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TABLE OF CONTENTS

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Approach to Detecting Forest Fire by Image Processing Captured from IP Cameras

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ABSTRACT

In this paper, the results show an algorithm to detect the presence of smoke and flame using image sequences captured by Internet Protocol (IP) cameras is represented. The important characteristics of smoke such as color, motion and growth properties are employed to detect fire. For the efficient smoke and fire detection in the captured images by the IP camera, a detection algorithm must operate directly in the Discrete Cosine Transform (DCT) domain to reduce computational weigh, avoiding a complete decoding process required for algorithms that operate in spatial domain. In order to assess the possibility and the accuracy of proposed algorithm, the author used the video sequences which are captured by IP camera from control forest fire at different spatial location and levels of fire intensity. Evaluation results illustrated the efficiency of the proposed algorithm in effectively detecting forest fires with accuracy at 97%.

Keywords: Forest fire; Smoke and Fire Detection; DCT; IP Camera; Images Processing

1 Introduction

Forest fire is a complex physiological process which includes numerous direct and indirect impacts on the atmosphere, biosphere and hydrosphere. That is one of the key drivers of major changes in term of air pollution in many parts of the world. Forest fires often occur on a large scale especially in complex mountainous terrain, intricate to access. Therefore, forest fire detection by traditional approaches is inappropriate.

In recently years, Vietnam annually has 650 forest fires which are damaged average 4.340 ha of forest. In which, it has about 3.200 ha plantation forest and approximately 1.140 ha of natural forest. In 2002, forest fires in U Minh Thuong and U Minh Ha destroyed 5.500 ha of Melaleuca forest, including 60% of primary forest. In early 2010, forest fires in Hoang Lien - Lao Cai National Park destroyed more than 700 ha of forest. The deprivations caused by forest fires in term of economic, social and environmental are quite enormous and difficult to calculate.

Early detection of forest fires can help to alarm and prevent disasters, resulting in major human and property damage. The combustion of objects usually begins with the emission of smoke, even before igniting. Therefore, smoke is an essential element for early fires detection. The smoke characteristics depend on the chemical properties, temperature, oxygen content, etc. The color of the smoke ranges from white to white-blue when fired at low temperatures and from gray to black when the temperature rises to ignition. The most general smoke detectors are based on infrared or ultraviolet cameras. In addition, other detection techniques are based on particle analysis, temperature, relative humidity, and air transpiration. These systems will operate when smoke or fire particles are close to

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fire detection devices and unable to provide information regarding the exact location, intensity, spread, etc. [1] To provide more accurate and reliable smoke detection, some video-based detection systems have been proposed. The algorithm for detecting fire through video is based on two main characteristics of fire: flame and smoke. Most fire detection algorithms in the theory use some of the characteristics of fire and smoke, such as fire / smoke color, flaking, changing of fire area boundary.

Recently, the use of IP cameras with video surveillance has grown significantly, due to the simple IP-based monitoring system at low cost. Therefore, the use of cable systems and wireless Internet infrastructure has been widely applied [3]. Furthermore, an IP camera not only captures sequences of images but also has its own processor, memory and operating system, allowing programs to process information obtained without additional computer equipment. IP cameras can be connected to form networks that make a video surveillance system more reliable. Data is the information provided by encrypted IP cameras in many format: Motion-JPEG (MJPEG), H.264, or so on… [3].

This paper focuses on image processing techniques based on the use of smoke detection algorithms from IP camera. Proposed algorithms operate directly in the DCT domain and can be implemented on IP camera surveillance systems. This algorithm has used a number of smoke features including color, motion and spread characteristics that extracted directly from the DCT coefficient during decoding.

2 Materials and Methodology

2.1 Forest fire detection algorithm for IP camera

2.1.1 IP camera – image receiver

The use of IP technology for forest fire detection give a countless advantage, for example IP-camera networks can detect fire origin magnitude and propagation in more accurate manner compared with a single video surveillance system. However, to efficiently use the IP technology for fire detection purposes, the smoke detection algorithm must perform directly in the Discrete Cosine Transform (DCT) domain, because decoding (from DCT domain to spatial domain) and possible encoding (from spatial domain to DCT domain) are considerably high time consuming processes. Moreover, almost all fire detection algorithms including those proposed in [2, 5, 6] are carried out in the spatial domain, analyzing the value of each pixel or block of pixels. Therefore, any implementation of these algorithms in IP technology requires considerably high extra processing time.

Generally, an IP camera captured sequences of images, the number of frame captured depend on each different camera, normally it can reach over 20 frames per second. In addition, has its own processor, memory and operating system, allowing loaded programs to process the captured information without the need of additional computer equipment and the information provided by IP camera is encoded data in JPEG or MJPEG format.

Additionally, the quality of images captured by IP camera is stable without disturbance by signal transmission process. For normal cameras which are set up in less interfering environment and the signal is transmitted by coaxial cable to the receiver, signal still affected by material of it's cable. Therefore, the quality of images cannot be remaining for analysis process to detect objects, particularly forest fires.

2.1.2 Image processing to detect forest fires

Normally, IP camera uses two basic protocols to access the images that captured from the sensor via internet: *http* protocol (HyperText Transfer Protocol) and *rtsp* protocol (Real Time Streaming

Protocol). These protocols allow access data from IP camera in two different formats: (1) *http* protocol allows assess and download directly JPEG images; (2) *rtsp* protocol uses H.264 codec, thus the received signal need a decoder to covert it ino JPEG images. Each protocol is used depending on different IP camera. Captured images by IP camera would be sort by time and then put in image processor to detect smoke or flame or event both of these signals (see fig. i).

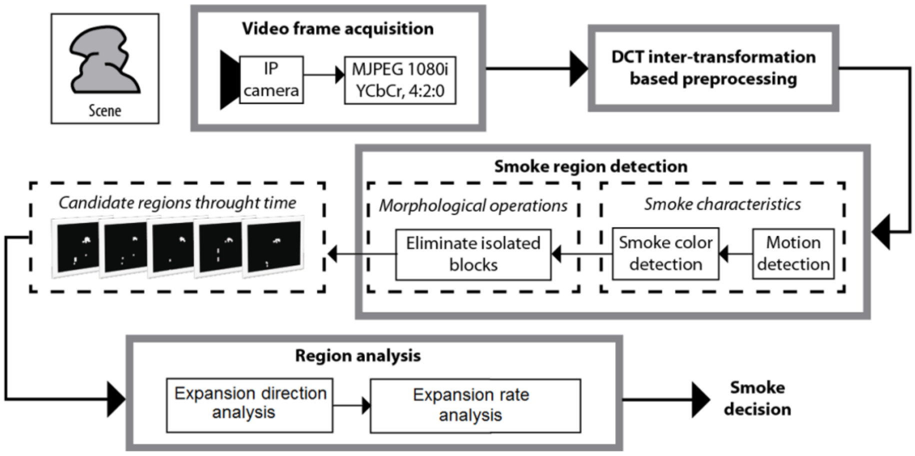

Figure 1. Block diagram of the proposed smoke detection scheme (Leonardo et al, 2012)

Captured images from IP camera usually have relatively high resolution and the minimum resolution is 1280 x 720 px. If these images are processed directly, the processes are highly time consuming operations but high accuracy. By contrast, if these images are zoom out, the processing time requires less but low accuracy. To detect forest fire, it is not requiring high speed but need high accuracy, thus the captured images will be remaining quality for processing.

In this paper, the author not establish a new algorithm for image processing, they use the combination of many algorithms that are applying in detecting forest fire in the world [2, 4]. Including:

The image that captured by camera is divided into blocks of 8 x 8 pixels of each frame. After that, the DCT inter-transformation is applied to all DCT blocks of 8 × 8 coefficients of each frame to get DCT blocks of 4 × 4 coefficients. Using the DC values of each DCT block of the 4 × 4 coefficients of several consecutive frames, motion and color properties of smoke are analyzed to get the smoke region candidates. Each DCT block can define 3 channels including Y, Cb and Cr. In which, to identify the motion of DTC blocks, the author use channel Y, and to classify the characteristics color of smoke and flame use channel Cb and Cr.

- *Motion detection*: Consider the DC coefficients of block DCT block of S_b x S_b (S_b = 8), this coefficient is the value to analyze the characteristics of motion of a block. S_b times the average value of the block in spatial domain which is given by:

$$C(0,0) = \sqrt{\frac{2}{S_b}}\alpha(0)\sum_{q=0}^{S_b-1}\left(\sqrt{\frac{2}{S_b}}\alpha(0)\sum_{q=0}^{S_b-1}B(p,q)cos\left(\frac{(2p+1)\times 0\times\pi}{2S_b}\right)\right)\cos\left(\frac{(2p+1)\times 0\times\pi}{2S_b}\right) \quad (1)$$

$$= S_b \times \left(\frac{1}{S_b^2}\sum_{q=0}^{S_b-1}\sum_{p=0}^{S_b-1}B(p,q)\right) \quad (2)$$

In which, $Y_t(x, y)$ is the DC coefficient value of a block at location (x, y) in frame *t*. Each DCT block is classified into motion or statistic block as equation below:

$$f_m\left(Y_{t-1}^{DC}(x,y), Y_t^{DC}(x,y)\right) = \begin{cases} 1 \; if \; th_1 < \frac{1}{S_b}\left|Y_{t-1}^{DC}(x,y) - Y_t^{DC}(x,y)\right| < th_2 \\ otherwise \end{cases} \quad (3)$$

Considering that f_m is a binary matrix of size M × N (M is width, N is the height of captured image). And th1 and th2 are two threshold values are experimentally determined as 12 and 80 respectively which considering the general motion speed presented by smoke

-*Smoke color analysis*: color is another integral feature of smoke that have been used commonly in several smoke detection algorithms. Almost al algorithms used RGB and YcbCr (Y: Luminance; Cb: Chrominance-Blue; and Cr: Chrominance-Red) color space-based rules to determine smoke color.

+ These rules are given by equation:

$$\text{Rule 1: } R \pm \alpha = G \pm \alpha = B \pm \alpha \quad (4)$$

$$\text{Rule 2: } 80 \leq (R + G + B) / 3 \leq 220 \quad (5)$$

Where $15 \leq \alpha \leq 20$

- The pixel is considered as smoke if these adapted as follows:

$$\text{Rule 1: } (C_b - 128)^2 + (C_r - 128)^2 \leq \alpha^2 \quad (6)$$

$$\text{Rule 2: } Th_3 \leq Y \leq Th_4 \quad (7)$$

Where C_b, C_r, Y are the DC values of two Chrominance and Luminance of (x,y) block, applying the linear transform between RGB and YCbCr, it follows that $\alpha = 10$, *Th3* = 80 and *Th4* = 220. Thus, if both rules are satisfied, DCT block is considered as smoke by color property, that is $f_c = (Y, C_b, C_r) = 1$, otherwise $f_c = (Y, C_b, C_r) = 0$.

Therefore, both feature analyses are conducted, the blocks that satisfy both smoke features are considered as smoke candidate region, as follows:

$$B_t = f_m \wedge f_c \wedge f_l. \quad (8)$$

- Region analysis

After detecting smoke candidate, it necessary to eliminate some objects possess similar properties to smoke. The connection of several connection blocks is used and each candidate region is denoted by A_k, k = 1, 2, 3, … K. where *k* means the label number. Considering that smoke has a property of continuously expansion, the corresponding of two adjacent smoke regions presents an expansion overlapping. To analyze this smoke property, each region is updated using Equation:

$$A_t^k = \begin{cases} A_{t-1}^k \cup A_t^k \text{ , nếu } A_{t-1}^k \cap A_t^k \neq \emptyset \\ A_t^k \text{ , otherwise} \end{cases} \quad k = 1, 2, \dots, K \quad (9)$$

In consequence, a new image includes motion region and is labeled can be considered as smoke region. On the other hand, if captured images are not satisfied with al the rules above, it is not considered a smoke region.

2.1.3 System architecture (Ground monitoring station)

An overview of the ground monitoring system is illustrated in fig. ii. The system is designed as a unified block that automatically captures images around the station.

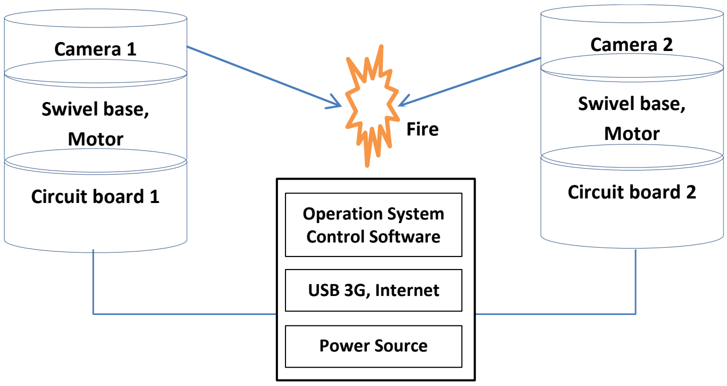

Figure 2. The block scheme of fire watch system

This system has 2 independent cameras which are rotated in a circle. All these motions are programmed to cover the area surveillance automatically by mean of repetitive sweeps. In a rotation, each camera provides 36 images evenly.

