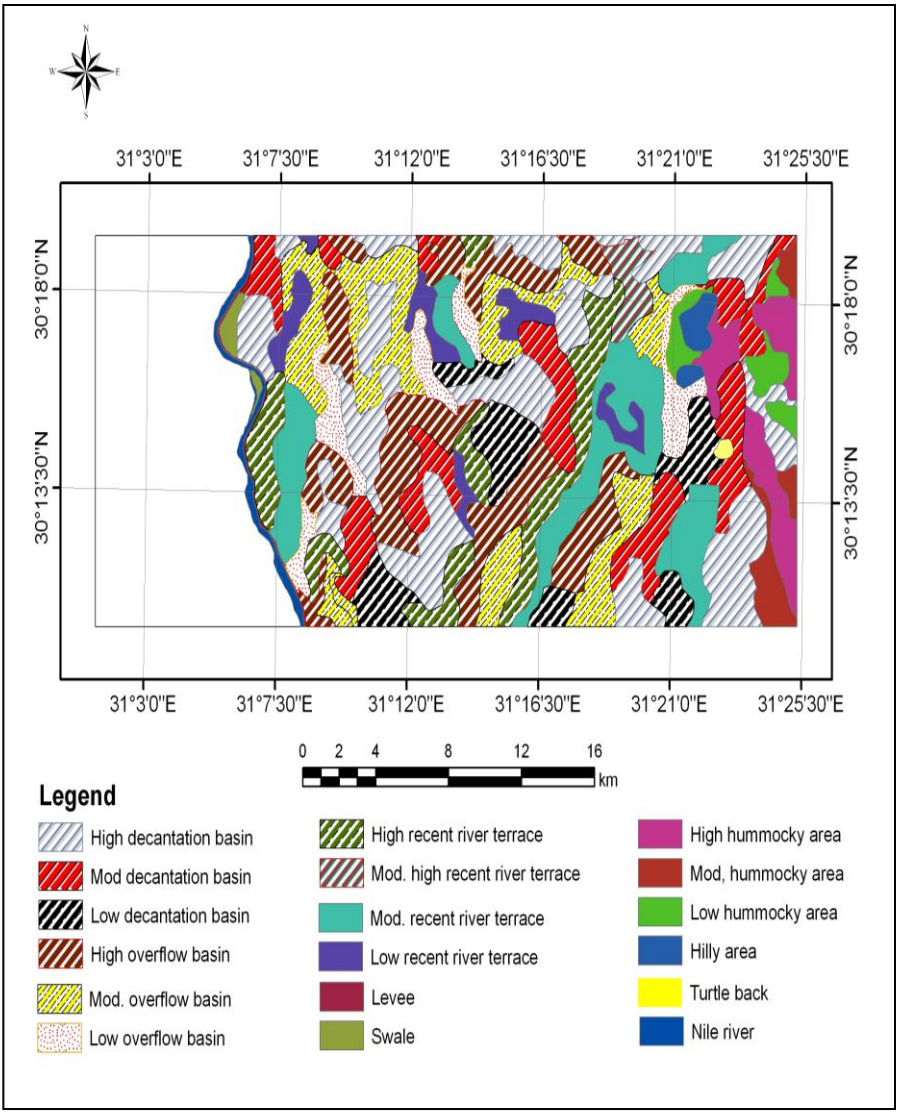


Fig 18 Geomorphology of the investigated area

Table 9: Geomorphic legend and areas of the different mapping units:

Landscape	**Relief/ Molding**	**Lithology/ Origin**	**Landform**	**Map unit**	**Area Feddan**	**Area %**
Flood plain	Flat to almost flat F1	Alluvial deposits F11	High decantation basin	F111	2155.54	2.41
			Mod. decantation basin	F112	12789.71	14.29
			Low decantation basin	F113	7810.02	8.73
					22755.27	**25.43**
			High overflow basin	F114	15011.76	16.78
			Mod. Overflow basin	F115	14245.43	15.92
			Low overflow basin	F116	5396.37	6.02
					34653.56	**38.72**
			High recent river terraces.	F117	9479.06	10.58
			Mod. High recent terraces	F118	1517.48	1.7
			Mod. recent river terraces	F119	12771.83	14.26
			Low recent river terraces	F110	4131.47	4.61
					27899.84	**31.15**
			Levees	F1111	401	0.45
			Swales	**F1112**	556.64	0.63
Hummocky Area	Undulating Hu1	Aeolian deposits Hu11	High hummocky area	Hu111	1307.01	1.47
			Mod. Hummocky area	Hu112	449.98	0.5
			Low hummocky area	Hu113	266.41	0.29
					2023.4	**2.26**
Hilly area	Hi1 Undulating	Hi11	Hilly area	Hi111	1064.79	1.19
Turtle back	T1 Undulating	T11	Turtle back	T111	158.36	0.17
					89512.86	**100**

5.4. Pedogeomorphology and soils of the different landforms

Recent research is increasingly demonstrating the close dependence of soils and geomorphology and a new discipline ‘soil geomorphology or pedogeomorphology has emerged, incorporating traditional approaches to soils.

These landforms and their associated soils were classified according to Keys of Soil Taxonomy (**USDA, 2010b**).

The current morpho-pedological study resulted in four soil types:

1-Soils of flood plain, 2- Soils of hummocky area, 3- Soils of hilly area and 4- Soils of turtle back.

5.4.1 Soils of flood plain:

Flood plain, is flat or nearly flat land adjacent to a stream or river that experiences occasional or periodic flooding. It includes the floodway, which consists of the stream channel and adjacent areas that carry flood flows, and the flood fringe, which are areas covered by the flood, but which do not experience a strong current **(Free encyclopedia, 2010b)**. The investigated soils of the flood plain originated from Nile sediments before High Dam construction. These deposits were developed from sediments of Ethiopian highlands transported by Nile River then deposited in the valley and Delta. Flood plain soils are divided into four units: 1- Soils of basins, 2- Soils of recent river terraces 3- Soils of levees and 4-Soils of swales**.**

Soils of basins:

Basin is low and usually sinking region that is filled with sediments from adjacent positive areas. They are formed as a result of deposition in low laying areas. This mapping unit is subdivided into two subunits according to elevation 1-decantation basins and 2-overflow basins.

(1)Soils of decantation basins:

A low-lying soils which is mainly surrounded by high elevated lands. It gets its deposits from overflow basins forming its geomorphologic shape. Decantation basins were subdivided into three sub-units: 1-high decantation basins, 2- moderate decantation basins, 3-low decantation basins.

(a) Soils of high decantation basin:

Profile No. 2 was selected to represent these soils. The morphological description and the analytical data were shown in the Table 10 and Figure 19.

Data of the representative profile indicate that, soil texture class is clay, where clay represents the main constitutes of the mechanical fractions in the successive layers of the studied soil profile.

In the investigated area $CaCO_3$ content differs from very few to moderate, where it ranges between 32.6 and 7.5 g/kg in the different layers of the representative soil profile.

Gypsum content is low to moderate ranging between 11 and 26.6 g/kg in the successive layers of soil profile.

Organic matter content in these soils varies from 7 to 20 g/kg decreasing regularly with depth. The high value existed in the top layer (40 cm) pointing to the continuous addition of organic fertilizers and plant residues.

Soil salinity expressed as the electrical conductivity (EC) of the soil paste extract of the representative soil profile is moderate and ranging between 4.20 and 6.20 dS/m. Data of soluble cations and anions revealed that, sodium followed by calcium are the dominant cations in the different layers of the studied profile. On the other hand, chloride is the dominant soluble anion in this profile, and thus sodium chloride is the dominant salt in the studied soil profile. Data of Table (10b) illustrate that concentration of soluble potassium in the surface layer was high as it recorded 1.4 mmolc/L. Such high value may be ascribed to the continuous addition of fertilizers.

Concerning soil acidity the obtained data revealed that pH values did not show wide variation in the different layers of the studied soil profile, as it recorded 8.0 in top 40 cm increased to 8.1 in the deepest layers.

As for cation exchange capacity (CEC) data show that, cation exchange capacity (CEC) ranges between 35.70 and 43.00 cmolc/kg soil. The high value of CEC indicates high contents of clay and organic matter. Calcium and magnesium form the main portion of the exchangeable cations and ranging from 16.89 to 20.10 cmolc/kg for calcium and 14.86 to 17.90 cmolc/kg for magnesium. The exchangeable sodium percentage (ESP) varies between 2.74 and 10.22.

Status of macro and micro nutrients in the upper 40 cm of the studied soil profile shows that nitrogen has a low value of 18.04 mg/kg; while phosphorus has a high value of 22.15 mg/kg and potassium have a high value of 410.25 mg/kg. For the micronutrients, zinc has moderate value of 1.30 mg/kg in the surface layer of the studied soil profile while iron, manganese and copper have a high values of 9.78, 17.02, 5.98 mg/kg, respectively.

Profile No. : 2
Date of description : 25 /7/2008
Mapping unit : F111.
Elevation :15 m. a.s.l
Coordinates :Lat. 30^0 14` 23`` Long 31$^0$ 08` 05``
Classification : Typic Haplargids.
Soil temperature regime : Thermic.
Soil moisture regime : Torric.
Topography : Flat.
Land form : Flood plain.
Slope on which profile is sited : Flat
Land use : Cultivated with maize.
Humans influence : Cultivation .
Native vegetation : None.
Parent material : Alluvial deposits.
Soil depth : Deep.
Evidence of surface stones or rock outcrop: None.
Evidence of Erosion : None.
Other surface features : Cracks (2cm Width and 30 cm depth).
Drainage conditions : Well drained.
Depth of ground water : >150 cm.

Depth cm	**Description**
0-40 Ap	Dark grayish brown (10YR 4/2, dry) to very dark grayish brown (10YR 3/2, moist) clay; moderate medium sub-angular blocky structure; sticky and plastic; hard; common fine discontinuous interstitial pores; many fine to medium roots; few elongate gypsum crystals; moderate fine angular hard yellowish brown concretion of $CaCO_3$; few effervescence with HCl; pH 8.0 ; clear smooth boundary.
40-90 Bt	Brown (10YR 5/3, dry) to dark brown (10YR 3/3, moist); clay; moderate strong angular to sub-angular blocky structure; very sticky and very plastic, hard; common medium discontinuous interstitial pores; clay films coat the pores, medium coarse roots; few fine angular hard yellowish brown concretion of $CaCO_3$; few fine elongate soft white crystals of gypsum; few effervescence with HCl; pH 8.1; defuse smooth boundary.
90-150 C1	Brown (10YR 5/3, dry), dark brown (10YR 3/3, moist); clay; moderate medium angular to sub-angular blocky structure; very sticky and very plastic, hard; common medium discontinuous interstitial pores; medium coarse roots; very few fine angular hard yellowish brown concretion of $CaCO_3$; few common fine elongate soft white crystal of gypsum; moderate effervescence with HCl; pH 8.1.

Table 10: Soil characteristics of profile No. 2:

(a) Particle-size distribution and $CaCO_3$ content:

Depth (cm)	Particle-size distribution (%)				Texture class	$CaCO_3$ (g/kg)
	C.*sand	F.** sand	Silt	Clay		
0-40	13.2	23.5	22.8	40.5	Clay	32.6
40-90	6.8	19.6	21.4	52.2	Clay	24.5
90-150	11.4	20.4	22.9	45.3	Clay	7.5

***C: Coarse, ** F: Fine.**

(b) EC, pH, soluble cations and anions, and gypsum:

Depth (cm)	EC dS/m	pH 1:2.5 suspesion	Soluble cations (mmolc/L)				Soluble anions (mmolc/L)				Gypsum (g/kg)
			Ca^{++}	Mg^{+}	Na^{+}	K^{+}	$SO_4^{=}$	$CO_3^{=}$	HCO^{-}_3	Cl^{-}	
0-40	6.20	8.0	16.87	6.61	36.12	1.40	11.85	0.00	15.66	34.49	11.0
40-90	4.25	8.1	12.90	7.85	21.52	1.23	4.20	0.00	10.30	28.00	26.6
90-150	4.20	8.1	12.30	7.51	21.09	1.10	3.30	0.00	9.80	25.90	13.2

(c) Cation Exchange capacity (CEC), Exchangeable cations, ESP, and O.M:

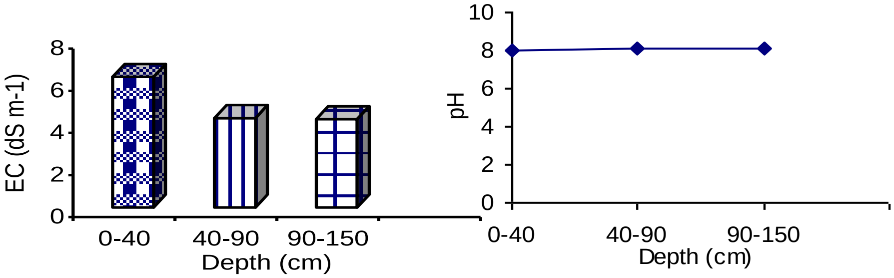
Depth (cm)	CEC Cmolc/ kg	Exchangeable cations (cmolc/ kg)				ESP	O.M (g/kg)
		Ca^{++}	Mg^{++}	Na^{+}	K^{+}		
0-40	36.5	20.10	14.90	1.00	0.50	2.74	20.0
40-90	43.00	20.00	17.90	3.90	1.20	9.07	15.0
90-150	35.70	16.89	14.86	3.65	0.30	10.22	7.0

(d) Available macro and micro nutrients in the surface layer:

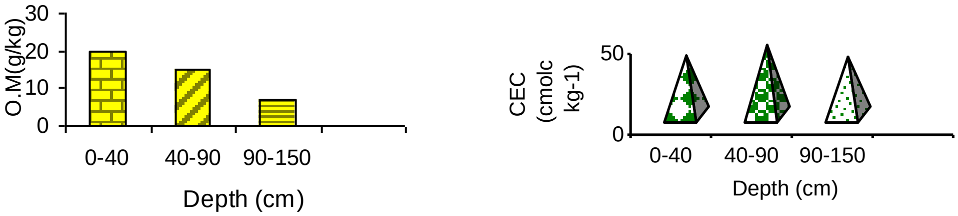
Depth (cm)	Macro nutrients (mg/kg)			Micro nutrients (mg/kg)			
	N	P	K	Fe	Mn	Zn	Cu
0-40	18. 04	22.15	410.25	9.78	17.02	1.30	5.98

N: extracted by KCl; other extracted by NH_4-HCO_3-DTPA; EC and soluble ions of saturation extract.

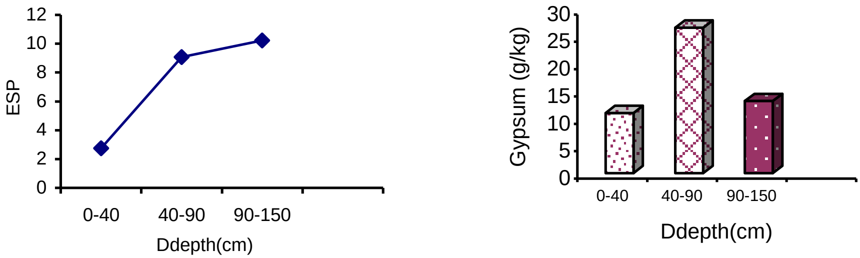
Fig. 19: Descriptive graphs of some soil characteristics of profile No. 2:



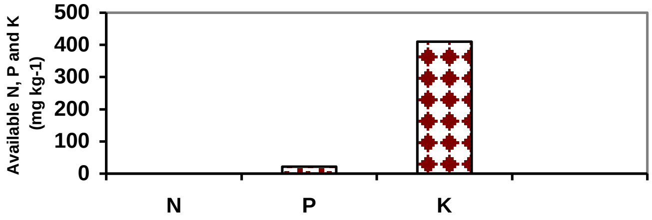
Soil salinity (dS m-1) **Soil Reaction (pH)**



Organic matter (g/kg) **Cation exchange capacity(cmolc kg-1)**



Exchangeable sodium percentage **Gypsum (g/kg)**



Available N, P and K (mg/kg)

(b) Soils of moderate decantation basin:

This unit is represented by Profile No. 3. The morphological description and the analytical data are given in the following pages, Table 11 and Figure 20.

The particle-size distribution illustrates that, the soil texture class is silt loam for the surface layer, where it is clay and silty clay loam in the tow subsurface layers. Clay and silt are the main components of these soils, while sand is the secondary one.

Calcium carbonate accumulation has a major influence in semiarid soil development. In these soils it differs from very low to low, as it ranges between 14.5 and 25.5 g/kg of the different layers of the studied soil profile.

Gypsum content is very low in these soils, with a value of 8.9 to 8.0 g/kg in the successive layers of the investigated soil profile.

Organic matter content ranges from 3.6 to 14.0 g/kg. It decreases regularly with depth. The high value in the surface layer associated with maintaining good levels requires by sustained effort that includes returning organic materials to soils and rotations with high-residue crops and deep- or dense-rooting crops. It is especially difficult to raise the organic matter content of soils that are well aerated, such as coarse sands, and soils in warm-hot and arid regions because the added materials decompose rapidly.

Soil salinity values expressed as the electrical conductivity (EC) of the soil paste extract is low and ranges between 1.40 and 2.55 dS/m. The data of soluble cations and anions revealed that, sodium followed by magnesium are the dominant cations in the different layers of the studied profile; on the other side, chloride is the dominant soluble anion, so sodium chloride is the dominant salt in the studied soil profile.

The pH values recorded values of 8.0 and 8.2 decreasing regularly with depth in the successive layers of the investigated soil profile.

The cation exchange capacity ranges between 18.50 and 39.00 cmolc/kg soil. The low value of CEC especially in the surface layer could be attributed to its low content of the fine materials (clay and organic fractions). The four major exchangeable cations are K, Ca, Mg, and Na. Calcium forms the main portion of the exchangeable cations followed by magnesium ad potassium ranging between 11.55 and 21.79 cmolc/kg soil; 4.49 and 12.42 cmolc/kg; and between 1.09 and 2.53 cmolc/kg for Ca, Mg and K, respectively. The exchangeable sodium percentage differs from 2.84 to 5.51.

For the status of macro and micro nutrients, phosphorus has a high level of 15.14 mg/kg, while nitrogen and potassium have low values of 26.5, 16.11 mg/kg; respectively. Iron has a moderate value of 5.04 mg/kg and manganese, zinc and copper have high values of 12.43, 6.07, 4.79, mg/kg, respectively.

Profile No. : 3
Date of description. : 25 /7/ 2008
Mapping unit. : F112.
Elevation . : 14m . a.s.l.
Coordinates. :. Lat. 30^{O} 12` 34 `` Long. 31 $^{O}$ 08` 49 ``
Classification. : Typic Haplargids.
Soil temperature regime . : Thermic.
Soil moisture regime . : Torric.
Topography. : Flat.
Land form. : Flood plain.
Slope on which profile is sited : Moderate.
Land use. : Cultivated with maize.
Humans influence . : Cultivation.
Native vegetation. : None.
Parent material . : Alluvial deposits.
Soil depth . : Very deep.
Evidence of surface stones or rock outcrop: None.
Evidence of Erosion. : None.
Other surface features. : Cracks 0.5-2 cm width and 30 cm depth.
Drainage conditions. : Well drained.
Depth of ground water. : >150 m.

Depth cm	**Description**
0-40 A_p	Grayish brown (10YR 5/2, dry) to very dark grayish brown (10YR3/2, moist); silt loam; weak medium angular and sub-angular blocky structure; sticky and plastic, firm, hard; common fine discontinuous random interstitial pores; many coarse roots; moderate fine soft white segregation of $CaCO_3$; very few fine elongate soft white crystals of gypsum; moderate effervescence with HCl; pH 8.2; diffuse smooth boundary.
40-90 Bt	Dark grayish brown (10YR 4/2, dry) to very dark brown (10YR 3/2, moist); clay; moderate medium angular and sub-angular blocky structure; very sticky and very plastic, firm, extremely hard ,common fine to medium continuous and discontinuous interstitial pores; clay films coat the pores; many fine to moderate roots; moderate fine soft white segregation of $CaCO_3$; very few very fine elongate soft white crystals of gypsum ; moderate effervescence with HCl; pH 8.1 ; diffuse smooth boundary .
90-150 C1	Brown (10YR 4/ 2, dry) to very dark grayish brown (10YR 3/2, moist); clay; weak angular to sub-angular blocky structure; sticky and plastic, firm, hard; common fine to medium continuous and discontinuous random interstitial pores; no roots; few very fine soft white segregation of $CaCO_3$; very few fine elongate soft white crystals of gypsum; few effervescence with HCl; pH 8.0.

Table 11: Soil characteristics of profile No. 3:

(a) Particle-size distribution, and $CaCO_3$ content:

Depth (cm)	Particle-size distribution (%)				Texture class	$CaCO_3$ (g/kg)
	C. sand	F. sand	Silt	Clay		
0-30	19.0	12.5	50	18.5	Clay	25.5
30-80	7.1	10.9	30.9	51.1	Clay	22.0
80-150	4.1	12.3	47.6	36.0	Silty Clay loam	14.5

(b) EC, pH, soluble cations and anions, and gypsum:

Depth (cm)	EC dS/m	pH 1:2.5	Soluble cations (mmolc/L)				Soluble anions (mmolc/L)				Gypsum (g/kg)
			Ca^{++}	Mg^{++}	Na+	K^+	$SO_4^=$	$CO_3^=$	HCO^-_3	Cl^-	
0-30	**2.55**	**8.2**	**3.98**	**4.98**	**15.50**	**1.04**	**4.24**	**0.00**	**3.04**	**18.22**	**8.9**
30-80	**2.00**	**8.1**	**1.88**	**0.38**	**4.60**	**1.00**	**6.00**	**0.00**	**6.63**	**7.37**	**8.5**
80-150	**1.40**	**8.0**	**4.04**	**2.83**	**6.13**	**1.00**	**3.00**	**0.00**	**0.80**	**10.20**	**8.0**

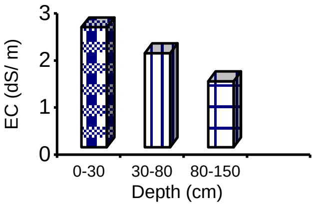
(c) Cation Exchange capacity (CEC), Exchangeable cations, ESP, and O.M.

Depth (cm)	CEC (cmolc/ kg)	Exchangeable cation (cmolc/ kg)				ESP	O.M (g/kg)
		Ca^{++}	Mg^{++}	Na+	K^+		
0-30	18.50	11.55	4.49	1.02	1.44	5.51	14.0
30-80	39.00	21.79	12.42	2.26	2.53	2.88	8.1
80-150	27.43	13.56	12.00	0.78	1.09	2.84	3.6

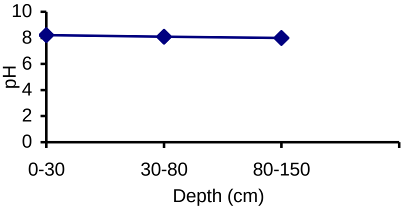
(d) Available macro and micro nutrients in the surface layer:

Depth (cm)	Macro nutrients (mg/kg)			Micro nutrients (mg/kg)			
	N	P	K	Fe	Mn	Zn	Cu
0-30	26.5	15.14	16.11	5.04	12.43	6.07	4.79

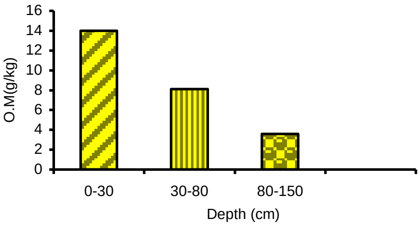
Fig. 20: Descriptive graphs of some soil characteristics of profile No. 3:

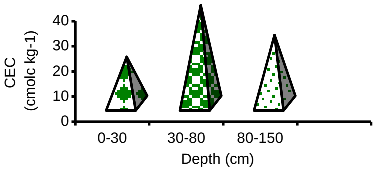


Soil salinity (dS/ m)



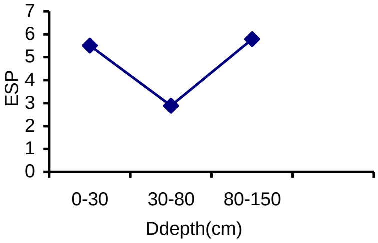
Soil Reaction (pH)



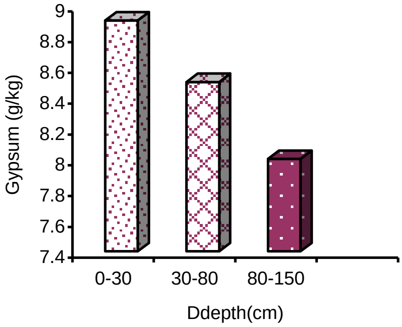


Organic matter (g/kg)

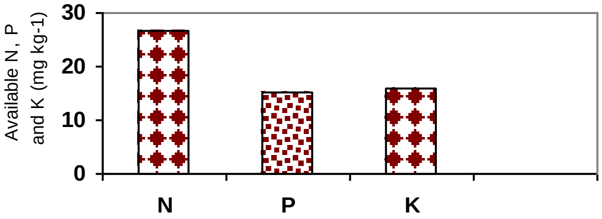
Cation exchange capacity (cmolc/ kg)



Exchangeable sodium percentage



Gypsum (g/kg)



Available N, P and K (mg/kg)

(c) Soils of low decantation basin:

Profile No. 4 represents these soils. The morphological description and the analytical data are given in the following pages, Table 12 and Figure 21.

The particle-size distribution shows that, soil texture classes are clay loam, silt clay loam and clay in the successive layers of the representative soil profile.

Calcium carbonate content differs from very few in the surface layer to moderate in the subsurface layers, and ranges between 5 and 25.9 g/kg in the different layers of the investigated soil profile.

Gypsum content is very few, where it has values of 6.2 and 7 g/kg in the successive layers of the studied soil profile.

The organic matter content differs from 1.4 and 12 g/kg and decreases regularly downwards. The high value in the surface layer (40 cm) may be due to the continuous addition of organic matter as fertilizer and plant residues.

Soil salinity values expressed as the electrical conductivity (EC) of the soil paste extract of representative soil profile is low and varies from 1.28 to 3.0 dS/m. Data of soluble cations and anions showed that, sodium followed by calcium are the dominant cations in the different layers of the studied soil profile; On the other hand, chloride is the dominant soluble anion, so sodium chloride is the dominant salt in these soils.

The pH values differ from 8.0 to 8.1 in the successive layers of the studied soil profile.

Cation exchange capacity ranges between 27.91 and 35.2 cmolc/ kg. Calcium followed by magnesium form the main components of the exchangeable cations in these soils ranging between 19.82 and 23.23 cmolc/ kg. The ESP ranges between 1.55 and 5.12.

Macro and micro nutrients in the surface layer of the investigated soil profile showed that nitrogen, potassium and phosphorus have low levels of 25.34, 200.43 and 2.75 mg/kg, respectively. Manganese and copper have high levels of 12.99 and 2.97 mg/kg, successively, while Iron and zinc have low values of 2.41 and 1.03 mg/kg.

Profile No. : 4
Date of description : 25 /7/ 2008
Mapping unit : F113.
Elevation : 13 m. a.s.l
Coordinates : Lat. 30^{o} 11` 42`` Long. 31 11` 44`` .
Classification : Typic Haplargids.
Soil temperature regime. : Thermic.
Soil moisture regime. : Torric.
Topography : Flat.
Land form : Flood plain.
Slope on which profile is sited : Flat
Land use : Cultivated with maize.
Humans influence : Cultivation.
Native vegetation : None.
Parent material : Alluvial deposits.
Soil depth : Deep.
Evidence of surface stones : None.
Evidence of Erosion : None.
Other surface features : None.
Drainage conditions : Well drained.
Depth of ground water : >150 cm.

Depth (cm)	**Description.**
0-40 Ap	Dark yellowish brown (10 YR 3/4, dry) to dark brown (10YR 3/3, moist); clay loam; weak angular to sub-angular blocky structure ; sticky, plastic, hard, common fine discontinuous interstitial pores; few fine roots; very few fine elongate soft white crystals of gypsum, very few fine soft white segregation of $CaCO_3$, none effervescence with HCl ; pH 8.0; clear smooth boundary.
40-90 B	Brownish yellow (10 YR 6/6, dry) to brown (10YR 5/3, moist) t; silt clay loam; weak angular to sub-angular blocky structure; sticky; plastic; hard; common medium continuous and discontinuous interstitial pores; no roots; moderate very fine angular yellowish brown concretion of $CaCO_3$; very few fine elongate soft white crystals of gypsum; shiny faces (slicken sides); moderate effervescence with HCl; pH 8.0; defuse smooth boundary.
90-150 C	Dark grayish brown (10 YR 4/2, dry) to very dark grayish brown (10YR 3/2 moist); clay; strong angular to sub-angular blocky structure; very sticky and very plastic, extremely hard; common medium continuous and discontinuous interstitial pores; no roots; moderate fine angular yellowish brown concretion of $CaCO_3$, very few fine elongate soft white crystals of gypsum; moderate effervescence with HCl; pH 8.1.

