بسم الله الرحمن الرحيم

Sudan University of Science and Technology

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Study of variations in sugarcane yield in Guneid scheme based on land evaluation system

دراسة تباين إنتاجية قصب السكر في مشروع الجنيد بناء على نظام تقييم الاراضي

By

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Dedication

This work is dedicated to my:

Mother, father and brothers,

Teachers, colleagues,

Friends,

And the people I love...

Acknowledgements

Praise is to Allah who gave me the health strength and patience to complete this study.

This study would not have been possible without moral, academic and moral support rendered from various institutions, individuals and friends.

I wish to express my sincere thanks to all who directly or indirectly contributed to the completion of this study.

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I would never forget all the chats and beautiful moments I shared with my friends and classmates. They were fundamental in supporting me during these stressful and difficult moments.

Finally, my deepest gratitude goes to my family for their unflagging love and unconditional support throughout my life and my studies. They have made me live the most unique, magic and carefree childhood that have made me who I am now!

Special thanks warmly go to my father A.E. Osama Mohamed Nour Ahmed, for supporting and helping me in this study, I am proud of you, dad.

المستخلص:

يقع مشروع سكر الجنيد جنوب شرق الخرطومعلى الضفة الشرقيةللنيلالأزرق بالقرب من رفاعة بمساحة 42,000فدان تقريبا (17640 هكتار)، ويمتد من الهلالية شمالا الى مدينة رفاعةجنوباً، ومن النيل الابيض غرباً الى تمبول شرقا. تم تخصيص هذا المشروع لزراعة قصب السكر وهو يعتبر من المشاريع الرائدة في مجال زراعة وتصنيع قصب السكربالسودان.

تم إجراء هذه الدراسة لمقارنة التقييم السابق لصلاحية التربة بانتاجية الارض حيث توفرت إحصائيات كافية عن الانتاجية فى كل قنوات المشروع مما يساهم في الادارة الفلاحية السليمة بهدف رفع الانتاجية مع المحافظة على الأرض. تم تقسيم المشروع الى قسمين شمالي وجنوبي وإختيار 8 قنوات تقع كل منها فى أحد وحدات التربة بالمشروع (وحدة التربة 14 ووحدة التربة 17) وذلك استنادا على خرائط التربة وخرائط الصلاحية. تم توفير ورصد احصائيات الانتاجية لعدد 12 موسم زراعي على التوالي من (2000-2013) لهذه القنوات المختارة. تم استخدام نظام المعلومات الجغرافية (GPS) لتحديد مواقع القنوات في خريطة صلاحية التربة.

بناءا على نتائج حصر التربة السابق بوجود نوعين مختلفين من التربة (الوحدة 14 و 17) بأقسام المشروع أوضحتالدراسة تفوّق الوحدة 14 على 17 بقلة محدداتها على نمو محصول قصب السكر. كما أكدت الدراسة بوضوح أن إنتاجية قصب السكر فى القنوات التى تقع فى وحدة التربة 14 تتفوق عن تلك التى تقع فى 17 الوحدة بمقدار(3-5 طن/فدان). كما أكدت الدراسة أن هنالك اختلاف فى الانتاجية لكل وحدة من وحدات التربة فى القسم الشمالى والجنوبى حيث ان الانتاجية فى وحدات التربة الجنوبية تفوق الشمالية. وبما أن وحدات التربة تتشابه صفاتها فى الاقسام المختلفة فسر الباحث اختلافات الإنتاج داخل وحدات التربة بإختلاف المعاملات الفلاحية بين القسم الجنوبى والشمالى. وفى هذا الشأن أكدت مشاهدات الزراعيين بالمشروع تفوق الإدارة الفلاحية فى القسم الجنوبى عن الشمالى مما يؤكد تفسيرات الباحث. إن الإختلافات الواضحة فى إنتاجية القنوات ذات وحدات التربة المختلفة يؤكد علاقة الانتاجية ومستواها بنوع وخواص التربة.

توصي هذه الدراسة بإستخدم نظام المعلومات الجغرافية (GIS) عند إجراء دراسات تقييم الاراضي المرتبطة بالانتاج لانه يمكّن من اخذ الانتاج من مناطق ذات تربة محددة وبالتالي يمكن تحديد درجات الصلاحية بدقة اكثر وتقديم توصيات فلاحية مناسبة.

Abstract

Guneid sugar Scheme is located South East of Khartoum on the eastern bank of the Blue Nile near Rufaa, with an estimated area of 42,000 feddans (17640 hectares) were stretching from Alhilia at North toRufaa cityat South, andTambul at East and Blue Nile at West. This scheme specified for sugarcane productionand it was consider as a pilot projects in cane productionand sugar industry in Sudan.

This study was to compare the previous land evaluation with the production, which will develop and participate in a good management. The scheme was divided into two main parts; Northern and Southern section which obtained (8) canals depend on the soil and suitability maps, as it has been provision of statistics and monitoring the yield data for 12 seasons from (2000-2013). GPS system is a program used to determine the canals locations based on the soil and suitability maps.

Based on the results of the previous soil survey the existence of two different types of soil (unit 14 and 17) sections of the project study showed superiority of the unit 14 to 17 lacks of limitations on the growth of the sugar cane crop. The study clearly confirmed that the sugar cane productivity in the channels which is located in Unit 14 soil excels for those in the unit by 17 (3-5 tons / fed). The study also confirmed that there is a difference in the productivity per unit of land in the north and the south, where the production units in north and south soil superiority. As the soil units are similar characteristics in different sections explained researcher differences within the production units for different types of agricultural soil transactions between the southern and northern section. In this regard it confirmed the views outweigh the farming agricultural project management in the southern section from the North, which confirms explanations researcher. The obvious differences in productivity of different soil units canals confirms the relationship and level of production and the type of properties

This studyrecommends the use ofgeographic information systems(GIS)when makingland evaluationstudiesrelated to productionbecause itcan betakenfrom theproductionofspecificareasofsoiland thus candetermine thesuitabilitydegreesmoreaccuratelyand make appropriaterecommendationsfarming.