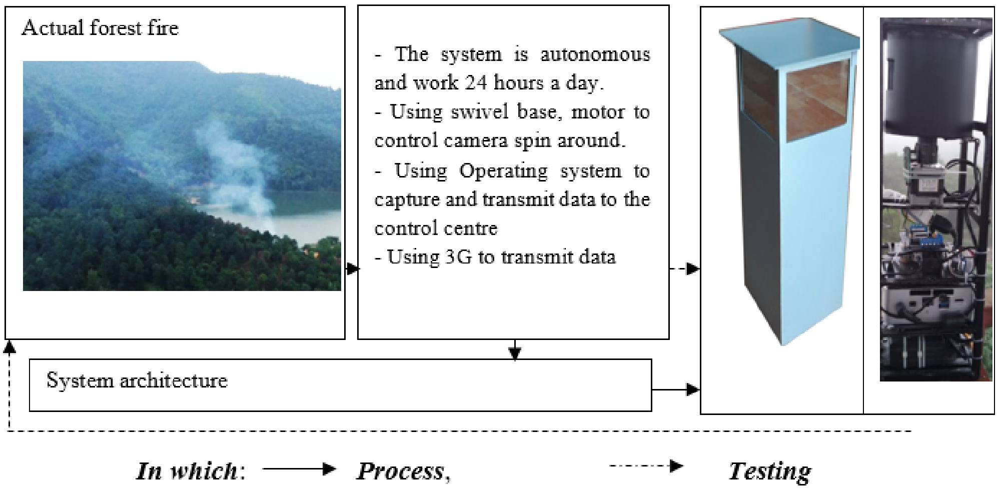

Figure 3 The diagram of the system's function

2.2 The image-based fire detection software

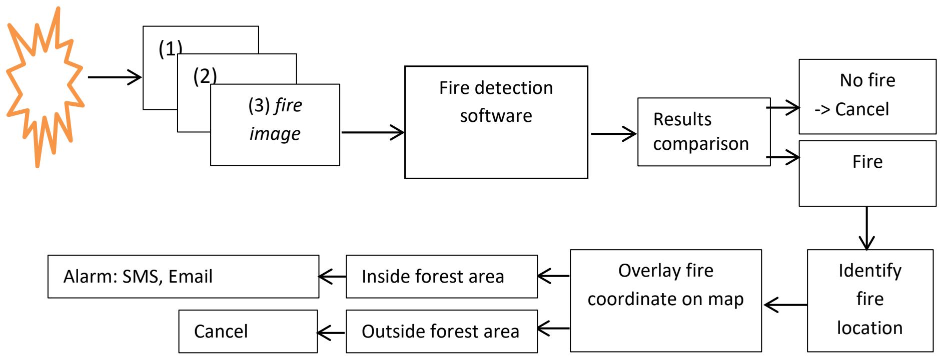

Figure 4. Block diagram of proposed fire detection software

At the same location, camera captured a number of images in different time which are processing and comparing with each other by detection algorithms to give a final result. The coordinate of fires is determined by the two integrated camera. These coordinate are overlaid with forest map, road map and hydrograph map to classify it belong to forest area or not. If the fire occurs in forest area, a fire-alarming is given immediately through email and SMS.

Combination of software and hardware in the system is illustrated in figure. 5.

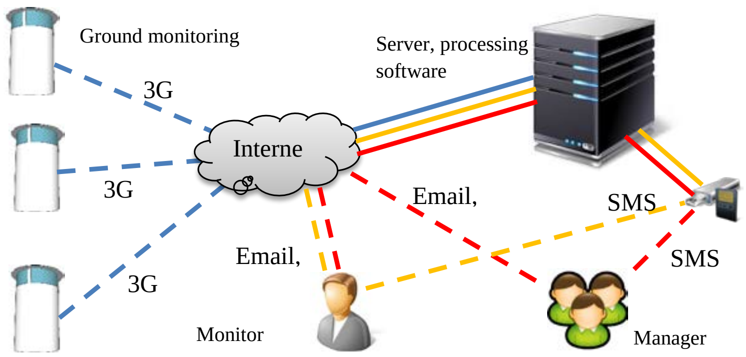

Figure 5. The forest fire detection system architecture

2.3 2.4. System operation

Each monitoring system include 01 IP camera connected to the Internet to transmit to the server by 3G signal. These data are captured images which after a predetermined period of time are retrieved automatically by software from serve for analyzing process. In the case of many stations connected to sever, this software will set up the time for assess to station in a fixed cycle that all images could be collected. There more stations connected to server the more operation in the system and the cycle is more complicated.

Each captured images will be analyzed to detect smoke and flame by some smoke or fire detecting algorithms (fig vi). When a fire is detected, system will will identify the exact it's location and give an alarm. The coordinate of a fire can be determined by coordinated of 2 monitoring stations and 2 observation angles from camera in these stations. By overlaying fire's coordinates on forest map, software will define exactly where fire occur in forest or non forest. When detected an abnormality (flame, smoke) the system will give a message to phone, email or website to warning users automatically. The manager can access and chose appropriate solutions.

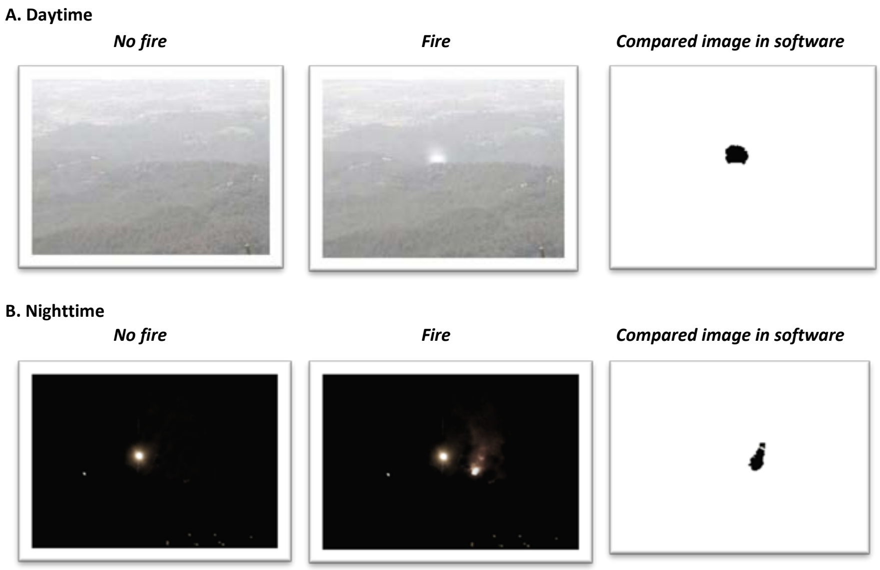

Figure 6. Captured images from camera to determined fire

Time for analyzing an image is about 0.3 second. Time for loading an image from station depends on the connection speed of 3G network. However, the image resolution is low (280 x 720 Pixel- up space of about 140 Kb), loading image is not taking too long time. Hence, a camera will load about 1440 images approximate 197 Mb in a day. These images are stored in hardware and will be delete after period of time depend on the space of hardware.

2.4 2.5. Materials

The performance of smoke, flame detection and the accuracy of proposed algorithm is evaluated by using different sample video sequences and conducted some "control burnings".

Table 1. The description some of video sequences used in evaluation of the proposed algorithm

TT	Content	Quality
1	The vertical background is crowded with vehicles, near camera has a large branch of tree that affected by strong winds.	- Video size: 320 x 240 pixel - Frame speed: 9fps - Time: 00:11:02
2	View from the hill to around in sunny condition, faint image, effected by insect, weak wind.	- Video size: 352 x 288 pixel - Frame speed: 25fps - Time: 00:04:01
3	The frame of a fire in sunny conditions, the location of fire coincides with horizon, slow fire speed, weak wind.	- Video size: 720 x 576 pixel - Frame speed: 7fps - Time: 00:02:01
4	The frame of smoke is produced by a factory in residential area which is crowded with vehicles and people, weak wind.	- Video size: 720 x 576 pixel - Frame speed: 10fps - Time: 00:01:00
5	A frame contains a "control burning" in closely distance, people walked around the fire.	- Video size: 320 x 240 pixel - Frame speed: 15fps - Time: 00:00:47
6	A frame contains a forest fire in closely distance, the image of the fire covered the frame.	- Video size: 400 x 256 pixel - Frame speed: 15fps - Time: 00:00:13

a. U Minh Thuong National Park *b. Soc Son – Ha Noi* *c. Ba Vi National Park*

Figure 7: The test image of control burning to evaluate the smoke and fire detection capabilities of proposed algorithm

3 Results and discussions

3.1 Testing proposed algorithm with video

The results of testing some video sequences indicates the performance of the proposed algorithm in detecting smoke and fire.

Table 2 The results of evaluating the accuracy of proposed algorithm in video sequences

No	Video 1		Video 2		Video		Video 4		Video 5		Video 6	
	Detected	No detected	Detected	No detected	Detected	No detected	Detected	No detected	Detected	No detected	Detected	No detected
1	532	3	180	0	49	0	24	0	130	0	154	0
2	337	6	210	1	65	1	38	0	112	0	128	0
3	465	22	191	0	51	0	39	0	168	0	153	0
4	531	7	208	1	39	1	35	1	132	0	154	0
5	531	6	177	0	35	0	32	1	149	0	130	0
6	531	7	147	0	32	1	21	0	151	0	151	0
7	401	25	206	0	21	0	21	0	162	1	154	0
8	332	36	226	1	21	0	21	0	145	0	154	0
9	216	6	238	1	23	0	23	0	122	0	154	0
10	314	8	220	0	29	0	29	1	156	1	154	0
Ave.	419	12.6	200.3	0.2	36.5	0.82	28.3	1.06	142.7	0.2	148.6	0

Table 2 shows that there is only video 01 have got a false alarm (3%), and the number of video remaining perform the rate of detecting that approach to 100 % in term of accuracy. There are some reasons that affect on false alarm in video 01. Firstly, in the video many vehicles are running in the road. The second reason is near the camera has a large branch of tree that affected by winds. In contrast, the remaining video, the objects are in static state and clearly background. This indicates that apply proposed algorithm in detecting smoke and fire is effectiveness.

3.2 Testing proposed algorithm with reality fire

The yield of proposed algorithm is calculated based on "control burning" in some areas. Fig 07 and 08 show the video sequences in evaluate performance of detecting smoke and fire algorithm, Fig (a1, a2, a3, a4 and b1, b2, b3, b4) are the frame of fire and Fig (c1, c2, c3, c4) are images after processed.

- Smoke detection results

a1 b1 c1

Control burning in Ba Vi National park

a2 b2 c2

Control burning in Development Centre of Forestry in Ha Noi (Soc Son)

a3 b3 c3

Control burning in U Minh Thuong National Park

a4 b4 c4

Control burning in U Minh Thuong National Park

Figure 8. Smoke detection performance; (a_i, b_i) Frame sequences; (c_i) image after processing

- Fire detection results (night time)

a b c

Figure 9. Fire detection performance; (a, b) video sequences; (b) image after processing.

Performance results on video sequences show that there are to cases including detected or non-detected. In the second case, smoke or fire cannot be detected because of many different reasons such as the color of background and smoke/fire is the same, and the observation distance from camera effect on the accuracy (fig viii – a4, b4, c4).

4 Conclusions

The Discrete Cosine Transform (DCT) algorithm of each 8 × 8 block is the input for smoke processing and fire detection.

The characteristics of smoke, fire, motion, color and expansion are analyzed directly in the DCT domain to minimize the time and increase the accuracy of the results.

The DCT algorithm used video sequences and control burning, the results show the accuracy of detection up to 97%. The main cause of false detection is the similarity of color between background and smoke, the distance of the camera to the fire location.

The JPEG format processing algorithm from IP Camera can be applied efficiently in early detection of forest fires in Vietnam.

Application software for early detection of forest fires from the ground observation station is designed and developed based on the requirements of forest resource management and minimization of forest fire damage in areas where fire occurs frequently in Vietnam.

The software is integrated with ground observation stations, regular monitoring stations and fire monitoring by IP cameras. The monitoring stations are compact and stable designed with low cost and efficient for forest fire monitoring tasks in Vietnam.

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Investigating the Properties of the Vertisols at Kenana III and IV Towards Enhancing Management Practices (Sennar State - Sudan)

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ABSTRACT

A series of studies were initiated in Sudan in the early 1950s for utilization of the Nile Waters [19]. On the basis of these studies the Rosaries Dam was built on the Blue Nile. By the end of 2008 a programme to start the heightening of the dam was started with outlets for canals on both banks. At the same time further agricultural development on two irrigation projects, the Kenana and Rahad II commenced with soil surveys and irrigation design. The Kenana Area lies between the Blue Nile and the White Nile and runs south east to North West from Disa to Managil. Kenana Area is almost flat with predominantly clayey soils [21], [17]. Kenana III lies midway between the Blue Nile and the White Nile south of Sennar-Kosti railway line. Kenana IV area finally lies to the north west of Kenana III area.

The soil study area is partly semi-arid and partly arid, and experiences slight rainfall in the order of 350 mm in its northern edge, increasing to some 650 mm at its southern boundary near Jebel Dali. The soil surveys carried in the area were made at semi-detailed level and the key specifications are a field density of 1 observation each 100 ha and map scales of 1:50,000 and 1:100,000. Previously published soil survey information was reviewed and incorporated in these surveys. In these surveys a number of potential agricultural options in terms of adapted cropping patterns, systems of management and two methods of surface and pressure irrigation were considered for development [6]. The most dominant soils are the Vertisols which have high potential for crop production, but some constraints emerge affecting crop performance and decreasing yields. Those limitations are aspects of land degradation, manifested in deterioration of physical and chemical properties. Continuous cropping of Vertisols, through time, leads to compaction and eventually develops hardpan at the subsurface, reducing porosity, intensity of cracking and obliterating water movement. Such adverse effects are indicators of degraded soil physical properties. To minimize the concurrence of those hazards management procedures should adhere to land and crop management systems. Parallel to this approach, the fertility status is likely to decline due to intensive farming of some nutrient-depleting crops, but this nutrient deficiency is correctable through implementing a fertilizer programme. In the study area, some parameters are management-factors determining e.g. flat slope favouring uniform distribution of irrigation water through well designed irrigation and drainage network, and sub-soiling preparing proper seedbed. Those technical inputs if properly used and practiced they are expected to sustain crop production.