Table 12: Soil characteristics of profile No. 4

(a) particle-size distribution, and $CaCO_3$ content :

Depth (cm)	Particle-size distribution (%)				Texture class	$CaCO_3$ (g/kg)
	C. sand	F. sand	Silt	Clay		
0-40	18.4	8.9	33.4	39.3	Clay loam	5.0
40-90	5.9	3.6	50.5	40.0	Silty clay loam	25.9
90-150	10.0	4.3	37.6	48.1	Clay	24.0

(b) EC, pH, soluble cations and anions, and gypsum:

Depth (cm)	EC dS/m	pH 1:2.5 suspesion	Soluble cations(mmolc/L)				Soluble anions (mmolc/L)				Gypsum (g/kg)
			Ca^{++}	Mg^{++}	Na^{+}	K^{+}	$SO_4^{=}$	$CO_3^{=}$	HCO^{-}_3	Cl^{-}	
0-40	**3.00**	**8.0**	**19.69**	**18.67**	**24.54**	**1.02**	**6.36**	**0.00**	**7.66**	**21.50**	**7.0**
40-90	**1.50**	**8.0**	**7.13**	**7.11**	**10.62**	**1.00**	**6.37**	**0.00**	**7.83**	**11.86**	**6.5**
90-150	**1.28**	**8.1**	**4.95**	**3.68**	**9.51**	**0.99**	**5.67**	**0.00**	**0.79**	**6.25**	**6.2**

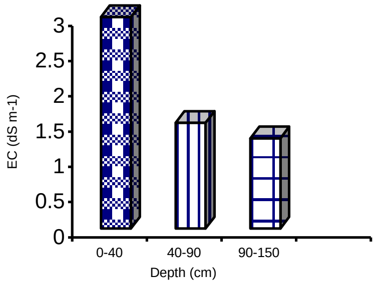
(c) Cation Exchange capacity (CEC), Exchangeable cations, ESP, and O.M

Depth (cm)	CEC (cmolc/ kg)	Exchangeable cations (cmolc/ kg)				ESP	O.M (g/kg)
		Ca++	Mg++	Na+	K+		
0-40	32.34	23.23	6.77	0.50	1.85	1.55	12.0
40-90	27.91	19.82	4.79	1.43	1.87	5.12	1.5
90-150	35.20	20.86	12.85	0.64	0.85	1.81	1.4

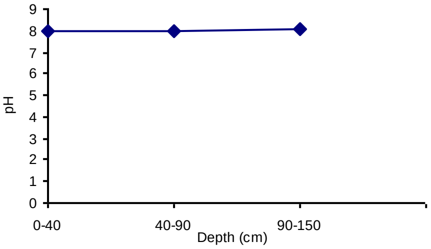
(d) Available macro and micro nutrients in the surface layer:

Depth (cm)	Macro nutrients (mg/kg)			Micro nutrients (mg/kg)			
	N	P	K	Fe	Mn	Zn	Cu
0-40	25.34	2.75	200.43	2.41	12.99	1.03	2.97

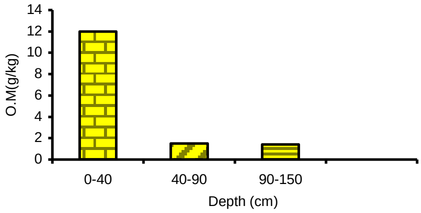
Fig. 21: Descriptive graphs of some soil characteristics of profile No. 4:



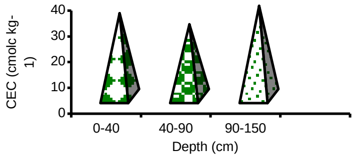
Soil salinity (dS/ m



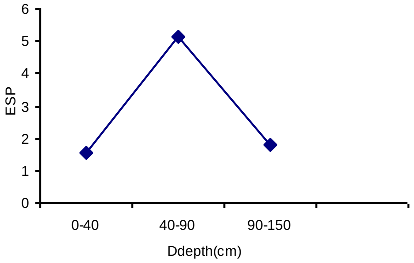
Soil Reaction (pH)



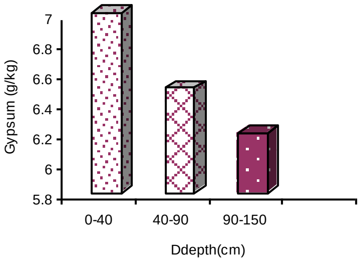
Organic matter (g/kg)



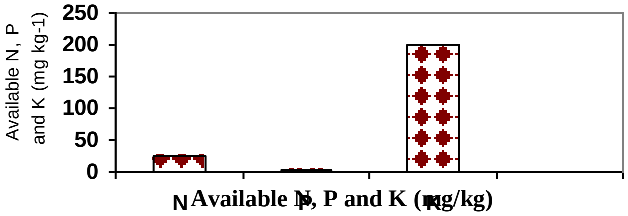
Cation exchange capacity(cmolc/ kg)



Exchangeable sodium percentage



Gypsum (g/kg)



Available N, P and K (mg/kg)

Soils of overflow basins:

Overflow basins are large, bowl-shaped depression in the surface of the land floor. They deposit their load of sedimentation which carried by water into decantation basins. These soils are represented by soil profiles number 8, 1 and 6. This unit is subdivided into three sub-units as follows:

(1) Soils of high overflow basins, (2) Soils of moderate overflow basins and (3) Soils of low overflow basins.

(a) Soils of high overflow basins:

Profile No. 8 represents these soils. The morphological description and the analytical data are explained in the following lines, Table 13 and Figure 22.

The particle-size distribution revealed that, soil texture class is clay, in the successive layers of the representative soil profile. Clay and silt represent the main portion of the soil fractions, except for the surface layer where clay and sand are the main component.

Calcium carbonate content is very few to few and ranges between 6.1 and 27.8 g/kg in the different layers of the investigated soil profile.

Gypsum content is very few to few in these soils, ranging between 8 and 23 g/kg in the successive layers of the representative soil profile.

The organic matter shows a regular decreasing with depth, as it ranges from 2.2 to 21.5 g/kg. The high value may be associated with the continuous addition of organic fertilizers.

The electrical conductivity (EC) of the soil paste extract of the representative soil profile is low and rages from 0.58 to

0.99 dS/m. The values of soluble cations and anions indicate that, sodium followed by calcium are the dominant cations in the different layers of the studied profile. On the other hand, bicarbonate is the dominant anion, so sodium bicarbonate is the dominant salt in the investigated soil profile.

The pH values are ranges between 8.0 and 8.4 in the successive layers of the studied soil profile. The high value indicates the effect of soluble sodium bicarbonate.

The cation exchange capacity ranges between 35.10 and 58.10 cmolc/kg soil. The high value of CEC could be attributed to the high content of clay and organic matter. Calcium followed by magnesium are the main exchangeable cations in these soils.

The ESP values range between 3.43 and 13.43. The high value indicates high sodicity.

In the upper 25 cm of the studied soil profile nitrogen has a low value of 25.78 mg/kg, while Phosphorus and Potassium have high levels of 8.67 and 650.54 mg/kg, respectively. Zinc has a low value of 0.94 mg/kg; while Iron, manganese and copper have high values of 11.99, 13.96 and 31.67 mg/kg, successively.

Profile No.	: 8
Date of description	: 22 /7 2008.
Mapping unit	: F114 .
Elevation	: 9 m. a.s.l
Coordinates	: Lat. 30^o 10\` 52\`\` Long. 31$^o$ 11\` 11\`\`
Classification	: Vertic Torrifluvents.
Soil temperature regime .	: Thermic.
Soil moisture regime .	: Torric,
Topography	: Flat.
Land form	: Flood plain.
Slope on which profile is sited	: Flat
Land use	: Cultivated with maize.
Humans influence	: Cultivation.
Native vegetation	: None.
Parent material	: Alluvial deposits.
Soil depth	: Deep.
Evidence of surface stones or rock outcrop	: None.
Evidence of Erosion	: None.
Other surface features	: Cracks (1-2 cm width).
Drainage conditions	: Well drained.
Depth of ground water	: >150 cm.

Depth cm	**Description**
0-25 Ap	Dark grayish brown (10YR 4/2, dry) to very dark grayish brown(10YR 3/2, moist); clay; strong angular to sub- granular blocky structure ; very sticky and very plastic, firm, very hard; common fine discontinuous interstitial pores; few fine roots; few very fine elongate crystals of gypsum, very few fine soft white segregation of $CaCO_3$, weak effervescence with HCl; pH 8.0; clear smooth boundary.
25-80 C1	Brown (10YR 5/3 dry) to dark brown (10YR 3/3, moist); clay; strong angular to sub- angular blocky structure; very sticky and very plastic, firm, ;very hard; common medium discontinuous interstitial pores; no roots; moderate fine soft white segregation of $CaCO_3$; few very fine elongate gypsum crystals; moderate effervescence with HCl; pH 8.2 clear smooth boundary.
80-150 C2	Dark grayish brown (10YR 4/2, dry) to very dark grayish brown (10YR 3/2, moist); clay; medium angular to sub-granular blocky structure; very sticky and very plastic, firm, very hard; common fine discontinuous interstitial pores; no roots; very few fine soft white segregation of $CaCO_3$; very few very fine elongate gypsum crystals; weak effervescence with HCl; pH 8.2.

Table 13: Soil characteristics of profile No. 8:

(a) Particle-size distribution and $CaCO_3$ content:

Depth (cm)	**Particle-size distribution (%)**				**Texture class**	**$CaCO_3$ (g/kg)**
	C. sand	**F. sand**	**Silt**	**Clay**		
0-25	7.8	9.9	12.4	69.9	Clay	9.7
25-80	8.9	13	26.2	51.9	Clay	27.8
80-150	2.8	21.9	27.5	47.8	Clay	6.1

(b) EC, pH, soluble cations and anions, and gypsum:

Depth (cm)	**EC dS/m suspension**	**pH 1: 2.5**	**Soluble cations (mmolc/L)**				**Soluble anions (mmolc/L)**				**Gypsum (g/kg)**
			Ca^{++}	**Mg^{++}**	**Na+**	**K^+**	**$SO_4^=$**	**$CO_3^=$**	**HCO_3^-**	**Cl^-**	
0-25	**0.58**	**8.0**	**3.68**	**2.82**	**3.98**	**1.08**	**3.69**	**0.00**	**4.22**	**2.33**	**23.0**
25-80	**0.99**	**8.2**	**6.98**	**7.18**	**8.70**	**1.38**	**1.50**	**0.00**	**5.27**	**3.13**	**11.0**
80-150	**0.79**	**8.2**	**5.91**	**4.90**	**6.03**	**1.11**	**2.30**	**0.00**	**5.92**	**3.52**	**8.0**

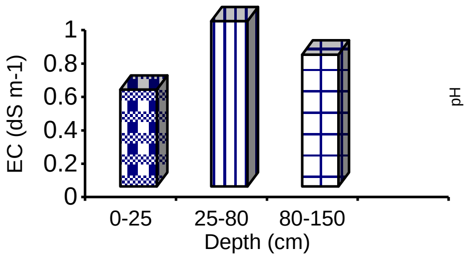
(c) Cation Exchange capacity (CEC), Exchangeable cations, ESP, and O.M.

Depth (cm)	**CEC cmolc/ kg**	**Exchangeable cations (cmolc/ kg)**				**ESP**	**O.M (g/kg)**
		Ca^{++}	**Mg^{++}**	**Na+**	**K^+**		
0-25	58.10	27.65	27.22	1.99	1.24	3.43	21.5
25-80	36.70	17.08	13.54	4.93	1.15	13.43	3.0
80-150	35.10	14.80	18.50	1.30	0.50	3.70	2.2

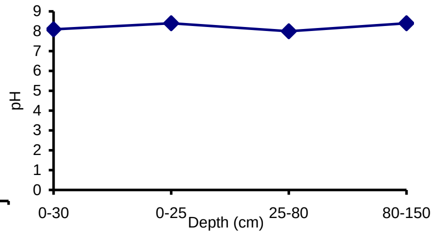
(d) Available macro and micro nutrients in the surface layer:

Depth (cm)	**Macro nutrients (mg/kg)**			**Micro nutrients (mg/kg)**			
	N	**P**	**K**	***Fe***	**Mn**	**Zn**	**Cu**
0-25	25.78	8.67	650.54	11.99	13.96	0.94	31.67

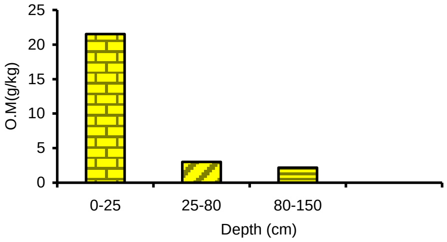
Fig. 22: Descriptive graphs of some soil characteristics of profile No. 8:



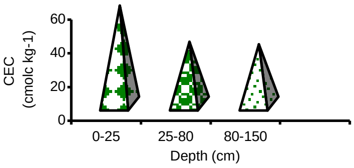
Soil salinity (dS/ m)



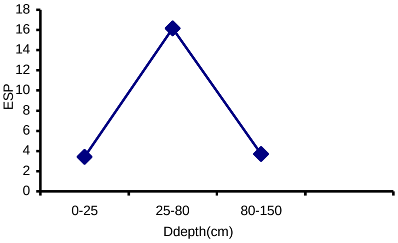
Soil Reaction (pH)



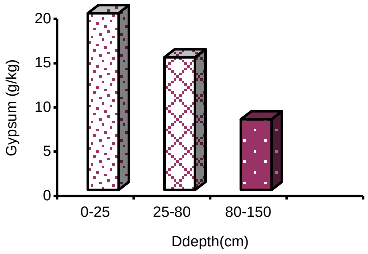
Organic matter (g/kg)



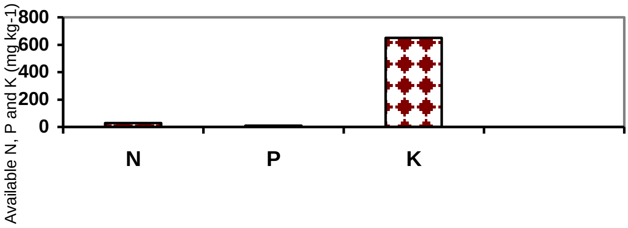
Cation exchange capacity(cmolc kg-1)



Exchangeable sodium ercentage



Gypsum (g/kg)



Available N, P and K (mg/kg)

(b) Soils of moderate overflow basins:

These soils are represented by soil Profile No. 1. The morphological description and the analytical data are shown in the following lines, Table 14 and Figure 23.

The texture class of these soils is clay, where clay and silt form the main soil mechanical fractions. Calcium carbonate content is very few and ranging between 17 and 18 g/kg in the different layers of the representative soil profile.

Gypsum content in these soils is few, as it ranges between 14.4 and 18.5 g/kg in the successive layers of soil profile.

These soils shows a regular decreasing in the organic matter content with depth, as it ranges between 2.1 and 12.0 g/kg. The low values indicate the conditions of entisols order.

Soil salinity values expressed as the electrical conductivity (EC) of the representative soil profile are low and varying from 0.64 to 1.53 dS/m. The values of soluble cations and anions show that, sodium is the dominant cation in the different layers of the studied soil profile, with one exception for the surface layer where calcium is the dominant cation. On the other hand, chloride is the dominant anion, so sodium chloride is the dominant salt in this soil profile.

The pH values differ from 8.0 to 8.1 in the successive layers of the investigated soil profile.

The cation exchange capacity ranges between 42.48 and 44.00 cmolc/kg soil. The high values of CEC could be attributed to the high content of the fine materials (clay and organic matter).

Calcium followed by magnesium are the main exchangeable cations in these soils as it ranges between 19.27 and 20.62 cmolc/kg and this indicates gypsum addition to these soils.

The exchangeable sodium percentage ranges between 6.7 and 15.40.

Macro and micro nutrients in the surface layer of the representative soil profile revealed that, nitrogen has a low value of 27 mg/kg; While phosphorus and potassium have the same behavior, as they have high values of 15.24 and 625.76 mg/kg, respectively. All of micro nutrients (Fe, Mn, Zn, and Cu) have high values of 15.22, 18.55, 8.56 and 3.86 mg/kg, successively.

Profile No. : 1
Date of description : 25 /7 / 2008
Mapping unit : F115.
Elevation : 8 m. a.s.l
Coordinates. : Lat. 30^0 16` 55`` Long. $31^0$ 07` 42``
Classification. : Vertic Torrifluvents
Soil temperature regime . : Thermic.
Soil moisture regime . : Torric.
Topography : Flat.
Land form : Flood plain (Mod. Overflow basin).
Slope on which profile is sited : Flat
Land use : Cultivated with maize.
Humans influence : Cultivation.
Native vegetation : None.
Parent material : Alluvial deposits.
Soil depth : Deep.
Evidence of surface stones or rock outcrop: None.
Evidence of Erosion : None.
Other surface features : Cracks (1cm width and 30 cm depth).
Drainage conditions : Well drained.
Depth of ground water : >150 cm.

Depth cm	**Description**
0-40 Ap	Brown (10YR 5/3, dry) to dark grayish brown (10YR 4/2, moist); clay; strong angular to sub-angular blocky structure ; very sticky and very plastic; firm; hard; slickenside; common fine discontinuous random interstitial pores; few fine to coarse roots; few fine elongate gypsum crystals; moderate fine soft white segregation of $CaCO_3$; moderate effervescence with HCl; pH 8.0; clear smooth boundary.
40-90 C1	Dark grayish brown (10YR 4/2, dry) to very dark grayish brown (10YR 3/2, moist); clay; strong angular to sub-angular blocky structure; very sticky and very plastic, very hard; firm, hard, common fine discontinuous random interstitial pores; few fine to coarse roots; few small elongate gypsum crystals; moderate fine soft white segregation of $CaCO_3$; moderate effervescence with HCl; pH 8.0; clear smooth boundary.
90-150 C2	Brown (10YR 5/3, dry) to dark brown (10YR 3/2, moist); clay; strong angular to sub-angular blocky structure; very sticky and very plastic, very hard; firm; common fine discontinuous random interstitial pores; few fine to coarse roots; few gypsum in the form of powder; moderate fine soft white segregation of $CaCO_3$, moderate effervescence with HCl; pH 8.1.

Table 14: Soil characteristics of profile No. 1

(a) Particle-size distribution, and $CaCO_3$ content:

Depth (cm)	Particle-size distribution (%)				Texture class	$CaCO_3$ (g/kg)
	C. sand	F. sand	Silt	Clay		
0-40	3.2	12.7	29.8	54.3	Clay	18.0
40-90	4.0	8.5	29.8	57.7	Clay	17.0
90-150	3.9	12.1	24.7	59.3	Clay	17.0

(b) EC, pH, soluble cations and anions, and gypsum:

Depth (cm)	EC dS/m	pH 1:2.5 suspension	Soluble cations (mmolc/L)				Soluble anions (mmolc/L)				Gypsum (g/kg)
			Ca^{++}	Mg^{++}	Na+	K^+	$SO_4^=$	$CO_3^=$	HCO^-_3	Cl^-	
0-40	1.53	8.0	5.80	3.60	4.84	1.06	0.20	0.00	1.40	13.71	18.5
40-90	1.50	8.0	3.70	1.86	8.38	1.06	2.95	0.00	2.97	9.08	14.8
90-150	0.64	8.1	1.60	0.76	3.64	0.40	0.54	0.00	2.56	3.54	14.4

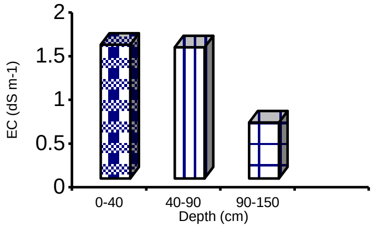
(c)Cation Exchange capacity (CEC), Exchangeable cations, ESP, and O.M.

Depth (cm)	CEC Cmolc/ kg	Exchangeable cations (cmolc/ kg)				ESP	O.M (g/kg)
		Ca^{++}	Mg^{++}	Na+	K^+		
0-40	43.45	20.45	17.14	5.25	0.61	12.08	12.0
40-90	44.00	20.62	19.96	2.95	0.47	6.70	4.5
90-150	42.48	19.27	15.59	6.54	1.08	15.40	2.1

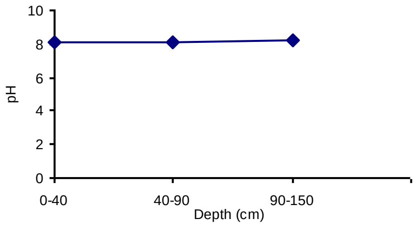
(d) Available macro and micro nutrients in the surface layer:

Depth (cm)	Macro nutrients (mg/kg)			Micro nutrients (mg/kg)			
	N	P	K	Fe	Mn	Zn	Cu
0-40	27	15.24	625.76	15.22	18.55	8.56	3.86

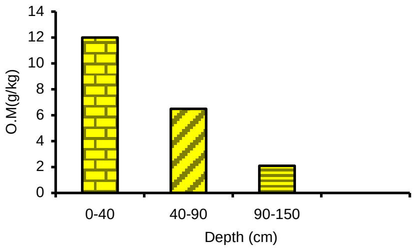
Fig. 23: Descriptive graphs of some soil characteristics of profile No. 1:



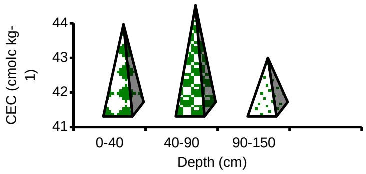
Soil salinity (dS/ m)



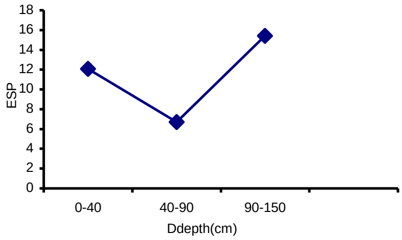
Soil Reaction (pH)



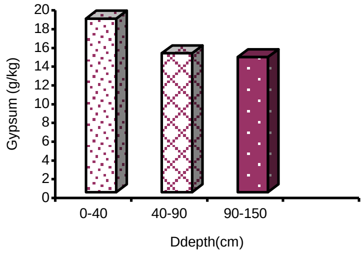
Organic matter (g/kg)



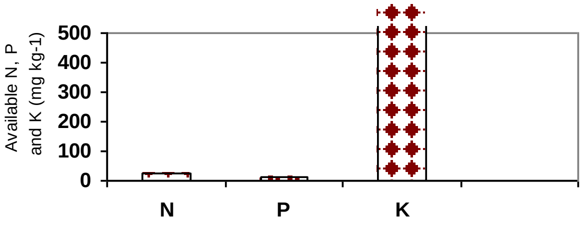
Cation exchange capacity(cmolc/ kg)



Exchangeable sodium percentage



Gypsum (g/kg)



Available N, P and K (mg/kg)

(c) Soils of low overflow basins:

Profile No. 6 represents these soils. The morphological description and the analytical data are given in Table 15 and Figure 24.

The particle-size distribution shows that, texture class of these soils is clay, except for the surface layer, where it is silty clay loam.

The content of calcium carbonate is very few and ranging between 14.2 and 19.9 g/kg in the different layers of this profile.

Gypsum content is few and ranges between 11.6 and 11.8 g/kg in the successive layers of the representative soil profile.

The values of organic matter content decrease regularly with depth and range between 4.1 and 10 g/kg.

Soil salinity expressed as the electrical conductivity (EC) of the soil paste extract of the studied soil profile is low and ranges between 1.25 and 1.61 dS/m. The values of soluble cations and anions illustrated that, sodium is the dominant cation in the different layers of the studied profile. On the other hand, chloride is the dominant anion, so, sodium chloride is the dominant salt in this soil profile.

The successive layers of the representative soil profile have not showed big difference in pH value, where it records 8.1 except for the upper layer it records 8.0.

The cation exchange capacity ranges between 31.17 and 47.09 cmolc/kg soil.

Calcium followed by magnesium form the main exchangeable cations in these soils. The exchangeable cations could be arranged in the following descending order: Ca^{++} > Mg^{++} > Na^{+} > K^{+}.

The exchangeable sodium percentage ranges between 11.38 and 5.30 decreasing with depth.

Nitrogen and potassium have a low values, where they recorded values of 18 and 198.55 mg/kg, respectively, while phosphorus has a high level of 19.22 mg/kg. Micro nutrients (Fe, Mn and Cu) have high values of 15.99, 8.12 and 4.97 mg/kg, however, zinc had a moderate value of 2.07 mg/kg, successively.

Profile No. : 6

Date of description. : 25 /7/2008
Mapping unit. : F116
Elevation. :7 m. a.s.l.
Coordinates. :. Lat. 30° 11` 25`` Long 31° 08` 31``
Classification. : Typic Haplargids.
Soil temperature regime. : Thermic.
Soil moisture regime. : Torric.
Topography. : Flat.
Land form. : Flood Plain.
Slope on which profile is sited. : Gradient (Flat.) Form (Straight).
Land use. : Cultivated with maize.
Humans influence. :cultivation
Native vegetation. : None.
Parent material. : Alluvial Deposits.
Soil depth. : Very deep.
Evidence of surface stones or rock outcrop: None.
Evidence of Erosion. : None.
Other surface features. : None.
Drainage conditions. : Well drained.
Depth of ground water. : >150cm.

Depth cm	**Description**
0-30 Ap	Grayish brown (10 YR 5/2, dry) to dark grayish brown (10YR 4/2, moist); silt clay loam; weak angular to sub-angular blocky structure; very sticky and very plastic, firm, hard; common fine to medium continuous and discontinuous random interstitial pores; few fine to coarse roots; moderate fine yellowish brown concretion of CaCO3; very few to few gypsum in the form of powder; moderate effervescence with HCl; pH 8.0; diffuse smooth boundary.
30-85 Bt	very dark grayish brown (10YR 3/2, dry) to very dark brown (10YR 3/2, moist); clay; strong angular to sub-angular blocky structure; very sticky and very plastic, very firm, very hard,; common fine to medium continuous and discontinuous interstitial pores; clay films coat the pores; few fine to coarse roots, few fine hard yellowish brown concretion of CaCO3; few small crystals of gypsum; weak effervescence with HCl; pH 8.1 diffuse smooth boundary.
85-150 C	Very dark grayish brown (10YR 3/2, dry) to very dark grayish brown (10YR 3/2, moist); clay; strong angular to sub-angular blocky structure; very sticky and very plastic, firm, very hard; common fine to medium continuous and discontinuous random interstitial pores, few fine to coarse roots; moderate fine hard yellowish brown concretion of $CaCO_3$; few Gypsum in the form of powder; moderate effervescence with HCl ; pH 8.1.

Table 15: Soil characteristics of profile No. 6:

(a) Particle-size distribution, and $CaCO_3$ content:

Depth (cm)	Particle-size distribution (%)				Texture class	$CaCO_3$ (g/kg)
	C. sand	F. sand	Silt	Clay		
0-30	4.6	8.4	52.5	34.5	Silt clay loam	19.9
30-85	3.7	16.8	18.9	58.5	Clay	14.2
85-150	3.8	16.3	16.4	63.5	Clay	19.1

(b) EC, pH, soluble cations and anions, and gypsum:

Depth (cm)	EC dS/m	pH 1:2.5 suspension	Soluble cations (mmolc/L)				Soluble anions (mmolc/L)				Gypsum (g/kg)
			Ca^{++}	Mg^{++}	Na+	K^+	$SO_4^=$	$CO_3^=$	HCO^-_3	Cl^-	
0-30	1.31	8.0	4.06	1.69	6.29	1.06	1.79	0.00	4.20	7.11	11.6
30-85	1.25	8.1	2.71	3.11	5.84	0.84	0.88	0.00	2.08	9..54	11.8
85-150	1.61	8.1	4.64	3.01	7.26	1.18	2.45	0.00	3.64	10.02	11.6

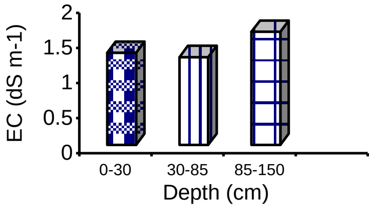
(c) Cation Exchange capacity (CEC), Exchangeable cations, ESP, and O.M.

Depth (cm)	CEC (cmolc/ kg)	Exchangeable cation (cmolc/ kg)				ESP	O.M (g/kg)
		Ca^{++}	Mg^{++}	Na+	K^+		
0-30	31.17	15.63	11.41	3.55	0.58	11.38	10.0
30-85	39.80	21.84	15.19	2.11	0.66	5.30	6.5
85-150	47.09	23.34	19.20	3.75	0.80	7.96	4.1

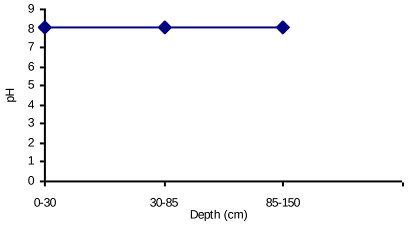
(d) Available macro and micro nutrients in the surface layer:

Depth (cm)	Macro nutrients (mg/kg)			Micro nutrients (mg/kg)			
	N	P	K	Fe	Mn	Zn	Cu
0-30	18.00	19.22	198.55	15.99	8.12	2.07	4.97

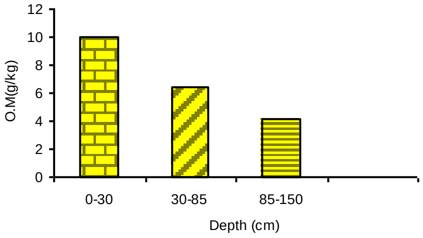
Fig. (24): Descriptive graphs of some soil characteristics of profile No. 6:



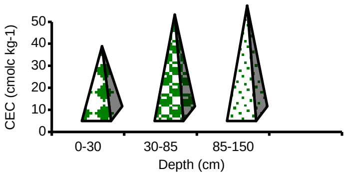
Soil salinity (dS m-1)



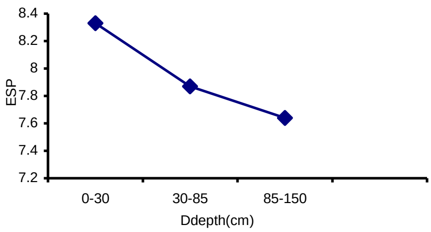
Soil Reaction (pH)



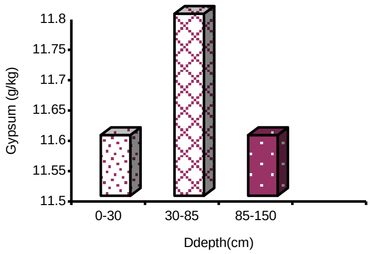
Organic matter (g/kg)



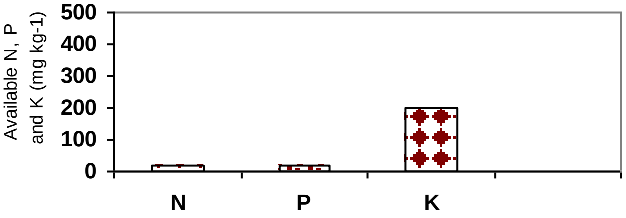
Cation exchange capacity(cmolc kg-1)



Exchangeable sodium percentage



Gypsum (g/kg)



Available N, P and K (mg/kg)

Soils of recent river terraces:

The recent river terraces are remnants of the former floodplain of a stream of river. They are formed by the down-cutting of a river or stream channel into and the abandonment and lateral erosion of its former floodplain. The down-cutting, abandonment, and lateral erosion of a former floodplain could be the result of either changes in sea level, local or regional tectonic uplift; changes in local or regional climate; changes the amount of sediment being carried by the river or stream; change in discharge of the river; or a complex mixture of these and other factors. The most common sources of the variations in rivers and streams that create fluvial terraces are vegetative, geomorpHic, and hydrologic responses to climate. More recently, the direct modification of rivers and streams and their watersheds by cultural processes have result in the development of terraces along many rivers and streams (**Fairbridge, 1968 ; Blum and Tonqvist, 2000**)

This unit is subdivided into four sub-units according to relief:

(1) Soils of high recent river terraces, (2) Soils of moderate recent river terraces, (3) Soils of moderately high recent river terraces and (4) Soils of low recent river terraces.

(a) Soils of high recent river terraces:

These soils are represented by profile No. 5. The morphological description is presented in the following pages and the analytical data are shown in Figure 25 and Table 16.

The soil texture is clay loam in the successive layers of the studied soil profile.

Calcium carbonate content is very few to few ranges between 7.4 and 11.4 g/kg in the different layers of the soil profile.

The gypsum content is very few to few and ranges between 14.5 and 17.0 g/kg in the successive layers of the investigated soil profile.

The content of organic matter ranges between 4.65 and 16.0 g/kg.

Soil salinity expressed as the electrical conductivity (EC) of the soil paste extract ranges between 1.10 to 4.51 dS/m. The values of soluble cations and anions showed that, sodium and calcium are the dominant cations in the different layers of the studied soil profile. On the other side chloride is the dominant anion.

The pH values range between 8.0 and 8.2 increasing regularly with depth in the successive layers of the studied soil profile. The cation exchange capacity ranges between 24.39 and 30.20 cmolc/kg soil in the successive layers of the studied soil profile.