LIST OF CONTENTS:

Glossary of Special Terms and Abbreviations:

dm^3	Volume unit equivalent to a liter (one cubic decimeter).
SSC	The Sudanese Sugar Company.
AAAID	Arab authority for agricultural investment and development.
SSMS	Site specific management systems.
Feddan	An area of land approximately equal to an acre. 1 Feddan = 1.038 Acre = 0.42 hectares.
IFC	the International Finance Corporation

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CHAPTER ONE

INTRODUCTION

1.1. Back ground:

Sugarcane belongs to the grass family (Poaceae), an economically important grain plant family that includes maize, wheat, rice, sorghum and many forage crops (Jannoo et al., 2007). It is one of the most important field crops in the tropics (Kwong and Ramasawmy Chellen, 2006).

Guneid Agricultural Irrigation Scheme (GAIS) in which this study was carried is Sudan's first experience in sugarcane (saccharum officinarum) cultivation. It lies on the eastern bank of the Blue Nile River north of Rufaa town, and the total area of scheme is about 37.500 feddan. The sugar processing plant, mounted with the help of the German technical aid, had its first production in 1962 (Idris, M.A.M., 1990; Ali, M.A., 1969). The consistent decline in sugarcane yields during the first season, has urged Sudan government to establish the Guneid agricultural Research substation in 1964. The main objectives were to establish cultural practices best suited for cane cultivation, introducing cane varieties and testing their suitability for Sudan environment. Before the establishment of Guneid scheme; the land was cultivated by cotton (1955-1962), and the Sugar cane since then (Ali, M.A.1969).

Soils of the Guneid area are similar to those of the Gezira on the western side of the Blue Nile. Most of the soils are dominantly dark brown with a contrasting gray layer at variable depths as is the case in Northern and Central Gezira. Such similarity in the soils was taken as a partial proof that Guneid soils were sometimes part of the Gezira clay plain, but now separated by the Blue Nile which was a later incised in the terrain (Idris, M.A.M., 1990).

During the late sixties, the Soil Survey Administration (SSA) conducted a semi-detailed soil survey on the scheme and its proposed extension with area of 46.700 feddans (Ali, M.A.1969).The study placed the soils of the scheme (Vertisols) into land capability subclass 11p (moderate agricultural land) due to adverse soil physical characteristics such as low available water holding capacity or slow permeability of subsoil according to the system developed by (Tahir and Robinson, 1969). The approximate equivalent using the presently used land suitability system (Kevie and El Tom 1987) is subclasses S2v (moderately suitable land due to Vertisolic limitation (v) as a result of the high content of swelling clay (Idris, M.A.M., 1990).

1.2. Problem definition:

The review of the limited research conducted at GAIS revealed that; the northern sector of the Guneid cane estate showed some low cane yielding problems. This sector which is at Wad Elfadul area contains 4 out of 26 canals in the scheme; namely Talha, Said, Abu Sugra and Wad Elfadul canals. Cane yield in these canals is comparatively lower than the other sectors in the scheme. There are always some questions both by the tenants and the scheme management regarding yield differences in these parts despite the apparent similarity of soils. Therefore, studying soil differences and yield variation constitute the core investigations of this research so as to find answers pertinent to the productivity of sugarcane at this part of the scheme.

1.3. Objectives:

The objectives of this study are to check the land evaluation of the Guneid scheme as followed:

1- To confirm the variation in the yield and soils at different parts of the scheme.
2- Check the existing land suitability unit against the produced soil map units.
3- Study the sugarcane yield relation to soil properties.
4- Advice on soil management practices.

CHAPTER TWO:

STUDY AREA

2. Environmental set Up:

2.1. Location and extent:

Guneid Sugar Cane Scheme and proposed extension lie on the eastern bank of the Blue Nile, and just north of Rufaa village. The area stretches along the river, roughly bounded by the following latitudes and longitudes: 33°19' – 33°27'E and 14°47'N in the south and 33°16' – 33°27'N and 15°-00' in the north. The total area of the scheme is about 15756 ha (37,500 fed) figure (1) is the location map showing the study area (Ali, M.A.1969, and Idris, M.A.M., 1990).