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Keywords: Vertisols, Kenana Area, Irrigated Agriculture; Soil survey; Landsat, Clay plain

1 Introduction

This study describes physical and chemical properties of soils at 322,322 ha situated in Kenana plain south of Gezira and Managil scheme. The area includes Kenana KIII and Kenana IV areas. Figure 1 shows the location of the study area. The Kenana III area lies to the west of Kenana II and is situated about half- way between the Blue and White Niles. The southern boundary is in the neighbourhood of Jebel Dali and the northern boundary about 10 km south of Jebel Moya. In the east, Kenana III is contiguous with Kenana II. In the west it adjoins the land being developed by the Kenana Sugar Company. The Kenana IV area lies to the north-west of Kenana III. It adjoins the land belonging to both the Kenana Sugar Company and Asalaya Sugar Project. In the north it adjoins the Es Shawal Extension of the Gezira Irrigated Scheme.

The climate of the study area lies in the semi-arid climatic zone [22]. Maximum temperatures of the hottest month (April or May) are 39-40 oC; whilst the mean minimum temperatures of the coldest month (December and January) are 13-17 Co. The average annual rainfall is 400-750 mm which falls mainly in the months of May–September, and is less than 44 per cent of the annual potential evapotranspiration. In at least one month the average rainfall exceeds the potential evapotranspiration (humid month); relative humidity being 20-40 per cent during most of the year rises to 70 per cent in the rainy season. The temperature and moisture regimes of the soil are used as criteria for taxonomic classification in the USDA Soil Taxonomy [21]. The study area has an isohyperthermic temperature regime (with the soil temperature at 50cm depth) having an annual average above 22 Co and with less than 5 annual variation, and an Ustic moisture regime [22].

Different discussions indicated that the origin of superficial alluvial deposits of the study area belongs to two separate distinct regions which are referred to broadly as the Blue Nile Basin and the White Nile trough [24], [10]. Most of these regions consist of plains which are mantled by dark alkaline cracking Vertisol clays [5]. Apart from few scattered Jebels and low Azaza (remnants of in situ weathered ridges) the study area comprises a vast, flat, clay plain where slopes are mostly ⩽ 1%. The clay plain slopes very gently from 0 to 1% at a general elevation of 360 m to 400 m. Within the plain gently undulating and undulating land is usually associated with shallow depressions and khors. The extent of these features is limited and land with slopes exceeding 1% amounts to no more than 1% of the overall area. In only a very few localities do slopes exceed 1%.

The plant community in the study area consists of Acacia mellifera, Boscia senegalensis, and Cadada rotundifolia with scattered Acacia senegal, Acacia seyal and Balanites aegyptiaca and open areas of grasses and herbs. Acacia mellifera is continuously being exploited to provide a new land for cultivation. Because of its gum Arabic production Acacia senegal is not destroyed. In contrast to Acacia senegal, Acacia seyal is regularly cut for charcoal making. Balanites aegyptiaca is widespread in the area forming parkland. The most abundant grasses include Cymbopogon nervatus, Sorghum purpureo – sericum, Hyparrhenia rufa and Cenchrus ciliaris. Most of the study area has extensive rainfed farming, mostly sorghum. Much of this is undertaken by large semi-mechanised enterprises either on their own account or by contractors working for village communities. Sorghum is by far the most widespread crop. Over the whole area it consistently occupies just fewer than 70% of the farmed area (excluding the non-agricultural land). The percentage of sesame grown – about 6% – is constant throughout the area. Outside of the sorghum and sesame cropped lands, other crops (e.g. millet) combined to occupy only about 3% of the cropped area.

2 Materials and Methods

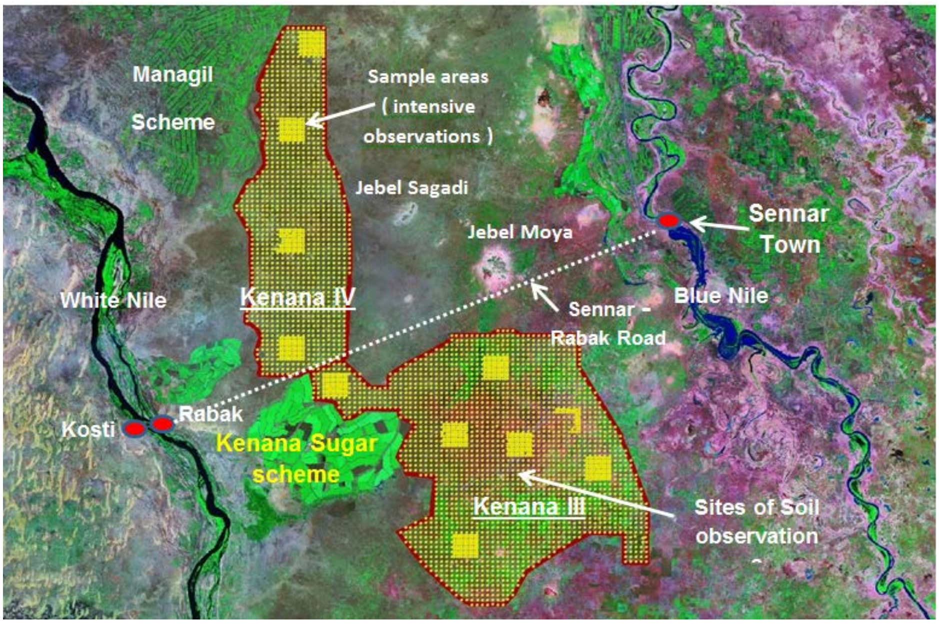
A total of 4092 augers and 125 profile pits were studied (Table 1 and Figure 1) to characterize the Vertisols of the two areas. The location of all pit and auger sites based on GPS co-ordinates are shown on figure 1 [6].

Table 1: Summary of Fieldwork for Soil Study of Kenana III and IV

Study area	Area	Profile pits	Soil augers	Auger samples	Pit samples
	ha	No.	No.	No.	No.
K III	208,440	80	2,616	7,848	332
K IV	113,882	45	1,476	4,428	191
Total	322,322	125	4,092	12,276	523

(Source: [6])

Field recording of soil auger sites and soil profiles was on standardized proformas and soils were described following the FAO "Guidelines for Soil Description" [9]. The observations included: Auger number; Surveyor; Data; GPS co-ordinates; Landform; Topography; Slope; Site; Surface features; Termitaria; Trees; Shrubs; Land Use; Water-table; Soil drainage class; Samples; Soil type; Depth of cracking; Soil code; Soil horizons (for each: boundary, colour, colour code, mottles, texture class, cracks, clay skins, slickensides, coarse fragments, reaction to dilute hydrochloric acid, calcium carbonate, iron-manganese, gypsum, and other features).



(Source: [6])

Figure 1: Kenana III and IV study areas on Landsat 2007 showing sampling sites and surrounding geographical features as part of the Central Clay Plain

3 Results and Discussions

3.1 Physical properties

All soils are > 2.0m deep. The Vertisols clay varies in depth from 1.5 to ≥ 4.0m. The strata beneath the clay are heterogeneous brown, dark brown or dark yellowish brown silty clays, clay loams or sandy clay loams. With the exception of infiltration test, no tests were carried out for bulk density (BD), permeability or AWC on the Vertisols of the survey area because conventional methods for measuring permeability don't apply to shrink-swell montmorillonitic clays as the clays do accept water at first, swell and then seals and become almost impermeable. It had also been realized that it was impractical to take undisturbed sample to laboratory on daily bases [6]. The values for such untested parameters for similar soils were extracted [15].

The infiltration tests were conducted in the survey area using double ring infiltrometers. The values represent the basic infiltration rates which show almost consistent trends of 1.4 cm/h due to the behavior of the homogenous soils of the survey area. The optimum basic infiltration rates for surface irrigation are considered to be in the range of 0.7 to 3.5 cm/h, although acceptable normal values range from about 0.3 to 6.5 cm/h [15]. However, it is reported that the methods of infiltration measurement can suffer from a number of errors including, lack of adequate pre-wetting of dry expanding clays that need weeks of pre-wetting before major shrinkage cracks are closed; and soil disturbance effects during project development which may alter the soil - water intake characteristics [15].

3.2 Chemical and mineralogical properties

The field descriptions of the soil morphological feature and the chemical analyses of the soil units indicated that Typic and Chromic Vertisols are dominating [21], [8], [6]. It is assumed that the gently undulating, shallow depressions, gravels in top 60cm and; calcium carbonate concretions in the top 60cm phases of any soil unit will have a similar chemistry to that soil unit. The soil particle size analysis recorded clay content in the range of 55-75% that belongs to the clayey class in the FAO textural triangle and to the likely smectitic mineralogy [9]: the CEC values are fairly consistent with this range of clay content as shown in Table 2 an example taken from a previous survey [2].

Table 2: Clay mineralogy of a Vertisol soil at Central Clay Plain - West of Sennar

Profile No.	Depth cm	Mt	Mi	Vm	Chl	K	Q
33 C	0 - 10	xxxx				xx	t
	10 – 42	xxxx				xx	t
	42 – 89	xxxx				xx	t
	89 – 146	xxxx				xx	t
	146 - 180	xxxx				xx	t

(Source: [2])

Mt	Montmorillonite	**Chl**	Chlorite	**Mi**	Mica
K	Kaolinite	**Vm**	Vermiculite	**Q**	Quartz
x	small	xx	moderate		
xxx	large	xxxx	Predominant		

The total nitrogen and organic carbon contents are very low ranging from 0.02 – 0.0 4 % to 0.6 – 0.8 % respectively indicating very low organic matter content that coincides with the amounts usually present in an arid climate (Table 3 and Table 4).

Table 3: Broad Ratings of Nitrogen Measurements

N content Kjeldahl method (% of soil by weight)	Rating
< 0.1	Very low
0.1 – 0.2	Low
0.2 – 0.5	Medium
0.5 – 1.0	High
> 1.0	Very high

(Source: [15])

Table 4: Broad Ratings of Organic Carbon Measurements

Organic carbon content Walkley-Black method (% of soil by weight)	Rating
< 2	Very low
2 – 4	Low
4 – 10	Medium
10 – 20	High
> 20	Very high

(Source: [15])

The available phosphorus, extracted with sodium carbonate buffered at pH 8.5, varies between 1 and 5 ppm and this amount is deficient for most crops and questionable for cereals and grasses – Table 5. The availability of phosphorus is critical to plant uptake because soil alkalinity (pH 8.5 – 9.0) causes fixation and/or formation of insoluble compounds. However, crops vary in response and therefore, requirement for fertilizers application need to be assessed after determining soil reactions [7].

Table 5: Interpretation of available phosphorus analyzed by Olsen's method

Characteristic crop demand	Examples	Indicative available phosphorus values		
		Deficient	Questionable	Adequate
Low P	Grass, cereals, soybean, maize	< 4	5 - 7	>8
Moderate P	Lucerne, cotton, sweet corn, tomatoes	< 7	8 - 13	>14
High P	Sugar beet, potatoes, celery, onions	< 11	12 – 20	>21

(Source: [15])

The soil reaction is alkaline varying between mildly to strongly alkaline in really all the soils of the area. The pH values of the saturation extract range from 7.4 – 8.9 increasing with the increase of the soil: water ratio (dilution effect). The pH values exceeding 9.1 are occasionally found in suspension 1:5 soil: water ratio. This high pH reduces the availability of micronutrients (such as Fe, Mn, Zn, and Cu) rendering them fixed into non-soluble forms, and hence the nutrient uptake by plants is retarded [1]. Although the reaction of the soil matrix is slightly to moderately calcareous, the $CaCO_3$ content ranges from 3.7%. Higher contents are infrequent and occur in the substratum in some profiles. However, these soils may contain $CaCO_3$ more than that recorded in the analytical results. This is because the analyses were carried out in the "fine earth" (< 2 mm dry soil sieved without any gravel) of the samples that passed the 2 mm sieve. In this regard, it is observed that $CaCO_3$ concretions larger than 2mm have been retained in the sieve as part of the gravel fraction of the sample which is not considered for the analysis. Smaller sized fragments of concretions will pass through the sieve and be included in the testing. The field method of applying HCL acid on the soil matrix to check the presence of $CaCO_3$ proved to be a reliable indicator of soil calcareousness.

The EC of the saturation extract rarely exceeded 4 dS/m at 25 °C which indicates a very low hazard for salinity in these soils. The types of salts, as given from analysis of the exchangeable and soluble cations and anions, are dominantly sulphates followed by chlorides. Bicarbonate is present in little amounts while carbonates are either as a trace or not detected. The exchange complex in soils of this area is fully saturated with basic cations of Ca^{++}, Mg^{++}, Na^{+}, and K^{+}. Exchangeable H^{+} and Al^{+++} (exchange acidity) is therefore, non-existing. The Cation Exchange Capacity CEC ranges from 55 – 75 meq/100gr soil. Potassium and sodium are determined separately and results indicated that potassium is very low compared to sodium. The Ca^{++} + Mg^{++} are calculated by difference between the CEC and exchangeable Na^{+} + K^{+}, and therefore are not reported separately. This approach is adopted because of the occurrence of calcium sulphates in water adding more Ca^{++} and Mg^{++} to the soil solution which likely giving rise to erroneous estimates [6]. The Sodium Adsorption Ration (SAR) values are used to assess if there is any adverse effect of sodium in waters and soils. It is estimated using the following formula:

$$SAR = \frac{Na^{+}}{\sqrt{\frac{Ca^{++} + Mg^{++}}{2}}}$$

The practical experience indicates that the SAR values obtained by applying 1:5 soil- water rates methods are low and under estimated and this could be attributed to the following:

1- Solubility of Ca^{++} and Mg^{++} increases in higher soil-water ratios than Na+ ;
2- The soil matrix is calcareous, containing $CaCO_3$ in very fine particles that release Ca^{++} into the solution, giving rise to increased Ca^{++}, and eventually Ca^{++} + Mg^{++}.

3.3 Micronutrients

The soil micronutrients that have been analyzed on this survey (Fe, Mn, Zn, and Cu) have provided data that indicates that the soils of project area are deficient in the available forms. The amounts being present in content are far below the crop requirements. The high soil pH and calcareous reaction of soil matrix apparently, are the main constrains to the availability of all determined micronutrients (DTPA test), which are evaluated in Table 7 [18].