The exchangeable calcium followed by magnesium form the main portion of the exchangeable cations in the successive layers of the studied soil profile.

The ESP values ranges between 8.34 and 12.05 in the different layers of the representative soil profile.

The macro nutrients (N and P) showed high values of 51.22 and 20.61 mg/kg, respectively, on the other hand, potassium has a low level of 196.08 mg/kg. All micro nutrients (Fe, Mn, Zn and Cu) showed the same behavior as recorded high values of 16.42, 33.14, 5.48 and 5.11 mg/kg, respectively.

Profile No. : 5
Date of description. : 25 /7 /2008
Mapping unit. : F117
Elevation. : 11 m. a.s.l.
Coordinates. : Lat. 30^{o} 10` 52`` Long. $31^{o}$ 09` 28`` .
Classification. : Vertic Torrifluvents
Soil temperature regime. : Thermic.
Soil moisture regime. : Torric.
Topography. : Almost flat.
Land form. : Flood plain.
Slope on which profile is sited. : Flat.
Land use. : Cultivated with maize.
Humans influence. : Cultivation.
Native vegetation. : None.
Parent material. : Alluvial Deposits.
Soil depth . : Very deep.
Evidence of surface stones or rock outcrop.: None.
Evidence of Erosion. : None.
Other surface features. : Cracks (2.5. cm) width
Drainage conditions. : Well drained.
Depth of ground water. : >150 cm.

Depth (cm)	**Description**
0-50 A	Grayish brown (10YR 5/2, dry) to dark brown (10YR 3/3, moist); clay; weak angular to sub-angular blocky structure; very sticky and very plastic, firm, extremely hard slickenside; common fine discontinuous random interstitial pores; many fine roots; few very fine crystals of gypsum; shinny faces(silken sides) , weak effervescence with HCl; pH 8.0,clear smooth boundary.
50-90 C1	Grayish brown (10YR 5/2, dry) to very dark grayish Brown (10YR 3/2, moist); clay; weak angular to sub-angular blocky structure; very sticky and very plastic, very firm, hard; common fine to medium continuous and discontinuous interstitial pores; few fine to coarse roots; shinny faces; few gypsum in the form of powder; very weak effervescence with HCl; PH 8.1; diffuse smooth boundary.
90-150 C2	Dark grayish brown (10YR 4/2, dry) to dark brown (10YR 3/3, moist); clay; weak angular to sub-angular blocky structure; sticky and plastic; firm; hard ;common fine discontinuous random interstitial pores; few fine to coarse roots; few very fine crystals of gypsum ;shinny faces(silken sides), weak effervescence with HCl; pH 8.2.

Table 16: Soil characteristics of profile No. 5:

(a) Particle-size distribution, and $CaCO_3$ content:

Depth (cm)	Particle-size distribution (%)				Texture class	$CaCO_3$ (g/kg)
	C. sand	F. sand	Silt	Clay		
0-50	12.5	24.7	29.4	33.4	Clay loam	11.4
50-90	7.4	22.5	37.6	32.5	Clay loam	8.8
90-150	6.1	21.9	42.2	29.8	Clay loam	7.4

(b) EC, pH, soluble cations and anions, and gypsum:

Depth (cm)	EC dS/m	pH 1:2.5 suspension	Soluble cations (mmolc/L)				Soluble anions (mmolc/L)				Gypsum (g/kg)
			Ca^{++}	Mg^{++}	Na+	K^+	$SO_4^=$	$CO_3^=$	HCO^-_3	Cl^-	
0-50	4.51	8.0	14.96	4.91	23.96	1.26	14.31	0.00	9.50	21.30	17.0
50-90	1.10	8.1	2.68	1.82	4.92	1.07	2.67	0.00	2.06	5.77	17.0
90-150	1.39	8.2	3.74	5.27	4.89	1.00	2.81	0.00	3.62	7.47	14.5

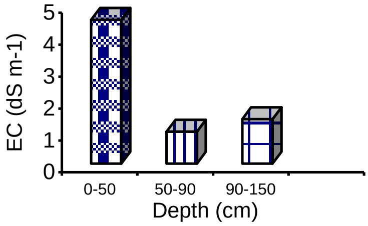
(c) Cation Exchange capacity (CEC), Exchangeable cations, ESP, and O.M.

Depth (cm)	CEC (cmolc/ kg)	Exchangeable cation (cmolc/ kg)				ESP	O.M (g/kg)
		Ca^{++}	Mg^{++}	Na+	K^+		
0-50	30.20	14.62	11.64	3.64	0.30	12.05	16.0
50-90	24.39	13.00	8.65	2.11	0.63	8.65	4.65
90-150	26.03	18.28	4.79	2.17	0.79	8.34	6.92

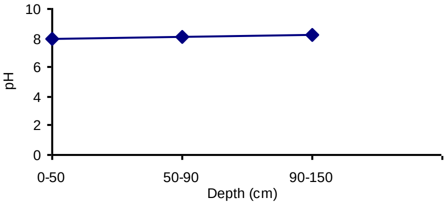
(d) Available macro and micro nutrients in the surface layer:

Depth (cm)	Macro nutrients (mg/kg)			Micro nutrients (mg/kg)			
	N	P	K	Fe	Mn	Zn	Cu
0-50	51.22	20.61	196.08	16.42	33.14	5.48	5.11

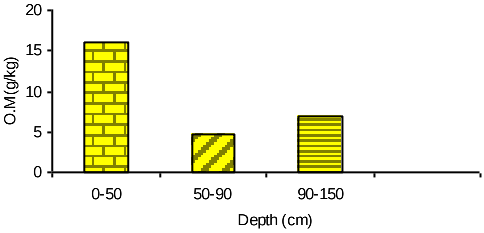
Fig. 25: Descriptive graphs of some soil characteristics of profile No. 5:



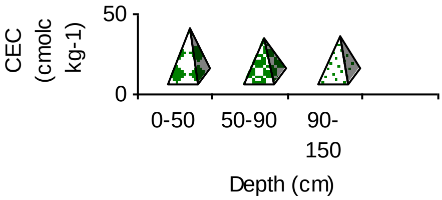
Soil salinity (dS m-1)



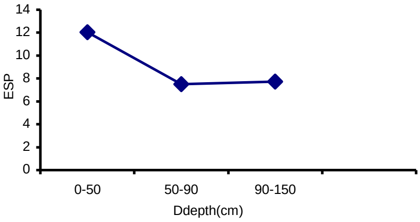
Soil Reaction (pH)



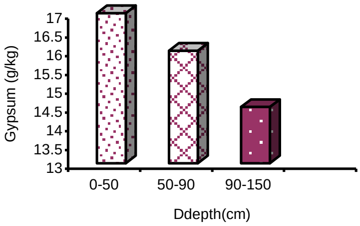
Organic matter (g/kg)



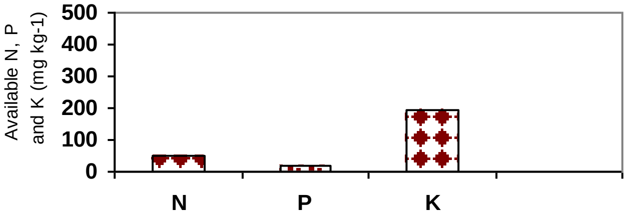
Cation exchange capacity(cmolc kg-1)



Exchangeable sodium percentage



Gypsum (g/kg)



Available N, P and K (mg/kg)

<u>**(b) Soils of moderately high recent river terraces**</u>:

This unit is represented by profile No. 10. The morphological description and the analytical data are shown in the following lines, Figure 26 and Table 17.

The particle-size distribution revealed that, the soil texture of the successive layers of the studied soil profile is clay

Calcium carbonate content is very few and ranges between 4.0 and 9.0 g/kg in the different layers of the profile.

The gypsum content is few and ranges between 13.0 and 25.0 g/kg in successive layers of the studied soil profile.

Organic matter content is low and ranging between 1.9 and 8.5 g/kg.

Soil salinity values expressed as the electrical conductivity (EC) of the soil paste extract differs from 1.90 and 4.43 dS/m. Values of soluble cations and anions revealed that, sodium and calcium are the dominant cations in the different layers of the studied soil profile. On the other side, chloride is the dominant anion, so sodium chloride is the dominant salt in these soils. The pH values range between 8.0 and 8.

Cation exchange capacity ranges between 48.80 and 70.00 cmolc/ kg soil in the successive layers of the studied soil profile. The high value of CEC may be due to the high content of the clay fraction.

The exchangeable calcium forms the main exchangeable cation in the successive layers of the studied soil profiles where it ranges between 24.83 and 39.61 cmolc/kg.

The ESP values range between 2.49 and 4.54 in the different layers of representative soil profile.

The macro nutrients (P and K) have high values of 14.90 and 750.45 mg/kg, respectively; while nitrogen has a low value of 15.66 mg/kg, on the other hand, all micro nutrients (Fe, Mn, Zn and Cu) recorded higher values of 7.01, 14.85, 5.98 and 4.80 mg/kg, successively.

Profile No. : 10
Date of description. : 25 /7/ 2008
Mapping unit. : F118
Elevation . : 8 m. a.s.l.
Coordinates . : Long. 30 ^{O} 17` 08 `` Lat. 31$^{O}$ 22` 00 ``.
Classification. :Typic Haplargids.
Soil temperature regime . : Thermic.
Soil moisture regime. : Torric.
Topography . : Flat.
Land form. : Flood plain
Slope on which profile is sited. : Flat.
Land use. : Cultivated with maize.
Humans influence. : Cultivation.
Native vegetation . : None.
Parent material . : Alluvial deposits.
Soil depth. : Deep.
Evidence of surface stones or rock outcrop.: None.
Evidence of Erosion. : None.
Other surface features. : None.
Drainage conditions. : Well drained.
Depth of ground water. :> 150 cm.

Depth cm	**Description**
0-30 Ap	Grayish brown (10YR 5/2) dry, dark brown (10YR 3/3) moist; clay; strong angular to sub-angular blocky structure; very sticky and very plastic; firm; extremely hard; common fine discontinuous random interstitial pores; many coarse roots; moderate very fine crystals of gypsum; shinny faces(silken sides); very weak effervescence with HCl; pH 8.1; clear smooth boundary.
30-90 A/B	Dark grayish brown (10YR 4/2) dry, dark brown (10YR 3/3) moist; clay; strong angular to sub-angular blocky structure; very sticky and very plastic, firm, extremely hard; common fine discontinuous random interstitial pores; clay films coat the pores; many fine roots; moderate very fine crystals of gypsum; shinny faces (silken sides), very weak effervescence with HCl; pH 8.0; clear smooth boundary.
90-150 Bt	Grayish brown (10YR 5/2) dry, very dark grayish brown (10YR 3/2) moist, clay; strong angular to sub-angular blocky structure; very sticky and very plastic; very firm; extremely hard; common fine to medium continuous and discontinuous interstitial pores; shinny faces; few gypsum in the form of powder; very weak effervescence with HCl; pH 8.0

Table 17: Soil characteristics of profile No. 10:

(a) Particle-size distribution, and $CaCO_3$ content:

Depth (cm)	Particle-size distribution (%)				Texture class	$CaCO_3$ (g/kg)
	C. sand	F. sand	Silt	Clay		
0-30	6.8	27.2	2.00	64.0	Clay	1.5
30-90	4.3	30.5	1.9	63.3	Clay	9.0
90-150	4.3	1.3	8.5	85.9	Clay	4.0

(b) EC, pH, soluble cations and anions, and gypsum:

Depth (cm)	EC dS/m	pH 1:2.5 suspension	Soluble cations (mmolc/L)				Soluble anions (mmolc/L)				Gypsum (g/kg)
			Ca^{++}	Mg^{++}	Na+	K^+	$SO_4^=$	$CO_3^=$	HCO_3^-	Cl^-	
0-30	4.43	8.1	10.80	6.90	25.40	1.20	9.76	0.00	11.17	23.37	25.0
30-90	3.42	8.0	7.70	6.34	18.70	1.20	4.74	0.00	8.88	20.58	24.5
90-150	1.90	8.0	5.68	4.39	7.71	1.22	1.66	0.00	5.57	11.77	13.0

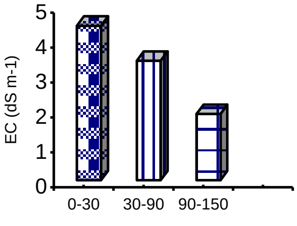
(c) Cation Exchange capacity (CEC), Exchangeable cations, ESP, and O.M.

Depth (cm)	CEC Cmolc/ kg	Exchangeable cations (cmolc/ kg)				ESP	O.M (g/kg)
		Ca^{++}	Mg^{++}	Na+	K^+		
0-30	48.80	24.83	21.25	1.22	1.50	2.49	8.5
30-90	48.44	30.14	15.57	1.89	0.84	3.90	1.9
90-150	70.00	39.61	24.00	3.18	3.21	4.54	1.9

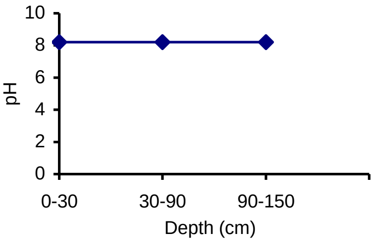
(d) Available macro and micro nutrients in the surface layer:

Depth (cm)	Macro nutrients (mg/kg)			Micro nutrients (mg/kg)			
	N	P	K	Fe	Mn	Zn	Cu
0-30	15.66	14.90	750.45	7.01	14.85	5.98	4.80

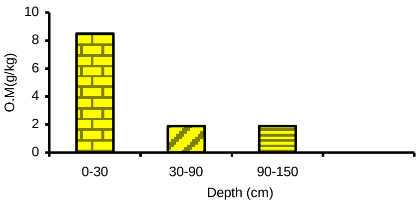
Fig. 26: Descriptive graphs of some soil characteristics of profile No. 10:



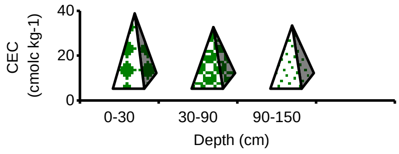
Soil salinity (dS/ m)



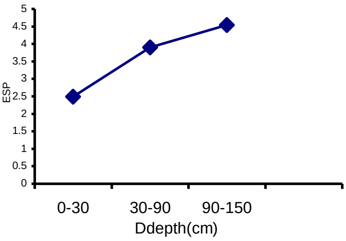
Soil Reaction (pH)



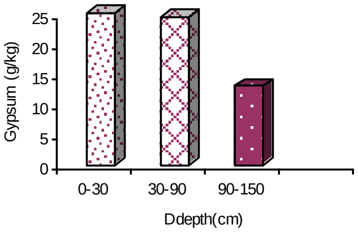
Organic matter (g/kg)



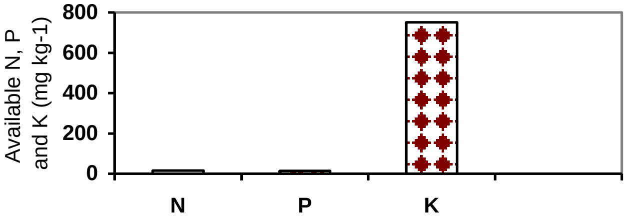
Cation exchange capacity(cmolc /kg)



Exchangeable sodium percentage



Gypsum (g/kg)



Available N, P and K (mg/kg)

(c) Soils of moderate recent river terraces:

These soils are represented by profiles No. 15 and 16. Profile No. 15 is selected to represent these soils and the other profile was tabulated in the appendix.

The morphological description and the analytical data are shown in Figure 27 and Table 18.

The particle-size distribution showed that, the soil texture class is clay, except for the surface layer, where it is clay loam in profile No.15. The texture class is clay in profile No. 16 except for the last layer, where it is silt clay.

Calcium carbonate content is few to moderate as it ranges between 12.0 and 30.71 g/kg in the different layers of the studied profiles.

Gypsum content is very few to moderate and ranges between 7.5 and 30.3 g/kg in successive layers of the studied soil profiles

Organic matter content ranges between 0.0 and 16.1 g/kg. It decreases regularly with depth.

The soil salinity values as expressed by the electrical conductivity (EC) varies from low to high and ranges between 0.60 and 12.38 dS/m. The highest value of EC occurred in the surface layer of profile (16), due to capillary forces in arid conditions which resulted in salt accumulation in the surface layer. The data of soluble cations and anions revealed that, sodium is the dominant cation followed by calcium in the different layers of the studied profiles. On the other hand, chloride and bicarbonate are the dominant anions.

The pH values range between 8.0 and 8.2 in the successive layers of the studied profiles.

The cation exchange capacity ranges between 31.40 and 61.01 cmolc/kg soil in the successive layers of the studied soil profiles.

The exchangeable calcium is the main exchangeable cations in the successive layers of the studied soil profiles.

The ESP values ranges between 1.58 and 11.08 in the different layers of representative soil profiles.

The status of macro and micro nutrients illustrated that, nitrogen has low values in the all surface layers of the studied profiles ranging between 15.76 and 2.16 mg/kg, and this may be due to the few content of the organic materials. Potassium showed the same behavior as it has low values also, it ranges between 99.39 and 220.45 mg/kg, while phosphorus has values of 6.89 (low) and 25.12 (high) mg/kg,

Available iron existed in higher concentrations in all the studied soil profiles, where it ranges between 8.98 and 7.16 mg/kg, manganese has followed the same trend of iron and its concentrations ranges between 11.05 and 9.04 mg/kg and copper revealed high values, range between 2.79 and 3.23 mg/kg in all the studied soil profiles. On the other side, zinc has occurred in low values, where they range between 0.55 and 0.49 mg/kg in all the studied soil profiles.

Profile No.	: 15
Date of description	: 25/7/ 2008
Mapping unit	: F119.
Elevation	: 12 m. a.s.l
Coordinates	: Lat. 30^{o} 12` 03 `` Long $31^{o}$ 17` 00``
Classification	: Typic Haplargids.
Soil temperature regime .	: Thermic.
Soil moisture regime .	: Torric.
Topography	: Flat.
Land form	: Flood plain.
Slope on which profile is sited	: Flat
Land use	: Cultivated with maize.
Humans influence	: Cultivation.
Native vegetation	: None.
Parent material	: Alluvial deposits.
Soil depth	: Deep.
Evidence of surface stones or rock outcrop	: None.
Evidence of Erosion	: None.
Other surface features	: Cracks 0.5-1cm width and 30 cm depth.
Drainage conditions	: Well drained.
Depth of ground water	: >150 cm.

Depth cm	**Description**
0-25 Ap	Grayish brown (10YR 5/2, dry) to dark brown (10YR 4/2 moist); clay; weak angular to sub- angular blocky structure ; very sticky and very plastic, extremely hard, common fine discontinuous pores; few fine roots; very few to few gypsum crystals; moderate very fine soft white segregation of $CaCO_3$; moderate effervescence with HCl; pH 8.2 ; defuse smooth boundary.
25-80 Bt	Grayish brown (10YR 5/2, dry) to dark brown (10YR 4/2, moist), clay; strong angular to sub-angular blocky structure; very sticky and very plastic; very hard; common medium continuous and discontinuous interstitial pores; clay films coat the pores; few fine to coarse roots; few small elongate gypsum crystals; moderate fine angular hard yellowish brown nodules of $CaCO_3$; moderate effervescence with HCl; pH 8.1; defuse smooth boundary.
80-150 C	Grayish brown (10YR 5/2, dry) to dark brown (10YR 4/2, moist); clay; strong angular to sub-angular blocky structure; very sticky and very plastic; extremely hard, common medium continuous and discontinuous interstitial pores; no roots; very few gypsum in the form of powder ; moderate fine angular hard yellowish brown nodules of $CaCO_3$; moderate effervescence with HCl; pH 8.1.

Table 18: Soil characteristics of profile No. 15:

(a) Particle-size distribution, and $CaCO_3$ content:

Depth (cm)	**Particle-size distribution (%)**				**Texture class**	**$CaCO_3$ (g/kg)**
	C. sand	**F. sand**	**Silt**	**Clay**		
0-25	1.9	20.4	41.00	36.7	Clay loam	12.5
25-80	2.6	21.7	23.1	52.6	Clay	12.0
80-150	3.7	21.9	22.4	52.0	Clay	12.0

(b) EC, pH, soluble cations and anions, and gypsum:

Depth (cm)	**EC dS/m**	**pH 1:2.5 suspension**	**Soluble cations (mmolc/L)**				**Soluble anions (mmolc/L)**				**Gypsum (g/kg)**
			Ca^{++}	**Mg^{++}**	**Na+**	**K^+**	**$SO_4^=$**	**$CO_3^=$**	**HCO^-_3**	**Cl^-**	
0-25	0.96	8.2	1.74	1.16	5.70	1.00	0.43	0.00	3.52	5.65	14.0
25-80	0.89	8.1	2.20	1.49	3.99	1.22	1.17	0.00	3.56	4.17	13.3
80-150	0.70	8.1	1.85	1.10	2.85	1.20	0.63	0.00	1.84	4.53	7.5

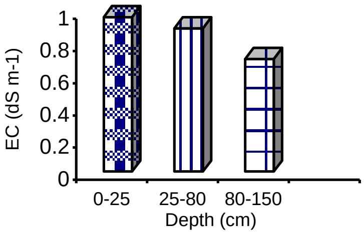
(c) Cation Exchange capacity (CEC), Exchangeable cations, ESP, and O.M.

Depth (cm)	**CEC cmolc/ kg**	**Exchangeable cations (cmolc/ kg)**				**ESP**	**O.M (g/kg)**
		Ca^{++}	**Mg^{++}**	**Na+**	**K^+**		
0-25	31.40	17.52	12.86	0.54	0.48	1.72	9.0
25-80	41.11	25.11	14.84	0.65	0.51	1.58	6.7
80-150	35.30	22.78	11.27	0.78	0.47	2.21	0.8

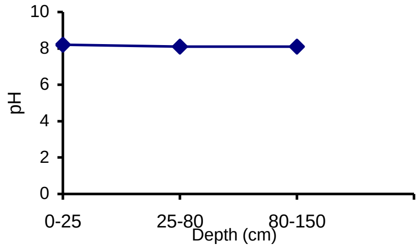
(d) Available macro and micro nutrients in the surface layer:

Depth (cm)	**Macro nutrients (mg/kg)**			**Micro nutrients (mg/kg)**			
	N	**P**	**K**	**Fe**	**Mn**	**Zn**	**Cu**
0-25	15.76	25.12	220.45	8.98	11.05	0.49	3.23

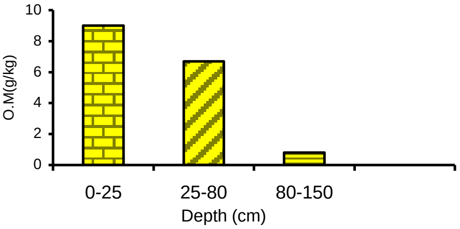
Fig. 27: Descriptive graphs of some soil characteristics of profile No. 15:



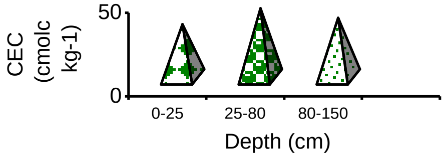
Soil salinity (dS/ m)



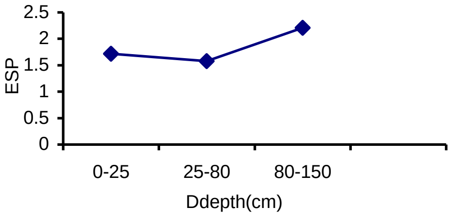
Soil Reaction (pH)



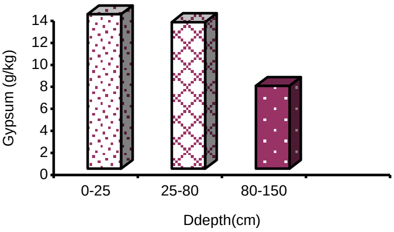
Organic matter (g/kg)



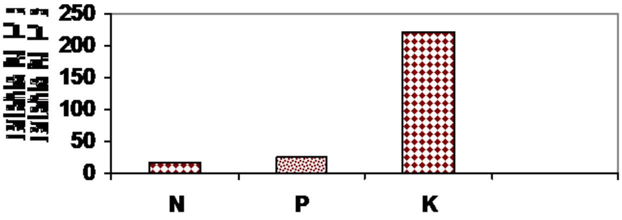
Cation exchange capacity(cmol/c kg)



Exchangeable sodium percentage



Gypsum (g/kg)



Available N, P and K (mg/kg)

(d) Soils of low recent river terraces:

Low lying soils are represented by profile No. 11. The morphological description and the analytical data are shown in the following pages, Figure 28 and Table 19.

The particle-size distribution data showed that, the soil texture class is silt clay in the successive layers, except for the last layer where it is silt loam.

The calcium carbonate content is very few, as it varies from 20.0 to 25.0 g/kg in the successive layers of the studied soil profile.

The gypsum content is very few to few and ranging between 6.0 and 13 g/kg in different layers of the studied soil profile.

The organic matter content ranges between 2.1 and 25.5 g/kg. The highest value which occurs in the surface layer indicates the continuous addition of organic fertilizers.

The soil salinity values expressed as the electrical conductivity (EC) are low and range between 1.10 and 1.54 dS/m. Values of soluble cations and anions revealed that, sodium is the dominant cation in the different layers of the investigated soil profile. On the other hand, bicarbonate is the dominant anion. Thus, sodium bicarbonate is the dominant salt.

The pH value is 8.3 in the successive layers of the studied profile, reflecting the influence of sodium bicarbonate.

The cation exchange capacity ranges between 20.10 and 40.66 cmolc/kg soil in the successive layers of the studied soil profile.

The exchangeable calcium followed by magnesium are the main exchangeable cations in the successive layers of the studied soil profile, where it ranges between 9.64 and 26.00 cmolc/kg for calcium and between 4.79 and 13.72 for magnesium.

The ESP values range between 5.41 and 27.56 in the different layers of the representative soil profile. The high value indicates high sodicity.

Nitrogen has a low level of 12.00 mg/kg; while phosphorus and potassium occurred in high values of 8.20 and 475.22 mg/kg, respectively. On the other side, all micro nutrients (Fe, Mn, Zn and Cu) recorded high values of 16.22, 8.02, 2.14 and 4.92 mg/kg, successively.

Profile No. : 11
Date of description : 22/7/ 2008
Mapping unit : F1110
Elevation : 10 m. a.s.l
Coordinates : Lat. 30° 18` 09`` Long. 31° 12` 03 ``
Classification : Typic Torrifluvents.
Soil temperature regime . : Thermic.
Soil moisture regime . : Torric.
Topography : Flat.
Land form : Flood plain.
Slope on which profile is sited : Flat
Land use : Cultivated with maize.
Humans influence : Cultivation.
Native vegetation : None.
Parent material : Alluvial deposits.
Soil depth : Deep.
Evidence of surface stones or rock outcrop : None.
Evidence of Erosion : None.
Other surface features : None.
Drainage conditions : Very well drained.
Depth of ground water : >150 cm.

Depth cm	**Description**
0-35 Ap	Dark grayish brown (10YR 4/2, dry) to very dark grayish brown (10YR 3/2, moist); clay; moderate angular to sub-angular blocky structure; very sticky and very plastic, hard; shinny faces (slicken sides); common fine discontinuous random interstitial pores; many coarse roots; few fine gypsum crystals; moderate fine soft white segregations of $CaCO_3$; moderate effervescence with HCl; pH 8.3; defuse smooth boundary.
35-85 C1	Dark grayish brown (10YR 4/2, dry) to dark brown (10YR 3/3, moist); silt clay; moderate angular to sub-angular blocky structure; very sticky and very plastic, extremely hard; common medium discontinuous interstitial pores; many coarse roots; very few gypsum in the form of powder; moderate angular yellowish brown nodules of $CaCO_3$; moderate effervescence with HCl; pH 8.3; defuse smooth boundary.
85-150 C2	Dark grayish brown (10YR 4/2, dry) to very dark grayish brown (10YR 3/3, moist); silt clay; weak angular to sub-angular blocky structure; very sticky and very plastic; extremely hard; common medium discontinuous interstitial pores; no roots; moderate angular hard yellowish brown nodules of $CaCO_3$; few small elongate gypsum crystals; moderate effervescence with HCl; pH 8.3.

Table 19: Soil characteristics of profile No. 11:

(a) Particle-size distribution, and $CaCO_3$ content:

Depth (cm)	Particle-size distribution (%)				Texture class	$CaCO_3$ (g/kg)
	C. sand	F. sand	Silt	Clay		
0-35	2.3	17.2	40.2	40.3	Silty Clay	4.0
35-85	5.6	11.0	42.5	40.9	Silty clay	25.0
85-150	2.9	14.2	57.2	25.7	Silt loam	20.0

(b) EC, pH, soluble cations and anions, and gypsum:

Depth (cm)	EC dS/m	pH 1: 2.5	Soluble cations (mmolc/L)				Soluble anions (mmolc/L)				Gypsum (g/kg)
			Ca^{++}	Mg^{++}	Na+	K^+	$SO_4^=$	$CO_3^=$	HCO^-_3	Cl^-	
0-35	1.30	8.3	4.74	2.71	4.6	0.89	2.43	0.00	5.48	5.09	10.0
35-85	1.54	8.3	5.65	2.75	6.18	0.82	3.17	0.00	8.12	4.11	6.0
85-150	1.10	8.3	3.02	0.77	6.99	0.22	0.76	0.00	8.52	1.72	13.0

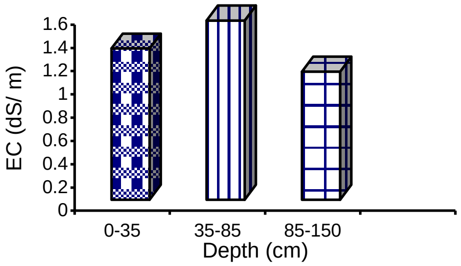
(c) Cation Exchange capacity (CEC), Exchangeable cations, ESP, and O.M.