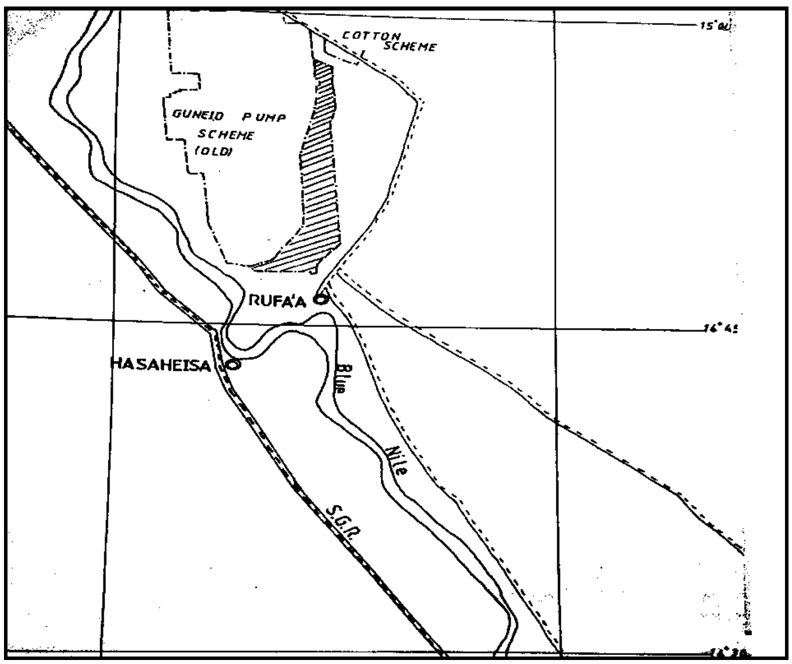

Figure (1): Guneid sugar scheme location map showing the study area (Abouna M.A., Ibrahim M.O., 2011).

2.2. Climate:

Guneid meteorological station has been selected to show the important climatic data and features of the scheme area. The scheme area falls within the aridic climatic zone with summer rain and warm winter (kevie, 1976). Maximum temperature of the hottest month (may or June) is 32.5 °C .The annual rainfall 266 mm is less than 44% of the annual potential evapotransporation (1994mm). There is one "intermediate" month (neither humid or dry) and the growing season per year (humid and intermediate months) hardly exceeds 2 months.

The relative humidity ranges from 27-60% during most of the year, but rises to 73% in august (humid month) (Idris M.A.M., 1990, and Ali M.A., 1969). The climate is hot and semi-arid. Winter months – November to March – are cool and dry. April and May are hot and dry; the predominant northerly winds cause dust storms. June to October are warm and rainy (Ali, M.A., 1969).

The world agro-ecological zone AEZ map rules out of possibility of producing sugarcane under rainfed conditions due to the very short growing season and therefore it is necessary to irrigate. The area lies within the semi-desert zone (Idris, M.A.M., 1990).

The highest humidity in this region occurs in August, when more than 35% of the annual rains fall. Humidity is lowest in March and April. It makes a sharp rise in May and June, and falls off after September. Slight rise in humidity recorded for December is probably due to the sharp decrease in daily temperature.

Table (1): Guneid important climatic data, covered period of 9 years (1961_ 70) extracted from Keive (1976), because the lack of data recently.

Month	**J**	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**
Mean temperature ºC	23	24	28	30	32.5	32.5	30	28	28	30	27.5	23.5
Mean rainfall mm.	0 (D)	0 (D)	0 (D)	TR (D)	5 (D)	17 (D)	75 (I)	105 (H)	41 (D)	22 (D)	0 (D)	0 (D)
Mean potential evapotranspo ration mm.	158	127	132	168	175	161	119	99	103	113	113	106

TR=traces; H=humid; I=intermediate; D= dry month.

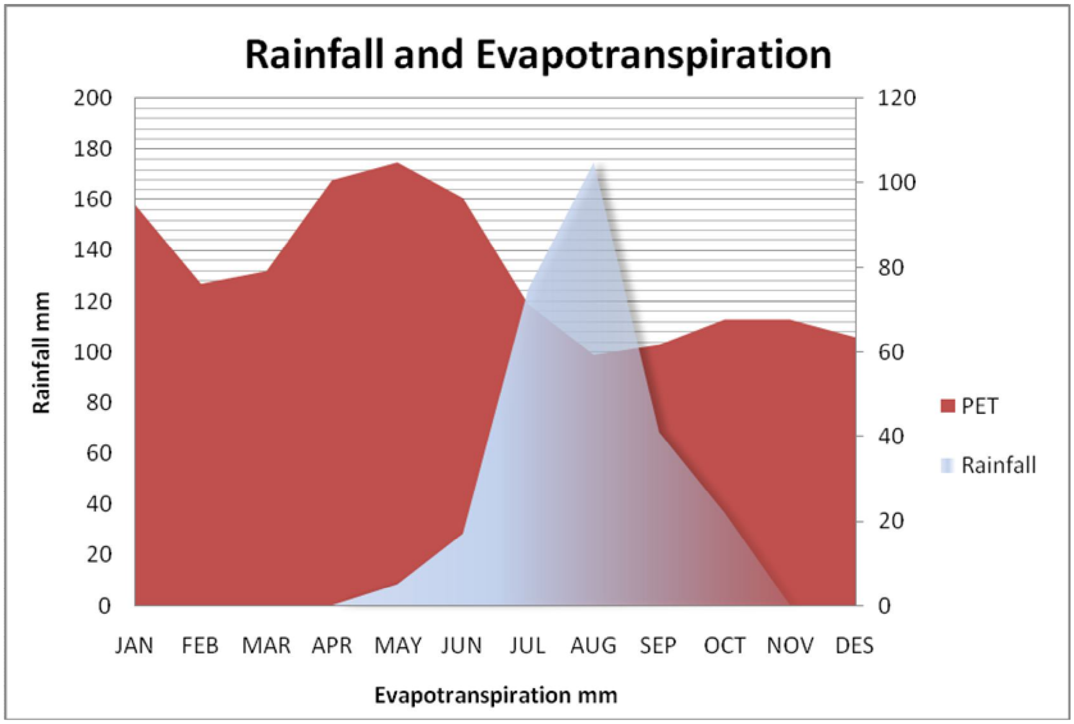

Figure (2): Guneid important climatic data.