Table 7: Evaluation of Soil Micronutrients (ppm) in the Soils of the KIII and KIV Areas

Grade	Fe	Mn	Zn	Cu
Low	< 2.0	< 1.8 **(15.5)**	< 1.0 **(0.17)**	< 0.5
Moderate	2.0-4.0 **(2.9)**	-	1.0-1.5	-
Adequate	> 4.0	> 1.8	> 1.5	> 0.5 **(0.95)**

The figures between brackets like **(15.5)** indicate averages in the soils of the project area while others indicate the ratings values [19]. Table 6.1 shows that Mn and Zn are low, Fe is moderate, while Cu is adequate. Zinc and Manganese deficiency is highly probable.

3.4 Salinity and Sodicity

Soil salinity and alkalinity (sodicity) can impose an adverse effect on crop performance and yield by limiting plant nutrients uptake and affecting soil moisture characteristics. The soil survey field operations in Kenana III and Kenana IV involved determinations of pH, EC and SAR to assess these risks. Samples were collected from 0-30, 30-60 and 60-90 cm depths, from 2,616 auger observations in Kenana III and 4,481 in Kenana IV. For carrying out these determinations the method of 1:5 soil-water suspensions was adopted (Table 8 and 9).

3.4.1 Salinity

The laboratory results show that the area in general may be classified as non-saline. The content of soluble salts are very low, such that it is considered that the growth of even sensitive crops would not be affected. The EC of the saturation extracts for all samples very rarely exceeds 4 dS/m at 25 ^{0}C. The types of soluble salts were determined for all samples collected. Soluble sulphates are the most dominant followed by chlorides. Bicarbonates are present in small amounts; carbonate is the least found, and completely lacking in many profiles (Table 8 and 9).

3.4.2 Sodicity

Calcium and magnesium are the dominant exchangeable cations but at increasing depth, their relative percentage decreases, whereas sodium increases in lower horizons. Some horizons below the surface, and at variable depths, have ESP values more than 15; the limit set up by the USDA's Salinity Laboratory at Riverside in California [18]. For long this was widely accepted for the definition of sodic soils. Local experience [23], at least with the Sudanese Vertisols has indicated that some relaxation was needed, and this limit may be increased to a value within the range of (25-35) before the adverse effect of exchangeable sodium is clearly shown in locally adapted field crops grown in this area. The performance of crops did not show a decline in yield that could be attributed to exchangeable sodium at the above mentioned range. Perhaps, the combination of high clay content and high CEC might have imparted a buffering effect to the harmful level of exchangeable sodium. In general terms, high ESP values have a greater deleterious effect upon soils with 2:1 lattice clays than on those with 1:1 clays [15]. However, although the onset of adverse physical conditions occurs generally at lower ESP levels in montmorillonitic soils, further comparatively large increases in Na content may not cause much additional deterioration.

Table 8: Ranges of pH, EC and SAR Values in K III

Soil Horizon	pH			EC			SAR		
	Range	No of observations with pH values > 8.5	%	Range	No of observations With EC values ≥ 2.5	%	Range	No of observations With SAR values ≥ 12	%
Surface	7.1-9.2	155	6.0	0.1-2.5	5	0.2	1.1-12.5	1	0.04
Subsoil	7.2-9.6	300	11.0	0.1-3.8	11	0.4	2.1-33.2	10	0.4

Total soil observations in KIII = 2696 (2616 augers+ 80 profiles) [6]

Table 9: Range of pH, EC and SAP Values in Kenana IV

Soil Horizon	pH			EC			SAR		
	Range	No of observations with pH values > 8.5	%	Range	No of observations With EC values ≥ 2.5	%	Range	No of observations With SAR values ≥ 12	%
Surface	7.4-9.3	50	1.1	0.1-2.5	2	0.04	0.3-13	2	0.5
Subsoil	7.3-9.1	125	2.8	1.0-21	6	0.13	0.9-26	25	0.6

Total soil observations in KIV = 1 520 (1475 augers+ 45 profiles) [6]

Table 8 and Table 9 indicates that moderate soil alkalinity occurs in higher values (> 8.5) in Kenana III area particularly within the soil substratum, compared to values recorded in Kenana IV. This situation could possibly be created as a result of the effect of relatively more moist climatic conditions prevailing in Kenana III area with possible movement of salts into the substratum (subsoil) due to availability of moisture. Similarly, this holds applicable for both the salinity (EC) and sodicity (SAR). The three tested parameters are commonly mild or nearly optimum in Kenana IV more than they are in Kenana III. Therefore, the adverse effect on the availability of nutrient elements would not be to the limit that renders low fertility statues. But the field descriptions of both areas revealed a slightly to moderately calcareous matrix which usually contains very fine particles of $CaCO_3$ which may enhance release of some calcium when the sample is shaken in the laboratory for the high soil: water (1:5) suspension. Furthermore, gypsum crystals will have similar performance releasing more calcium. Therefore, underestimated SAR values are obtained when applying the above mentioned SAR formula.

Useful to review the previous work [4] regarding the earlier (1951-52) reconnaissance soil survey carried out in the Kenana area (the present Kenana III in this project). On this early study 176 soil samples were collected. The salt percentage and sodium value were determined on these samples using soil water extract, and further converted into EC and ESP [19]. The following values are assigned in Table 10.

Table 10: Salt percentage and ESP values

EC_e		ESP	
175 observation	0 – 4	116 observation	0 -10
1 observation	>4.0	60 observation	>10 - 12

(Determined by Coyne et Bellier and Hunting Technical Service in 1977 [4])

These values in these categories fairly coincide with the findings obtained from Kenana III and Kenana IV project areas which designate the soil survey areas as non-saline and non-sodic. However, since this situation is so far debatable, there seems to be a need for determining the ESP in the saturation extract of some selected samples to set up criteria and standards for further correlation studies.

4 Conclusions

The Vertisols have high potential for crop production; but some constraints emerge affecting crop performance and decreasing yields. Those limitations are in fact aspects of land degradation, manifested in, 1) water erosion and; 2) deterioration of physical and chemical properties. In the study area, some parameters are management-factors determining e.g. topsoil structure; flat slope favouring uniform distribution of irrigation water through well designed irrigation and drainage network and; sub-soiling preparing seedbed for determining the tillage units (furrows and basins). Those technical inputs [19] if properly used and practiced are unlikely to leave a fragile soil surface susceptible to water erosion. Some other researchers [14] introduced the techniques of conservation tillage incorporating farm residues and also, described the procedures and benefits of minimum or zero-tillage, as farming practices against incidence of water erosion.

Continuous cropping of Vertisols, through time, leads to compaction and eventually develops a compacted layer at the subsurface, reducing porosity, intensity of cracking and obliterating water movement [3]. Such adverse effects are indicators of degraded soil physical properties. To minimize the concurrence of those hazards, management procedures should adhere to land and crop management systems [11], [13]. Parallel to this approach, the fertility status is likely to decline due to intensive farming of some nutrient-depleting crops, but this nutrient deficiency is commandable through implementing the fertilizer programme [16].

For the study area, sustainable land management scenarios [6] will require farming systems development and Action Plans through:

- Establishing research–based station conducting trials on the attributes of the Land Utilization Types, e.g. cultivars; sowing date; irrigation quantity and frequency; fertilizers; farm management units (basins, furrows) and rotation. Worth trying also, is the adaptive research on farmers' fields guiding them get handing the technologies being introduced in the project [12].
- Applying and disseminating agriculture research recommendations to the farmers through efficient extension work to ensure proper management and improved productivity. Similarly, a possibility exists for extrapolating the outcome of farming experience gained in the neighbouring agricultural schemes e.g. The Kenana Sugar Plantation and El-Shawal extension of the Gezira scheme.
- Maintaining balances between cropping intensity and the magnitude of technology input in order to avoid incidence of land degradation hazard, e.g. soil compaction, water erosion and fertility decline.
- Assign head of groups as facilitators for the farmers involved in small farms where their needs can be exposed and met through joint farming activities, increasing yields, upgrading income and improving their socio-economic welfare.

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Studying the Characteristics of Vertisols to Set Up Field Management Practices at Dinder Area (Sennar State - Sudan)

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ABSTRACT

The development of irrigated agriculture in Dinder area was part of the program to heighten the Rosaries Dam built on the Blue Nile and irrigate more lands on both banks of the river. The Dinder Area on the right bank of the river encompasses two parts, Dinder North (DN) and Dinder South (DS). The Dinder North area is situated between Dinder River in the west and Khor Al Atshan in the north east. The Dinder south area lies between Dinder River to the north east and Khor Al Aqalayin in the west. The area of Dinder is nearly flat to very slightly undulating with predominantly cracking clay soils (Vertisols). The soil study area is in semi-arid zone and experiences rainfall in the order of 500 mm in its northern edge, increasing to some 800mm at its southern boundary near Dinder National Reserve Park. This soil study has been based on semi-detailed soil survey data [13] with the key specifications are a field density of 1 observation each 150 ha and map scales of 1:50,000 and 1:100,000. Previously published soil study information was reviewed and incorporated in the findings and the database of this study. The Vertisols have high potential for crop production, but some constraints emerge affecting crop performance and decreasing yields. Those limitations are aspects of land degradation, manifested in, 1) water erosion and; 2) deterioration of physical and chemical properties. Continuous cropping of Vertisols, through time, can lead to compaction and in some cases development of a hardpan in the subsurface, reducing porosity, intensity of cracking and obliterating water movement. Such adverse effects are indicators of degraded soil physical properties. The aim of this study is to show the pedological characteristics of the Vertisols of Dinder area and as well to recommend on their use and management in order to minimize the concurrence management hazards. Field management procedures should adhere to the recommended land and crop management systems. Parallel to this approach, the fertility status is likely to decline due to intensive farming of some nutrient-depleting crops, but this nutrient deficiency is correctable through implementing a fertilizer program. Those technical inputs if properly used and practiced they are expected to sustain crop production.

Key words: Dinder area; Vertisols;Morphological, Physical and Chemical Properties

1 Introduction

This study describes the soils morphological, physical and chemical properties of area of 235,923 ha, out of which 168,910 ha in Dinder North and 67,013 ha in Dinder South. The Dinder North area is situated between Dinder River in the west and Khor Al Atshan in the north east. The Dinder South area lies between Dinder River to the north east and Khor El Aqalayin in the west. The two areas are

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connected by dry-weather road starting from Dinder town through the villages of Abu Hashiem, Al Azaza Damous, Um Baggara and terminating at the Dinder National Park. This road is suitable for accessing Dinder North area, but a crossing of the Dinder River at Al Azaza Damus was used to reach the northern parts of Dinder South area; the southern parts of Dinder South could easily be accessed from Umm Bagara [13].

Source : Development Plan [25].

Figure 1: Climatic Zones 1 and 2 at Dinder North and South Areas

Table 1: Dinder Area Monthly Rainfall and Evapotranspiration in Zone 1 and 2

Zone	(mm)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Zone 1 Southern Parts of Dinder (M1.1)	ETo (mm/day)	5.9	6.5	7.3	7.7	7.3	6.2	4.7	4.3	4.6	5.2	5.7	5.5	2,152
	Mean Monthly Rainfall	0.1	0.0	1.4	5.1	34.7	105.1	168.4	168.7	108.9	32.1	1.6	0.0	626
	1 in 5 year Low Monthly Rainfall	0.0	0.0	0.0	0.0	15.1	72.1	112.3	118.6	68.7	13.6	0.0	0.0	401
Zone 2 Northern Parts of Dinder (S1.1)	ETo (mm/day)	5.8	6.5	7.4	8.1	7.7	6.5	5.3	4.8	5.1	5.6	5.8	5.4	2,248
	Mean Monthly Rainfall	0.1	0.0	0.8	2.3	25.5	86.8	149.1	172.2	84.8	23.5	1.0	0.0	546
	1 in 5 year Low Monthly Rainfall	0.0	0.0	0.0	0.0	8.0	51.6	92.7	120.2	41.0	6.0	0.0	0.0	319

(Source: Rosaries-Dinder-Rahad Development Plan [25])

Recent climatic maps showing the different climatic regimens in Sudan were produced based on Papadakis climatic classification [38]. The climatic zones are based primarily on the water balance, using monthly rainfall and potential evapotranspiration data (Penman formula). The differentiating criteria are significant for agriculture, whilst the zones also correspond with natural vegetation zones. In this context two main climatic zones are defined, in which the climate of the northern parts of the study areas lie in the semi-arid zone whereas the southern parts lie in the monsoon zone (Figure 1). Brief descriptive account of the main climatic parameters is given in Table 1.

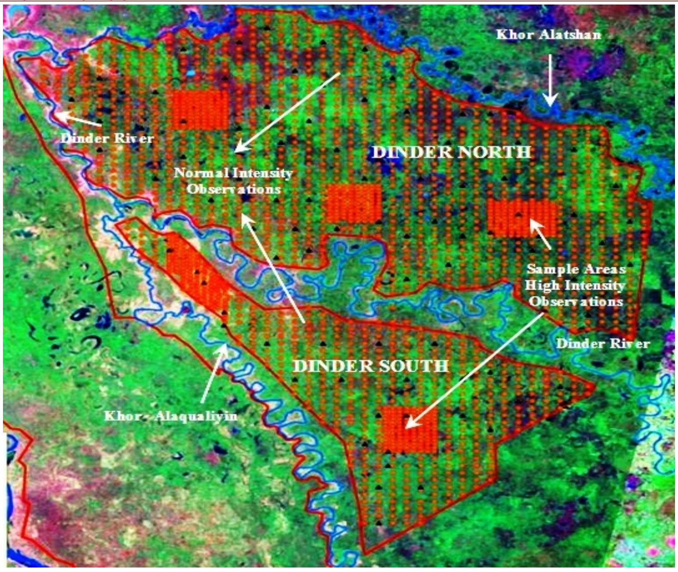
No bedrock exposures are seen in the study area of Dinder North and South, but data from the Geological Research Authority of Sudan (GRAS) maps and published works [36], [20] and [30] has shown that the underlying geological formations include Basement Complex metamorphosed schist, gneisses, and igneous rocks, overlain by Nubian Formation sandstones, in turn covered by a thick fill of alluvial sediments of the late Cenozoic El Atshan Formation. The area lies in the south eastern part of the Blue Nile basin, a tectonic trough with over one thousand meters of sediments in parts, and subject to continued petroleum exploration. The origin of superficial alluvial deposits of the study area was briefly discussed by [39] in relation to the old course of Rahad and Dinder rivers, and by [35] who indicated that the alluvium in this area consist of plains which are mantled by dark, alkaline, cracking Vertisol clays.