Depth (cm)	CEC Cmolc/ kg	Exchangeable cations (cmolc/ kg)				ESP	O.M (g/kg)
		Ca^{++}	Mg^{++}	Na+	K^+		
0-35	40.66	26.00	11.89	2.20	0.57	5.41	25.5
35-85	31.18	14.55	13.73	2.32	0.58	7.44	2.1
85-150	20.10	9.64	4.79	5.54	0.13	27.56	2.1

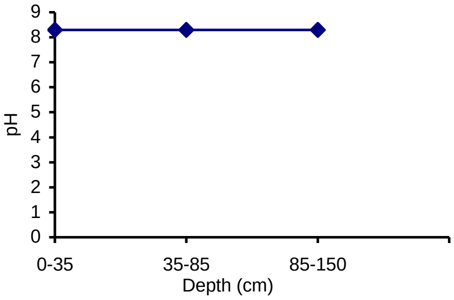
(d) Available macro and micro nutrients in the surface layer:

Depth (cm)	Macro nutrients (mg/kg)			Micro nutrients (mg/kg)			
	N	P	K	Fe	Mn	Zn	Cu
0-35	12.00	8.20	475.22	16.22	8.02	2.14	4.92

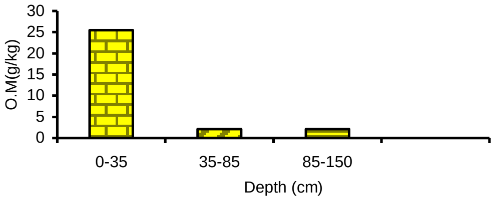
Fig. 28: Descriptive graphs of some soil characteristics of profile No. 11:



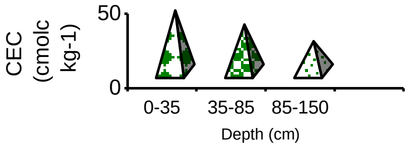
Soil salinity (dS/ m)



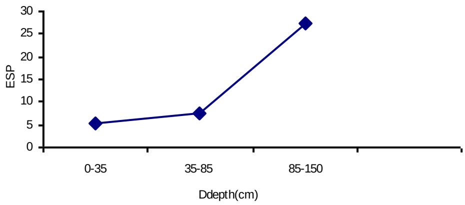
Soil Reaction (pH)



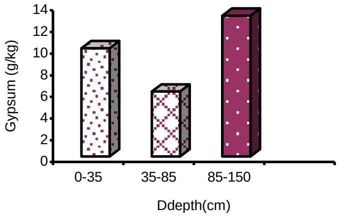
Organic matter (g/kg)



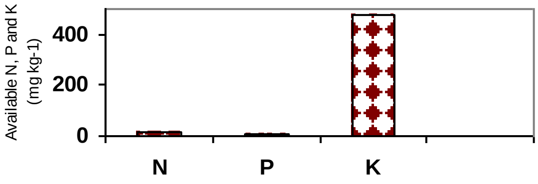
Cation exchange capacity(cmolc/ kg)



Exchangeable sodium percentage



Gypsum (g/kg)



Available N, P and K (mg/kg)

Soils of levees:

A levee has many names i.e. embankment, flood bank or stop bank. It is a natural or artificial slope or wall to regulate water levels. It is usually earthen and often parallel to the course of a river or the coast **(Petroski, 2006)**.

In the investigated area and during the successive floods before instruction of high dam, the river's banks were built up above the level of the rest of the floodplain resulting in ridges called natural levees.

Soil profile No. 14 is selected to represent these soils, as shown in morphological description, Table 20 and Figure 29.

The particle-size distribution shows that, the soil texture class is clay except for the last layer, where it is loam.

Calcium carbonate content is few as it ranges between 24.0 and 24.5 g/kg in the different layers of the studied soil profile.

Gypsum content is few and ranges between 10 and 16 g/kg increasing regularly in the successive layers of the studied soil profile. Organic matter content is few to moderate ranges between 4 and 20 g/kg, decreasing regularly with depth. The high value of organic matter indicates the continuous addition of organic fertilizers.

The electrical conductivity (EC) of soil paste extract is low as it ranges between 0.91 and 1.99 dS/m. Values of soluble cations and anions showed that, sodium and calcium are the dominant cations in the different layers of the studied profile. On the other hand, chloride followed by bicarbonate is the dominant soluble anion, so sodium chloride is the dominant salt in the studied soil profile.

The soil pH values vary between 8.0 and 8.2, decreasing regularly with depth in the successive layers of the studied profile.

The cation exchange capacity varies between 30.16 and 38.23 cmolc/kg soil decreasing regularly with depth, parallel to the organic matter decreasing in the successive layers of the studied soil profile.

The exchangeable calcium followed by magnesium is the main exchangeable cations in the successive layers of the studied soil Profile.

The ESP values increases regularly with depth, range between 2.62 and 5.34 in the different layers of the representative soil profile.

The macro nutrients in the first 30 cm of the studied profile revealed that, nitrogen has a low value of 15.93 mg/kg; while phosphorus and potassium have high values of 28.75 and 455.98 mg/kg, successively. All micro nutrients (Fe, Mn, Zn and Cu) have high values of 20.66, 11.56, 3.98 and 5.16 mg/kg, respectively.

Profile No. : 14
Date of description. : 22/7//2008
Mapping unit. : L1111.
Elevation. : 9 m . a.s.l.
Coordinates. : Lat. 30° 19` 00`` Long. 31° 06` 55``.
Classification. : Aquic Haplargids. .
Soil temperature regime. : Thermic .
Soil moisture regime. : Aquic.
Topography. : Flat.
Land form. : Flood plain.
Slope on which profile is sited. : Gradient (Flat) Form (Straight).
Land use . :Cultivated with maize and some other trees.
Humans influence . : Cultivation.
Native vegetation . : None.
Parent material . : Alluvial deposits.
Soil depth . : Deep.
Evidence of surface stones or rock outcrop.: None.
Evidence of Erosion . : None.
Other surface features . : Cracks (1- 0.5 cm width).
Drainage conditions. : Moderately well drained.
Depth of ground water . : 70 cm.

Depth cm	**Description**
0-30 Ap	Dark grayish brown (10 YR 4/2, dry) to very dark grayish brown (10 YR 3/2, moist); clay; moderate angular to sub-angular blocky structure; very sticky and very plastic; very hard; few gypsum in the form of powder; moderate fine soft white segregation of $CaCO_3$; common fine to medium discontinuous random interstitial pores; many coarse roots; moderate effervescence with HCl; pH8.2; defuse smooth boundary.
30-55 Bt	Dark grayish brown (10 YR 5/2, dry) to very dark grayish brown (10 YR 3/2, moist); clay; moderate angular to sub-angular blocky structure; sticky and plastic, moderately hard; common fine to medium discontinuous random interstitial pores; clay films coat the pores; few gypsum in the form of powder; moderate fine soft white segregation of $CaCO_3$;; moderate effervescence with HCl; pH8.1; defuse smooth boundary.
55-70 C	Dark grayish brown (10 YR 5/2, dry), very dark grayish brown (10 YR 3/2, moist); clay; weak angular blocky structure; slicken sides , sticky and plastic, hard, few small gypsum crystals; moderate fine soft segregation of $CaCO_3$; common fine to medium discontinuous random interstitial pores; no roots; moderate weak effervescence with HCl; pH 8.0.
Water table	

Table 20: Soil characteristics of profile No. 14:

(a) Particle-size distribution, and $CaCo_3$ content:

Depth (cm)	Particle-size distribution (%)				Texture class	$CaCO_3$ (g/kg)
	C. sand	F. sand	Silt	Clay		
0-30	3.3	25.0	30.1	41.6	Clay	24.0
30-55	3.4	12.8	31.2	52.6	Clay	24.4
55-70	2.5	24.0	45.4	28.1	loam	24.5

(b) EC, pH, soluble cations and anions, and gypsum:

Depth (cm)	EC dS/m	pH 1: 2.5	Soluble cations (mmolc/L)				Soluble anions (mmolc/L)				Gypsum (g/kg)
			Ca^{++}	Mg^{++}	Na+	K^{+}	$SO_4^{=}$	$CO_3^{=}$	HCO^{-}_3	Cl^{-}	
0-30	1.99	8.2	5.02	4.97	8.85	1.06	1.49	0.00	6.44	11.97	10.0
30-55	1.45	8.1	4.88	2.83	5.77	1.02	1.58	0.00	5.91	7.02	16.0
55-70	0.91	8.0	4.23	1.72	2.36	0.79	1.12	0.00	3.10	4.88	16.0

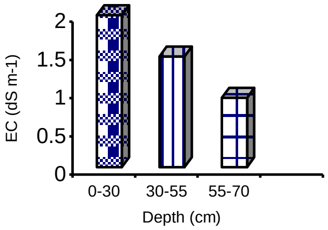
(c) Cation Exchange capacity (CEC), Exchangeable cations, ESP, and O.M.

Depth (cm)	CEC (cmolc/ kg)	Exchangeable cation (cmolc/ kg)				ESP	O.M (g/kg)
		Ca^{++}	Mg^{++}	Na+	K^{+}		
0-30	38.23	22.54	13.96	1.00	0.73	2.62	20.0
30-55	34.75	20.11	12.14	1.75	0.75	5.04	4.0
55-70	30.16	17.60	10.29	1.61	0.66	5.34	4.0

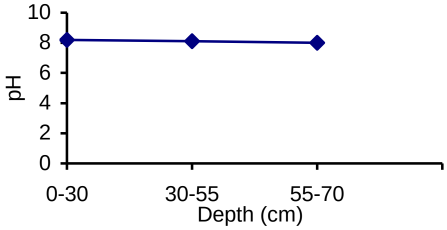
(d) Available macro and micro nutrients in the surface layer:

Depth (cm)	Macro nutrients (mg/kg)			Micro nutrients (mg/kg)			
	N	P	K	Fe	Mn	Zn	Cu
0-30	15.93	28.75	455.98	20.66	11.56	3.98	5.16

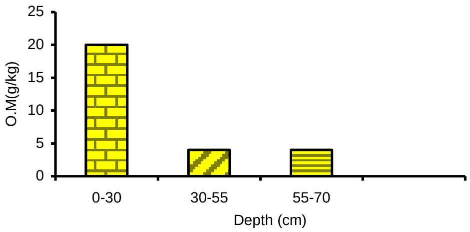
Fig. 29: Descriptive graphs of some soil characteristics of profile No. 14:



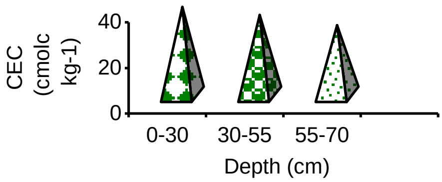
Soil salinity (dS/ m)



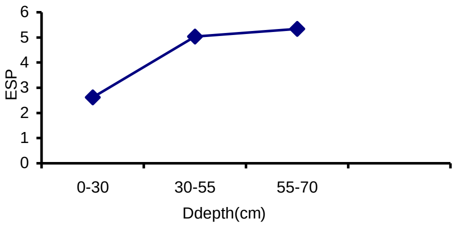
Soil Reaction (pH)



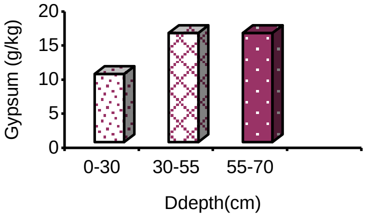
Organic matter (g/kg)



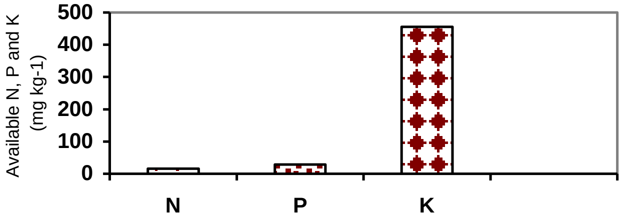
Cation exchange capacity(cmol/c kg)



Exchangeable sodium percentage



Gypsum (g/kg)



Available N, P and K (mg/kg)

Soils of the swales:

A swale is a low tract of land, especially one that is moist or marshy **(Webster, 2009).**

It is contour ditch. It receives and holds water or deposits and allow it to infiltrate gradually in the soil. Deposits run-off are caught in the swales which becomes a fertile area. Water and nutrients and the decomposed roots of plants grow in these swales improving soil structure down-slope.

Soil profile No. 13 is selected to represent these soils and the collected data of that profile are shown in the following pages, Table 21 and illustrated in Figure 30.

The data of particle-size distribution revealed that, the soil texture class is clay in the different layers of the studied soil profile, except for the surface layer where it is sandy clay.

Calcium carbonate content differs from very few to few, with values range between 17.0 and 30.0 g/kg in the different layers of the studied soil profile.

The gypsum content is very few to few and ranges between 0.00 and 18.0 g/kg in the successive layers of the studied soil profile.

Organic matter content shows low values range between 4.4 and 7.9 g/kg decreasing regularly with depth. The low level of O.M could be attributed to the low content of the organic residues.

Soil salinity data expressed by the electrical conductivity (EC) of the soil paste extract is low and vary from 0.9 to 2.1 dS/m. Values of soluble cations and anions revealed that, sodium and calcium are the dominant cations in the different layers of this soil profile. On the other hand, chloride is the dominant soluble anion, thus sodium chloride is the dominant salt in the studied soil profile.

Soil pH shows values of 8.1 and 8.2 in the successive layers of the studied profile.

The cation exchange capacity ranges between 30.0 and 45.91 cmolc/kg soil in the successive layers of the studied soil profile. The high value of CEC is paralleling with the high content of fine sediments (clay and organic matter).

The exchangeable calcium followed by magnesium are the main exchangeable cations in the successive layers of the studied soil profile.

ESP Values range between 3.43 and 5.96, increasing irregularly with depth in the different layers of the representative soil profile.

Regarding to soil surface layer nutrients, N value was 17.55 mg/kg; while phosphorus value was 5.85 and high potassium value of 416.20 mg/kg was existed. On the other hand, all micro nutrients (Fe, Mn, Zn and Cu) showed high values of 15.24, 11.12, 4.50 and 2.79 mg/kg, respectively.

Profile No. : 13
Date of description. :22/7 /2008
Mapping unit. : S112.
Elevation . : 10 m . a.s.l.
Coordinates . :. Lat. 30^{o} 18` 07 `` Long 31$^{o}$ 06` 40``
Classification. : Typic Haplargids. .
Soil temperature regime . : Thermic.
Soil moisture regime . : Torric.
Topography . : Flat.
Land form. : Flood plain.
Slope on which profile is sited . : Gradient (Flat.) Form (Straight).
Land use . : Cultivated with maize.
Humans influence . : Cultivation.
Native vegetation . : None.
Soil depth . : Deeep.
Parent material : Alluvial deposits.
Evidence of surface stones or rock outcrop. : None.
Evidence of Erosion . : None.
Other surface features . : None.
Drainage conditions. : Well drained.
Depth of ground water . :> 150 cm.

Depth cm	**Description**
0-50 Ap	Brown (10 YR 5/3, dry) to dark brown (10 YR 3/3, moist); sandy clay; moderate angular to sub-angular blocky structure; sticky and plastic; moderately hard; common fine to medium discontinuous interstitial pores; few coarse roots; few very fine gypsum crystals; moderate fine soft white segregation of CaCO$_3$; moderate effervescence with HCl; pH 8.2; defuse smooth boundary.
50-85	Brown (10 YR 5/3, dry) to dark grayish brown (10 YR 4/2, moist);

Bt	clay; strong angular to sub-angular blocky structure; very sticky and very plastic; extremely hard; common fine discontinuous interstitial pores; clay films coat the pores; no roots; moderate fine soft white segregation of $CaCO_3$; few gypsum in the form of powder; moderate effervescence with HCl; pH 8.2; defuse smooth boundary.
85-150 C2	Brown (10 YR 5/3, dry) to dark grayish brown (10 YR 4/2, moist), clay; strong angular to sub-angular blocky structure; very sticky and very plastic, extremely hard; common fine discontinuous interstitial pores; very few fine soft white segregation of $CaCO_3$; few small gypsum crystals; very weak effervescence with HCl; pH 8.1.

Table 21: Soil characteristics profile No. 13:

(a) Particle-size distribution and $CaCO_3$ content:

Depth (cm)	**Particle-size distribution (%)**				**Texture class**	**$CaCO_3$ (g/kg)**
	C. sand	**F. sand**	**Silt**	**Clay**		
0-50	11.0	42.3	11.1	35.6	Sandy clay	30.0
50-85	2.1	16.7	18.0	63.2	Clay	20.0
85-150	1.7	31.1	16.0	51.2	Clay	17.0

(b) EC, pH, soluble cations and anions, and gypsum:

Depth (cm)	**EC dS/m**	**pH 1:2.5 suspension**	**Soluble cations(mmolc/L)**				**Soluble anions (mmolc/L)**				**Gypsum (g/kg)**
			Ca^{++}	**Mg^{++}**	**Na+**	**K^{+}**	**SO$_4^{=}$**	**CO$_3^{=}$**	**HCO$^{-}_3$**	**Cl^{-}**	
0-50	2.10	8.2	6.95	4.41	9.26	0.38	2.87	0.00	4.67	13.46	18.0
50-85	1.25	8.2	3.75	1.81	6.04	0.90	1.77	0.00	3.77	6.96	17.5
85-150	0.90	8.1	2.07	1.55	4.87	0.50	0.90	0.00	2.55	5.56	0.0

(c) Cation Exchange capacity (CEC), Exchangeable cations, ESP, and O.M.

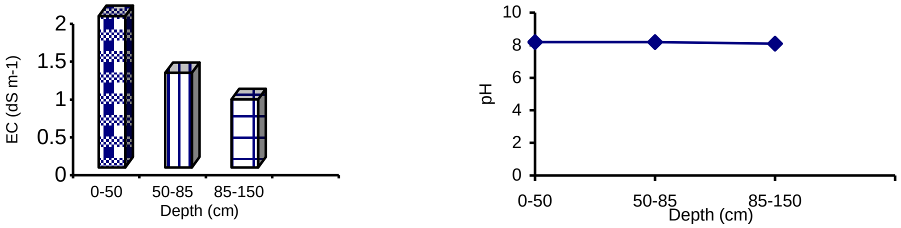
Depth (cm)	**CEC (cmolc/ kg)**	**Exchangeable cation (cmolc/ kg)**				**ESP**	**O.M (g/kg)**
		Ca^{++}	**Mg^{++}**	**Na+**	**K^{+}**		

0-50	30.00	14.33	14.03	1.03	0.61	3.43	7.9
50-85	45.91	26.30	17.20	1.95	0.46	4.25	5.4
85-150	36.24	20.12	13.08	2.16	0.88	5.96	4.4

(d) Available macro and micro nutrients in the surface layer:

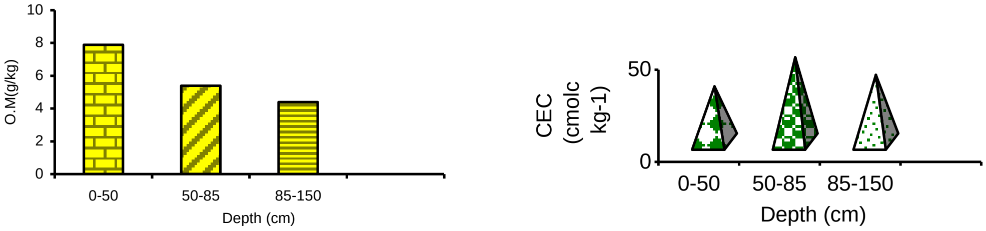
Depth (cm)	**Macro nutrients (mg/kg)**			**Micro nutrients (mg/kg)**			
	N	**P**	**K**	**Fe**	**Mn**	**Zn**	**Cu**
0-50	17.55	5.85	416.20	15.24	11.12	4.50	2.97

Fig. 30: Descriptive graphs of some soil characteristics of profile No. 13:



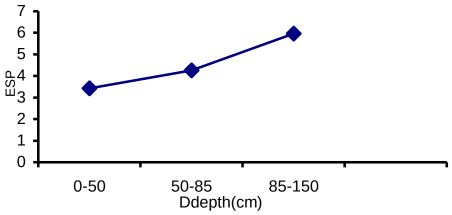
Soil salinity (dS/ m)

Soil Reaction (pH)

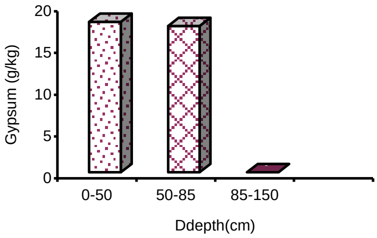


Organic matter (g/kg)

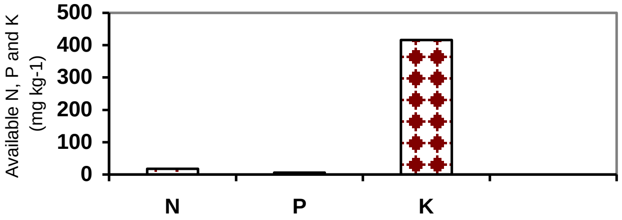
Cation exchange capacity(cmolc/ kg)



Exchangeable sodium percentage



Gypsum (g/kg)



Available N, P and K (mg/kg)

5.4.2. Soils of the hummocks:

Hummock is a general geological term referring to a small knoll or mound above ground **(Bates *et al.*, 1984)**.

They are typically less than 15.2 meters in height and tend to appear in groups or fields. It is difficult to make generalizations about hummocks because hummocks are diverse in their morphology and sedimentology **(Stefan, 2003).**

The term hummock, or hummocky, is also applied to extremely irregular surfaces **(Willams *et al.*, 1989).**

Hummocks In the area under study are well developed but severely degraded.

These soils have been divided into three sub-units according to relief, i.e. high hummocky area (Hu111), moderate hummocky area (Hu112), and low hummocky area (Hu113). Hummocky areas are represented by soil profiles No. 18, 17 and 7 as follows:

(a) Soils of high hummocky area:

Soil profile Number 18 represents these soils and their characteristics are presented in Table 22 and Figure 31.

The particle-size distribution is characterized by the same pattern of sedimentation in the stratified layers of the representing soil profile, where the texture class is sand. Sand fraction forms the main portion of these soils.

Calcium carbonate content is very few and ranges between 0.7 and 4.0 g/kg of the fine earth in the different layers of the studied soil profile.

Gypsum content ranges between very few to few in these soils and varies from 1.0 to 20.4 g/kg in the successive layers of the representative soil profile.

Organic matter content decreases regularly with depth and differed from 0.10 to 15 g/kg. The high values of organic materials in the surface layer of the studied profile could be attributed to the continuous addition of organic material to this soil as organic fertilizer.

Soil salinity values expressed as electric conductivity (EC) are low and range between 0.62 and 1.40 dS/m, indicating the efficiency of drain network. Data of soluble cations and anions revealed that, sodium followed by calcium are the dominant cations in the different layers of the studied profile. On the other hand, chloride is the dominant soluble anion in the successive layers, so sodium chloride is the dominant salt in these soils.

Values of pH range between 7.1 and 7.2 in the successive layers of the studied profile and regularly decreased with depth.

Cations exchange capacity is low due to the lack of clay content as it ranges between 2.40 and 9.00 cmolc/kg soil in the different layers of the studied soil profile.

The exchangeable calcium followed by magnesium form the main portion of the exchangeable cations in the successive layers of the studied soil profile.

The ESP values range between 5.0 and 43.75 in the different layers of the studied soil profile.

Data of available nutrients revealed that, available nitrogen, phosphorus and potassium are low, with values of 20.00, 4.72 and 8.54 mg/kg. On The other hand, iron, zinc and copper have high values of 12.71, 17.99 and 4.94 mg/kg, respectively; while manganese has a moderate value of 3.98 mg/kg in the surface layer of the studied soil profile.

Profile No. : 18
Date of description : 22 / 7/ 2008
Mapping unit : Hu111
Elevation : 12 m. a.s.l.
Coordinates : Lat. 30° 17` 00`` Long. 31° 22` 05``.
Classification : Typic Torripsamments.
Soil temperature regime : Thermic
Soil moisture regime : Torric
Topography : Flat.
Land form : High hummocky area
Slope on which profile is sited : Flat.
Land use : Cultivated with maize.
Humans influence : Cultivation.
Native vegetation : None.
Parent material : Aeolian deposits.
Soil depth : Deep.
Evidence of surface stones or rock outcrop: None.
Evidence of Erosion : None.
Other surface features : None.
Drainage conditions : Well drained.

Depth of ground water : >150 cm.

Depth (cm)	**Description**
0-40 A_p	Grayish brown (10YR5/2, dry) to very dark grayish brown (10YR3/2, moist) ;sand; granular structure; none sticky and none plastic; loose; common fine to medium discontinuous vertical pores; many fine to coarse roots; very few fine soft white segregation of $CaCO_3$; very few effervescence with HCl; pH 7.1 ; clear smooth boundary.
C1 40-90	Dark brown (10YR 3/3, dry) to very dark brown (10YR2/2, moist) , sand; granular structure; none sticky and none plastic, loose, common fine to medium discontinuous vertical pores; many fine to coarse roots; moderate fine soft white segregation of $CaCO_3$; very effervescence with HCl; pH 7.1; clear smooth boundary
90-150 C	Light yellowish brown (10YR 6/4, dry) to pale brown (10YR 6/3, moist); sand; granular structure; none sticky and none plastic; loose; common fine to medium discontinuous vertical pores; no roots; very few gypsum crystals, very weak effervescence with HCl, pH 7.2.

Table 22: Soil characteristics of profile No. 18:

(a) Particle-size distribution, and $CaCO_3$ content:

Depth (cm)	**Particle-size distribution (%)**				**Texture class**	**$CaCO_3$ (g/kg)**
	C. sand	**F. sand**	**Silt**	**Clay**		
0-40	84.1	10.8	2.4	2.7	Sand	4.0
40-90	79.0	11.1	4.8	4.98	Sand	3.0
90-150	89.3	5.1	2.7	2.9	Sand	0.7

(b) EC, pH, soluble cations and anions, and gypsum:

Depth (cm)	**EC dS/m**	**pH 1:2.5 suspension**	**Soluble cations (mmolc/L)**				**Soluble anions (mmolc/L)**				**Gypsum (g/kg)**
			Ca^{++}	**Mg^{++}**	**Na+**	**K^+**	**$SO_4^=$**	**$CO_3^=$**	**HCO^-_3**	**Cl^-**	
0-40	1.40	7.1	3.77	2.27	7.45	0.51	2.08	0.00	4.17	7.75	20.4
40-90	0.81	7.2	2.40	1.60	3.55	0.55	0.54	0.00	3.13	4.43	20.0

90-150	0.62	7.2	2.00	1.32	2.50	0.38	1.02	0.00	2.43	2.75	1.0

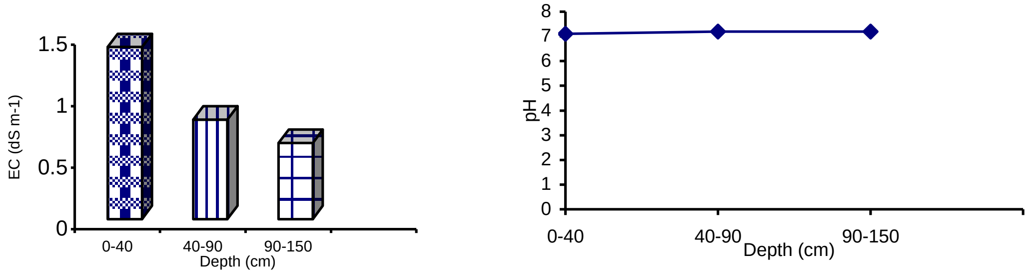
(c) Cation Exchange capacity (CEC), Exchangeable cations, ESP, and O.M.

Depth (cm)	**CEC (cmolc/ kg)**	**Exchangeable cation (cmolc/ kg)**				**ESP**	**O.M (g/kg)**
		Ca^{++}	**Mg^{++}**	**Na+**	**K^{+}**		
0-40	8.00	3.39	2.38	1.63	0.60	20.38	15.0
40-90	9.00	5.46	2.77	0.45	0.32	5.00	9.9
90-150	2.40	1.00	0.35	1.05	0.15	43.75	0.1

(d) Available macro and micro nutrients in the surface layer:

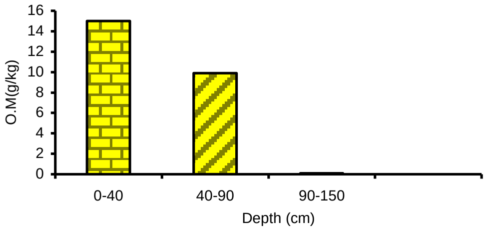
Depth (cm)	**Macro nutrients (mg/kg)**			**Micro nutrients (mg/kg)**			
	N	**P**	**K**	**Fe**	**Mn**	**Zn**	**Cu**
0-40	20.00	4.72	8.54	12.71	3.98	17.99	4.94

Fig. 31: Descriptive graphs of some soil characteristics of profile No. 18:

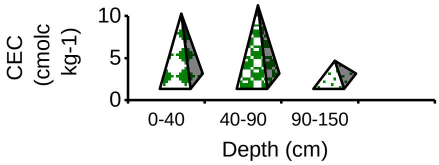


Soil salinity (dS/ m)

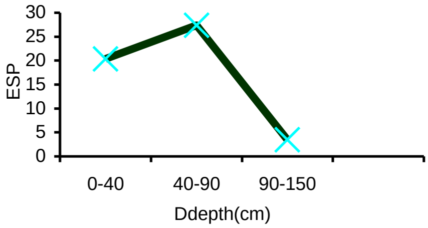
Soil Reaction (pH)



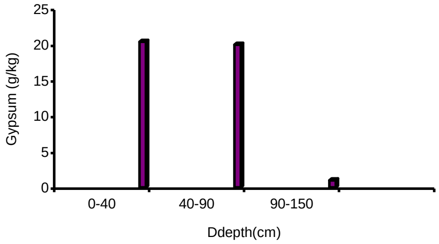
Organic matter (g/kg)



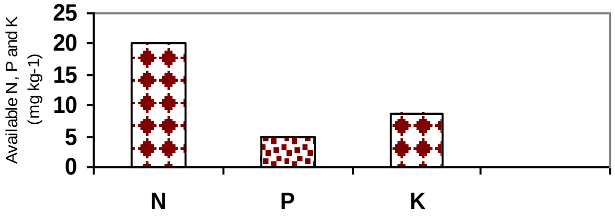
Cation exchange capacity(cmolc/ kg)



Exchangeable sodium percentage



Gypsum (g/kg)



Available N, P and K (mg/kg)

(b)Soils of moderate hummocky area:

Soil profile No. 17 is selected to represent these soils. The obtained data are given in Table 23 and Figure 32.

The particle-size distribution of the representing soil profile showed that, the texture class is sandy loam in the surface layer and sand in the sub-surface layers. The sand fraction constituents the main component of these soils.

Calcium carbonate content is very few and its values range between 6.5 and 6.8 g/kg of the fine earth in the successive layers of the studied soil profile.

Gypsum content is few and ranges between 15.2 and 18.0 g/kg in the successive layers of soil profiles.

Organic matter content varies from low to high and with 4.7 and 20.0 g/kg. The high values of organic matter in the surface layer of the studied profile are resulted from the continuous addition of organic fertilizers.

Soil salinity values expressed as electric conductivity (EC) of the soil paste extract are low and vary from 0.90 to 1.20 dS/m, reflecting adequate soil conservation.

Data of soluble cations and anions revealed that, sodium followed by calcium are the dominant cations in the different layers of the studied profile. On the other hand, chloride is the dominant soluble anion, so sodium chloride is expressed to be the dominant salt in the studied soil profile.

Values of pH ranges between 7.2 and 7.8 in the successive layers of the studied profile and regularly increased with depth.

The cation exchange capacity is low, due to the lack of organic matter and clay contents, as it ranges between 3.55 and 16.97 cmolc/kg soil in the different layers of the investigated soil profile.

The exchangeable calcium followed by magnesium are the main exchangeable cations in the successive layers of the studied soil profile.

Values of ESP were 5.63 to 10.79 in the different layers of the studied soil profile.

Available nitrogen, potassium and phosphorus values are low, and they recorded 12.56 and 18.70, and 4.55 mg/kg; successively. On The other hand, all micro nutrients (Fe, Mn, Zn and Cu) have high values of 38.00, 9.75, 6.07 and 12.09 mg/kg; respectively.