Table (2): Guneid main climatic features:

Annual R. Mm	Annual PE mm	Mean annual T. °C	W.S Mm	Number of (H), (I) and (D) month	Length of G.S month
266	159.4	27.5	6	H=1	2
				I=1	
				D=10	

(Abouna M.A., Ibrahim M.O., 2011).

R= Rain fall; PE= potential evapotransporation; T=Temperature (°C); W.S=Water Surplus (R- PE); H=Humid, I= Intermediate, D= Dry; G.S= Growing Season; (H+ I months) (Abouna M.A., Ibrahim M.O., 2011)

2.3. Geomorphology:

The geological map of the Sudan at scale 1:2,000,000 featured the presence of the following geological formations in the scheme area (Whiteman, 1971):

- Gezeira formation
- Butana clays

The Gezeira formation consists of unconsolidated clays, silt, sand, and gravel. The upper part of the formation, the dark montomorillonitic clay, is probably of Pleistocene age and according to Whiteman 1971, older than 11,300 + 400 years BP. The whole Gezeira formation may well be both tertiary and Pleistocene in age and difficult to separate from the Um Ruaba and El Atshan formation. The Butana clays are considered to be part of a series of pediments developed on basement complex (Whiteman, 1971) forming the ‘’degradational clay plains” in Kassala province (kevie 1976).

Whiteman (1971) argued that the basement complex rocks form the structural platform on which all geological formations are deposits. They are former sediments and volcanic rocks that have been completely altered by high grade metamorphism, granitisation and intrusion by igneous rocks. They are assumed to be mainly of pre-Cambrian age although some formations may be younger. The elevation of the scheme area is about 500m. The general relief of the area is almost flat. Sites with relatively higher landscapes exist mainly in the northern part of the scheme. Here, control of gravity irrigation is obviously somewhat difficult (Idris M.A.M., 1990).

2.4 General properties of Guneid Soils:

Soils of the survey area are deep, dark brown, alkaline cracking clays. The profile is calcareous with dark gray fine to medium calcium carbonate nodules. In areas under irrigation moist surface colour was dark brown (10YR3/3) fields recently watered had brown colour of (10YR4/3) when a wet piece of soil was removed from a fresh face and directly compared with the Munsell colour chips. But after a short time when the water film disappeared, the colour turned dark brown (10YR3/3). Areas under rain cultivation (terus) had moist surface colour of very dark grayish brown to dark brown (10YR3/2.5). Such minor colour differences were not taken into consideration when mapping (Ali M.A., 1969).

Ali M.A., (1969) mentioned that; in the irrigated part of the survey, fields under crops did not show any cracks due to heavy watering. Uncultivated fields had shallow cracks of 40-50 cm 0f 2-3 cm width at the top. Soils of the proposed extension had cracks down to more than 90 cm. Surface "mulch" due to heavy machine ploughing and subsequent disintegration of the clods on drying was not taken into consideration. In the un-irrigated part of the survey area surface mulch was recognized and sampled. No structural differences were observed in these soils. Generally every profile showed all or most of the following structural zones:

(a) A hard weak fine to medium sub angular blocky structure in the top dark brown layer.
(b) The middle grayish brown layer is massive and tends to be slightly compacted.
(c) At depths of more than 1.5 meters a layer of very fine blocky structure exists. This layer has the best structure expressed as the grade is strong and peds are visible-broken surfaces of ped faces are darker than the interior. Consistence in all the soils examined was extremely hard in the dry condition and sticky when wet.

2.5. Vegetation:

The survey area lies in the semi-desert grassland of the clay plain. Uncultivated areas are covered with open grassland of *Aristida* sp, *Shenefoldia gracilis*. Trees, mainly Acacia tortilis, *Acacia seyal* and *Balanites aegyptiaca*, occur thinly spread. This vegetation is most probably a secondary community since grain sorghum cultivation by terus-is widely practiced and the original vegetation must have been removed (Ali M. A., 1969). The main species consist of *Acacia tortilis*, *Acacia seyal*, *and Balanites aegyptiaca* with a grass cover of *Aristida* spp. and *Shenefoldia* (Idris, M.A.M., 1990).

2.6. Land and human activity:

Before the establishment of Guneid scheme in 1955 (cotton 1955-1962, Sugar cane since then) the area was inhabited by villagers who grew rain-fed dura by "terus" cultivation method. They graze as well cattle and sheep freely and watered them at the Blue Nile, such villagers were mainly of the Shukria tribe. Nomads of the Rufaa Sharq, who keep camels, came far north in their summer migration. Most of the villagers were given tenancies when the scheme was established. The original rotation included dura, but on replacement of cotton by Sugar cane, it was excluded. Presently dura is brought from neighboring "terus" land, and partly imported from dura production centers (Ali M.A., 1969).

As the Sugar cane industry is engaging a large number of labourers, both permanent and casual – the population has soared in the scheme area. Many town amenities e.g. electricity, tap water, clinic etc. have been introduced. Tamboul famous of being an old animal market has benefited from its vicinity to the Sugar scheme and the new Guneid cotton Extension. Animal and animal product prices shot up due to the improved-income (Ali M.A., 1969).

2.7. Infrastructure:

The scheme is connected by dry weather roads with the neighboring villages, Hillalya and Rufaa towns. Rufaa town on the east side on the Nile River is connected to Khartoum also by dry weather roads. The ferry service connects the scheme with the Wad Madani –Khartoum asphalt road on the west side of the Blue Nile River. The domestic water supply for the study area is primarily the Blue Nile River and bore wells (Idris M.A.M., 1990).