The plant community in study area consists of a mix of Acacia mellifera, Bosciasenegalensis, and Cadadarotundifolia, withscattered Acacia senegal, Acacia seyal and Balanitesaegyptiaca, and open areas of grasses and herbs (Figure 3). Acacia mellifera is continuously being exploited to provide a new land for cultivation. Because of its gum Arabic production Acacia senegal is not destroyed. In contrast to Acacia senegal, Acacia seyal is regularly cut for charcoal making. Acacia seyal was noted to be regenerating well in the area. Balanitesaegyptiaca is widespread in the area forming parkland. It is fire–resistant, hard to cut, does not produce a good quality charcoal, is good for shade, and has edible fruits which are collected and sold. The most abundant grasses include Cymbopogon nervatus, Sorghum purpureo–sericum, HyparrheniarufaandCenchrusciliaris. Most of the study area has extensive rainfed farming, mostly sorghum. Much of this is undertaken by large semi-mechanised enterprises either on their own account or by contractors working for village communities. A considerable number of grazing animals and nomadic tribes were noticed all over the area and most probably they come at the end of the rainy seasons to look for water which remains in the depressions and khors for quite some time. Sorghum is by far the most widespread crop. Over the whole area it consistently occupies just fewer than 70% of the farmed area (excluding the non-agricultural land). The percentage of sesame grown – about 6% – is constant throughout the area. Outside of the sorghum and sesame cropped lands, other crops combined to occupy only about 3% of the cropped area [13].

2 Materials and Methods

A total of 4091 augers and 86 profile pits were made (DIU, 2009). The locations of all pit and auger sites are demarcated on Landsat images 2006. These locationsare based on GPS co-ordinates and shown on figure 1. Field recording of soil auger sites and soil profiles was on standardized proformas and soils were described following the [17] "Guidelines for Soil Description".

The observations included: Auger number; Surveyor; Date; GPS co-ordinates; Landform; Topography; Slope; Site; Surface Features; Termitaria; Trees; Shrubs; Land Use; Water-table; Soil drainage class; Samples; Soil type; Depth of cracking; Soil code; Soil horizons (for each: boundary, color, color code, mottles, texture class, cracks, clay skins, slickensides, coarse fragments, reaction to dilute hydrochloric acid, calcium carbonates, iron-manganese, gypsum, and other recorded features).At all auger sites soil samples were collected from the 0.0-0.3, 0.3-0.6 and 0.6-1.0 m depths, for pH, salinity (EC) and sodicity (SAR) screening.



(Source: DIU, 2009)

Figure 4: Sites of Soil Augers and Profile Pit Observations (red dots) in Dinder Area that are Demarcated on Landsat (October 2007).

3 Results and Discussions

3.1 Surface Features and Morphological Properties

The unique character of Vertisols is derived from the interaction and development of morphological features manifested both in the surface and in the soil profile. They have specific properties related to smectitic mineralogy [8] causing high coefficient of expansion and contraction leading to cracking and mulching. This sets up a steady churning process in the pedon, resulting in a process of vertical mixing and developing specific features uncommon to other soils. These features include:

3.2 Surface mulch

The surface mulch comprises fine and medium sized granules (5-15 mm) occasionally obscuring surface cracks in depressions. It is the first surface feature to be identified on the soils of the study area, and varies in thickness between 10-30 mm, but is thicker on the shedding sites particularly on the usually higher yielding lands associated with *nal* grass *(Cymbopogon nervatus*) when under fallow. The mulch is a water-conserving feature reflecting beneficial agronomic practices, such as harvesting of groundnuts, tubers and shallow-rooted vegetable and growing of food grain (sorghum and sesame). Such cropped areas are relatively more in Dinder North than Dinder South. It is reported that soils having thick surface mulch requires less energy to till. In irrigated farming, sprinkler irrigation may be more satisfactory because it would make gradual wetting possible and offering the possibility of structural improvement [21]. However, some of the clays do not form mulch on drying but produce "crusty surface". These crusty surface soils are commonly found in depressions.

3.3 Cracks and Slickenside

Cracks are soil surface and subsurface manifestations. In the study area they vary in width between 1.0 and 5.0cm and extend to a depth of 60-80 cm, and occasionally deeper to 1.5 m. Water deficiency and tillage are the most important plant growth factors for the management of Vertisols. Lack of water is a problem, at times, in all Vertisols because taxonomic criteria dictate that they must have desiccation cracks at 50 cm depth and 1.0 cm width in most years [33]. [21] Have indicated that presence of cracks implies that there are at least seasonal periods of high water suction and water deficiency. They further have viewed the cracks into three groups: The first group includes vertically oriented cracks that outline prisms that are relatively wide, usually exceeding 5mm width at the surface when the soils becomes dry, and develop progressively deeper as further drying occurs. The second group represents randomly oriented narrow cracks, 1.0 mm or less in width and tend to be closer together and do not develop until water contents are around 15 bar retention. These outline the angular blocks and have less importance as regard to root ramification, because soil fabric has reached strength where root entry is limited. The third group of cracks occurring at about half meter-depth, are formed by soil movement, and made up of intersecting slickensides. The low angles at which these intersect give this zone a platy appearance. In the study area, the cracking intensity in terms of width and depth is much more than postulated by [21].

The first and second groups of cracks are dominantly manifested in the soil profiles developed on flat shedding sites where water movement via the cracks is rather well distributed favoring increased cracking intensity in terms of width and depth. On the other hand, the third category of cracking pattern is described in soils developed on the receiving sites and depressions; the intensity of which is partially obliterated by increased water content at shallow to medium depths of the profile where vertisolic characteristics of slickensides and pressure faces are common and pronounced. Generally the types of cracks, as elaborated above, furnish a plausible explanation as to their functions in accelerating water movement that determine the depth and frequency of irrigation water required and hence improving water management in the soils of the study area. However, [9] reported that most of the normal irrigation application 10 cm of water can be accommodated in the cracks. They added that the cyclic depth of water penetration appears to be limited to about 60cm.

3.4 Gilgai and Depressions

"Gilgai" however denotes micro-relief at a larger scale, superimposed on this unevenness [16]. In Dinder area Gilgai consists of small mounds in a continuous pattern of small depressions, or depressions surrounded by a continuous network of narrow ridges. Several hypotheses have been put forward to explain the Gilgai micro-relief. These have in common that they relate Gilgai to mass movement in swell/shrink soils. For Gilgai to form the soil must have sufficient cohesion to transfer pressures all the way to the soil surface and this occurs during the process of swelling and shrinking. Apart from the dissected complex riverain lands along Dinder River, Khor Al Atshan and Al Aqalayin, the study area comprises a vast, flat to very slightly undulating, clay plain. Within the plain gently undulating and undulating land is usually associated with shallow depressions and khors (Figure 2 and Figure 3; [13]. Landsat 2006 interpretations and ground checking have confirmed their presence. The shallow depressions receive run-off and can remain wet for 2 to 3 months after the rains. Some of these receiving sites are old back swamps that have been cut off from the rivers and, whilst often apparent from imagery, are almost imperceptible during field study. Soils of the depressions are Vertisols similar to the surrounding plain and often the only indications of shallow depressions in the dry season are by flood marks on trees, uncultivated soil, or a cover of low weeds.

Figure 2: Local Depressions in Old Back swamps (maya) created by River Meanders.

Figure 3: Heglig Tree (Balanitesaegyptiaca) in a Depression. Dinder North (The water mark at its stem indicates the level of water during rainy season).

3.5 Calcium Carbonate Concretions and Aggregates

Glaebular and other forms of pedogenic carbonate have been described from profiles in the clay plains of Central Sudan [3]. The carbonate concentrations have differentiated into types based on their appearance in thin sections. Carbonate has also been described from stereomicroscopic observation of undisturbed soil fragments and wet-sieved fractions over 0.5 mm and in soil profile walls. X-ray diffraction shows that in all samples the carbonate mineral is calcite [3], [4]. Soft, powdery types of carbonate are diffused nodules or channel neo-calcitants; hard, discrete types are generally nodules, sometimes concretions, septaria and pedodes (Figure 5). The hard types have been differentiated on the presence and form of “impregnations” by iron and manganese (dendrites of manganese, neo- or quasiferans) and of cutans (generally manganese).

Often there is a relation between types of pedogentic carbonate present and other profile characteristics. soft, powdery types appear to have formed in situ. Hard, discrete types in Vertisols are inherited by transport within the profile, due to churning. The accretion of the carbonate and formation of “impregnations” and cutans are due to processes which are – or have been- active in the lower part of the profile, below the present churning zone [3]. In Dinder area prominent, hard, whitish $CaCO_3$ nodule of small and medium sizes (5 -25 mm) are commonly found at the surface of the relatively depressional areas. At substratum depth dominant soft and hard calcium carbonate concretions and nodules are usually found where these depth are often moist and high concentration are associated with the dark brown old alluvium calcareous layers (Figure 5). It seems that the fluctuating relatively high moisture content at lower depths coupled with churning processes in

Vertisols largely determined the amount and translocations and eventually distribution of calcium carbonate nodules and concretions.

3.6 Physical properties

All soils are > 2.0m deep. The Vertisols clay varies in depth from 1.5 to ⩾ 4.0m. The strata beneath the clay are heterogeneous brown, dark brown or dark yellowish brown silty clay, clay loams or sandy clay loams. With the exception of infiltration test, no tests were carried out for bulk density (BD), infiltration, permeability or AWC on the Vertisols of the study area because conventional methods don't apply to shrink-swell montmorillonitic clays. The values for such untested parameters were extracted from [26]. The infiltration tests were conducted in the study area using double ring infiltrometers. The values represent the basic infiltration rates which show almost consistent trends of 1.4 cm/h due to the behavior of the homogenous soils of the study area. The optimum basic infiltration rates for surface irrigation are considered to be in the range of 0.7 to 3.5 cm/h, although acceptable normal values range from about 0.3 to 6.5 cm/h. However, it is reported that the methods of infiltration measurement can suffer from a number of errors including, lack of adequate pre-wetting of dry expanding clays that need weeks of pre-wetting before major shrinkage cracks are closed; and soil disturbance effects during project development which may alter the soil - water intake characteristics [26].

3.7 Chemical and mineralogical properties

The soil particle size analysis recorded clay content in the range of 55-75% that belongs to the clayey class in the FAO textural triangle and to the likely smectitic mineralogy. The CEC values are fairly consistent with this range of clay content [8], [4] also provides important data on clay mineralogy of the central Sudan soils. The total nitrogen and organic carbon contents are very low ranging from 0.02 – 0.0 4 % to 0.6 – 0.8 % respectively indicating very low organic matter content that coincides with the amounts usually present in an arid climate. The total phosphorus, extracted with sodium carbonate buffered at pH 8.5, dominantly varies between 1 and 5 ppm but exceptional few high figures range between 12-34 ppm. Dominant amounts are deficient for most crops and questionable for cereals and grasses. The availability of phosphorus is critical to plant uptake because soil alkalinity (pH 8.5 – 9.0) causes fixation and/or formation of insoluble compounds. However, crops vary in response and therefore the requirement for fertilizers application need to be assessed after determining soil reactions.

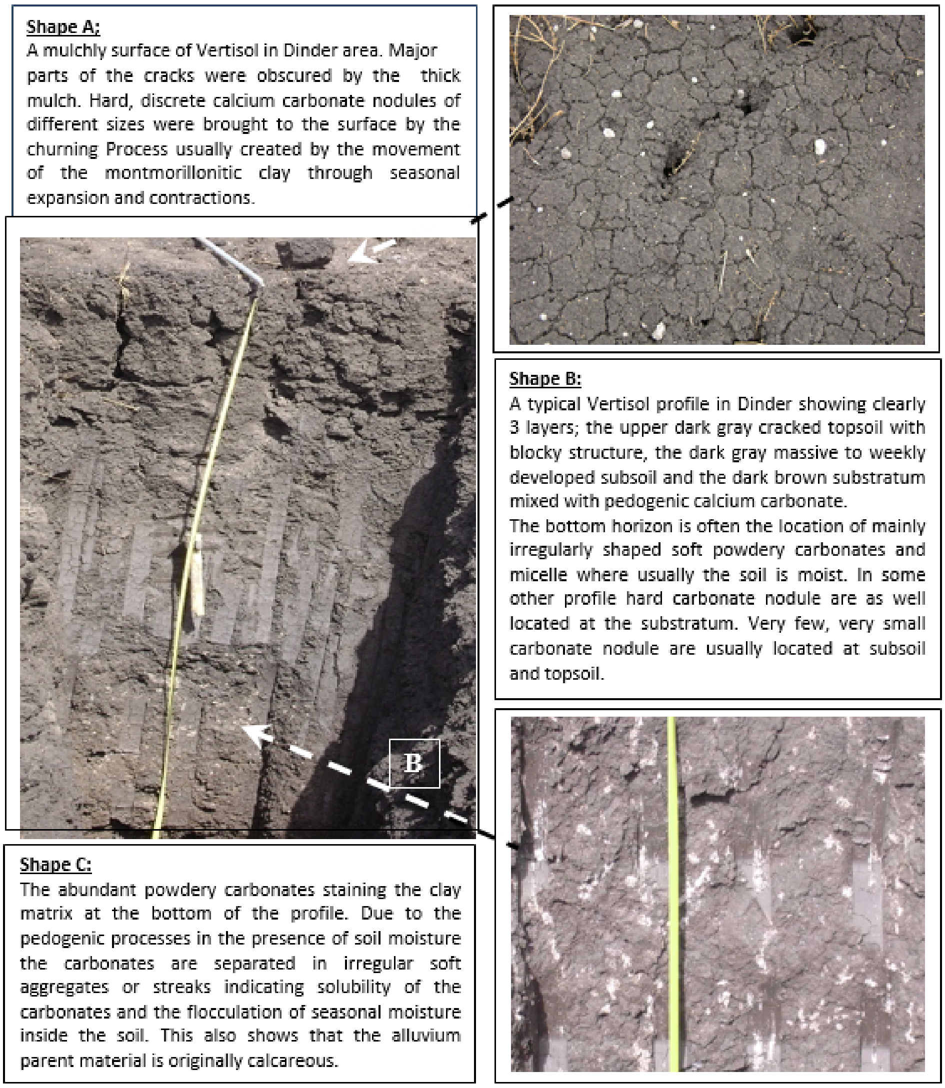


Figure 5: Calcium Carbonate nodules, concretions and aggregates in Vertisols of Dinder

The soil reaction is alkaline varying between mildly to strongly alkaline in almost all of the soils of the area. The pH values of the saturation extract range from 7.4 – 8.9 but these rates tend to be higher with the increase of the soil-water ratio (dilution effect). In this respect, pH values exceeding 9.1 are occasionally found in the suspension 1:5 soil-water ratio. Although the reaction of the soil matrix is slightly to moderately calcareous, the CaCO3content ranges from 3.7%. Higher contents are infrequent and occur in the substratum in some profiles. However, these soils may contain CaCO3 more than that recorded in the analytical results: this is because the analyses were carried out in the "fine earth" (< 2 mm dry soil sieved without any gravel) of the samples that passed the 2 mm sieve. In this regard, it is observed that CaCO3 concretions larger than 2mm have been retained in the sieve as part of the gravel fraction of the sample which is not considered for the analysis. Smaller sized fragments of concretions will pass through the sieve and be included in the testing. The field method of applying HCL acid on the soil matrix to check the presence of CaCO3 proved to be a reliable indicator of soil calcareousness.