Profile No. : 17
Date of description : 22 /7/ 2008
Mapping unit : Hu112
Elevation : 23 m. a.s.l
Coordinates : Lat. 30^{o} 10` 03`` Long. 31$^{o}$ 24` 04``.
Classification : Typic Torripsaments.
Soil temperature regime . : Thermic.
Soil moisture regime . : Torric.
Topography : Flat.
Land form : Mod. hummocky area.

Slope on which profile is sited	: Flat
Land use	: Cultivated with maize.
Humans influence	: Cultivation.
Native vegetation	: None.
Parent material	: Aeolian deposits.
Soil depth	: Deep.

Evidence of surface stones or rock outcrop: None.

Evidence of Erosion	: None.
Other surface features	: None.
Drainage conditions	: Very well drained.
Depth of ground water	:> 150 cm.

Depth cm	**Description**
0-35 Ap	Strong brown (7.5YR 5/6, dry) to strong brown (7.5YR 4/6, moist); loamy sand; granular structure; none sticky and none plastic, loose, common fine to medium discontinuous random pores; few fine roots; moderate gypsum in the form of powder; very few fine soft white segregation of $CaCO_3$; very weak effervescence with HCl; pH 7.2 ; clear smooth boundary.
35-80 C1	Strong brown (7.5YR 5/8, dry) to dark yellowish brown (10YR 4/4, moist); sand; single grains; none sticky and none plastic, loose; common fine to medium discontinuous vertical interstitial pores; very few fine soft white segregation of $CaCO_3$; few fine roots; moderate gypsum in the form of powder ; very few effervescence with HCl; pH 7.8.
80-150 C	Strong brown (7.5YR 5/8, dry) to dark yellowish brown (10YR 4/4, moist); sand; single grains; none sticky and none plastic, loose; common fine to medium discontinuous vertical interstitial pores; very few fine soft white segregation of $CaCO_3$; few fine roots; moderate gypsum in the form of powder ; very few effervescence with HCl; pH 7.8.

Table 23: Soil characteristics of profile No. 17:

(a) Particle-size distribution, and $CaCO_3$ content:

Depth (cm)	**Particle-size distribution (%)**				**Texture class**	**$CaCO_3$ (g/kg)**
	C. sand	**F. sand**	**Silt**	**Clay**		
0-35	50.4	28.1	11.9	9.6	Sandy loam	8.8
35-80	79.8	15.0	3.2	2.0	Sand	8.8

80-150	70.6	21.55	6.05	1.8	Sand	6.5

(b) EC, pH, soluble cations and anions, and gypsum:

Depth (cm)	**EC dSz/m**	**PH 1:2.5 suspension**	**Soluble cations (mmolc/L)**				**Soluble anions (mmolc/L)**				**Gypsum (g/kg)**
			Ca^{++}	**Mg^{++}**	**Na+**	**K^+**	**$SO_4^=$**	**$CO_3^=$**	**HCO_3^-**	**Cl^-**	
0-35	0.90	7.2	1.83	0.75	5.43	0.99	0.53	0.00	1.83	6.64	18.0
35-80	1.10	7.8	2.87	1.60	5.52	1.01	0.98	0.00	2.18	7.84	16.5
80-150	1.20	7.8	3.72	1.85	5.37	1.06	1.32	0.00	2.51	8.17	15.2

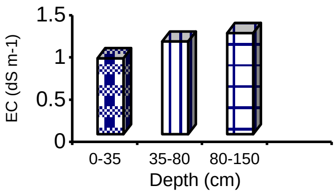
(c) Cation Exchange capacity (CEC), Exchangeable cations, ESP, and O.M.

Depth (cm)	**CEC cmolc/ kg**	**Exchangeable cations (cmolc/ kg)**				**ESP**	**O.M (g/kg)**
		Ca^{++}	**Mg^{++}**	**Na+**	**K^+**		
0-35	16.97	9.7	4.97	1.21	1.09	7.133	20.0
35-80	8.15	4.21	2.76	0.88	0.30	10.79	7.1
80-150	3.55	1.78	0.59	0.20	0.28	5.63	4.7

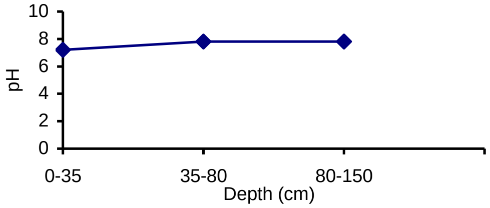
(d) Available macro and micro nutrients in the surface layer:

Depth (cm)	**Macro nutrients (mg/kg)**			**Micro nutrients (mg/kg)**			
	N	**P**	**K**	**Fe**	**Mn**	**Zn**	**Cu**
0-35	12.56	4.55	18.70	38.00	9.75	6.07	12.09

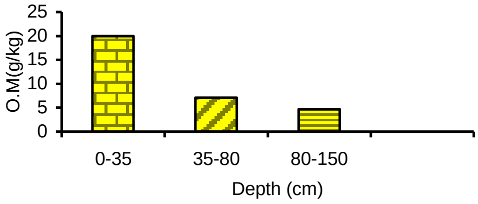
Fig. 32: Descriptive graphs of some soil characteristics of profile No. 17:



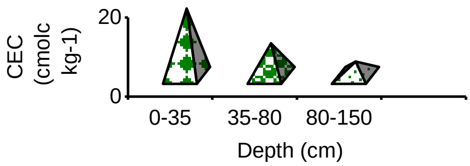
Soil salinity (dS m-1)



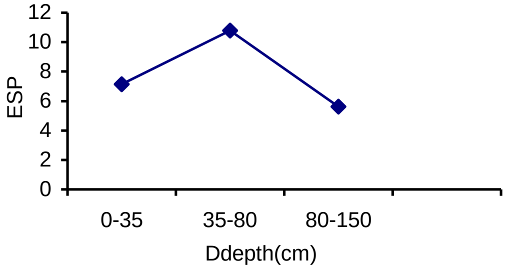
Soil Reaction (pH)



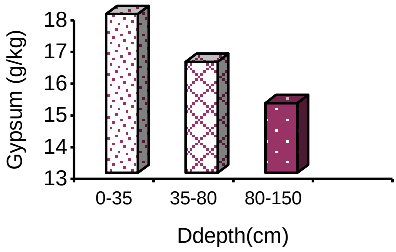
Organic matter (g/kg)



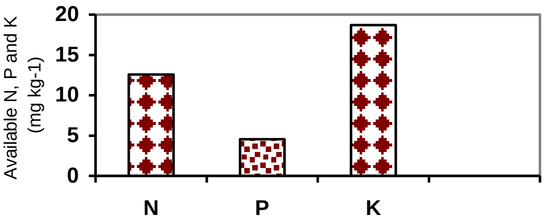
Cation exchange capacity(cmolc kg-1)



Exchangeable sodium percentage



Gypsum (g/kg)



Available N, P and K (mg/kg)

Soils of low hummocky area

Soil profile No. 7 is selected to represent these soils.

The obtained data are shown in Table 24 and illustrated in Figure 33.

The particle-size distribution of the representative soil profile shows that, the texture class is sandy loam in the first and last layer and sandy clay loam in the second layer, where the sand fraction forms the main component of these soils.

The content of calcium carbonate is very few to moderate and ranges between 19.9 and 27.7 g/kg of the fine earth in the different layers of the studied profile.

Gypsum content is very few to few in these soils. It ranges between 6.5 and 20.0 g/kg in the successive layers of the studied soil profile.

Organic matter content is low to moderate and differs from 2.4 and 10.0 g/kg.

Soil salinity data expressed as the electric conductivity (EC) of the soil paste extract is low as it ranges between 1.25 and 1.56 dS/m.

Data of soluble cations and anions revealed that, sodium is the dominant cation in the different layers of the studied profile. On the other hand, chloride is the dominant soluble anion in the successive layers, thus, sodium chloride may be the dominant salt in the studied soil profile.

Values of pH recorded 8.1 and 8.2 and in the successive layers of the studied soil profile.

Cations exchange capacity are few due to lack of organic matter and clay contents, where it ranges between 8.3 and 20.10 cmolc/kg soil in the different layers of the studied soil profile.

The exchangeable calcium and magnesium are the main exchangeable cations in the successive layers of the studied soil profile.

The ESP values range between 7.11 and 12.05 in the different layers of the studied soil profile.

Data of available nutrients declared that, available nitrogen and phosphorus have high values of 54.79 and 17.67 mg/kg, successively; while potassium has a low level of 10.87 mg/kg. On the other side, all micro nutrients (Fe, Mn, Zn and Cu) have high values of 25.98, 7.78, 6.88 and 8.76 mg/kg, respectively.

Profile No. : 7
Date of description : 22 /7/ 2008
Mapping unit : Hu113
Elevation : 6 m. a.s.l
Coordinates : Lat. 30^{o} 21` 06`` Long. $31^{o}$ 24` 04 ``

Classification	: Typic Torripsamment.
Soil temperature regime .	: Thermic.
Soil moisture regime .	: Torric..
Topography	: Flat.
Land form	: Low hummocky area.
Slope on which profile is sited	: Flat
Land use	: Cultivated with maize.
Humans influence	: Cultivation.
Native vegetation	: None.
Parent material	: Aeolian deposits.
Soil depth	: Deep.
Evidence of surface stones or rock outcrop	: None.
Evidence of Erosion	: None.
Other surface features	: None.
Drainage conditions	: well drained.
Depth of ground water	: >150 cm.

Depth cm	**Description**
0-25 Ap	Pale yellow (5Y 7/3, dry) to Olive (5Y 5/3, moist); sandy loam; weak angular to sub-angular blocky structure; non sticky and non plastic, firm, hard; common fine continuous and discontinuous random interstitial pores; many fine to coarse roots; moderate very fine crystals of gypsum; moderate fine soft white segregation of $CaCO_3$; moderate effervescence with HCl; pH 8.1; clear smooth boundary.
25-40 C1	Pale yellow (2.5Y 7/4, dry) to Light olive brown (2.5Y 5/6, moist); sandy clay loam, weak angular to sub-angular blocky structure; slightly sticky and slightly plastic, firm, hard; common fine to medium continuous and discontinuous interstitial pores; no roots; moderate very fine crystals of gypsum; moderate fine soft white segregation of $CaCO_3$; moderate effervescence with HCl; pH 8.2; defuse smooth boundary.
40-150 C2	Pale yellow (2.5 Y 7/4, dry), light olive brown (2.5Y 5/6, moist); sandy loam; weak sub-angular blocky structure; none sticky and none plastic; loose; common fine to medium continuous and discontinuous random interstitial pores; no roots; very few very fine crystals of gypsum; moderate fine soft white segregation of $CaCO_3$ few effervescence with HCl; pH 8.2.

Table 24: Soil characteristics of profile No. 7

(a) Particle-size distribution, and $CaCO_3$ content:

Depth (cm)	**Particle-size distribution (%)**				**Texture class**	**$CaCO_3$ (g/kg)**
	C. sand	**F. sand**	**Silt**	**Clay**		
0-25	59.0	7.3	25.1	8.6	Sandy loam	19.9
25-40	62.3	9.5	8.0	22.2	Sandy clay loam	27.7
40-150	65.6	3.2	22.3	8.9	Sandy loam	26.7

(b) EC, pH, soluble cations and anions, and gypsum:

Depth (cm)	**EC dS/m**	**PH 1:2.5 suspension**	**Soluble cations (mmolc/L)**				**Soluble anions (mmolc/L)**				**Gypsum (g/kg)**
			Ca^{++}	**Mg^{++}**	**Na+**	**K^+**	**$SO_4^=$**	**$CO_3^=$**	**HCO^-_3**	**Cl^-**	
0-25	1.56	8.1	4.00	2.68	7.90	1.02	0.43	0.00	0.11	15.06	20.0
25-40	1.30	8.2	3.84	2.22	5.89	1.05	1.72	0.00	5.54	5.74	16.5
40-150	1.25	8.2	1.94	4.42	5.82	0.36	0.78	0.00	2.1	9.62	6.5

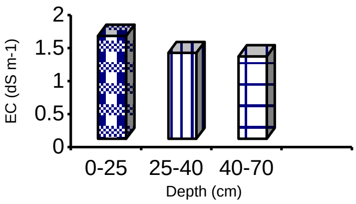
(c) Cation Exchange capacity (CEC), Exchangeable cations, ESP, and O.M.

Depth (cm)	**CEC cmolc/ kg**	**Exchangeable cations (cmolc/ kg)**				**ESP**	**O.M (g/kg)**
		Ca^{++}	**Mg^{++}**	**Na+**	**K^+**		
0-25	10.50	5.00	4.00	1.00	0.50	9.52	10.0
25-40	20.10	12.48	5.67	1.43	0.52	7.11	10.0
40-150	8.30	4.00	3.10	1.00	0.20	12.05	2.4

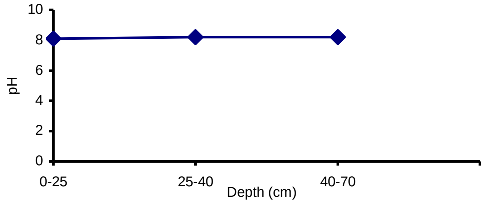
(d) Available macro and micro nutrients in the surface layer:

Depth (cm)	**Macro nutrients (mg/kg)**			**Micro nutrients (mg/kg)**			
	N	**P**	**K**	**Fe**	**Mn**	**Zn**	**Cu**
0-25	54.79	17.67	10.87	25.98	7.78	6.88	8.76

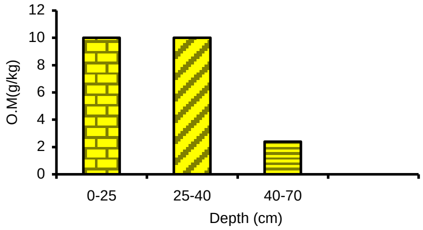
Fig. 33: Descriptive graphs of some soil characteristics of profile No. 7:



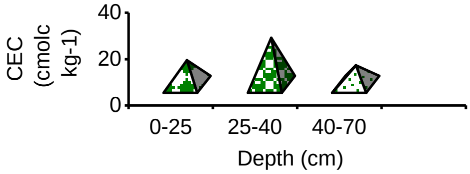
Soil salinity (dS m-1)



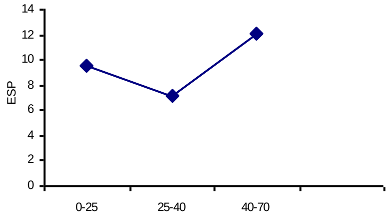
Soil Reaction (pH)



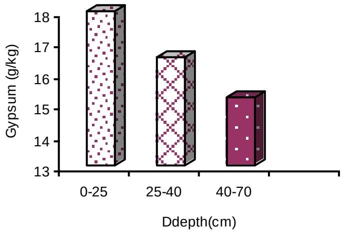
Organic matter (g/kg)



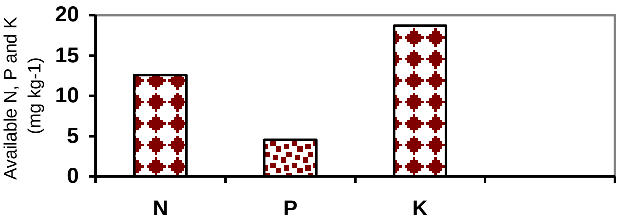
Cation exchange capacity(cmolc kg-1)



Exchangeable sodium percentage



Gypsum (g/kg)



Available N, P and K (mg/kg)

5.4.3. Soil of the hilly area:

Hills of the investigated area have a well-defined rounded natural elevation (small heaps, piles, or mounds) smaller than mountains. A hill may be formed from rocks or unconsolidated materials. Hills of the studied area are formed from unconsolidated materials such as, coarse and fine sands.

Soil profile Number 9 represents these soils. The obtained data are shown in Table 25 and illustrated in Figure 34.

The particle-size distribution data illustrated that, the soil texture class is sandy loam in the different layers of the studied soil profile, except for the deepest layer where it is sandy clay loam.

Calcium carbonate content ranges from very few to few, and its percentages rang between 0.00 and 11.00 g/kg in the different layers of the studied soil profile.

Gypsum content is very few, and its values ranges between 4.9 and 10.0 g/kg in the successive layers of the studied soil profile.

Organic matter content ranges between 8.0 and 15.0 g/kg and decreasing with depth regularly.

Soil salinity values expressed as the electric conductivity (EC) of the soil paste extract is low. It ranges between 0.91 and 1.00 dS/m. The data of soluble cations and anions revealed that, sodium and calcium are the dominant cations in the different layers of the studied profile. On the other hand, chloride is the dominant soluble anion, thus, sodium chloride is the dominant salt in the representative soil profile.

The soil pH values vary between 7.9 and 8.0 in the successive layers of the studied soil profile.

Cation exchange capacity varies from 11.0 to 17.4 cmolc/kg soil in the successive layers of the studied soil profile.

The exchangeable calcium followed by magnesium represent the main exchangeable cations in the successive layers of the studied soil profile.

The ESP values range between 2.47 and 7.73 in the different layers of the representative soil profile, increasing irregularly with depth.

Macro and micro nutrients data revealed that, Phosphorus has a high value of 17.44 mg/kg and that could be attributed to the low value of pH, while nitrogen and potassium have low values of 13.95 and 14.05 mg/kg, respectively.

On the other side, (Fe, Mn and Cu) existed in high values of 10.57, 5.92 and 3.03 mg/kg, respectively; while zinc has a moderate value of 1.77 mg/kg.

Profile No. : 9
Date of description. : 25 /7 /2008
Mapping unit. : hi111

Elevation . : 13 m . a.s.l.
Coordinates . :Lat. 30° 17` 08`` Long. 31° 22` 00``
Classification. : Typic Torrifluvents.
Soil temperature regime . : Thermic .
Soil moisture regime . : Torric.
Topography . : Undulating.
Land form. : Hilly area.
Slope on which profile is sited . : Gradient (Flat.) Form (Straight).
Land use . : Cultivated with maize
Humans influence . : Cultivation.
Native vegetation . : None.
Parent material . : Alluvial deposits.
Soil depth . : Deep.
Evidence of surface stones or rock outcrop: None.
Evidence of Erosion . : None.
Other surface features . : None.
Drainage conditions. : Well drained.
Depth of ground water . : >150 cm.

Depth cm	**Description**
0-40 Ap	Strong brown (7.5 Y 5/4, dry) to strong brown (7.5 YR 4/6, moist); sandy loam; weak sub-angular blocky structure; none sticky and none plastic; loose; very few small gypsum crystals; few fine soft white segregation of $CaCO_3$; common fine to medium discontinuous random interstitial pores; few fine to medium coarse roots; weak effervescence with HCl; pH 7.9; clear smooth boundary.
40-90 C1	Strong brown (7.5 Y 5/4, dry) to strong brown (7.5 YR 4/6, moist); sandy loam; weak sub-angular blocky structure; none sticky and none plastic; loose; very few small gypsum crystals; few fine soft white segregation of $CaCO_{3;}$ common fine to medium discontinuous random vesicular open pores; few fine to medium coarse roots; weak effervescence with HCl; pH 7.9; defuse smooth boundary.
90-150 C3	Strong brown (7.5 Y 5/4, dry) to strong brown (7.5 YR 4/6, moist); sandy clay loam; granular structure; none sticky and none plastic; loose ;very few gypsum crystals; common fine to medium discontinuous random interstitial pores; weak effervescence with HCl; pH 8.0.

Table 25: Soil characteristics of profile No. 9:

(a) Particle-size distribution, and $CaCO_3$ content:

Depth (cm)	Particle-size distribution (%)				Texture class	$CaCO_3$ (g/kg)
	C. sand	F. sand	Silt	Clay		
0-50	66.2	7.8	11.2	14.8	Sandy loam	11.0
50-85	60.9	10.4	18.4	10.5	Sandy loam	10.0
85-150	59.6	9.2	9.3	22.1	Sandy clay loam	0.00

(b) EC, pH, soluble cations and anions, and gypsum:

Depth (cm)	EC dS/m	pH 1:2.5 suspension	Soluble cations (mmolc/L)				Soluble anions (mmolc/L)				Gypsum (g/kg)
			Ca^{++}	Mg^{++}	Na+	K^+	$SO_4^=$	$CO_3^=$	HCO^-_3	Cl^-	
0-50	1.00	7.9	1.81	0.86	6.86	0.47	0.61	0.00	2.43	6.96	4.90
50-85	0.91	7.9	1.85	0.84	5.89	0.52	0.61	0.00	3.31	5.18	5.80
85-150	1.00	8.0	1.07	0.37	4.15	0.81	0.92	0.00	2.53	6.55	10.00

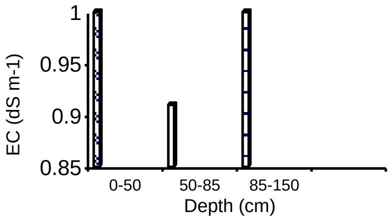
(c) Cation Exchange capacity (CEC), Exchangeable cations, ESP, and O.M.

Depth (cm)	CEC (cmolc/ kg)	Exchangeable cation (cmolc/ kg)				ESP	O.M (g/kg)
		Ca^{++}	Mg^{++}	Na+	K^+		
0-50	17.40	11.18	5.30	0.53	0.39	3.05	15.0
50-85	11.00	7.32	2.09	0.85	0.74	7.73	8.0
85-150	19.00	12.30	5.57	0.47	0.66	2.47	8.0

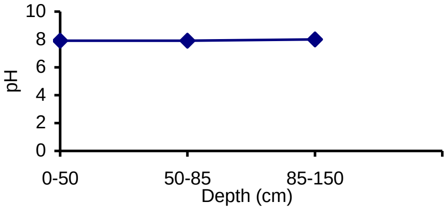
(d) Available macro and micro nutrients in the surface layer:

Depth (cm)	Macro nutrients (mg/kg)			Micro nutrients (mg/kg)			
	N	P	K	Fe	Mn	Zn	Cu
0-50	13.95	17.44	14.05	10.57	5.92	1.77	3.03

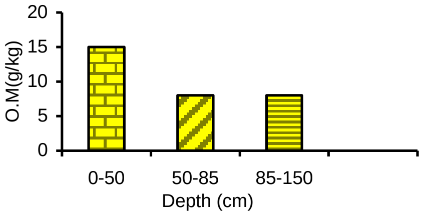
Fig. 34: Descriptive graphs of some soil characteristics of profile No. 9:



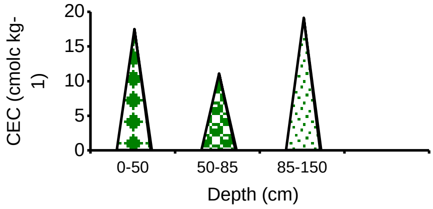
Soil salinity (dS m-1)



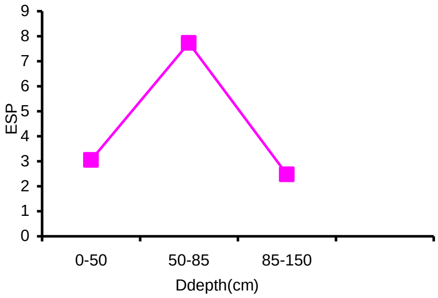
Soil Reaction (pH)



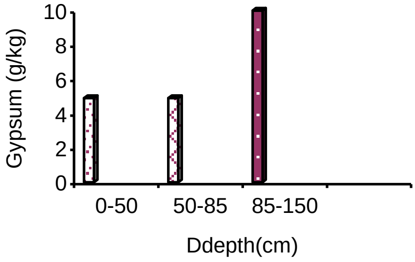
Organic matter (g/kg)



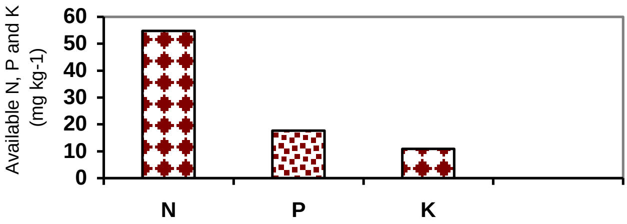
Cation exchange capacity (cmolc kg-1)



Exchangeable sodium percentage



Gypsum (g/kg)



Available N, P and K (mg/kg)

5.4.4. Soils of turtle back

The turtleback-like pattern means the tilling of hexagons. Soils of turtleback consist mainly of immense quantities of gravel and sand .They have been carried by the Nile River in its youth age taking the shape of turtle back.

These soils are represented by profile No. 12. The morphological features of these soils are shown in Figure (35). Soil characteristics are shown in Table 26 and illustrated in Fig. 36.

Fig. 35: Turtle back.

The particle-size distribution data reveal that, the soil texture class is sandy loam in the studied soil profile, except for the surface layer where it is loamy sand.

Calcium carbonate content ranges between very few and moderate, varying between 20.0 and 55.1 g/kg in the different layers of the studied profile.

The gypsum content is moderate and ranges between 30.0 and 36.1 g/kg in the successive layers of the studied soil profile. The high value could be related to the formation processes of turtle backs as well as geological formation during the old era.

Organic matter content is low and ranges between 0.00 and 0.60 g/kg with a regular decrease in depth.

Soil salinity values expressed as the electric conductivity (EC) of the soil paste extract is high to extremely high and ranging between 12.0 and 72.40 dS/m. The data of soluble cations and anions revealed that, sodium is the dominant cation in the different layers of the studied profile. On the other hand, chloride is the dominant anion, thus sodium chloride is the dominant salt in the stratified layers of the representative soil profile.

Values of pH range between 8.4 and 8.6 in successive layers of the studied profile.

Cation exchange capacity ranges between 7.20 and 10.98 cmolc/kg soil in the successive layers of the investigated soil profile. The low value of CEC indicates the low level of the fine particles (clay) and organic matter.

The exchangeable sodium followed by calcium represent the main exchangeable cations in the successive layers of the studied soil profile. Values of ESP range between 45.53 and 90.00 indicate the high sodicity in the different layers of representative soil profile.

Data of macro nutrients in the surface layer revealed that, phosphorus has a low value of 0.8 mg/kg and that could be due to the high sodicity; while N and K have low values of 14.0 and 15.22 mg/kg, successively. Such low values could be attributed to the low content of the organic matter and clay fractions.

Regarding the micro nutrients, iron and copper exist in low values of 1.15 and 0.81, mg/kg, respectively; while manganese shows a moderate value of 3.36 mg/kg and finally zinc has a high value of 3.78 mg/kg.

Profile No.	: 12
Date of description.	: 22 /7 /2008
Mapping unit.	: T111.
Elevation .	: 14 m . a.s.l.
Coordinates .	: Lat. 30^{o} 14` 05`` Long. $31^{o}$ 22` 46``
Classification.	: Typic Haplsalids.
Soil temperature regime .	: Thermic.
Soil moisture regime .	: Torric.
Topography .	: Undulating
Land form.	: Turtle back.
Slope on which profile is sited.	: Almost flat.
Land use.	: None.
Humans influence.	: None.
Native vegetation .	: None.
Parent material.	:Aeolian deposits
Soil depth.	: Deep.
Evidence of surface stones or rock outcrop.	: None.
Evidence of Erosion .	: None.
Other surface features .	: Gravels, stones.
Drainage conditions.	: Well drained.
Depth of ground water .	: >150 cm.

Depth cm	**Description**
0-30 A_p	Pale yellow (5Y 7/3, dry) to olive (5 Y 5/3, moist); loamy sand; single grains with few fin to medium gravels; none sticky and none plastic, loose; common fine to medium discontinuous random vertical pores; no roots; moderate elongate gypsum crystals; moderate fine soft white segregation of $CaCO_3$; strong effervescence with HCl; pH 8.4; clear smooth boundary.
30-80 C1	Pale yellow (2.5Y 7/4, dry) to light olive brown (2.5Y 5/6, moist); sandy loam, granular structure; none sticky and none plastic, loose; common fine discontinuous random vertical pores; no roots; moderate elongate gypsum crystals; moderate fine soft white segregation of $CaCO_3$ strong effervescence with HCl, pH 8.5, pocket of clay, clear smooth boundary.
80-150 C2	Pale yellow (2.5Y 7/4, dry), light olive brown (2.5Y 5/6, moist), sandy loam; granular structure; none sticky and none plastic, loose; common fine discontinuous random vertical pores; no roots; moderate elongate gypsum crystals; moderate fine soft white segregation of $CaCO_{3;}$ very strong effervescence with HCl; pH 8.6.

Table 26: Soil characteristics of profile No. 12:

(a) Particle-size distribution, and $CaCO_3$ content:

Depth (cm)	Particle-size distribution (%)				Texture class	$CaCO_3$ (g/kg)
	C. sand	F. sand	Silt	Clay		
0-30	67.2	17.6	7.0	8.2	Loamy sand	20.0
30-80	58.8	15.0	15.4	10.8	Sandy loam	47.0
80-150	61.4	13.8	17.5	7.3	Sandy loam	55.1

(b) EC, pH, soluble cations and anions, and gypsum:

Depth (cm)	EC dS/m	pH 1:2.5 suspension	Soluble cations (mmolc/L)				Soluble anions (mmolc/L)				Gypsum (g/kg)
			Ca^{++}	Mg^{++}	Na+	K^+	$SO_4^=$	$CO_3^=$	HCO^-_3	Cl^-	
0-30	12.00	8.4	29.84	24.60	65.32	0.24	24.67	0.00	11.98	83.36	30.0
30-80	24.98	8.5	32.86	22.51	194.16	0.27	87.74	0.00	3.13	158.93	35.5
80-150	72.40	8.6	109.89	98.32	515.29	0.50	10.94	0.00	17.18	695.85	36.1

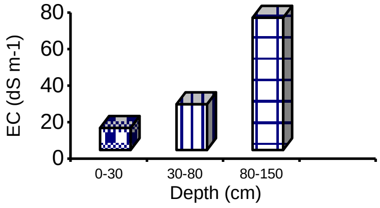
(c) Cation Exchange capacity (CEC), Exchangeable cations, ESP, and O.M.:

Depth (cm)	CEC (cmolc/ kg)	Exchangeable cation (cmolc/ kg)				ESP	O.M (g/kg)
		Ca^{++}	Mg^{++}	Na+	K^+		
0-30	10.98	3.05	2.71	5.00	0.22	45.53	6.0
30-80	8.36	0.74	0.35	7.07	0.20	84.57	1.8
80-150	7.20	0.42	0.20	6.48	0.10	90.00	0.0

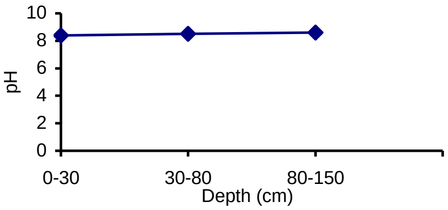
(d) Available macro and micro nutrients in the surface layer:

Depth (cm)	Macro nutrients (mg/kg)			Micro nutrients (mg/kg)			
	N	P	K	Fe	Mn	Zn	Cu
0-30	14.00	0.80	15.22	1.15	3.36	3.78	0.81

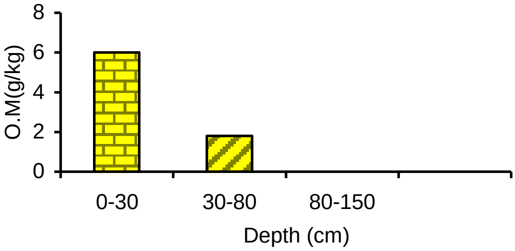
Fig. 36: Descriptive graphs of soil characteristics of profile No. 12:



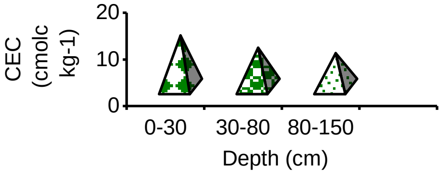
Soil salinity (dS m-1)



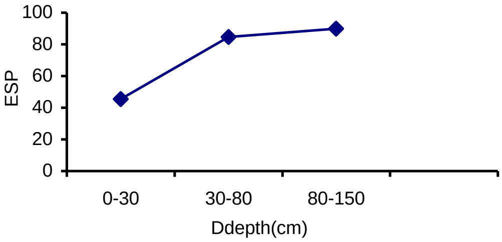
Soil Reaction (pH)



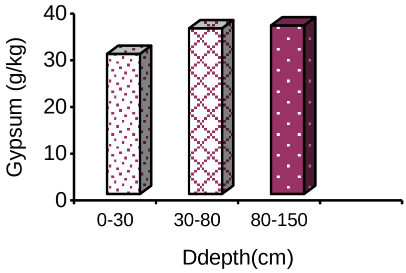
Organic matter (g/kg)



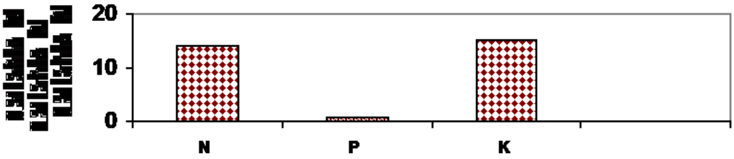
Cation exchange capacity(cmolc kg-1)



Exchangeable sodium percentage



Gypsum (g/kg)



Available N, P and K (mg/kg)

5.5. Spatial variability of soil characteristics of the studied area:

Soil characteristics vary spatially, and have strong fluctuations over long and short distances **(Trangmar *et al.* 1985; Warrick *et al.* 1986).**

Behind a locally erratic aspect, some spatial structure is often discerned and may be related to the combined action of several physical, chemical or biological processes that act at different spatial scales.