CHAPTER THREE:
LITERATURE REVIEW

3.1 Introduction:

Sugar cane is one of the most agricultural crops in terms of economic returns and in addition to sugar production enjoyed it allows many by products such as molasses and its derivatives as well as feed and paper and cardboard industry. In Sudan, due to the integration of many factors, such as appropriate climate, fertile soils, labour and reasonable infrastructures, the sugar production started in 1962 with the establishment of the Guneid Sugar Factory in the Gezira Province. Later on five other sugar factories came into operation at New-Halfa in 1965–1966, North West Sennar in 1976–1977, Assalaya in 1980–1981, Kenana in1980 –1981, and finally White Nile Sugar Company in 2004 (Ganawa, E. and Awadalla F. A. (2010); and Ahmed, A.E. and Alam-Eldin, A.O.M.,2014).

Prior to the secession of the South Sudan, agriculture represents the main sector of the economy in Sudan. It contributes over 30% of the national gross product and more than 95% of the foreign trade (Bank of Sudan, 2010). Sugar is considered as one of the major strategic commodities in the country. Sugarcane production and industry are of growing importance since it is the world's major source of sucrose sugar. It is grown mainly in the tropics and subtropics between latitude 35 N and 35 S but it can also be grown under irrigation in dry lower latitudes. The yield and quality of cane tended to vary tremendously due to the variations in soil fertility, cultural practies and weather conditions (Yassin 1985).

Since the establishment of the first sugar factory in 1962; the domestic sugar industry has sustained steady growth and expansion. In addition to progressing on the knowledge and expertise accumulated over its 50 years history, the Sudan sugar industry is also advancing amid global technological developments in the fields of bio-energy: cogeneration and ethanol (Federal Ministry of Agriculture, 2010).

(Ministry of Investment 2003), reported that Sudan has a relatively advantageous distinction of having all the desired factors of sugar cane production, in addition to low production costs compared to international prices. This advantageous circumstance provides great opportunities for further investments in the field of sugar industry, these include**:**

1- The establishment of small plantations for sugar cane and sugar beet in the various provinces, and the establishment of small sugar factories for the production of brown sugar (Guggary),

2- The establishment of big farms for sugar cane and big factories for the production of sugar for export.

3- The promotion of manufacturing by-products from sugar refining, such as syrups and glucose, the establishment of factories for manufacturing other by products, using the residuals of sugar cane. These by products include: Synthetic alcohol and spirit (combined with benzene) as a fuel, Bakers' and fodder yeast, Chemical products such as acetic and citric acids… etc., and Animal fodder.

3.2. Guneid sugarcane scheme:

The agricultural area of Guneid scheme was a part of Al-Gazera scheme and has been planted with cotton. The land later was allotted for growing sugarcane, and the factory buys sugarcane from the farmers. This arrangement increased the farmer’s income by the participation of all family members in the agricultural process. The level of education in the Guneid is very high because it’s near to the Rufaa city and Khartoum, and it’s like the other sugar projects in Sudan, concerned with security, health and educational aspects, regarding the children of workers and employees. Several residential neighborhoods have been established, including the popular housing and the homes of solidarity, Asphalt road Khartoum-Madani east, and recently transformative power station. And after the establishment of the factory there was a significant urban development (personal communication- Osama M. N. 2015).

Agricultural management operations includes land preparation, selection of seeds, whether imported or domestic and deported, irrigation (usually 36 times during the season), applying fertilizers and pesticides operations and remove weeds manually or chemically, spraying the inhibitor of flowers by the planes, because the flowering was reduces the amount of sugar in the plant. The farmers were following the agricultural rotation by planting vegetables, leguminous and other crops. Canes are drying for 25 days in summer and 35 days in the winter according to the factors that affected on humidity. The canes relay to the factory to extract the juice and sugar. The yield since the establishment of the factory was low about (16-17 tons /fed.) has reached to (40-45 tons/fed.) recently. The quality of the cane is measured by the amount of sugar quantity. Productivity usually be high in the first planting (PC 70 tons / acre) and it was reduce according to the type of ratoon (45 in 1st ratoon, 40 in 2nd ratoon and 30 for 3rd ratoon). The main product of the factory is sugar; it is also produce molasses and bagasse (personal communication- Osama M. N. 2015)

3.2.1. Soil characterization and research in Guneid scheme:

Soils of Guneid scheme have profile characteristics such as horizon sequence, texture, EC, ESP, similar to those of parts of Gezira (Central Gezira).This means that soils of Guneid were formed of the same origin and under the same conditions as soils of the Gezira and that the Blue Nile was a later incision in flat plain .In the Gezira dark gray soils (10YR4/1) were mapped in extensive areas of shallow trough. Such soils were more subject to pudding than the dark brown or dark grayish brown soils of Guneid and Gezira. They are of lower quality for irrigated agriculture. No such soils were mapped at Guneid (Ali M.A., 1969).

Soils of the Guneid scheme generally do not show any salinity or sodicity levels that are higher than comparable soils of Central and Northern Gezira. Areas already under cultivation in sugar cane scheme with soils of E.C. about 4 mmohs/cm within 90 cm (unit 14 (t) but receive adequate watering, are giving comparatively good yields. Poorer yields in soils of the same unit are due to low standard management, mainly weeding and inadequate watering. The probable soil characteristics that are affecting the cane in such soils are E.C. of 3.5 and more and the hard compact layer when they occur within 90 cm of the surface. With such comparatively high salinity and inadequate and infrequent watering the osmatic relations between the soil solution and plant roots will be unfavorable to the healthy growth of the cane crop. Ploughing in the compact layer is important (Ali M.A., 1969).