The EC of the saturation extract rarely exceeded 4 dS/m at 25 °C. which indicates a very low hazard of salinity in these soils? The types of salts, as given from analysis of the exchangeable and soluble cations and anions, are dominantly sulphates followed by chlorides. Bicarbonate is present in little amounts while carbonates are either as a trace or not detected. The exchange complex in soils of this area is fully saturated with basic cations of Ca++, Mg++, Na+, and K+. Exchangeable H+ and Al+++ (exchange acidity) is therefore, non-existing. The Cation Exchange Capacity CEC ranges from 55 – 75 meq/100gr soil. Potassium and sodium are determined separately and results indicated that potassium is very low compared to sodium. The Ca++ + Mg++ are calculated by difference between the CEC and exchangeable Na+ + K+, and therefore are not reported separately. This approach is adopted because of the occurrence of calcium sulphates in water adding more Ca++ and Mg++ to the soil solution which likely giving rise to erroneous estimates. The practical experience indicates that the SAR values, obtained by applying 1:5 soil-water rates methods are low and under estimated and this could be attributed to the following:

1- Solubility of Ca++ and Mg++ increases in higher soil-water ratios than Na+ ;

2- The soil matrix is calcareous, containing CaCO3 in very fine particles that release Ca++ into the solution, giving rise to increased Ca++, and eventually Ca++ + Mg++.

3.8 Micronutrients

The soil micronutrients that have been analyzed on this survey (Fe, Mn, Zn, and Cu) have provided data that indicates that the soils of study area are deficient in some of the available forms. In the case of Fe, and Zn, they are present in contents well below the crop requirements. Levels for Mn and Cu (subsoil only) are adequate, and this difference appears to confirm the recycling of nutrients down cracks to the deep subsoil where they are largely unavailable to field crops. The high soil pH and calcareous reaction of soil matrix apparently, are the main constraints to the availability of all determined micronutrients (DTPA test), which are evaluated in Table 2, following [31]. The figures between brackets like (1.16) indicate averages in the soils of Dinder study area while other indicates the ratings [31]. Table 2 shows that Fe and Zn are low while Cu and Mn are adequate. Accordingly Zinc and Iron deficiency is highly probable.

Table 2:Evaluation of Soil Micronutrients (ppm) in the Soils of the Dinder Area

Grade	Fe	Mn	Zn	Cu
Low	< 2.0 **(1.16)**	< 1.8	< 1.0 **(0.16)**	< 0.5
Moderate	2.0-4.0	-	1.0-1.5	-
Adequate	> 4.0	> 1.8 **(4.0)**	> 1.5	> 0.5 **(0.85)**

3.9 Salinity and Sodicity in Dinder Areas

The laboratory results show that the Dinder North and South areas in general may be classified as non-saline (Table 3 and 4). The content of soluble salts is very low, such that it is considered the growth of even sensitive crops would not be affected. The EC of the saturation extracts for all samples very rarely exceeds 4 dS/m at 25 ^{0}C. The types of soluble salts were determined for all samples collected. Soluble sulphates are the most dominant followed by chlorides. Bicarbonates are present in small amounts; carbonate is the least found, and is completely lacking in many profiles. The low salinity would appear to reflect the increased rainfall in the Dinder area and its effect on leaching of soluble salts.

Table 3: Ranges of pH, EC and SAR Values in Dinder North

Soil horizon	Auger Data									Profiles Data		
	pH			EC			SAR			ESP		
	Range	No of samples with pH values > 8.5	%	Range	No of samples With EC values ≥ 2.5	%	Range	No of samples With SAR values ≥ 12	%	Range	No of samples With ESP values ≥ 25	%
Surface	6.6– 9.3	41	3.1	0.1 – 1.0	0	0.0	1.0- 9.0	0	0.0	1 – 25	2	3.3
Subsoil	6.1 – 9.7	83	6.2	0.1 – 0.6	0	0.0	1.0- 9.0	0	0.0	1 – 32	2	3.3

Total soil observations in Dinder North = 1390 (1330 augers+ 60 profiles)

Table 4: Ranges of pH, EC, SAR and ESP Values in Dinder South

Soil horizon	Auger Data									Profile Data		
	pH			EC			SAR			ESP		
	Range	No of samples with pH values > 8.5	%	Range	No of samples With EC values ≥ 2.5	%	Range	No of samples With values ≥ 12	%	Range	No of samples With ESP values ≥ 25	%
Surface	5.5 – 9.1	11	1.8	0.04- 8.3	1	0.2	0.1- 12.0	1	0.2	1 - 33	8	30.8
Subsoil	6.1 – 9.0	33	5.2	0.01- 1.0	0	0.0	0.8- 12.0	2	0.3	2 - 31	10	38.5

Total soil observations in Dinder South = 642 (616 augers+ 26 profiles)

Calcium and magnesium are the dominant exchangeable cations in the soils. With increasing depth their relative percentage decreases, whereas sodium increases in these lower horizons. Some horizons below the surface, and at variable depths, have ESP values more than 15 which was the original limit set up by the USDA's Salinity Laboratory at Riverside, California. For long this was widely accepted as a boundary defining sodic soils. Local experience, with Sudanese Vertisols had indicated that some relaxation was needed, and this limit may be increased to a value within the range of (25-35) before the adverse effect of exchangeable sodium is clearly shown in locally adapted field crops grown in this area [37]. The performance of crops had not shown a decline in yield that could be attributed to an ESP of 15. It was considered that the combination of high clay content and high CEC might have imparted a buffering effect to the harmful level of exchangeable sodium [14].

Based on a worldwide review of soils [26] stated that in general terms, high ESP values have a greater deleterious effect upon soils with 2:1 lattice clays than on those with 1:1 clays. Moderate soil alkalinity occurs in higher values (pH > 8.5) in limited sites within Dinder North area (Table 3) particularly within the soil substratum, compared to the values of very limited sites recorded in Dinder South (Table 4). This situation could possibly be created as a result of the effect of apparent relatively more moist climatic conditions prevailing in Dinder South area (Figure 1 and Table 1) with possible movement of salts into the substratum (subsoil) due to availability of moisture. Similarly, this holds applicable for both the salinity (EC) and sodicity (SAR). The three tested parameters are commonly mild or nearly optimum in most parts of Dinder Areas. Therefore, the adverse effect on the availability of nutrient elements would not be to the limit that renders low fertility statues.

Table 5: FAO (1970) Sodic Phase Units Compared to Present Survey Data

Soil Survey Study	Sodic Phase Units	Details	pH 1:5		ECe 1: 5		ESP	
			Topsoil	Subsoil	Topsoil	Subsoil	Topsoil	Subsoil
FAO (1970)	Dinder sodic Phase 1970	Average	8.6	8.6	0.59	0.98	9.1	18.05
		Range	8.6	8.5 – 8.7	0.56 – 0.61	0.95 – 1.0	6.1 – 12	18 – 18.1
	Abel Sodic Phase1970	Average	9.2	9.4	0.67	0.86	14	26
		Range	8.8 – 9.6	9.3 – 9.5	0.55 – 0.88	0.84 – 0.88	4 – 27	25 – 27
Dinder Area (Present Survey, 2008)	2008 Profiles within Dinder sodic Phase	Average	7.05	7.2	0.55	0.5	12	19
		Range	7.0 – 7.1	7.0 – 7.4	0.5 - 0.6	0.5	6 – 18	18 - 20
	2008 Profiles within Abel sodic Phase	Average	7.7	7.8	0.5	0.44	18.2	19.4
		Range	7.1 – 8.3	7.4 – 8.4	0.3 – 0.8	0.2 – 0.8	5 – 29	4 – 36

Useful to review the semi-detailed soil survey study carried out by [35] in Dinder area (including both Dinder North and South). On this early study soil samples were collected from profiles representing the different soil series and their sodic phases. These are the Dinder series (slightly sodic) and Abel series (sodic phase). The pH, salt percentage and sodium value were determined on these samples using soil water extract, and further converted into EC and ESP [35]. A comparative analysis is given in Table 5. This is based on placing soil sites within the sodic phase map units of the FAO study. Analyses from these areas have been related to profile data from the representative sites elsewhere in the Dinder N and S areas. The values in these categories coincide fairly well with the findings obtained from Dinder soil study areas which designate the study areas as non-saline and non-sodic with good nutrient status (Table 6).

Table 6: Levels of Selected Chemical Characteristics Used to Evaluate Relative Nutrient Status of the Dinder-Kenana soils

Relative nutrient status	pH Paste (1:5)	% Base Saturation	C/N Ratio	ESP	Water soluble Ca meq/L	ECe dS/cm
Good	6.6-8.4	>80	<11	<25	3.0	0-4
Fair	8.4-9.0	50-80	11-15	25-35	1.3	4-8
Poor	>9.0	>50	>15	>35	<1.0	>8

3.10 Prediction of ESP from SAR values as determined in 1:5 Soil-water suspension

The validity of the relationship between SAR and ESP is based on the equilibrium that may exist between soluble cations and exchangeable cations when the soil moisture content is within the field moisture range. Good correlations between the two parameters are more satisfactory when the soils under study are saline-sodic. When the water: soil ratio is increased from saturation to moisture content sufficient to dissolve gypsum and/or the fine particles of calcium carbonate, SAR values are underestimated. This is due to the fact that the content of soluble divalent cations (Ca^{++} and Mg^{++}) is increased in the extract at a ratio much higher than that of (Na^{+}), and this result in low SAR values.

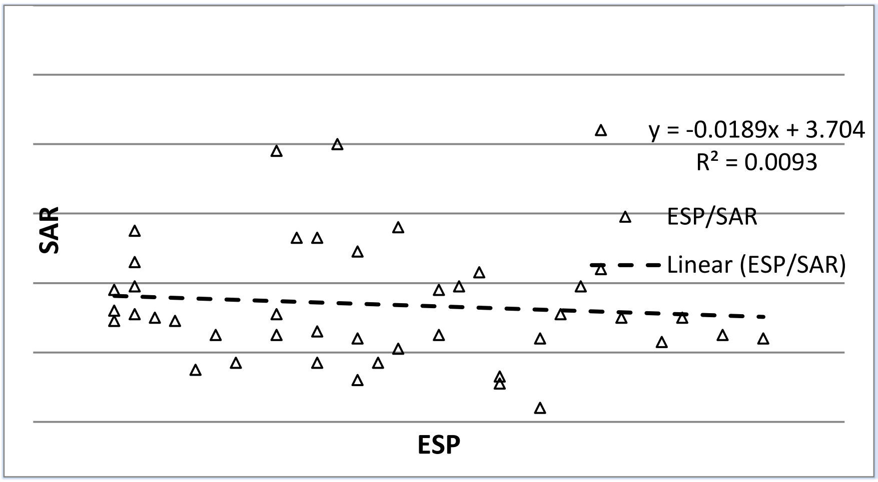


Figure 6: SAR (1:5 soil-water) Correlated with ESP Values in Dinder Area

Accordingly, the SAR values based on 1:5 soil-water suspensions do not correlate significantly with ESP values (Figure 6) so as to be taken to reflect accurately the amounts of sodium in the soil, and this could be attributed to a number of reasons [14]. Dinder soils are calcareous throughout the study area (DN and DS). The calcareous matrix of the soil contains very fine particles of $CaCO_3$ which may release some Ca^{++} in the analysis. Furthermore, gypsum crystals are commonly observed at the lower horizons of the soil profile. Therefore, it is likely that the low SAR values obtained for Dinder area are due to the increased solubility of the fine particles of calcium carbonate and gypsum crystals that are lowering sodium in the soil.

4 Conclusions

The problems involved with working the heavy clay Vertisols in the Central Clay plains of Sudan, whether for rainfed or irrigated cropping have received considerable attention over many decades [8]; [11]; [24]; [28]; [4]; [2]; [12]. The sustainable management of the cracking clays (Vertisols) identified and mapped in the study areas of Dinder North and Dinder South requires the application of appropriate and Sudan-proved techniques in land management and husbandry. Some techniques and components must be combined to perform the best management practices package. Therefore, this package includes six attributes, namely, 1) Farming and land management systems; 2) Fertility and fertilization 3) Crop management systems 4) Irrigation system;5) Drainage; 6) Soil conservation.