The characterization of the spatial variability of soil characteristics is essential to achieve a better understanding of complex relations between soil properties and environmental factors. Modeling of spatial dependence between soil data can be used to estimate characteristics at unsampled locations, leading to better recommendations for the application.

Incorporating the spatial coordinates of soil observations in data processing, allowing for description and modeling of spatial patterns, prediction at unsampled locations, and assessment of the uncertainty attached to these predictions.

Since the publication of the first applications of geostatistics to soil data in the early 1980s **(Burgess and Webster, 1980, Webster and Burgess, 1980; Burgess *et al.*, 1981)** geostatistical methods have become popular in soil science, as illustrated by the increasing number of studies reported in the literature Geostatistical analyst was used to provide spatial soil characteristics.

Kriging(1) interpolation technique was used to produce continuous surfaces of fertility and some soil properties by filling gabs between points **(Goovaerts, 1998).**

The spatial variability analyses were conducted for weighted values of soil profile concerning calcium carbonates, electrical conductivity, exchangeable sodium percentage, organic matter, macro nutrients (nitrogen, phosphorus, and potassium) and micro nutrients (iron, zinc, manganese, and copper).

5.5.1 Calcium carbonates ($CaCO_3$)

The spatial variability of soil calcium carbonates of the studied area was estimated as shown in the following lines and Figure 37.

The semivariogram model for soil calcium carbonate content of the studied area shows that, the major distance at which the model reaches its limiting value is 29360.5 m and the minor range is 26636.4 m. with direction angle of 13.3° Soil calcium carbonates content distribution in the studied area could be expressed by the following equation:

7.9491{Spherical (29361, 26636, 13.3)} + 36.53Nugget(2)

---

(1) Kriging is a moderately quick interpolator that can be exact or smoothed depending on the measurement error model. It is very flexible and allows you to investigate graphs of spatial autocorrelation. Kriging uses statistical models that allow a variety of map outputs including predictions, prediction standard errors, probability, etc. The flexibility of kriging can require a lot of decision-making. Kriging assumes the data come from a stationary stochastic process, and some methods assume normally-distributed data.

(2) The nugget represents measurement error and/or microscale variation (variation at spatial scales are too fine to detect). It is possible to estimate the measurement error if you have multiple observations per location, or you can decompose the nugget into measurement error and microscale variation using the Error Measurement control.

The Root-Mean-Square-Standerized (RMSS) value is 1.088 for the studied soil profile.

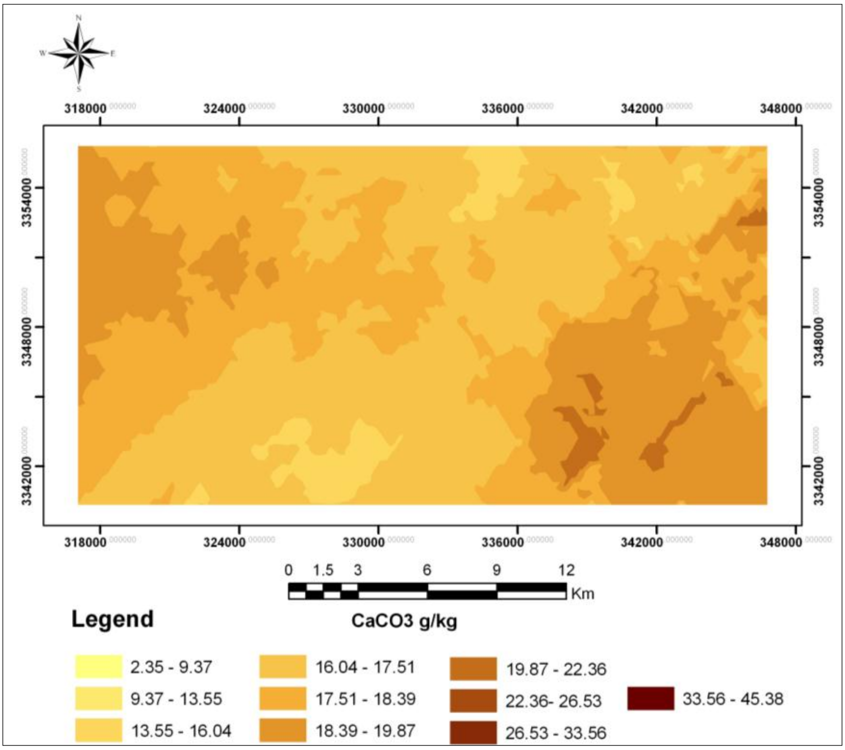


Fig. 37: spatial variability of soil calcium carbonates of the studied area

From Fig. 37, soil calcium carbonate content ranges between 2.35 and 45.38 g/kg of the fine earth in the surface layer of the studied area with regression function according to the following equation: **$Y = 0.080 X + 18.963$**

Where: Y : the spatial variability and X: $CaCO_3$

5.5.2. Gypsum content:

The spatial variability of gypsum of the studied area was estimated as shown in the following lines and Figure 38.

The semivariogram model for gypsum content of the studied area shows that, the major distance at which the model reaches its limiting value is 28852.9 m and the minor range is 24339.8 m. with direction angle of 32.4^{O}. Gypsum content distribution in the studied area could be expressed by the following equation:

Gypsum= 2.2642*Spherical {(28853, 24340, 32.4)} +15.155 Nugget

The Root-Mean-Square-Standerized (RMSS) value is 1.052 for the studied soil profile.

From Fig 38, gypsum content ranges between 6.51 and 34.68 g/kg of the fine earth in the surface layer of the studied area with regression function: **Y = 0.048 x + 13.033.**

Where: Y is the spatial variability and X: gypsum content.

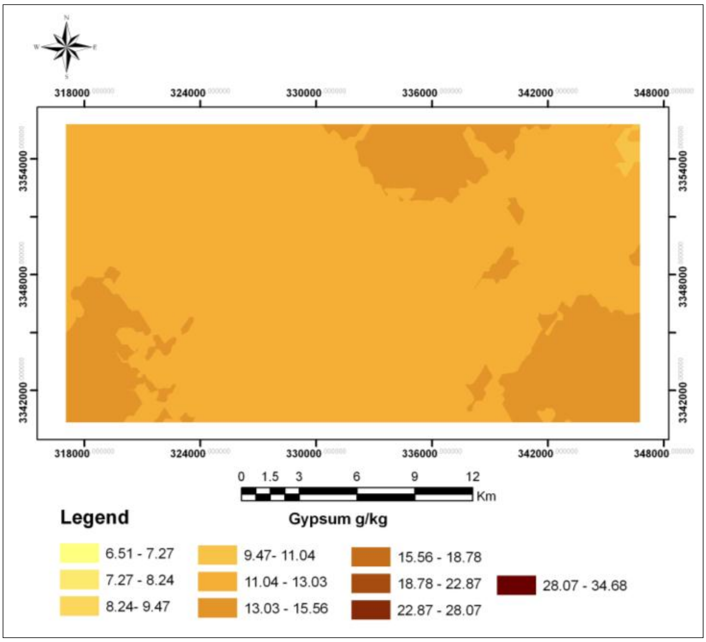


Fig. 38: spatial variability of gypsum of the studied area

5.5.3. Electrical Conductivity (EC)

The spatial variability of soil salinity of the studied area was estimated as shown in the following lines and Figure 39.

The semivariogram model for soil salinity content of studied area shows that, the major distance at which the model reaches its limiting value is 28829.8 m and the minor range is 24346.2 m. with direction angle of 33.6^{O} direction. Soil salinity content distribution in the studied area could be expressed by the following equation:

EC= 6.6574*Spherical {(28830, 24346, 33.6)} +20.525 Nugget

The Root-Mean-Square-Standerized (RMSS) value is 1.086 for the studied soil profile. From Figure 39, soil salinity content expressed as soil electrical conductivity (EC) ranges between 0.83 and 44.51 dS/m in the soil paste extract of in the surface layer of the studied area with regression function: **Y = 0.007 X + 2.701** Where: Y is the spatial variability and X: EC.

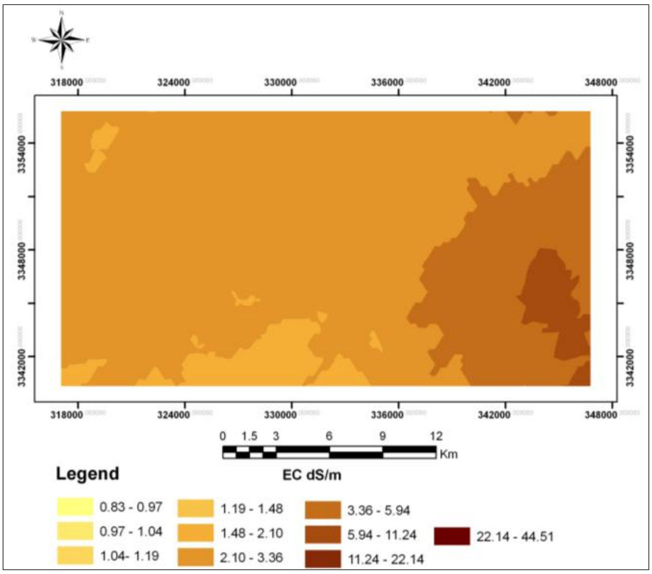


Fig. 39: spatial variability of soil salinity of the studied area

5.5.4. Exchangeable Sodium Percentage (ESP)

The spatial variability of ESP of the studied area was estimated as shown in the following lines and Figure 40.

The semivariogram model for ESP content of studied area shows that, the major distance at which the model reaches its limiting value is 28973.8 m and the minor range is 24365.2 m. with direction angle of $34.5^{O.}$. ESP distribution in the studied area could be expressed by the following equation:

ESP=22.192*Spherical {(28974, 24365, 34.5)} +64.753 Nugget

The Root-Mean-Square-Standerized (RMSS) value is 1.085 for the studied soil profile. From Figure 40, ESP ranges between 2.84 and 79.30 in the surface layer of the studied area with regression function: **Y = 0.001 X + 8.722**

Where: Y is the spatial variability and X: ESP.

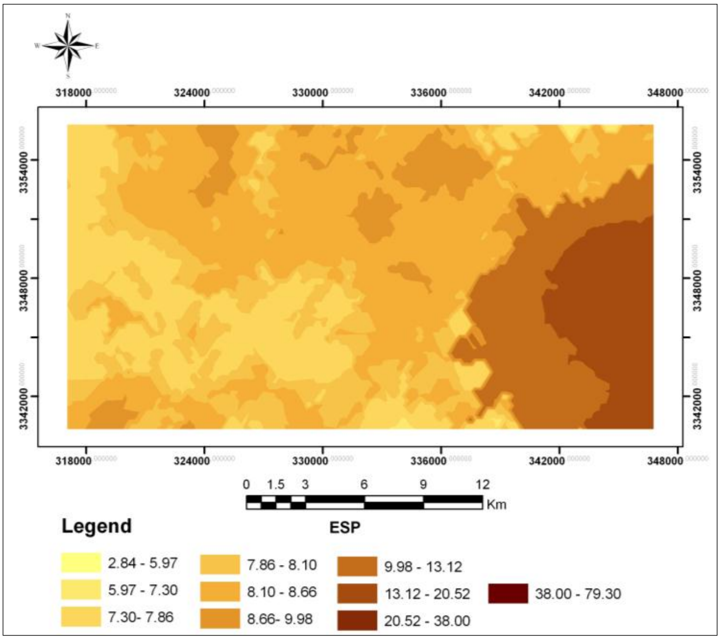


Fig. 40: spatial variability of ESP of the studied area

5.5.6. Organic Matter content (OM)

The spatial variability of soil OM of the studied area was estimated as shown in the following lines and Figure 41.

The semivariogram model for soil OM of the studied area shows that, the major distance at which the model reaches its limiting value is 28350 m and the minor range is 20614.4 m. with direction angle of 81.4^{O}. OM content distribution in the studied area could be expressed by the following equation:

OM= 0.41114*Spherical {(28350, 20614, 81.4)} +7.1883 Nugget

The Root-Mean-Square-Standerized (RMSS) value is 1.022 for the studied soil profile. From Fig 41, OM content ranges between 1.80 and 12.07 g/kg in the surface layer of the studied area with regression function: **Y = 0.019 X + 7.922**

Where: Y is the spatial variability and X: OM.

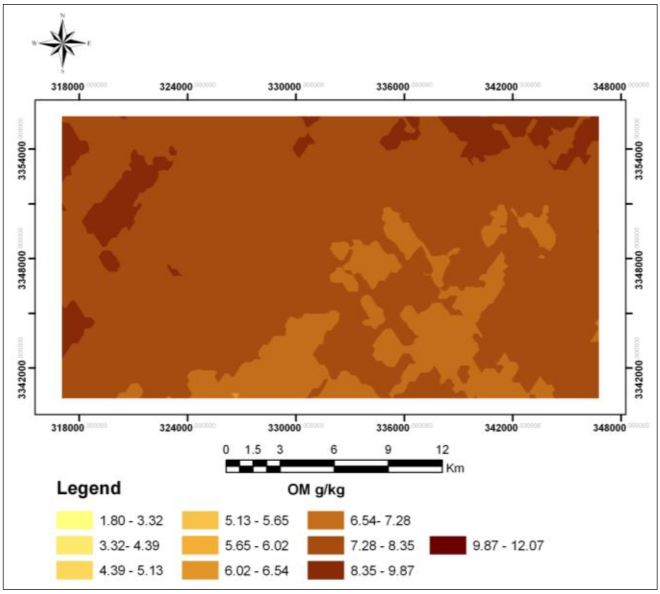


Fig. 41: spatial variability of soil OM of the studied area

5.5.7. Macro nutrients:

(1) Available nitrogen (N)

The spatial variability of nitrogen of the studied area was estimated as shown in the following lines and Figure 42.

The semivariogram model for soil nitrogen of the studied area shows that, the major distance at which the model reaches its limiting value is 2606.18 m and the minor range is 591.231 m. with direction angle of 87.9^{O}. Soil nitrogen content distribution in the studied area could be expressed by the following equation:

N= 125.43*Spherical {(2606.2, 591.23, 87.9)} + 0 Nugget

The Root-Mean-Square-Standerized (RMSS) value is 0.9334 for the studied soil profile. From Figure 42, Nitrogen content ranges between 12.00 and 54.79 mg/kg of the fine earth in the surface layer of the studied area with regression function: **Y= 0.020 X + 24.394** Where: Y is the spatial variability and X: N.

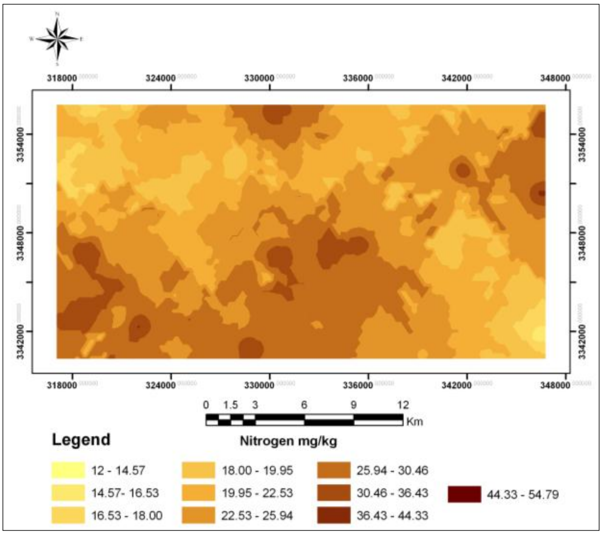


Fig. 42: spatial variability of nitrogen of the studied area

(2) Available phosphorus (P)

The spatial variability of phosphorus of the studied area was estimated as shown in the following lines and Figure 43.

The semivariogram model for soil phosphorus of the studied area shows that, the major distance at which the model reaches its limiting value is 29360.5 m and the minor range is 19019 m. with direction angle of 59.9^{O}. Soil phosphorus content distribution in the studied area could be expressed by the following equation:

6.2419*Spherical {(29361, 19019, 59.9)} +42.347 Nugget

The Root-Mean-Square-Standerized (RMSS) value is 1.041 for the studied soil profile. Figure 43 shows that, phosphorus content ranges between 0.80 and 28.75 mg/kg of the fine earth in the surface layer of the studied area with regression function: **Y = 0.003 X + 14.248**

Where: Y is the spatial variability and X: P

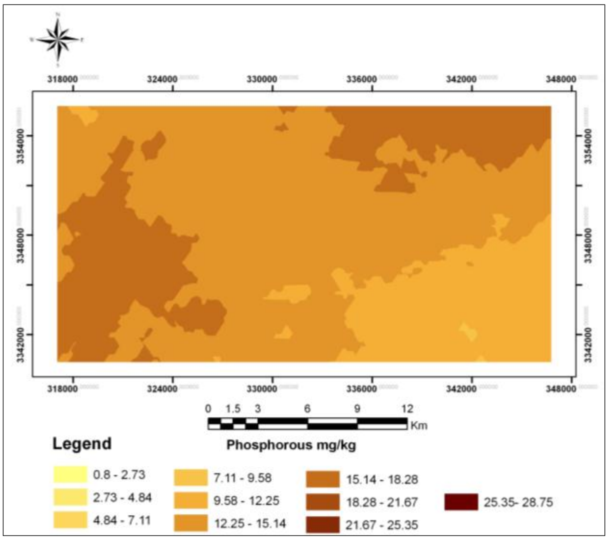


Fig. 43: Spatial variability of phosphorus of the studied area

(3) Available potassium (K)

The spatial variability of potassium of the studied area was estimated as shown in the following lines and Figure 44.

The semivariogram model for soil potassium of the studied area shows that, the major distance at which the model reaches its limiting value is 29163.4 m and the minor range is 25219.8 m. with direction angle of 10.1^{O}. Soil potassium content distribution in the studied area could be expressed by the following equation:

K= 15268*Spherical {(29163, 25220, 10.1)} + 44366 Nugget

The Root-Mean-Square-Standerized (RMSS) value is 0.9752 for the studied soil profile. From Figure 44, potassium content ranges between 8.54 and 750.45 mg/kg of the fine earth in the surface layer of the studied area with regression function: **Y = 0.116 X + 290.195** Where: Y is the spatial variability and X: K.

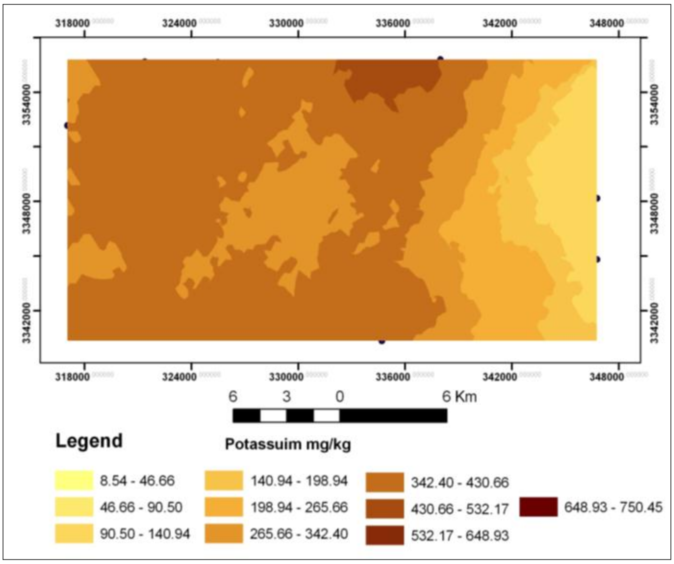


Fig. 44: Spatial variability of potassium of the studied area

5.5.8. Micro nutrient

(1) Iron (Fe)

The spatial variability of iron of the studied area was estimated as shown in the following lines and Figure 45.

The semivariogram model for soil iron of the studied area shows that, the major distance at which the model reaches its limiting value is 28506.7 m and the minor range is 23067.3 m. with direction angle of 51.8^{o}. Soil iron content distribution in the studied area could be expressed by the following equation:

Fe= 15.549*Spherical {(28507, 23067, 51.8)} + 25.017 Nugget

The Root-Mean-Square-Standerized (RMSS) value is 1.10 for the studied soil profile. Figure 45 shows that, iron content ranges between 1.15 and 38.00 mg/kg of the fine earth in the surface layer of the studied area with regression function:

$Y = 0.072 X + 12.165$ Where: Y is the spatial variability and X: Fe.

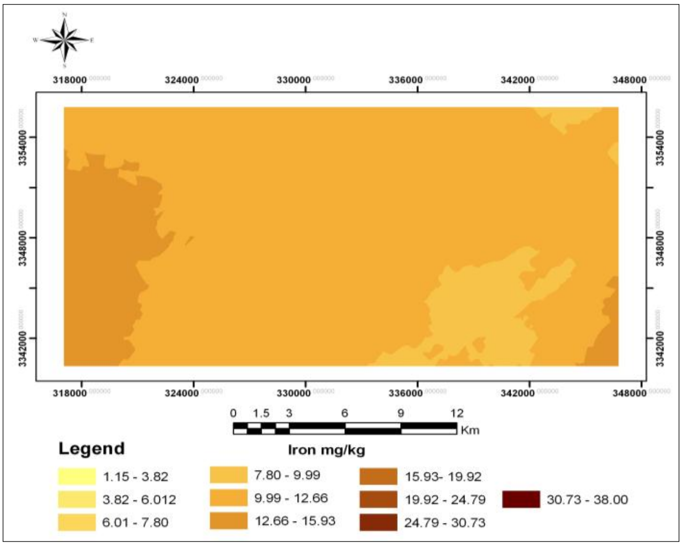


Fig. 45: spatial variability of iron of the studied area

(2) Manganese (Mn)

The spatial variability of manganese of the studied area was estimated as shown in the following lines and Figure 46.

The semivariogram model for soil manganese of the studied area shows that, the major distance at which the model reaches its limiting value is 20954.2 m and the minor range is 12457.2 m. with direction angle of 345.5^{O}. Soil manganese content distribution in the studied area could be expressed by the following equation:

Mn= 6.464*Spherical {(20954, 12457, 345.5)} +38.878 Nugget

The Root-Mean-Square-Standerized (RMSS) value is 1.001 for the studied soil profile. Figure 46 shows that, manganese content ranges between 3.36 and 33.14 mg/kg of the fine earth in the surface layer of the studied area with regression function: **Y = 0.068 X + 12.932**

Where: Y is the spatial variability and X: Mn.

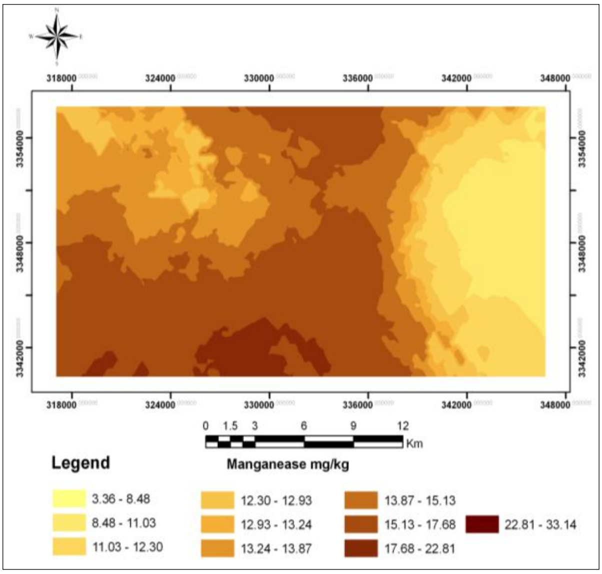


Fig. 46: Spatial variability of manganese of the studied area

(3) Zinc (Zn)

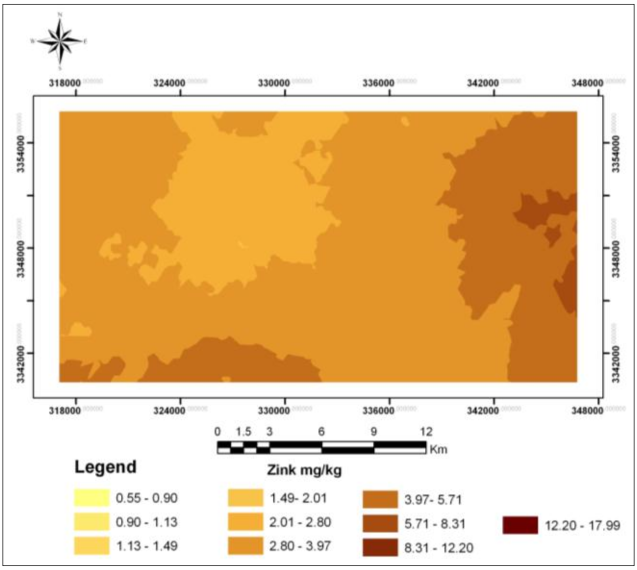
The spatial variability of zinc of the studied area was estimated as shown in the following lines and Figure 47.

The semivariogram model for soil zinc of the studied area shows that, the major distance at which the model reaches its limiting value is 29360.5 m and the minor range is 28494.7 m. with direction angle of 24.6^{O}. Soil zinc content distribution in the studied area could be expressed by the following equation:

Zn= 4.475*Spherical {(29361, 28495, 24.6)} + 9.199 Nugget

The Root-Mean-Square-Standerized (RMSS) value is 1.096 for the studied soil profile. From Figure 47 it could be deduced that, zinc content ranges between 0.55 and 17.99 mg/kg in the surface layer of the studied area with regression function:

Y= 0.008 X+ 3.523



Where: Y is the spatial variability and X: Zn.

Fig. 47: Spatial variability of zinc of the studied area

(4) Copper (Cu)

The spatial variability of copper of the studied area was estimated as shown in the following lines and Figure 48.

The semivariogram model for soil copper of the studied area shows that, the major distance at which the model reaches its limiting value is 2026.32 m and the minor range is 846.032 m. with direction angle of 29.1^{o}. Soil copper content distribution in the studied area could be expressed by the following equation:

Cu= 111.83*Spherical {(2026.3, 846.03, 29.1)} + 0 Nugget

The Root-Mean-Square-Standerized (RMSS) value is 0.898 for the studied soil profile. Figure 48 shows that, copper content ranges between 0.81 and 31.87 mg/kg of the fine earth in the surface layer of the studied area with regression function:

Y = 0.066 X + 7.915

Where: Y is the spatial variability and X: Cu.

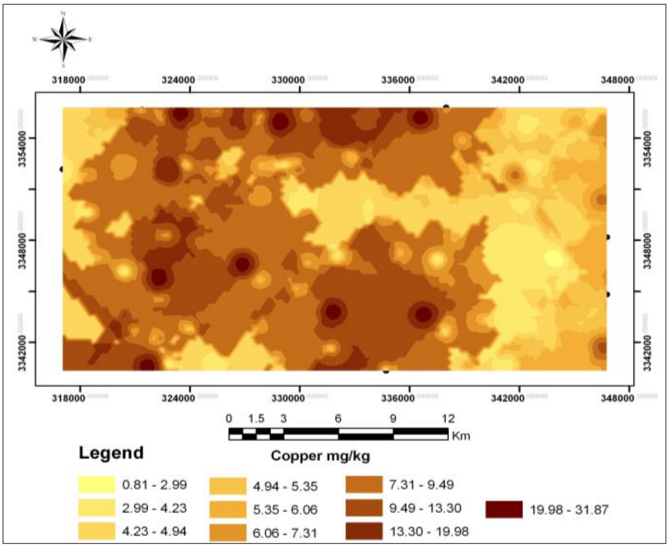


Fig. 48: Spatial variability of copper of the studied area

5.5.9 Cation exchange capacity (CEC):

Cation exchange capacity (CEC) is the capacity of a soil for ion exchange of cations between the soil and the soil solution. CEC is used as a measure of fertility, nutrient retention capacity, and the capacity to protect groundwater from cation contamination. The semivariogram model for soil CEC of studied area shows that, the major distance at which the model reaches its limiting value is 29163.4 m and the minor range is 25219.8 m. with direction angle of 10.1^{O}. Soil CEC content distribution in the studied area could be expressed by the following equation: **CEC= 15268*Spherical {(29163, 25220, 10.1)} + 44366 Nugget**

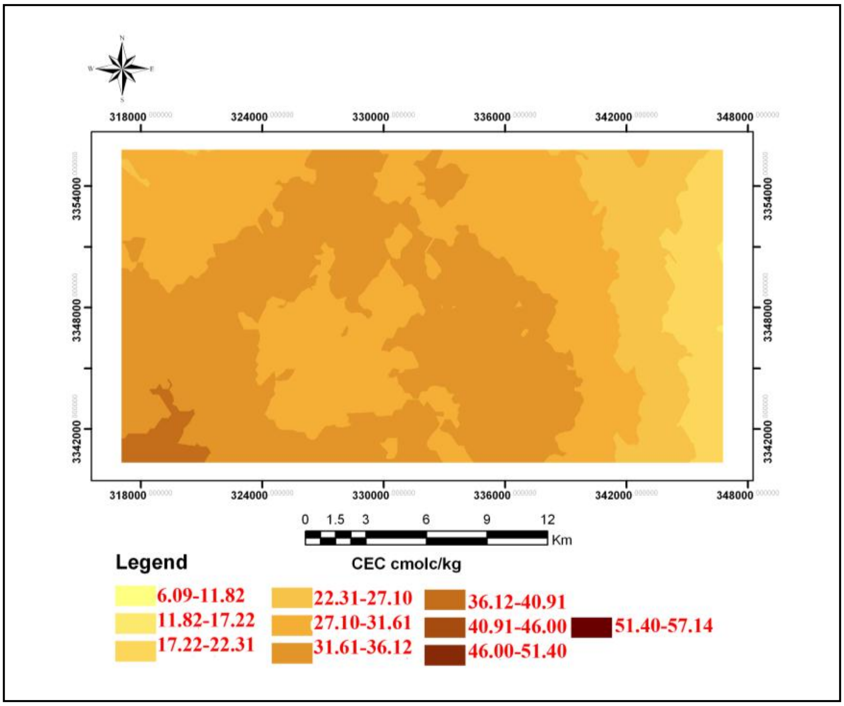


Figure 49: Spatial variability of soil CEC of the studied area

The Root-Mean-Square-Standerized (RMSS) value is 0.9752 for the studied soil profile. From Figure 49, soil CEC content ranges between 6.09 and 57.14 cmolc/kg of the surface layer of the studied area with regression function:

$$Y = 0.116 X + 290.195.$$

Where: Y is the spatial variability and X: CEC.