Soils of the proposed extension are primarily of the two kinds (98% of the area) that occur in the irrigated scheme i.e. map units 14 and 17 (subclass IIp). Some parts of these soils have surface mulch that is associated with coarse and sand gravel. Soils with such surface occur in the irrigated part also, but the plants did not show any difference from those on neighboring soils with no coarse fragments at the top. It is recommended that all soils of the extension area be developed for cane production by irrigation. One basic requirement will be proper water management. The present interval of water application (every 12 and 14 days) seems too long. More frequent application e.g. every 7-9 days, with probably less water applied at a time seems to be a partial remedy to the present low yields in comparison to other parts of the country e.g. Khashm El Girba. At Khashm El Girba although the watering frequency is about the same, the salinity levels are less and occur lower down the profile than at Guneid (Ali M.A., 1969).

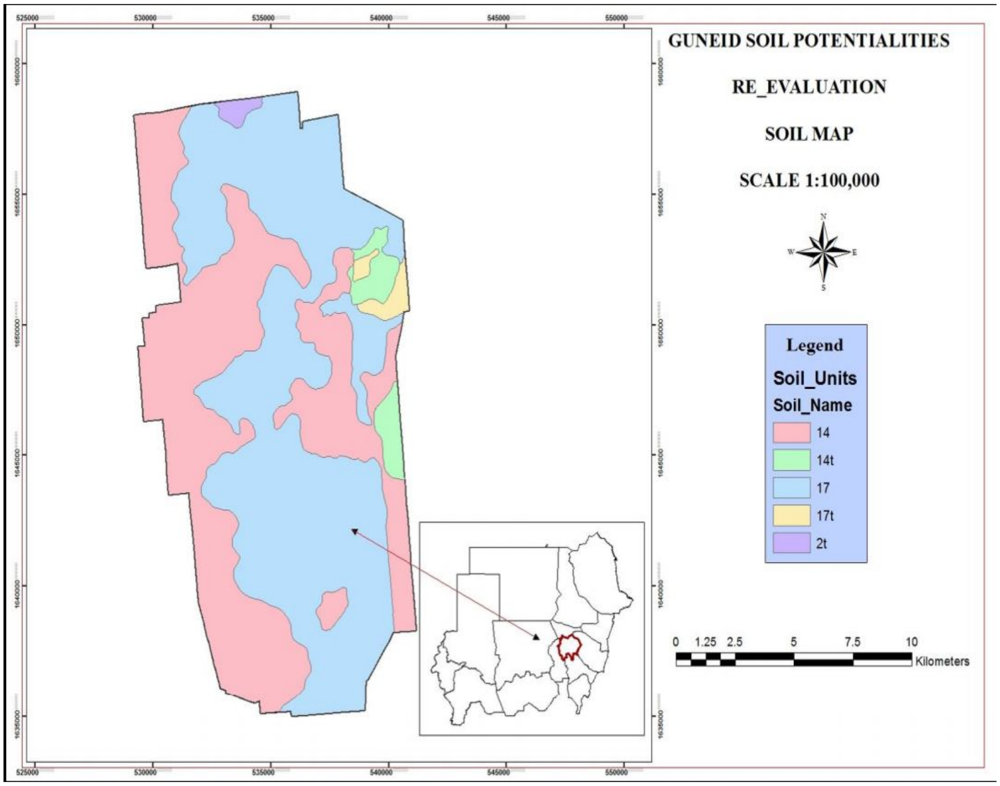

Figure (3): Guneid soil potentialities (Idris M.A.M., 1990)..

Table (3): Guneid sugar scheme mapping unit areas:

section	Canals	Total area (ha)	Map unit areas (ha)		Map unit (%)	
			14	17	14	17
Northern	Talha	890.67	424.37	466.38	47.64	52.36
	Said	907.14	302.52	604.62	33.35	66.65
	Abu sugra	906.72	256.30	650.42	28.27	71.73
	Wad alfadul	840.34	235.29	510.50	60.75	39.25
midmost	Ganomab	603.78	444.12	159.66	73.36	26.64
	Jagogab	876.05	659.66	216.39	75.53	24.47
	Sheikh abdalla	941.18	623.95	317.33	66.63	33.37
	Zurug	945.38	376.05	569.33	39.78	60.22
	Higelieg	556.72	329.83	226.89	59.25	40.75
southern	Adham	836.13	258.40	577.72	30.90	69.10
	Abusin	642.44	69.33	573.11	10.79	89.21
	Gad Elrub	567.23	10.50	556.73	1.85	98.15
	Abushara	566.81	10.50	556.31	1.85	98.15
	wad surur	488.45	286.76	201.69	58.71	41.29
	Alabas	926.26	926.26	-	100	-
	Alfirai	274.16	225.84	48.32	93.32	6.68
	alganabia	159.24	159.24	-	-	-
South eastern	Minor1	371.01	10.50	360.51	2.83	97.17
	Minor2	397.48	88.45	309.03	22.25	77.75
	Minor3	344.01	27.31	316.70	7.94	92.06
	Minor5	264.18	12.61	251.57	4.77	95.23
	Minor6	264.71	-	264.71	-	100
	Minor7	361.34	141.81	219.53	39.25	60.75
	Minor8	837.81	306.71	531.09	36.61	63.39
	Tambul	1146.55	344.12	732.43	30.28	69.22

(Abouna M.A., Ibrahim M.O., 2011)

Table (4): Quantitative paired comparisons between mapping units 14 and 17 (soil analysis):