4.1 Farming and land Management Systems

Vertisols are one of the most productive soils for irrigated agriculture. Their high water-holding capacity endows them with the ability to compensate better than most of the soils suffering from irrigation water deficit which is a major constraint for crop production and growth. Because of the widespread occurrence and high potential of Vertisols for increased productivity the Kenana Rahad II Irrigation Projects have been given a high priority for developing improved farming systems. The major kind of land use in the study area will be irrigated agriculture, under which the main farming system would be mechanized mixed cropping adopting diversified/intensified cropping and applying appropriate technology. Enhancing such an approach necessarily requires making use of land and crop management systems in which the agronomic practices likely to be employed in the study area will set up farming designs in terms of layout of basin, furrows or strips accommodating the proposed land utilization types. Tillage embraces all operations of seedbed preparation that optimize soil and environmental conditions for seed germination, seedling establishment and crop growth. It includes mechanical methods based on conventional techniques of ploughing and harrowing, weed control using herbicides, use of growth regulators, and fallowing with cover crop for direct seeding through residues mulch. The ploughing-till covers two operations, namely: Primary tillage: is the first and deepest tillage optimum, and forms the basis for the seedbed, and is based on ploughing or soil inversion; Secondary tillage: this operation is designed to refine the seedbed to conditions suitable for successful germination and unimpeded growth, using a disc.

Therefore, the soil moisture condition should be monitored for their optimum status before implementing tillage operations. This was recognized long ago at Tozi Research Farm on the Blue Nile left bank and discussed in the Rosaries, Dinder and Rahad Development Plan (Lahmeyer, 2008) and assessed earlier by others, for example [24] and [2].The actual time for tillage is short due to the soils either being too dry and hard, or wet and plastic and impassable. On the rainfed schemes at Agadi, to the south of Damazin on the left bank of the Blue Nile, no-till cultivation involves heavy use of herbicides, and they estimated they only have about 17 planting days [25]. Intensive tillage operations with machines could have adverse effects on physical soil characteristics by compaction of the soil. Soil compaction is the reduction of soil volume due to external factors. Soil compaction is produced mainly by tillage machines and equipment. The risk of soil compaction is greater today than in the past due to an increase in the size of farm equipment. Soil compaction reduces soil productivity. Research in tilled soils in USA showed average first-year yield losses due to compaction of approximately 15%. Performing field operations on wet soils, using multiple field operations for crop production, eliminating perennial crops from crop rotations, and using heavy equipment contribute to more extensive and deeper compaction [40].

4.2 Fertility and fertilization

The chemical data obtained from the Dinder North and South surveys shows that the exchange complex are highly saturated (> 60%) with exchangeable cations. The nutrients in the exchange are indicating a high CEC (> 40 meq/100gm soil). Their availability to plant uptake is strictly governed by soil pH. Therefore, a fertility management programme requires assessment of the macro-micro nutrient storage in the soils of the study area in order to identity nutrient imbalances requiring application of desired kinds and doses of fertilizers and to predict deficiencies that might be brought about by growing nutrient depleting crops and to set up correction measures. For the very low nitrogen content found in these soils, many agronomists have conducted experiments in similar soils in the central clay plain of Sudan and showed the need for nitrogen fertilizers [5]. It is also found, that for the efficient management of nitrogen and increased crop yields, nitrogen has to be applied with phosphorus fertilizers [6], [32], [27]; [23].

Phosphorus availability is probably the greatest constraint to agricultural production in Vertisols. This situation is linked up with pH dependant-available phosphorus and its response that shows a wide variation to reach maximum yields for different crops [32]; [41]. Another critical issue for phosphorus management in Vertisols is the source of phosphoric fertilizers being nitrophosphatic or mixture of ammonium sulphate and superphosphate, where the nitrophosphatic fertilizers gave better yields [27]. The third aspect in terms of phosphorous management is the use of organic waste and recycling of farm residues as a source of nutrients [1].. In this practice, decomposition of organic residues by microbial activity releases CO_2 that dissolves in water, forming organic and inorganic acids, lowering the soil pH rendering phosphorus soluble and hence making it available. Phosphorous fixation occurs in calcareous soils and is placed near the root zone (rhizosphere) since it is somewhat immobile. The potassium shows an unusual characteristic as the total content in the soils range from 1-3 meq/100g. Generally, within this range, response to potassium fertilizers is negative, because it is reported that response is likely when a soil has an exchangeable K value below 0.2 meq/100g of soil and unlikely when it is above 0.4 meq/100g [26]. Some research results attributed this mainly to potassium fixation by the dominantly 2:1 montmorillonitic clay [22]; [32]; [6]. Availability of trace elements to plants is influenced by many soil and environmental factors, which must be taken into consideration when interpreting soil test data The determination of the soil micronutrients (Fe, Mn, Zn and Cu) indicates that the soils of the study area and similar soils elsewhere (e.g. Gezira band Kenana) are invariably deficient in available forms [10]; [41]) and for some of them having trace element contents far below the levels required for plant uptake. The high soil pH is the main determining factor forming insoluble compounds.

- Zinc:The trace elements analyses have indicated low amounts of zinc in the soils of the Dinder area(0.16 ppm in topsoil only). Since the soils in Dinder Area are calcareous with relatively high pH and most of the proposed crops are sensitive to zinc deficiencies, the zinc content in the soil should be monitored and it would appear that adequate amounts of zinc should be added to the soils.
- Copper:The trace elements analyses have indicated adequate amounts of copper in the soils of Dinder Area with levels of 0.85 ppm in subsoil. Phosphate reduces the concentration of Cu in roots and leaves of plants, and heavy phosphate fertilization can induce Cu deficiency. Where application of phosphate fertilizers is practiced for soils low in Cu content, soils should be monitored to avoid depletion of this element.
- Iron:The trace elements analyses have indicated moderate amounts of iron in the soils of Dinder Area, with levels of 1.16 ppm in topsoil Since the soils in Dinder Area are calcareous with relatively high pH and most of the proposed horticultural crops are sensitive to iron deficiencies, the iron content in the soil should be monitored and additional amounts of iron may need to be added to the soils.
- Mn:A wide range of crops is sensitive to Mn deficiency, which is common in calcareous soils and soils of high pH similar to Dinder soils, although deficiencies are also frequently induced by liming and poor soil physical conditions, even in soil with pH >7.0 The of Mn is also highly dependent on the presence of other ions: Mn can induce Fe chlorosis, and there is some evidence which suggests that Fe and Zinc interfer with Mn uptake; Mn and P appear to be mutually antagonistic [26].

In the study areas no artificial chemical fertilizers are being applied for crop production under both the traditional and mechanized rainfed farming although good field crop performance was noticed. Apparently, the fallow farming system is widely practiced to allow soils to rest and regain its natural fertility in order to withstand on-farm operations and any consequent land degradation which might appear due to continuous cropping. The application of chemical fertilizers under irrigated farming in the future project will draw on experience and technical knowledge gained from the neighbouring irrigated schemes e.g. Kenana Sugar Estate, the Gezira Scheme, and ARC research data. Since the Dinder soils are dominantly alkaline, the use of common fertilizer products that have acidic residual effect for lowering the high pH to levels favoring plant nutrient availability might be a useful intervention. Trials though, are needed though to assess this suggestion. In such a case the recommended compounds would be potassium nitrate, ammonium nitrate, ammonium sulphates, urea and superphosphate.

4.3 Irrigation system

The water from the Blue Nile will be utilized for crop production in the seven land utilization types proposed for the study area. The most recent and elaborate analysis was presented by [14]. Using the method, quoted by [14], suggested for the classification of irrigation water by [29] and therefore the Blue Nile water could be classified as C1-S1 i.e., low salinity and low sodium risk water. Therefore, this water quality can be used for irrigation with most crops on most soils with little likelihood that soil salinity or sodicity will develop. The classification is based only on the electrical conductivity and SAR. It does not consider other harmful effects from bicarbonate and boron. It was also indicates that, generally, the water of the Blue Nile can be used for the irrigation of all crops [14].

4.4 Crop Management Systems

The crop management sequence has an intact relation with the tillage system, in that, crop management systems embrace different aspects e.g. seedbed preparation, soil management, management of plant pests and plant production. The crop production within the seven land utilization types is believed can be achieved through adopting crop management systems including crop rotations, sequential cropping and a cropping calendar.

- Crop rotations

The crop rotation involves the growing of one or more crops alternately with fallow or with each other. It may be simple such as the wheat-fallow system in which one crop is produced in 2 years or complex where several crops are grown in a system requiring five or more years for completion [34].

- Sequential cropping

It is adapted to any type of cultivation system e.g. labour intensive, modern-high technology. It is merely an intensification of crop production in time dimension where water and other resources are available. It affords an opportunity to use land and water resource effectively throughout the period that is favourable to growing crops. By having a crop on the land for most or all of the year, the potential for erosion is also decreased.

- Cropping calendar

It is a system set up for keeping chronological timing records of all the farm management operations including crop cultivations, tillage, sowing and harvesting date, length of growing periods, fertilizer doses and yields [15]. Having had the agronomic advantages of rotational and sequential cropping been envisaged, it is for practical and yield benefits, recommending both crop management systems as guided by the cropping calendar for crop production in all of the seven land utilization types proposed for the project area.

4.5 Irrigation system

The water from the Blue Nile will be utilized for crop production in the seven land utilization types proposed for the project area. The investigation of the composition of the water reported a calcium/sodium ratio of 4.2. The most recent and elaborate analysis is shown in Table 9.1 [14]. Using the method, quoted by Fadl (1969), suggested for the classification of irrigation water by [29], the Blue Nile water can be classified as C1-S1 i.e., low salinity and low sodium risk water. Therefore, this water quality can be used for irrigation with most crops on most soils with little likelihood that soil salinity or sodicity will develop. The classification is based only on the electrical conductivity and SAR. It does not consider other harmful effects from bicarbonate and boron. The water analysis of previous studies indicated that, generally, the water of the Blue Nile can be used for the irrigation of all crop components on proposed land utilization types. In this case, the possibility is remote for adding salts or building secondary salinization in the soils of the project area (Fadl 1969).

4.6 Drainage system

Excess surface water and internal soil water are potential limitations to crop production in cracking clays. Major irrigation systems often involve large areas, frequently covering either large farms or numerous small farms, and drainage of excess waters and leachates is essential. It is therefore; imperative that for nearly level fields with relatively flat slopes such as occur in the project area, a system of beds and furrows is most suitable. In the project area, the difficulty remains with the low-lying unconnected depressional areas (the receiving sites of seasonal flooding). Here drainage can be improved by connecting the enclosed depressions with a series of ditches which would permit discharge into natural drainage ways. If such soils are not drained, they will impose adverse drainage conditions that will severely limit crop growth [37]; such soils are given a wetness limitation (subclass symbol –w).

4.7 Soil conservation

The chemical analyses carried out for the soils of the project area indicated low contents of soluble salts and exchangeable sodium, that are generally well below the thresholds for development of salinity and/or sodicity, and hence the Dinder North and South soils are designated non-saline and non-sodic. The crop yields expected from cropping the proposed land utilization types are obtainable by applying the Nile water, which is classified as class C1-S1 irrigation water according to the USDA, Salinity Laboratory [29]. In this case, as long as the Blue Nile water does not deteriorate in quality, neither the irrigation water will add substantial amounts of salts to set up salinity, nor will a secondary salinization be developed in the soil. However, the possibility for the emergence of salinity and/or sodicity in the soils of the project area cannot be dismissed.

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Study of High Spot Lands in Irrigated Scheme Using Remote Sensing Data and GIS. Case Study: Rahad Irrigated Scheme, Sudan

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ABSTRACT

The study was carried out in selected sites that cover 1989.8 ha (4735.86 Feddans) in the Rahad Irrigatated Scheme, Gazera State, Sudan. The main objective was to identify the spatial distribution ofHigh Spot Lands that are created by management practices and study their physiognomies at Rahad Scheme using space technologies. Data from Landsat TM and ETM sensors with different spatial resolution (15 and 30m) and temporal resolution (1987, 2000, 2005 and 2013) was utilized to conduct land cover analysis in relation to farming patterns, irrigation system and residential areas. Satellite elevation data from STRM combined with Landsat ETM data and high resolution data from Google Earth were compiled to study the high spots and accumulated soils in relation to the topography of the study area. The GPS was used in the field investigations to delineate the study area and to identify the sites of the high spots and in locating the soil sampling sites. The results of Landsat and DEM analysis showed that a considerable amount of high spots exist within the study area and throughout the northern part of the farmland of the scheme. It was evident that the topography of the land was adequately considered during the initial irrigation system designs in 1987, but consequently little care was given to the levelling of the farming land during different tillage operations. The study concluded that data from Landsat, STRM, ASTER and high resolution data from Google Earth could be used to detect and identify fairly high spot Lands at Farm level and hence contribute to improve management.

Keywords: Digital Elevation Model (DEM), High Spot Lands, Space Technologies

1 Introduction

Remote sensing can be defined as the science of collection, processing and interpretation of images and related data, obtained from aircraft and satellites, which record the interaction between matter and electromagnetic radiation [11]. In the Sudan the use of remote sensing technology is a cost effective procedure for surveying natural resources. Starting from 1971 remote sensing has been used in natural resources surveys of specific areas chosen by Food and Agricultural Organization for testing the possible utilization of remote sensing for surveying, mapping, planning and developing natural resources [9]. [7] studied vegetation change in the Sudan using Landsat data and concluded that the desert was then moving southwards with a rate of 5-6 km per year. He attributed this spread of desertification to misuse of land by people. However, [5] showed that there was no systematic desert encroachment and criticized the findings of [7] as misinterpretations resulting from his application of

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the vegetation map of Jackson and Harrison(1958), which depended mainly on the100 mm rainfall isohyets. [5]; [6] stated that vegetation recovered during the rainy season.