These results are similar to those obtained by **(Ibrahim *et al.,* 2010)** who concluded that, generally, the CEC values of the Nile flood plain soils range between 35 and 80 cmolc/kg. On the other hand, **Lavelle and Spain (2001**) reported that, the CEC of the delta soils examined are within the range of that of cultivated soils of a high content of clay minerals.

5.6. Soil mapping and taxonomy.

Soil classification deals with the systematic categorization of soils based on distinguishing characteristics as well as criteria that dictate choices in use. It is a dynamic subject, from the structure of the system itself, to the definitions of classes, and finally in the application in the field. Soil classification could be approached from the perspective of soil as a material and soil as a resource. For soil resources, experience has shown that a natural system approach to classification, i.e. grouping soils by their intrinsic property (soil morphology), behaviour, or genesis, results in classes that can be interpreted for many diverse uses. Differing concepts of pedogenesis, and differences in the significance of morpHological features to various land uses can affect the classification approach. Despite these differences, in a well-constructed system, classification criteria group similar concepts so that interpretations do not vary widely. This is in contrast to a technical system approach to soil classification, where soils are grouped according to their fitness for a specific use and their edaphic characteristics. Soil taxonomy was done on the USDA Soil Taxonomy System **(USDA 1975)** and its update issue (USDA 2010b). Matching geomorphologic units with soil characteristics and soil taxonomy, the final soil map was produced. Soil map is reduced to scale 1: 250000 from base map of 1: 50000, as shown in Figure 50. Soil taxonomy and their representative areas of the area under study could be summarized in Table 27.

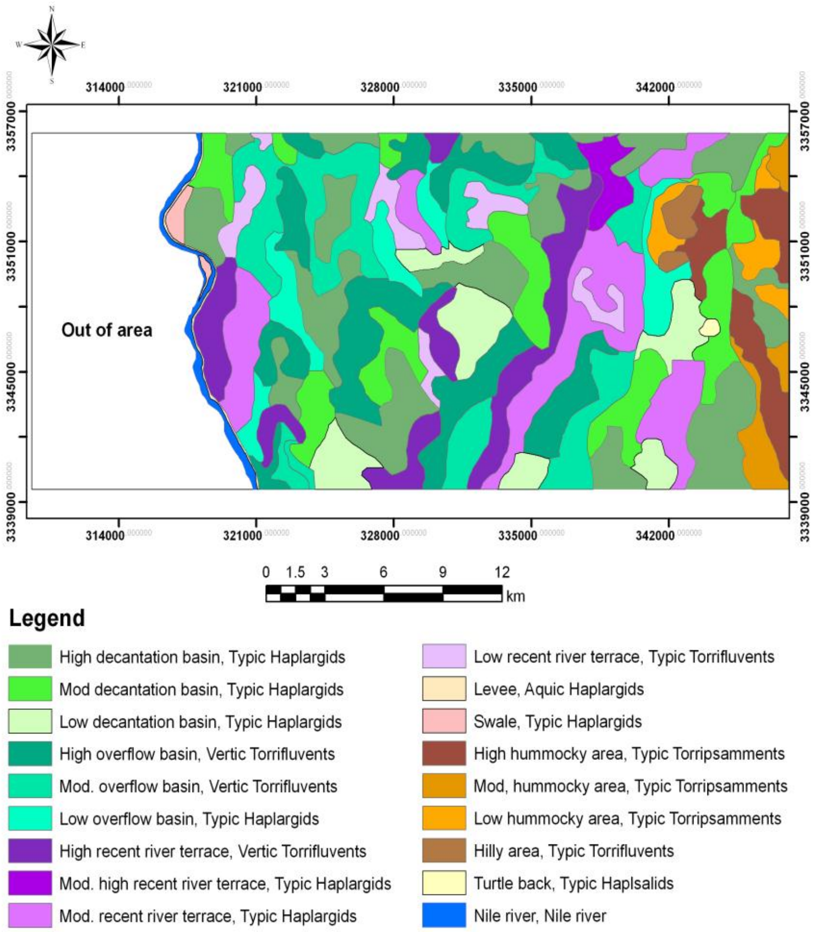
Table 27: Soil taxonomy and their representative areas:

Soil Taxonomy	**Area, fed.**	**Area (%)**
Typic Haplargids	42997.59	48.04
Vertic Torrifluvents	38736.25	43.27
Typic Torrifluvents	5196.26	5.81
Typic Torripsamments	2023.4	2.26
Aquic Haplargids	401	0.45
Typic Haplsalids	158.36	0.17
Total	**89512.86**	**100**

Geomorphologic units represented by soil profiles and their taxonomy could be summarized in Table 28**.**

Table 28: Taxonomy of geomorphologic units represented by soil profiles:

Geomorphological unit	Profile No.	Soil taxonomy
Soils of decantation basin		
High decantation basin	2	Typic Haplargids
Mod. Decantation basin	3	Typic Haplargids
Low decantation basin	4	Typic Haplargids
Soils of overflow basin		
High overflow basin	8	Vertic Torrifluvents
Mod. Overflow basin	1	Vertic Torrifluvents
Low overflow basin	6	Typic Haplargids
Soils of recent riverterraces:		
High recent river terraces	5	Vertic Torrifluvents
Mod. High recent river terraces	10	Typic Haplargids
Mod. Recent river terraces	15, 16	Typic Haplargids
Low recent river terraces	11	Typic Torrifluvents
Soils of Levee	14	Aquic Haplargids
Soil of swale	13	Typic Haplargids
soils of hummocky area:		
High hummocky area	18	Typic Torripsamments
Mod. Hummocky area	17	Typic Torripsamments
Low hummocky area	7	Typic Torripsamments
hilly area	9	Typic Torrifluvents
Turtle back	12	Typic Haplsalids



OID	taxonomy	Count_taxonomy	Sum_AREA
0	Aquic Haplargids	1	1684210
1	Nile river	1	5147890
2	Out of area	1	139616992
3	Typic Haplargids	45	260809969
4	Typic Haplsalids	1	665094
5	Typic Torrifluvents	8	21824271
6	Typic Torripsamments	3	8498290
7	Vertic Torrifluvents	23	162692300

Fig. 50: Soil map of the area under study.

5.7. Precision farming of the current work:

The main objectives of adopting precision farming is to realize land and water use efficiency ,determine the profitability of precision farming environmentally and economically on the farming system level (Experimental farm, Faculty of agriculture, Benha University).

Two field practices were carried out in two successive seasons, the first season practices (2009) and the second one (2010) as follows:

5.7.1. First season practices of traditional farming TF (2009):

In the first season the 18 plots were cultivated with maize using traditional practices after which the same plots were used for precision farming practices in the second season. At end of the first season soil were analyzed for EC, pH, organic matter, macro and micro nutrients.

5.7.1.1.Analyzing the traditional/common information following the first season:

In summer 2009, soil of the investigated area was ploughed after clover. Nitrogen was added at 120 Kg N/Fed. (260.86 kg urea), phosphorus was added with level of 6.8 kg P/Fed. as ordinary calcium super phosphate (100 kg). Fertilizers were applied through the soil under furrows irrigation system. Row spacing was 70 cm. seeds were sown on 21st of May. Plant was harvested on 12th of September. During this period, the plant growth and field conditions were observed accurately day by day without any interference to recognize the effect of traditional farming on plant growth and its yield. Figure 51 shows the yield of season 2009, which was estimated for the whole field at 3504 kg/ Fed. and the yield for each plot was recorded in Table No. 30.

Fig. 51: yield of season 2009.

5.7.1.2. Soil characteristics under traditional farming:

The soil of the field is mostly clay, with a high nutrient retention capacity. Surface is almost flat. Soil structure is angular to sub-angular blocky. Some soil characteristics of the investigated field are illustrated in Table 29.

Table 29: Some soil characteristics of the investigated field:

Plot No.	$CaCO_3$ g/kg	EC dS/m (paste extract)	pH 1:2.5 suspension	O.M g/kg	Available macro nutrient mg/kg			Available micro nutrient mg/kg			
					N	P	K	Fe	Mn	Zn	Cu
1	20.0	0.89	8.20	28.0	125.22	30.10	720.00	39.7	14.00	8.37	18.4
2	2.00	0.50	8.40	47.0	40.11	5.00	685.00	33.4	12.30	11.47	16.4
3	24.4	0.68	8.40	0.08	105.16	4.60	822.00	36.4	11.70	6.09	15.2
4	13.5	0.63	8.20	11.8	51.09	35.00	1226.00	29.00	10.00	4.81	21.3
5	2.00	0.82	8.20	42.7	52.76	37.00	975.00	34.00	13.30	9.31	16.7
6	18.8	0.54	8.20	54.4	70.14	7.44	863.00	30.50	11.80	8.68	12.8
7	20.0	0.80	8.20	36.2	84.34	7.48	1230.00	35.3	12.50	7.35	18.3
8	6.00	0.76	8.20	0.09	103.67	33.80	867.00	34.00	13.20	5.51	18.1
9	5.00	0.72	8.20	13.6	61.75	33.20	783.00	35.20	11.80	4.87	19.9
10	14.1	0.79	8.20	4.50	99.98	35.00	2152.00	30.20	11.50	4.82	18.8
11	3.00	0.63	8.20	61.6	102.05	28.00	2176.00	35.8	11.10	7.29	14.8
12	2.00	0.37	8.20	43.5	98.46	19.60	986.00	29.1	9.20	6.26	18.8
13	3.06	1.42	8.40	2.80	30.32	6.60	1192.00	36.20	11.1	4.91	17.5
14	2.00	0.63	8.20	44.4	103.43	33.20	1124.00	31.10	13.30	5.18	17.5
15	25.3	0.70	8.20	27.2	71.25	37.20	1982.00	37.30	14.30	4.61	10.9
16	2.00	0.46	8.40	3.50	38.12	14.20	2115.00	30.70	10.90	8.23	15.8
17	3.00	0.53	8.20	52.5	37.18	7.40	2711.00	34.80	14.30	5.86	14.9
18	1.00	0.51	8.20	51.6	35.46	7.30	2973.00	31.00	14.70	9.24	11.8
Particle size distribution % (Abbas, 2003)											
Depth (cm)		Coarse sand		Fine sand		silt		Clay		Texture class	
30		3.90		8.50		32.30		55.30		Clay	

N: extracted by KCl; other extracted by NH_4-HCO_3-DTPA; EC and soluble ions of saturation extract.

Table 29 shows that, all the plots have a relatively adequate soil characteristics represented by low $CaCO_3$ and EC values, high OM and pH values and adequate nutrients level ,except for plot No. 13 which has low nutrients levels, high EC (1.42 dS/m) and pH (8.4) values (compared with other plots).

5.7.1.3 Yield map under traditional farming:

The variation in yield levels for maize is clearly monitored. Variations of crop yield within plots are the most important input for crop management. A crop yield variation was related to a vast array of crop and soil characteristics such as moisture, nutrients and elevation. Linking the spatial information on these inputs, crop yield and field characteristics, through a GIS system allowed analyses of the factors that are present in determining crop production. Characteristics were analyzed to display current yield map and potential fertilizers application. The information was stored in a coordinate system for the layers to be related to each other. Figure 52 shows yield map at the end of 2009 season.

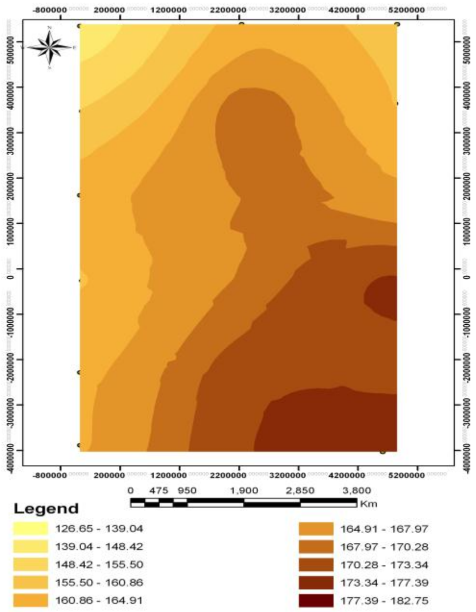


Fig 52: Yield (kg/plot) map (season 2009)

5.7.2 Second season practices of PF (2010):

5.7.2.1 Field scouting:

By the end of the growing season 2009 and after field survey which helped in getting vital information using satellite images and field observation , a field scouting record form was prepared as shown in Table 30. It is very necessary to design such field scouting record form to be a helpful guide when determining all production inputs and evaluating the current and potential stages of crop production. Investigating the abovementioned form, it is noticed that some practices like selecting maize type, seeding rates, seeding date, some tillage practices and water quality are accepted and followed in the successive season 2010. On the other hand, average of soil fertility status, water quantity, texture of some areas and drainage management, fertilizers rate and yield are not convinced and there is an urgent need to develop productivity through the procedures of precision farming.

5.7.2.2. Grid soil sampling:

Grid soil sampling provides an initial base of information for developing variable rate applications plans. This technique used a systematic method to reveal fertility patterns and assumes that, there is no logical reason for fertility patterns to vary within a field. After maize harvest of the first season 2009, soil samples were collected in a systematic grid (one sample from each plot) having location information that allows the data to be mapped. The goal of grid soil sampling is to identify the current status of nutrients and to identify the potential nutrient requirements.

5.7.2.3. Variable rate technology (VRT) and variable rate application (VRA):

Variable rate technology was applied in a limited scale. portable GPS was used to locate the plots boundary. The GIS system used this positional information from the GPS to access data about the field at specific location. Information is then sent to the operator about the field conditions. Using predetermined calculations allowed the required amount of fertilizers to be applied.

5.7.2.4. Mapping soil characteristics of the experimental field:

Geostatistical analyst was used to provide spatial soil characteristics within the experimental field. Kriging interpolation technique used grid sample points to produce continuous surfaces of fertility and some soil properties by filling gabs between points.

(1) Calcium carbonates ($CaCO_3$)

The spatial variability of soil calcium carbonates of the field was estimated as shown in the following lines and Figure 53.

The semivariogram model for soil calcium carbonate content of the studied area shows that, the major distance at which the model reaches its limiting value is 92.98 m and the minor range is 21.29 m. with direction angle of 284.4^{O} Soil calcium carbonates content distribution in the studied area could be expressed by the following equation:

$CaCO_3$= 50.594*Spherical {(92.98, 21.29, 284.4)} + 29.974 Nugget

From Figure 53, soil calcium carbonate content ranges between 1.0 and 25.3 g/kg of the fine earth of the surface layer of the studied area with regression function: **Y= 0.036 X+ 8.275.** Where: Y is the spatial variability and X: $CaCO_3$

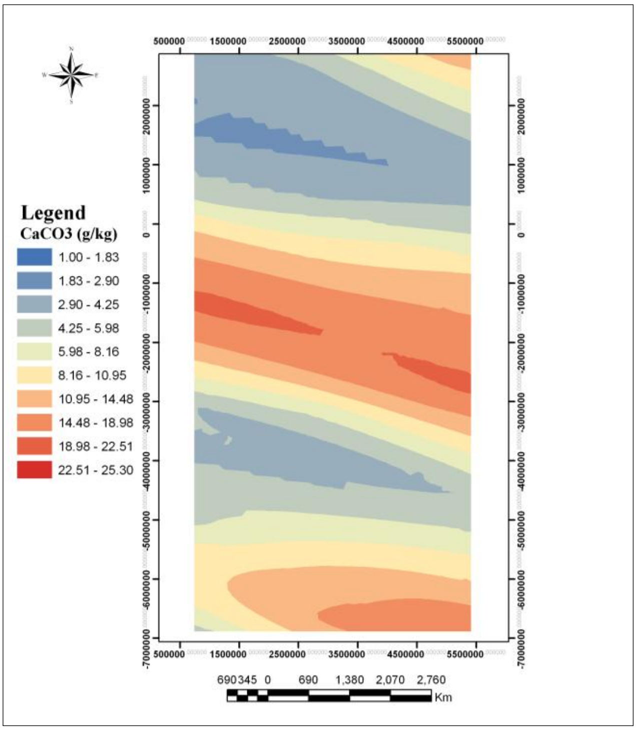


Fig. 53: Spatial variability of $CaCO_3$ of the experimental field

(2) Electric Conductivity (EC)

1- The spatial variability of salinity of the studied area was estimated as shown in the following lines and Figure 54.

The semivariogram model for soil salinity of the field shows that, the major distance at which the model reaches its limiting value is 92.98 m and the minor range is 59.02 m. with direction angle of 29.6°. Soil salinity content distribution in the studied area can be expressed by the following equation:

EC= 0.054747*Spherical {(92.98, 59.02, 29.6)} +0.010235 Nugget

From Fig 54, it is obvious that, soil salinity expressed as the electrical conductivity (EC) of the soil paste extract ranges between 0.37 and 1.42 dS/m of the fine earth in the surface layer of the studied area with regression function: **Y = 0.193 X + 0.790** Where: Y is the spatial variability and X: EC.

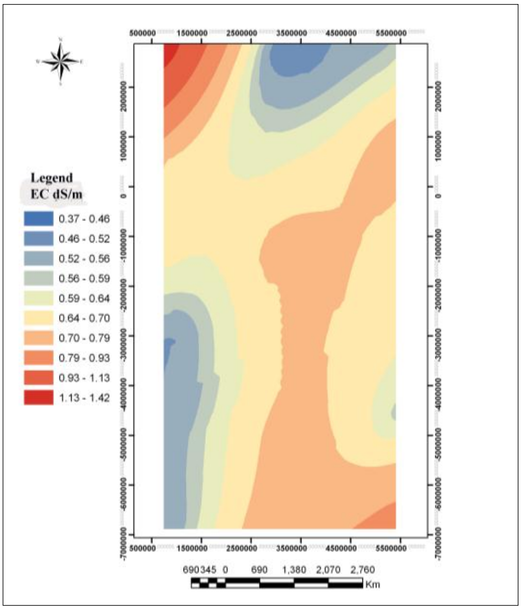


Fig. 54: Spatial variability of EC of the experimental field

(3) pH:

The spatial variability of soil pH of the field was estimated as shown in the following lines and Figure 55.

The semivariogram model for soil pH of the studied area shows that, the major distance at which the model reaches its limiting value is 77.96 m and the minor range is 40.85 m. with direction angle of 35.4^{O}. Soil pH distribution in the studied area could be expressed by the following equation:

pH= 0.0038914*Spherical {(77.96, 40.85, 35.4)} + 0.0043188 Nugget

From Figure 55, soil pH content ranges between 8.2 and 8.4 g/kg of the fine earth in the surface layer of the studied area with regression function: **Y = 0.081 X + 8.907.**

Where: Y is the spatial variability and X: pH.

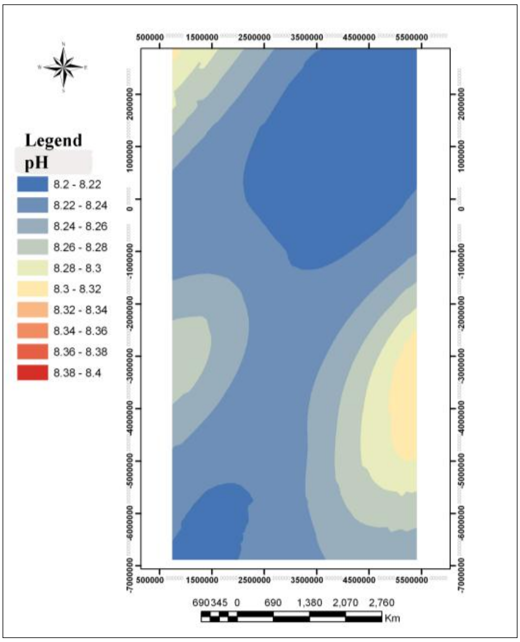


Fig. 55: Spatial variability of pH of the experimental field

(4) Available nitrogen:

The spatial variability of soil available nitrogen of the field was estimated as shown in the following lines and Figure 56.

The semivariogram model for soil available nitrogen content of the field shows that, the major distance at which the model reaches its limiting value is 92.98 m and the minor range is 40.15 m with direction angle of 80.6^{O} Soil available nitrogen content distribution in the field could be expressed by the following equation:

N= 629820*Spherical {(92.98, 40.15, 356.5)} + 0 Nugget

From Figure 56, it could be deduced that, soil available nitrogen ranges between 30.22 and 125.22 mg/kg of the fine earth in the surface layer of the field with regression function:

Y= 0.072 X + 21.177. Where: Y is the spatial variability and X: N.

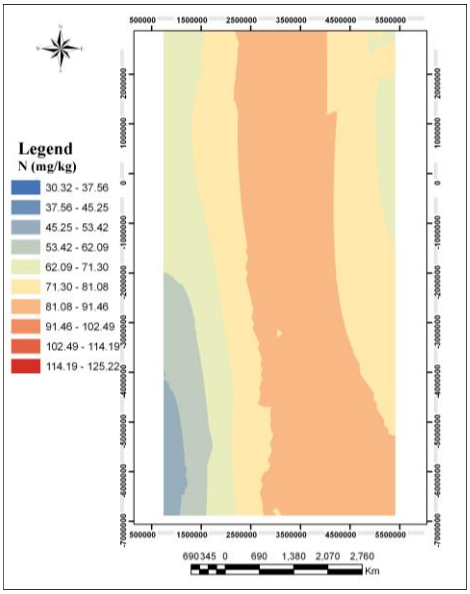


Fig. 56: Spatial variability of available nitrogen of the experimental field

(5) Available phosphorus:

The spatial variability of soil available phosphorus of the field was estimated as shown in the following lines and Figure 57.

The semivariogram model for soil available phosphorus content of the field shows that, the major distance at which the model reaches its limiting value is 92.98 m and the minor range is 51.47 m with direction angle of 80.6^{O}. Soil available phosphorus content distribution in the field could be expressed by the following equation:

P= 99.102*Spherical {(92.98, 51.47, 80.6)} +100.04 Nugget

From Fig 57, it is clear that, soil available phosphorus ranges between 4.6 and 7.20 mg/kg of the fine earth in the surface layer of the field with regression function: **Y = 0.072 X + 21.177.** Where: Y is the spatial variability and X: P.

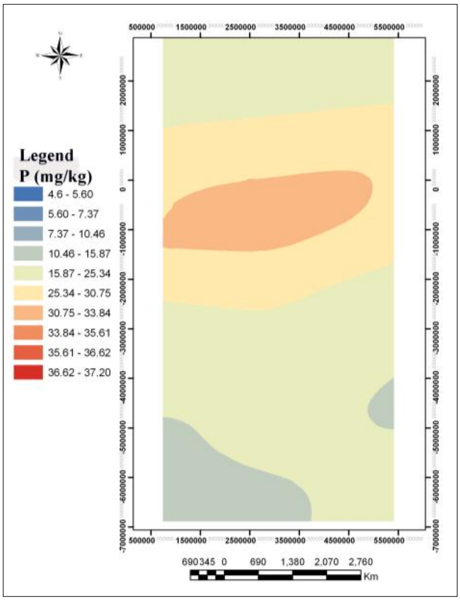


Fig. 57: Spatial variability of available phosphorus of the experimental field.

(6) Available potassium:

The spatial variability of soil Available potassium of the field was estimated as shown in the following lines and Figure 58.

The semivariogram model for soil Available potassium content of the field shows that, the major distance at which the model reaches its limiting value is 92.98 m and the minor range is 25.06 m. with direction angle of 0.5^O Soil Available potassium content distribution in the studied area could be expressed by the following equation:

K= 355.27*Spherical {(92.98, 25.06, 0.5)} +596.14 Nugget

Figure 58 shows that, soil available potassium content ranges between 665 and 2973 mg/kg of the fine earth in the surface layer of the field with regression function: **Y = 0.007 X + 74.378.** Where: Y is the spatial variability and X: K.

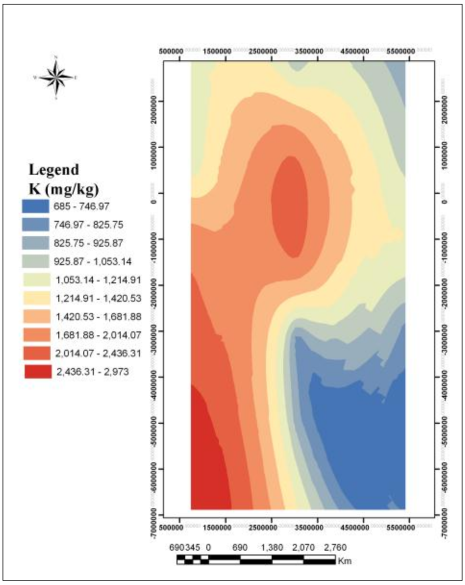


Fig. 58: Spatial variability of available potassium of the experimental field

5.7.2.5 Precision farming (PF) management practices:

Crop producers want to optimize fertilizer use (input) use in the production practices. The average of the field soil characteristics was determined to decide the fertilizer application levels for all eighteen locations (plots 1-18). The obtained information was combined with regular field survey, to give accurate identification and diagnosis of the existing problems for a successful crop management program. The information obtained from field scouting was useful to determine if any immediate actions should be taken as well as future reference to avoid problems in subsequent years. Factors limiting the productivity of a field often arise suddenly and must be corrected quickly to preserve the full yield potential of the crop, **(OMAFRA Staff, 2008)**. Every location in the field was evaluated according to its specific characteristics and assigned an optimal input application rate unique to that location. Thus, many different application rates across the field were obtained. The following lines discuss optimum fertilizers management within the scope of precision farming.

5.7.2.5.1. Fertilizer management for N, P and K:

Fertilizer applications were governed by the yield potential of the individual soil spots. In the current work, as precision agriculture bases, the use of fertilizers should be limited to areas of known deficiency, and only the deficient nutrient should be applied. Regarding the data obtained from the field scouting form (traditional farming), it was noticed that addition fertilizers due to the field as a whole led to excessive and useless nutrients especially in plots 1, 3, 8, 10, 11, 12 and 14. Adding fertilizers in traditional farming would lead to environmental hazards and economic stress. In precision farming, fertilizer recommendations are widely variable from plot to another due to precise requirements. Recommendations for nitrogen were 3.21, 2.62, 2.53, 1.60, 0.84, 2.05, 3.47, 1.54, 3.32, 3.37 and 3.46 kg N/plot for plots 2, 4, 5, 6, 7, 9, 13, 15, 16, 17 and 18 respectively, meanwhile the recommendations for phosphorus were 0.59, 0.61, 0.46, 0.46, 0.51, 0.10, 0.46, and 0.47 kg P for plots 2, 3, 6, 7, 13, 16, 17 and 18 respectively. Tables 31 and 32 illustrate the variation in N and P recommendations associated with their costs for the field unit.

Table 31: Amounts and costs of nitrogen application under precision farming:

Plot no.	**Plot area (m^2)**	**Available N in soil**		**Required (kg /fed.)**		**rice L.E./plot**
		mg/kg	**kg/ plot**	**N kg/plot**	**Fertilizer (kg /plot)**	
1	225	125.22	6.71	0.0	0.00	0.00
2	225	40.11	2.15	3.21	6.98	11.87
3	225	105.16	5.63	0.00	0.00	0.00
4	225	51.09	2.74	2.62	5.70	9.69
5	225	52.76	2.83	2.53	5.50	9.35
6	225	70.14	3.76	1.60	3.48	5.92
7	225	84.34	4.52	0.84	1.83	3.11
8	225	103.67	5.55	0.0	0.00	0.00
9	225	61.75	3.31	2.05	4.46	7.59
10	225	99.98	5.36	0.00	0.00	0.00
11	225	102.05	5.47	0.00	0.00	0.00
12	225	98.46	5.37	0.00	0.00	0.00
13	225	30.32	1.62	3.74	8.13	13.82
14	225	103.43	5.54	0.00	0.00	0.00
15	225	71.25	3.82	1.54	3.35	5.70
16	225	38.12	2.04	3.32	7.22	12.27
17	225	37.18	1.99	3.37	7.33	12.46
18	225	35.46	1.90	3.46	7.52	12.78
Total					61.50	104.56

Notes: Nitrogen in kg/fed. = soil depth (0.15 m)*area *soil bulk density*nitrogen% .Soil bulk density = 1580 kg/m^3.1kg urea coast 1.7 L.E. Traditional application 120 kg N/fed. i.e. 7.33 kg urea (costs 12.46 L.E./plot.)Total costs with PF application 104.56 L.E/ fed.

Table 32: Amounts and costs of phosphorus application under PF:

Plot No.	Plot area (m^2)	Available P in soil		Required P (kg/plot)		Price L.E./plot
		mg/kg	Kg/plot	P (kg/plot)	Fertilizer (kg/plot)	
1	225	30.10	1.61	0.00	0.00	0.00
2	225	5.00	0.27	0.59	8.67	10.41
3	225	4.60	0.25	0.61	8.79	10.55
4	225	35.00	1.88	0.00	0.00	0.00
5	225	37.00	1.98	0.00	0.00	0.00
6	225	7.44	0.40	0.46	6.76	8.11
7	225	7.48	0.40	0.46	6.76	8.11
8	225	33.80	1.8	0.00	0.00	0.00
9	225	33.20	1.78	0.00	0.00	0.00
10	225	35.00	1.88	0.00	0.00	0.00
11	225	28.00	1.50	0.00	0.00	0.00
12	225	19.60	1.05	0.00	0.00	0.00
13	225	6.60	0.35	0.51	7.50	9.00
14	225	33.20	1.78	0.00	0.00	0.00
15	225	37.20	1.99	0.00	0.00	0.00
16	225	14.20	0.76	0.10	1.47	1.77
17	225	7.40	0.40	0.46	6.76	8.11
18	225	7.30	0.39	0.47	6.91	8.26
Total/ fed					53.62	64.35

Notes: Phosphorus in kg/fed. = soil depth (0.15 m)*area*soil bulk density*phosphorus %. Soil bulk density = 1580 kg/m^3.1kg super phosphate coast 1.2 L.E. Traditional application 100 kg /fed. i.e. 40 kg super phosphate (costs 48 L.E./plot).