Soil characteristics	M.U.14	M.U.17	C
Clay %	52	55	+3(a; d)
Silt: clay ration	0.55	0.54	-0.01(d)*
(1)Moisture % (pw)	15	14.5	-0.5(d)
Saturation % (sp)	90	91	+1(a)
Hydraulic conductivity (H.C.) cm/hr.	1.04	0.64	-0.40(d)
Final infiltration rate cm / r	0.97	0.6	-0.37
Water holding capacity (AWC) cm	8	7	-1(d)
Index of structure (TS)	92	90.5	-1.5(d)
Coefficient o linear extensibility (COLE)	0.30	0.30	+0.10(d)
Dry bulk density (BD) gm / cm	1.8	1.8	0
pH- paste	8.1	7.6	-0.5(a)*
Organic carbon *	0.431	0.491	+0.060(a)*
Organic matter	0.741	0.845	+0.104(a)
Nitrogen	0.040	0.035	-0.010(d)*
C/N Ratio	10.77	14	+3.23(d)*
Available P p.p.m	3.77	3.18	-5.59(d)
Mobile-K meq / 100g soil	2.14	2.05	-0.09(d)
Exchangeable K meq / 100g soil	0.62	0.65	+0.03(a)
Exchangeable Na meq / 100g soil	10.73	8.30	-2.43(a)
Exchangeable (Ca + Mg meq / 100g soil)	88.65	91.05	+2.40(a)
Soil CEC, meq / 100g soil	58	61.5	+3.5(a)
Exchangeable Zn ppm	1.19	1.02	-0.17(d)
Cu ppm	1.23	1.05	-0.18(d)
Fe ppm	14.88	13.42	-1.48(d)
Mn ppm	7.34	4.69	-2.65(d)
ECe mmho /cm	4.24	3.52	-0.72(d)
Esp	18.5	13.5	-5(a)*
Ca Co3 % < 2mm	5.58	3.90	-1.68(a)
Chloride (Cl – H_2O) meq / L .	1.8	1.0	-0.8(d)
Sulphates (SO4 – H_2O) meq / L .	4.7	2.6	-2.1(d)

(Idris, M. A.M 1990)

* Significant at 5% level. Documented by
(a) Relative advantages.
(d) Relative disadvantages.

3.3. Sugarcane production:

Sugarcane belongs to the grass family (Poaceae), an economically important grain plant family that includes maize, wheat, rice, sorghum and many forage crops (Jannoo *et al.*, 2007).It is one of the most important field crops in the tropics (Kwong and Ramasawmy Chellen, 2006). Perennial tropical or subtropical grass are widely grown in a zone around the world within 30º of Equator (Ming *et al.,* 2006).

S. officinarum L. is generally known as the noble cane because it is stout and produces abundant sweet juice. Culms are thick (normally over 3.5 cm in diameter) and soft due to low fiber content. Successions of this species display long, wide leaf blades (1 m long×5 cm wide) and a relatively small, shallow root system (Scarpari MS, Beauclair EGF 2008). S. officinarum is highly demanding in specific climate conditions, high soil fertility and water supply .S. officinarum accessions are generally susceptible to diseases such as mosaic, gummosis, leaf scorch, root rot and Fiji disease (Martin JP 1961; Ricaud C, Autrey LJC 1989; Ricaud C, Ryan CC 1989), but they tend to be resistant to sugarcane smut (Segalla AL 1964). S. officinarum includes all old traditional sugarcane varieties that were cultivated throughout the world prior to the introduction of hybrid varieties (Segalla AL 1964).

Sugar cane is widely cultivated around the world within tropical climate and humid regions thereby optimizing photosynthesis (Lapola et al., 2009). It is cultivated on about 13 – 15 million hectares of land globally (Delgado *et al,* 2001). Sugarcane is highly efficient at converting sunlight into sugars. Brazil, India and China are its major producers. Cane is mainly seen as solely a source of sugar but it is also an important source of bio fuel in addition, leading to a constant increase in its global demand. Lapola et al 2009 claim that besides producing sugar for human consumption, India produces 11 dm^3 of ethanol produced from sugar cane, with the Indian Government's aim to achieve 75 dm^3 by 2015. Sugarcane grows within a long period of time ranging across multiple seasons. It is therefore cultivated around the world from warm to humid regions (Carr *et al.*, 2010). In order to model land suitability for sugar cane. Rasheed et al. 2009 stated that it is important to evaluate the soil in a given area for particular crop production under specific management system.

The Sudanese Sugar Company (SSC) had a very productive 2006/2007 season with remarkably high scores of cane and sugar yields. The average cane yield of the company's four sugar estates was 42.3 tons per feddan (100.7 tons per hectare). The total sugar yield was 352000 tons averaging 4.07 tons per feddan (9.69 tons per hectare). As part of the company's action plan and integrating with its endeavour to be more competent and sustainable, the Sugarcane Research Center at Guneid continued to run research work involving various disciplines such as crop improvement where more foreign varieties were introduced from Barbados and CIRAD – France. Most of those varieties were included in the replicated yield tests and/or utilized as parental lines at the museum plots of Sennar Breeding Station. The breeding and selection program is tailored to provide the industry with continues flow of outstanding varieties that have the ability to share some of the cultivated area occupied mostly by variety Co 6806 (Obeid, A. 2006).