Remote sensing, in conjunction with parallel development in Geographical Information Systems (GIS), Global Positioning System (GPS) and other ground data collection systems, now provide substantial amount of information about the land, to improve the understanding of the natural systems and offered better chances for preserving it [1]. GIS is needed for obtaining a more comprehensive view of the remote sensing analysis for a particular area of interest. Therefore, the integration of spatial information has been remarkably favoured by most users of satellite remote sensing. The use of GIS and remote sensing has gained much recognition as environmental resources management tools for data collation and analysis [11]. Remote sensing and GIS are known to be not only powerful, but also cost-effective tools for assessing the spatial distribution and dynamics of land cover [13]; [4]; [14]; [15]; [2].

In recent years, there has been an increasing interest in providing integration tools in the area of remote sensing, GIS and spatial models (Franklin, 2001). Nowadays, GIS is considered to be the nerve center that handles geographic information because it can integrate all source of spatial data (RS, cartography, census data, GPS … etc ([1] This research study provided a practical example on how such advanced technologies could be used to investigate spatial distribution of management practices problems such as High Spot Lands and evaluate their magnitude in order to advise on proper management practices.

2 Materials and Methods

2.1 Materials

2.1.1 The Study Area:

Rahad Agricultural Scheme is located about 276 km South Khartoum, on the eastern bank of the River Rahad (a tributary of the Blue Nile). It is subtended by latitudes 13° 08 N and 14° 05 N and longitudes 33° 06 E and 34° 01 E. The Scheme stretches on a narrow strip from south to north along the east bank of Rahad River for 160 km.

Rahad agricultural scheme is located in two states; Gedarif and Gezira with about 40 and 60% as share area in eachststerespectively, (Figure 1). Fieldwork conducted during the seasons 2010/2011 to 2011/2012 in a sample area, which is represented the total study area of the scheme.

The study area (Rahad Agricultural Scheme) covered by Landsat (TM) image zone 36 between the following two point’s co-ordinates in Universal Transference Marketer (UTM):

1. (335053.87E, 142422.91N)
2. (335123.26E, 142319.02N)

Figure 1: Location of the study Areanorth ofRahad Schemeat Gezira/ Gadarif States, Sudan (on Google satellite map)

2.1.2 Satellite Images

Set of satellite data from Landsat, SRTM, ASTER and Google Earth were used. Four sub images from Landsat covering the selected sites 1989.8 ha (4735.86 fed) were used in this study. Composed of three bands, for four time intervals, 1987 (Thematic Mapper) and 2000, 2005 and 2013 (Enhanced Thematic Mapper plus); the characteristics of these images were listed in Table 1.

Table 1: Characteristics of Landsat imageries used in the study

Image	Path/ Row	Sensor	Band	Resolution	Date D/M/Y
1	172/50	2.1.3	1-3	.4 30m	D/M/ 1987
2	172/50	ETM+	1-3	30m & 15m	2000
3	172/50	ETM+	1-3	30m & 15m	2005
4	172/50	ETM+	1-3	30m & 15m	2013

Source: Landsat Satellite images 1987, 2000, 2005 and 2013.

2.1.5 Digital Elevation Models (DEMs)

Several digital elevation models were used during this research. The global products include the NASA Shuttle Radar Topographic Mission (SRTM) produced DEM with spatial resolution of 90 m downloaded from http://srtm.csi.cgiar.org was used; and ASTER GDEM 30 m resolution a product of METI and NASA ; at regional scale a DEM with resolution 10 m and a local DEM with 5 m resolution, both based on topographic maps. For the macro landform classification also DEM with resolution of 200 m was prepared from SRTM DEM.

2.1.6 Data from Google Earth

Google Earth is the program for viewing anywhere on the planet, allowing you to view high resolution satellite imagery, elevation terrain, road and street labels, and more. High resolution data was obtained from Google Earth in 2014.

2.1.7 ARC Map

Arc Map 10 View (Advanced Spatial Analysis using Raster and Vector Data) was used for analysis and final production. Erdas Imagine 8.5 advance software was also used for image processing and analysis.

2.2 Methods

Remote Sensing (RS), Geographical Positioning System (GPS) and Geographical Information System (GIS) techniques were applied effectively in this research study. Remote sensing data consisting of images from Landsat ETM with different spectral and temporal resolution were utilized to conduct land cover analysis in relation to farming patterns, irrigation distribution and residential areas. Satellite elevation data from STRM combined with Landsat ETM data compiled to study the high spots and accumulated soils in relation to the topography of the study area. The GPS utilized in the field investigation to delineate the study area and to identify the sites of the high spots and accumulated soil. It was also used in locating thesoil sampling sites.

3 Results and Discussion

3.1 Identification of High Spot Soils through Landsat Images

Soil accumulation and build up as high spots were interpreted based on Landsat False Color Composite (FCC) (172/50), TM (172/50) for the years 1987, 2013.Digital elevation data (DEM) from SRTM combined with Landsat images 2007 was also used to study the topography of the study area. From this interpretation, it was possible to indicate that a considerable amount of high spots exist within the study area and throughout the northern part of the farmland of the scheme. From the layout of the irrigation canals, it seems that the topography of the land was adequately considered during the initial irrigation system designs, but consequently little care was given to the levelling of the farming land during different tillage operations. It appears that the apparent relatively high spots within farming blocks were being avoided and more soil was accumulated on them when leveling the surrounding ground which even worsened the problem of high spots.

3.2 The Use of the Digital Elevation Model (DEM):

Topography was identified by a Digital Elevation Model (DEM), which illustrates the elevation of any point on landin a given area at a specific spatial resolution as a digital file. [1] argued that the higher the resolution, the more difficult the evaluation of input data quality and the assessment of the resulting Digital Terrain Model (DTM) area. Experience indicates that the effort is proportional to the square of the inverse value of horizontal resolution. High resolution DTMs are thus more prone to errors. [9] added that visual methods can be very important for the evaluation of spatial data and can balance some weaknesses of statistical methods. They are still under used for at least three reasons. Visual approaches being qualitative are generally more neglected than statistical ones, which are considered more objective. The other two reasons for the lower acceptance of visual methods lie in the insufficient graphical capabilities of computers until recently and in the longer tradition of using statistical methods.

Finally, visualization of spatial data has traditionally been part of cartography. Figure (2) shows the study area on Landsat ETM 2007 panchromatic image with 15m spatial resolution. Figure (3) shows the DEM map of the study area (SRTM 90 m resolution). In this image, lighter patterns reflect low-lying areas at the northern and southern parts of the study area. High ridge on western part appears in dark tone. The Figure (4a) and (4b) show the contour map and its enlargement for the study area. The lines clearly show the low lying and relatively high grounds within the study area. As well, the elevated ridges west of the area are very prominent. This becomes clearer when comparing the enlarged contour map with DEM .The contour map indicated high landforms on western parts of the study area and within the study area; it shows some elevated and lower parts within 1 m differences. Considerable elevation differences are evident in the contour maps. Figure (5) shows the hill shade of the study area; figure (6) shows the hill shade couples with contour lines. All hill shade figures reflect the heights, slope in the study area and surroundings. As seen from hill shade figures the elevated ridges are particularly clear and these maps can used to separate high physiographic grounds (ridges and rock outcrops) from clay plain areas. Figure (7) shows the study area on Google satellite maps with visual interpretation that indicated the presence of higher rocky lands on the western parts of the study area that limited the expansion of the irrigated farming lands westward. As well, runoff water during rainy season from these high grounds might create flooding hazards to the adjacent farmland areas.

Figure 2: The study area on Landsat ETM 2007

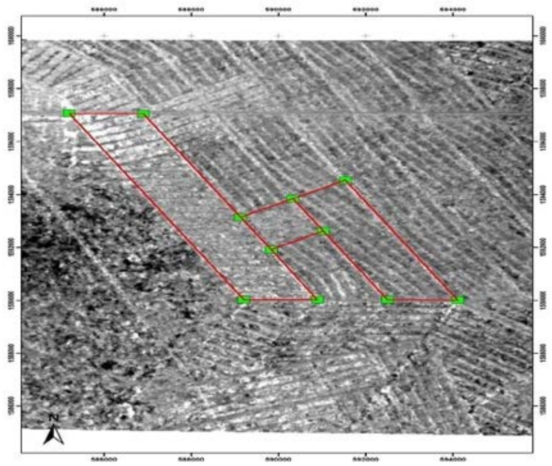
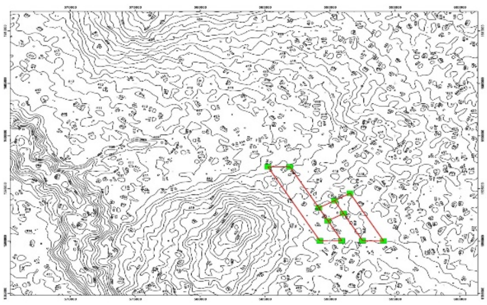


Figure 3: The Study Area Digital Elevation Model DEM SRTM



(Source: DIU; Personal communications)
Figure 4a: Contour Map for the Study Area (1 m intervals -SRTM elevation data)

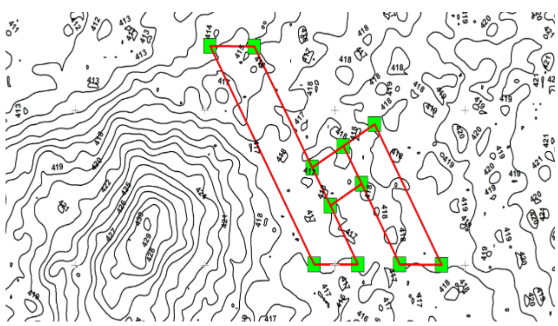
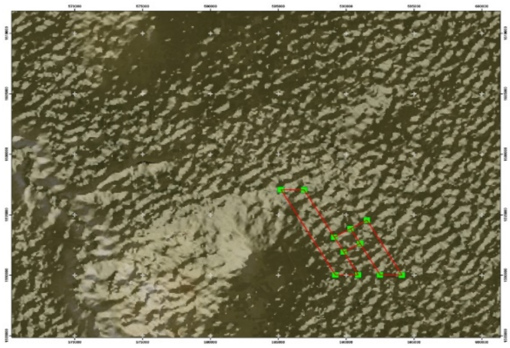
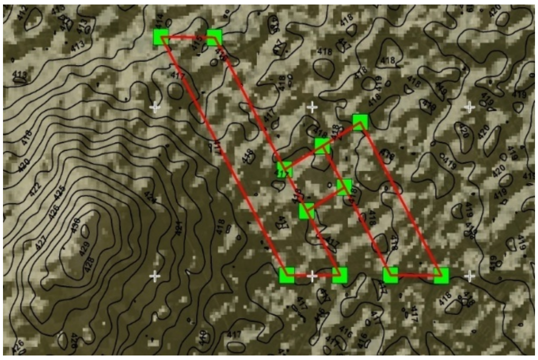


Figure 4b: Enlargement of Contour Map for the Study Area (1 m intervals) using SRTM elevation data (Source: DIU; Personal communications)



(Source: DIU; Personal communications)

Figure 5: Study Area Hill Shade Using (SRTM elevation data) demonstrating the topography of the area and surroundings



(Source: DIU; Personal communications)

Figure 6: Contour Map Superimposed on Hill Shade Using SRTM elevation data

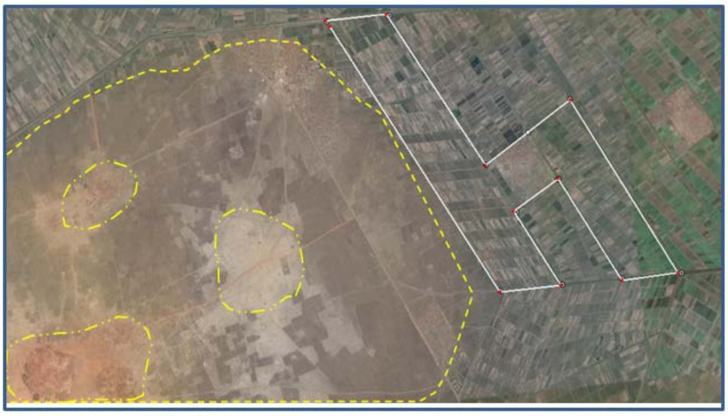


Figure 7: Visual Interpretation of Google Image showing High Landform Surrounding the Study Area from the West as shown in Hill Shade and Contour of SRTM

4 Conclusion and Recommendations

4.1 Conclusions

- The extensive spatial coverage, regular temporal coverage and reasonable cost of satellite imagery provide an opportunity to undertake routine natural resource monitoring. This can then contribute to efficient decision making in natural resource management. This was proved in this study since the use satellite images allow identification of high spot, their distribution and other physiographic features related to them.
- Remote sensing and GIS are time and cost–effective tools in characterization of land surface features and evaluation of land use land cover changes.
- GIS provides a great advantage to analyze multi-layers of geospatial and field quantitative data within a specific area like farm fields. The estimation of soil loss in farms and fields is a core capability of GIS. It does not only provide accurate results but also prove to be cost and time effective tool for analysis.
- The data available for this study was effectively employed for monitoring and mapping the prevailing land conditions in the study area. The hypothesis of this research that the ground observations and remote sensing data could be used to achieve reliable characterization of the high spot and land degradation proved to be correct.

4.2 Recommendations:

- Research efforts are highly needed to combine the newly emerging technologies including the remote sensing, GIS and GPS data with ground observed data to monitor and evaluate the landscape condition in the area especially in farm land areas where land use is expected to inflict some changes.
- Expand the use of the decision support tools like space technologies (GIS, RS and GPS) to plan for sustainable development and proper land management in the whole area of Rahad scheme.
- The integrated approach of remote sensing data from different sources Landsat, SRTM, GPS in addition to conventional field survey and GIS analysis could be followed and adopted to improve land management in the entire irrigated sector in Sudan.

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