The above data illustrate typical variation in soil nutrients (N and P) levels in both TF and PF. For potassium there was no need for adding potassium fertilizer as the soil has a sufficient amounts of this nutrient. Greater variation would be expected if fertilizer had been applied on a regular basis. There is no deficiency in micronutrients in the experimental field.

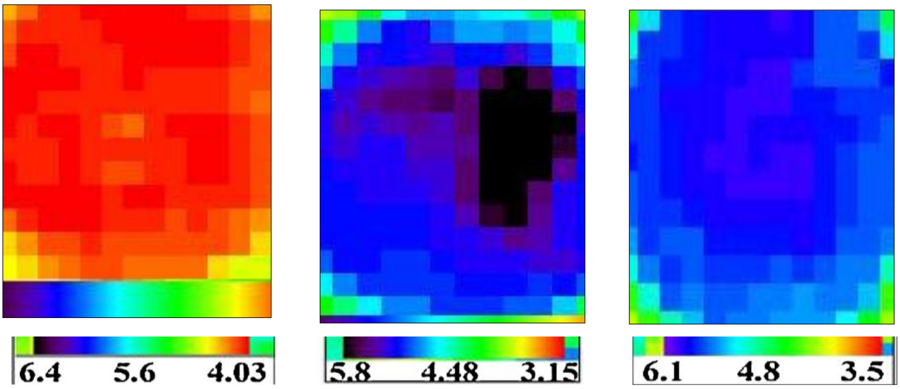
5.7.2.5.12. Water consumption:

(A) The surface energy balance algorithm for land (SEBAL) model (based on satellite images):

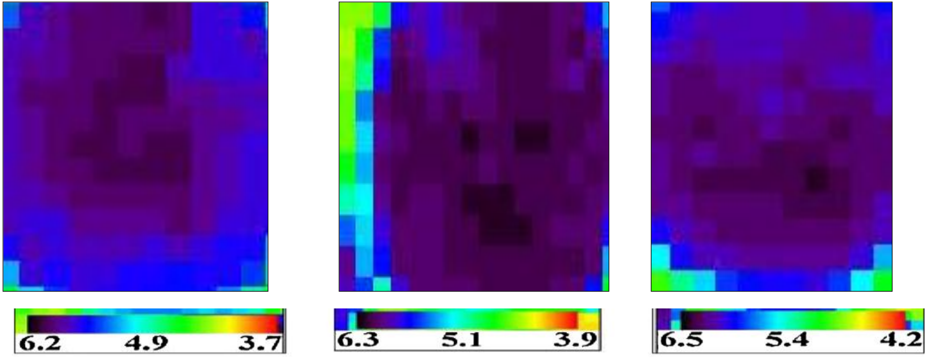
The surface energy balance algorithm for land (SEBAL) model was used for estimating crop evapotranspiration (ETc) on the experimental irrigation field scale under local climatic conditions of Kalubia governorate. SEBAL is an image processing model comprised of twenty five sub-models for calculating evapotranspiration as a residual of the surface energy balance. SEBAL is an emerging technology and has the potential to become widely adopted and used by water resources and irrigation community **(Allen *et al.,* 2002).** Applying water in adequate amounts is the cornerstone of variable rate application especially with shortage of irrigation water in such arid regions. First of all land surface temperature (LST) was derived using Eq. 1 and 2 (see chapter 4.7.1) for all 16 days instantaneous acquired ETM+ images consequently as 31.6, 34.7, 34.2, 34.3, 34.4 and 35.2 for May 28, June 13, June 29, July 15, July 31 and August 16. These results are in accordance with those obtained by **EL-Nahry *et al.* (2010)**. Using the derived LST and metrological data of relative humidity, wind speed and sunshine hours, a daily reference evapotranspiration (ET_{24}) is computed by solving the surface energy balance using Eq. 3 and 4 (see chapter 4.7.2). Based on the actual cropping calendar, the weighted crop coefficient Kc for different satellite overpass dates was calculated using Eq. 5 (see chapter 4.7.2) as 0.3, 0.54, 1.20 and 0.70 successively within the phonological stages of initial, development, mid-season and late-season. Fig. 59 shows the instantaneous evapo-transpiration of maize (mm/day). It shows that with 28.5 spatial resolution of ETM+ image, ET_{24} variable rate of initial stage on May 28 has a value of 4.03 mm. At development stage on June 13, ET_{24} values were ranged from 5.1 to 5.8. At mid-season stage on 29 June and July 15, ET_{24} values were ranged from 5.1 to 6.2 mm. At end-season stage on August 28 and ET_{24} values were ranged from 5.2 to 6.5 mm. Higher values (dark blue color with ET_{24} value of 6.5 mm) meanwhile, the yellow color shows low ET_{24} values of 3.15 to 4.03 mm. Missing values of ET_{24} were obtained by daily calculation of reference evapotranspiration (ETo) using the modified Penman–Monteith method **(Smith, 1992)**.

Solving the Eq. 6 (see chapter 4.7.2) the ET_{24} was converted into potential crop evapotranspiration (ETc) recording 1.53, 4.87, 5.31, 7.38, 7.56 and 8.53 mm/day. Results obtained from using SEBAL with the aid of Penman–Monteith method throughout the CROPWAT model indicated that, accumulated water consumption of the investigated field, averaged 571.5 mm/season for maize grown without water deficit. So it is worthy to mention that, under PF the total quantities of irrigation water added to maize growing in the investigated field were estimated at 2398.2 m^3/growing season against 2996.53

m3/growing season under TF, saving an amount of water equal to 689.20 m3. To demonstrate crop water requirements and irrigation scheme of maize, FAO CROPWAT model was used.



(a)ET$_C$May 20 (b)ET$_C$ June 05 (c)ET$_C$ June 21



(d)ET$_C$ July 07 (e)ET$_C$ July 23 (f) ET$_C$ August 08

Fig. 59 Instantaneous evapo-transpiration of maize (mm/day)

(B) CROPWAT model (based on FAO Penman–Monteith approach):

This approach overcomes shortcomings of the FAO Penman method **(Smith, 1992)**. From the original Penman–Monteith equation and the equations of the aerodynamic and surface resistance, the FAO Penman–Monteith model was used to estimate the reference evapotranspiration (ETo).

Reference evapotranspiration (ETo):

The FAO Penman–Monteith method through CROPWAT window model was recommended as the sole method for determining ETo. This method explicitly incorporates both physiological and aerodynamic parameters. To determine ETo in the experimental field, daily climatic data within the growing season were used. For simplicity, monthly climatic data and associated ETo is displayed in Figure 60. Monthly ETo values were determined as 6.28, 7.00, 6.08 and 5.67 mm with an average of 6.25 mm for the growing season (May, June, July and August 2009 successively). The reference crop evapotranspiration was at peak (6.28 mm/day) at the initial stage of growth; slightly increased at development stage of growth (7.00 mm/day), meanwhile decreased at mid season stage of growth (6.08 mm/day), and at end season stage of growth to reach 5.67 mm/day. Decreasing of ETo values may be due to increasing of relative humidity.

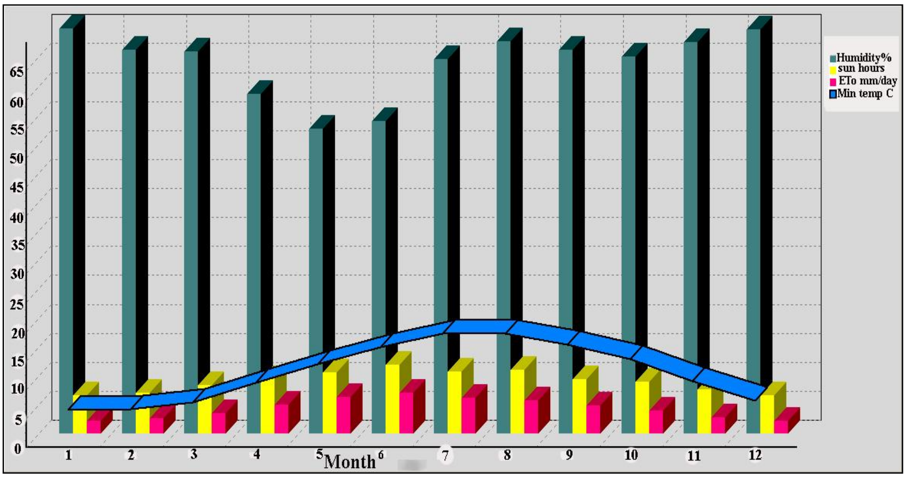


Fig. 60: Monthly climatic data and associated ETo for maize.

(C) Crop water requirement (CWR):

The amount of water required to compensate the evapotranspiration loss from the cropped field is defined as crop water requirement. Although the values for crop evapotranspiration under standard conditions (ETc) and crop water requirement are identical, crop water requirement refers to the amount of water that needs to be supplied, while crop evapotranspiration refers to the amount of water that is lost through evapotranspiration. Crop water requirement are illustrated in Table 33 and Fig. 61.

Table 33: Crop water requirement:

Month	Decade	Stage	Kc Coefficient	ETc Mm/day	ETc mm/dec	Effective rain mm/decade	Irr. Req. mm/decade
May	3	Initial	0.3	1.96	21.5	0.4	21.1
June	1	Development	0.3	2.08	20.8	0.1	20.7
June	2	Development	0.47	3.36	33.6	0	33.6
June	3	Development	0.72	4.94	49.4	0	49.4
July	1	Development	0.98	6.26	62.6	0	62.6
July	2	Mid-season	1.18	7.19	71.9	0	71.9
July	3	Mid-season	1.2	7.12	78.3	0	78.3
August	1	Mid-season	1.2	6.96	69.6	0	69.6
August	2	Mid-season	1.2	6.79	67.9	0	67.9
August	3	Late-season	1.06	5.71	62.8	0	62.8
September	1	Late-season	0.63	3.19	31.9	0	31.9
September	2	Late-season	0.37	1.79	3.6	0	3.6
					573.9	0.6	573.3

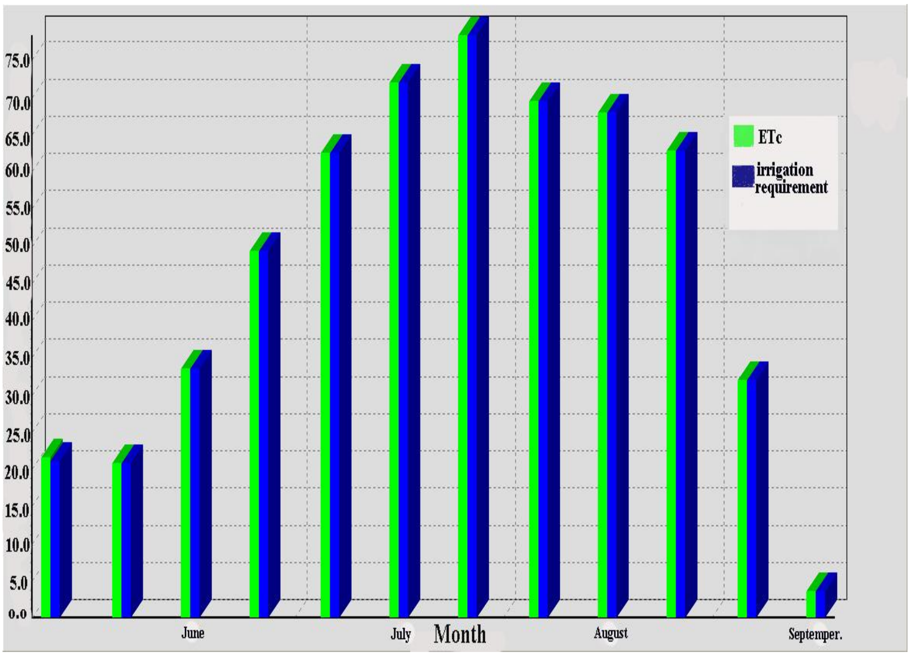


Fig. 61: Water requirement for maize crop during the growing season.

As shown in Table 33 and Fig. 61, the initial stage required water requirement of 21.1 mm/decade of days due to growth of plants and climatic conditions. By the end of development stage of growth irrigation requirement increased to reach 62.6 mm/decade of days. The highest amount of required irrigation water of 78.3 mm/decade of days was recorded at the third decade of July (mid-season stage of growth) due to the higher plant growth. Needs to water was reduced sharply in the second decade of days in September (late-season stage of growth) till it reaches the lowest value of 3.6 mm to encourage grains maturity. Generally ETc ranged between 1.79 and 7.19 mm/day during the growing season, while total Etc was determined at 573.9 mm/growing season. Reviewing the obtained results from the two models, it was noticed that, insignificant difference was found between ETc determined by SEBAL (571.5 mm) and that determined by CROPWAT (573.9 mm). Thus using remote sensing with tighten temporal resolution (quick site revisit i.e. daily visit) and GIS to determine ETc is essential, especially in areas that not covered by meteorological stations like Sahara.

(D) Irrigation schedule of maize:

Essentially, maize irrigation schedule included calculations, producing a soil-water balance on a daily step. Irrigation schedule always rely on gross and net irrigation. Gross irrigation (GI) represents the water depth in mm applied to the field while net irrigation (NI) represents the water depth in mm that is used beneficially. This allowed developing indicative irrigation schedules to improve water management. Table 34 illustrates the irrigation schedule for maize crop.

Table 34: Irrigation schedule for maize crop:

Date	Day	Stage	Rain mm	Ks fraction	Eta %	Depletion %	Net Irrigation mm	Loss mm	Gross Irrigation mm	Flow l/s/ha
2-Jul	43	Development	0	1	100	56	137.2	0	196.1	0.53
26-Jul	67	Mid-season	0	1	100	57	164.7	0	235.3	1.13
18-ug	90	Mid-season	0	1	100	55	159.5	0	227.9	1.15
12-Sep	End	End-season	0	1	0	38				

Table 34 shows that, on the 2ed of July gross and net irrigation recorded values of 196.1 and 137.2 mm/stage, respectively in the development vegetative growth stage, and then they increased to reach 235.3 and 164.7 mm/stage successively on the 67th day of planting in the mid-season stage. On the 90th day of planting (mid-season stsge of growth), both of GI and NI reached their minimums of 227.9 and 159.5 mm/stage respectively. Water depletion increased gradually from development stage of growth to end –season stage of growth to reach its maximum of 57% on July 26 in the mid-season stage. Actual evapotranspiration (ET_a) recorded 100% at all the growth stages because water stress coefficient (Ks) was equal to 1.0. Thus ET_c adjusted value equaled to ET_c. Converting the gross irrigation application depth into a permanent supply was called “flow”. A remarkable difference between total gross irrigation (659.2 mm) and total net irrigation (461.5 mm) implied an irrigation efficiency of 70%.

(E) Soil water retention:

Fig. 62 shows the relationship between soil water retention and days after planting considering readily available moisture (RAM), total available moisture (TAM) and water depletion. It was noticed that at initial stage within 10 days after planting there was a narrow gab between RAM and TAM with low water depletion, where soil water retention fall in the range of 10 to 30 mm. This gab was enlarged to reach its maximum after 35 days of planting (end of vegetative development growth stage), then it was stabilized for 25 days at mid-season stage realizing soil water retention in the range of 32.5 to 60 mm. Finally at end-season stage this gab between RAM and TAM was narrowed again to reach soil water retention in the range of 47.5 to 60.0 mm. Water depletion was increasing with time.

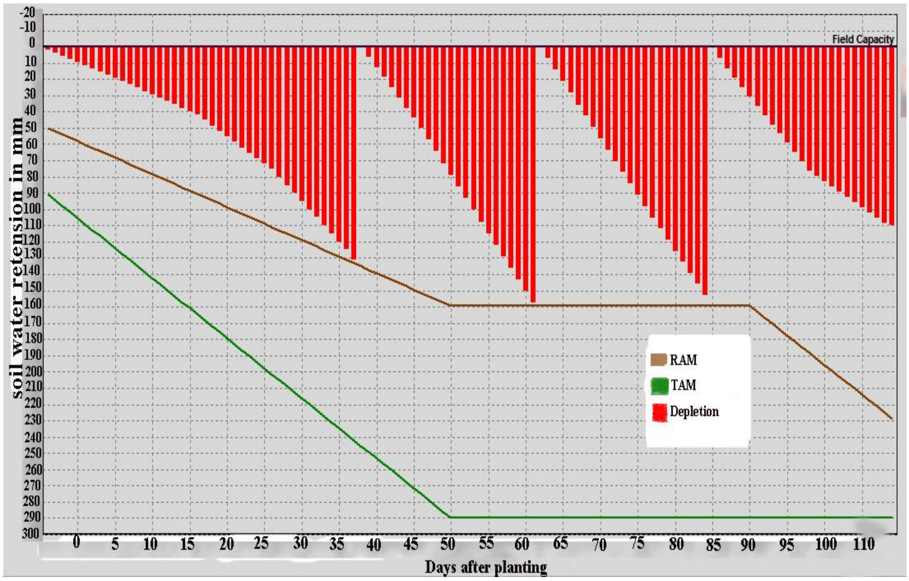


Fig. 62. Relationship between soil water retention and days after planting.

5.7.3 Yield mapping:

Yield mapping is very important technique in precision farming. Yield mapping system measures and records the amount of grain being harvested at any point in the field. Yield data are sent to the on-board computer where measured yield is matched with its appropriate field position and normalized difference vegetation index (NDVI) obtained from satellite images Figure 63.

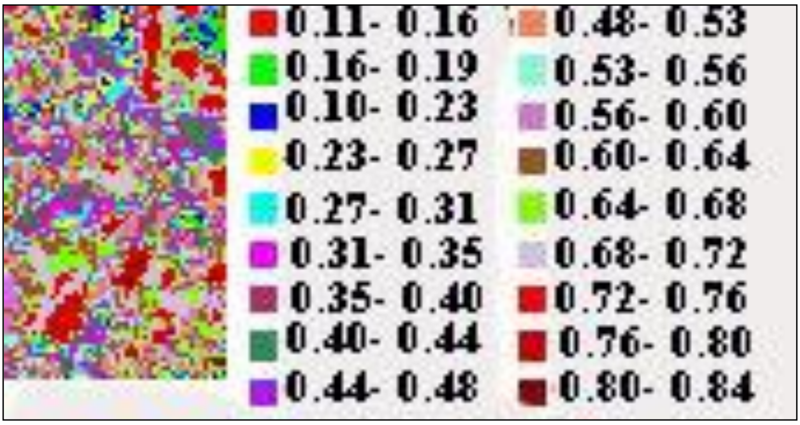


Fig.63: Normalized difference vegetation index NDVI of the field under precision farming

The obtained data were transferred to a yield map using Arc GIS software (Fig. 64). It is noticed that, there is a dramatic change in plot yields after applying precision farming (PF).

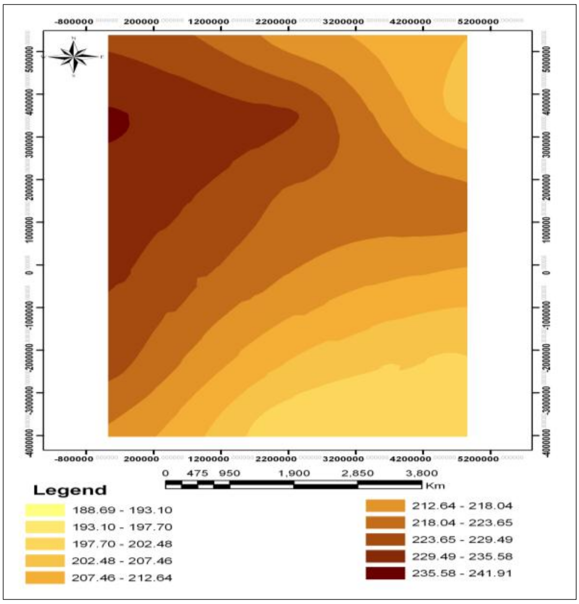


Fig. 64: Yield map of the experimental field under precision farming.

5.7.4. Correlation analysis of normalized difference vegetation index (NDVI) vs. maize yield:

Remote sensing measures specific wavelengths of light that are reflected from the leaves of plants in the field either it was visible or near infrared. The amount of near infra red (NIR) reflectance is related to the biomass (leaf area) of the plant and the plant’s vigor. Larger plants with more leaves will reflect more NIR light than smaller plants, just as healthy vigorous plants of a given size will reflect more NIR light than stressed plants of the same size. Reflectance data were measured and used to calculate NDVI, which has been found to be correlated to plant size, vigor and yield of crops. In this study, at different critical periods the correlation between NDVI and yield was derived. Though variations could be observed between NDVI and yield, yet a positive correlation was obtained. Figure 65 shows that as follows:

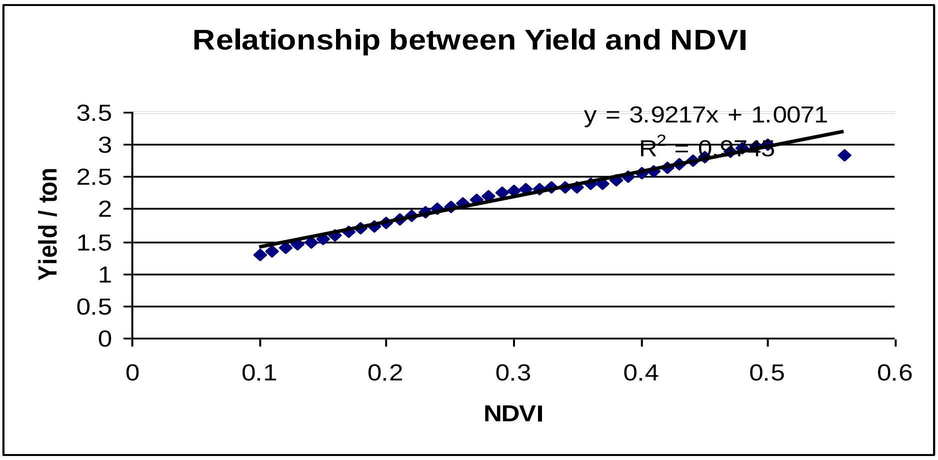


Fig. 65: Relationship between normalized difference vegetation index (NDVI) and grain yield

5.8. Economic and environmental profitability of PF at the experimental field level:

The economic profitability of precision farming is as variable as field conditions. In highly uniform fields, better knowledge of soil and plant parameters is not as likely to result in greater economic return as it is in fields with variable conditions. Return and costs are compared in both TF and PF as illustrated in Tables 35 and 36.

Table 36 illustrates that, the costs of applying PF were lower than TF; the productive area increased achieving high returns where, total returns were increased from 2084.46 to 2794.42 LE representing an increase percentage of (34.06 %). The economic profitability (Returns -costs) recorded 1110.96 LE for TF and 1952.74 LE for PF representing an increase percentage of (56.90 %). From the environmental point of view NPK application decreased in all zones. This decrease in fertilizers use reduce the environmental hazards especially pollution by excessive nitrate.

5.9. Economic and environmental profitability of PF at the studied area level:

First of all the cultivated area with maize crop was identified using the hyperspectral imagery as shown in Fig. 66. The total cultivated area with maize has been defined by 19107 feddans.

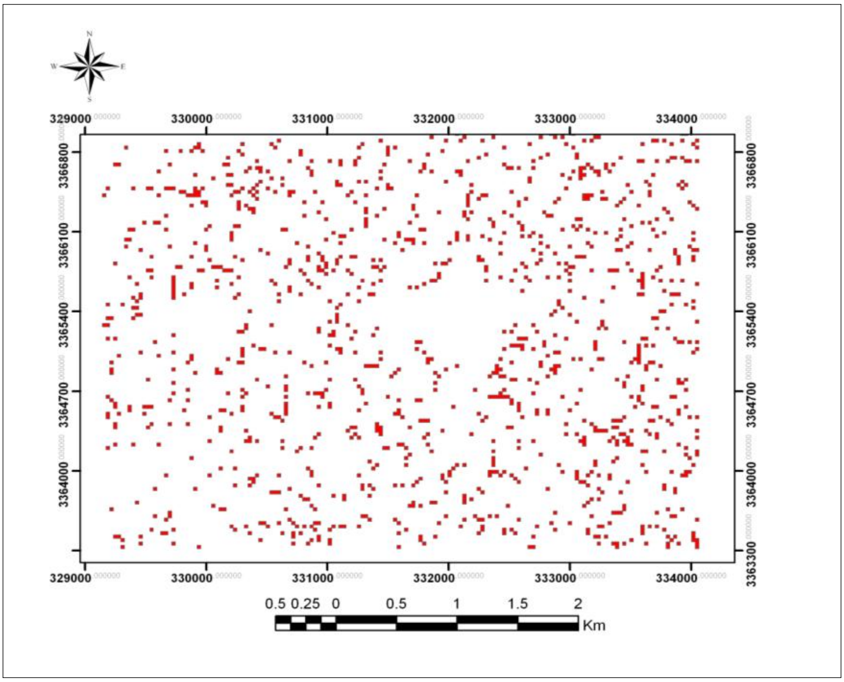


Fig. 66: Spatial distribution of maize in the studied area

Applying precision farming (PF) on the studied area level had led to both economic and environmental profitability.

(a) Economic profitability under traditional farming (TF) and precision farming (PF):

Economic profitability has been realized as follows:

(1) Yield under TF = Cultivated area xYield (Ardab)/feddan

=19107 x 20

= 382140 Ardab.   (1 Ardab maize = 140 kg)

(2) Return under TF = yield x price

= 382140 x 98   (price of 1 maize Ardab = 98 LE)

= 37449720 LE.

(3) Yield under PF = Cultivated area x Yield/feddan

=19107 x 27.8

=531174.6 Ardab.

(4) Return under PF = yield x price

= 531174.6 x 98

= 52055110.8 LE.

(5) Yield difference between PF and TF = 531174.6 – 382140

=149034.6 Ardab.

(6) Net return = yield x price

= 149034.6 x 98

= 14605390.8 LE.

(b) Environmental profitability:

Under traditional (TF) the amounts of applied fertilizers to the studied area were 2292840 kg N (120 Kg N/Fed) and that equals 6687450 kg urea (350 kg/ Fed.). For phosphorus the total added amounts were 129927.6 kg P (6.8 kg P/Fed.) and that equals to 1910700 kg single super phosphate (100 kg/ fed. and that are large amounts of fertilizers causing an environmental hazards especially for nitrogen represented in the pollution with nitrate. On the other side, the amounts of fertilizers have been decreased in PF practices to record 540345.96 kg N and that equals to 1175080.5 kg of urea. Four phosphorus the total added amounts are 60951.33 kg P (3.19 kg P/Fed) and that equals to 1024517.34 kg single super phosphate (53.62 kg/ fed). The saved fertilizers amounts are 1752494.04 kg N (**5512370** kg urea) and 68976.27 kg P (**886182.66** kg super phosphate) this would make the environment more clean and safe.

5.10 Precision Farming Spatial Model (PFSM):

The study developed precision farming spatial model to identify the most appropriate areas/fields for precision farming based on the interaction among physical /chemical soil properties using spatial analysis tools in an ARCGIS environment. The model input included six variables i.e., EC, ESP, CEC, gypsum content, $CaCO_3$ content and OM content. The model resulted in five precision farming classes 1-Farms not meeting the requirements of precision farming, 2-Farms below the threshold of precision farming, 3-Farms meeting the threshold of precision farming practices, 4-Farms above the threshold of precision farming practices and 5-Farms meeting the requirements of precision farming. Figure 68 shows the model structure; and Figure 67 shows the precision farming map resulting.

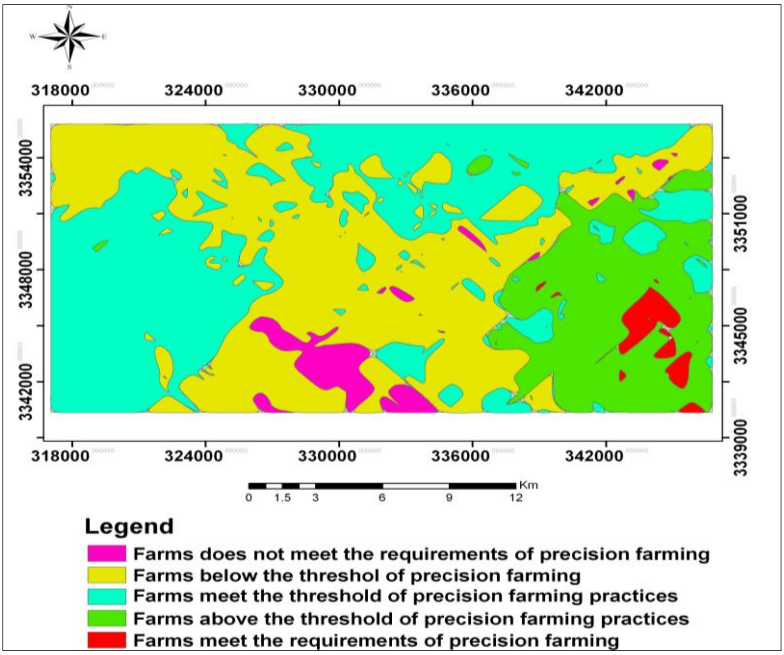


Fig. 67: Precision Farming map of the investigated area.

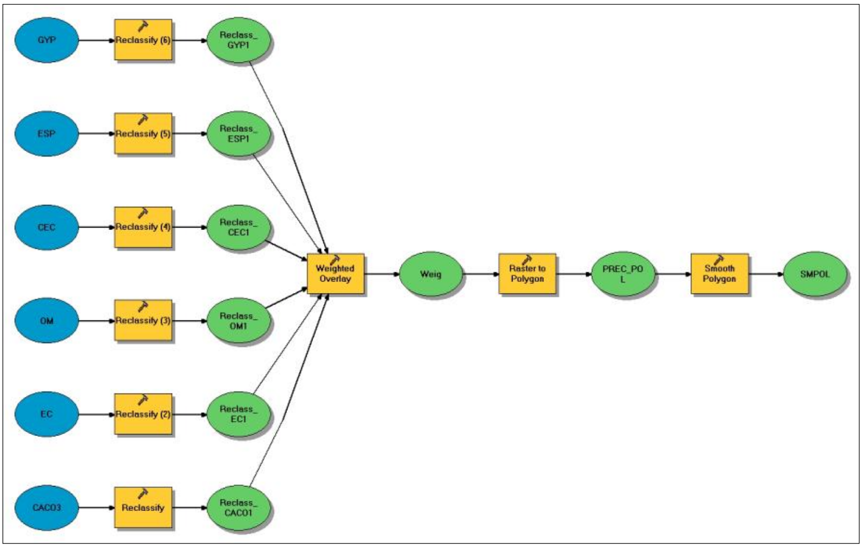


Fig. 68: Precision farming spatial model of the investigated area.