It is usually vegetatively propagated from auxiliary buds on the stem (or stalk) cuttings. The first, "plant" crop is generally harvested from 12 to 24 Months after planting; thereafter, "ratoon" crops may be harvested at shorter to equal time periods. Ratoon crops may be grown in several cycles. The large, mature stalks contain juice of 9 to 18% sucrose. The juice is extracted by crushing the stalks with high-pressure rollers in a mill. Sucrose is crystallized from the juice after water is removed by boiling to produce a brown-colored raw sugar. White sugar is produced by re-crystallization from raw sugar in a refinery (Ming *et al*., 2006). The main sugarcane growing countries include: India, Brazil, Cuba, Australia and Mexico (Ali, 1986).

In spite of the expansion of cane cultivation in Sudan, yield per unit area and the sucrose content are well below those obtained elsewhere. High yield and sucrose content, which are considered the major objectives of sugarcane growers, are controlled by the cultural practices that vary widely and must be adapted to the local conditions, especially fertilization. The use of nitrogen, phosphorous and potassium fertilizers play an important role in increasing cane and sugar yields, because sugar cane is known as a heavy feeder crop that depletes the soil of essential nutrients and therefore, adequate nutrient addition is of utmost importance (Korndorfer, 1990). Therefore, it is necessary to supply sugarcane crop with the big three (N,P,and K) to secure good cane quantity and quality. Fertilizetion of cane fields in sudan was geared towards using nitrogen fertilizers and phophorous to small extent. Very meager research work was assigned for theresponce of cane to the added phosphorous and potassium fertilizers (El-Tilib *et al.,* 2004).

Sugarcane being a giant crop producing huge quantity of biomass generally demands higher amounts of nutrient elements (Moberly, P. and Meyer, J.H. 1984). A large number of research experiments have clearly demonstrated that for producing higher cane and sugar yields on a sustainable basis, the application of adequate amounts of fertilizer nutrients viz. nitrogen, phosphorous and potassium is essential. Sugarcane is a high bio-mass producer in a sense that it is one of the most photo-synthetically efficient C4 plants. Bakker, M. 1999 reported that sugarcane can remove about 300 kg nitrogen / ha/ season from the soil (126 Kg nitrogen/feddan/season).

3.3.1. Sugarcane and its environment:

Sugarcane, Saccharum spp, is a strongly growing grass with a C4 carbon cycle photosynthetic pathway and a high chromosome number. It is highly adapted to a wide range of tropical and subtropical climates. The sugarcane production cycle typically lasts five to six years in most countries, during which time four to five harvests are made, but under irrigation and with the right cultivar, the cycle can be extended to over 30 harvests, as is the case with some growers in Swaziland. There can be little doubt that as a source of food and renewable energy, and supplier of income to millions of people, occupying more than 20 million hectares of land, sugarcane must rank amongst the top agricultural crops in the world. For potential entrepreneurs, entry into the sugar industry becomes more difficult because young aspiring farmers are attracted to more 'rewarding' industries, causing the number of farmers to decrease whilst the average age of growers is increasing, as evidenced in the Australian industry (Jan Meyer, 2011).

3.3.2. Soils of sugarcane:

Moberly P. K. and Meyer J. H. (1984) ;The soils of the sugar industry differ substantially in their physical and chemical characteristics and one of the main reasons for developing a soil classification system is to enable farming areas to be mapped according to their land use capabilities so that appropriate agronomic practices can be followed. Soils of the sugarcane Estates Farms lay within the Central Clay Plain of Sudan. These soils are calcareous with high pH known to be deficient N, P, Mn, Zn; Cu. Levels of Zn & Cu are very low 0.5 & 0.1 ppm respectively (Elhagwa, 2000). Addition of these elements as foliar spray may results in improving the gain of the sugarcane crop from other nutrients especially N which is lacking response for high rates (Ali 2003, Elhag *et.al* 2007).

3.3.3. Agronomic Practices:

3.3.3.1. Land preparation and soil conservation:

Cane fields are most vulnerable to soil erosion when they are ploughed and fallowed before replanting and before the plant crop has formed a complete leaf canopy. The highly erodible soils which are usually also very shallow are particularly vulnerable, but there are ways in which this potential hazard can be averted. It has been shown that deep tillage of soil when preparing land for planting is unnecessary in most soils of the Natal sugar belt (Moberly, P. K. 1972). On highly erodible and poorly drained soils such as those of the Long lands form, the minimum tillage system, in which Round up is used to kill the old crop, results in minimal soil erosion and improved cane yield when compared with the conventional system of preparing land (Moberly, P. K. and Meyer, J. H. 1978). In Mauritius, McIntyre, G., *et al* 1983 showed that cane yields increased where minimum tillage was practiced in four trials on sloping land. Yield increases in subsequent ratoon crops have also been recorded in Natal and Mauritius. Soil which is lost through erosion cannot be replaced so every technique of preventing erosion should be employed. Minimum tillage is therefore recommended for erodible soils and sloping fields in the rainfed regions of the sugar industry. Soil form is undoubtedly the main factor determining the erodibility of soil, a characteristic which can be changed radically by mechanical operations.

3.3.3.2. Stool eradication:

The importance of fields being free of volunteers at planting is well known but the methods of eradicating the old crop are not always effective and are affected by the type of soil. Eradicating the old crop with chemicals is effective only when treatment is applied to actively growing cane. Hence mechanical methods should be used during the dry winter months. In trials conducted by Dicks, E. N., *et al*, (1981) a shallow mould board ploughing followed by a disc blowing or power harrowing was the most effective method of eradicating stools in a clay loam soil, and in a very sandy soil, a rotary hoe operating at a shallow depth was the most effective equipment. Where chemical eradication of the old crop is considered to be too expensive and where labour is available, growers have resorted to hand hoeing or chipping which is very effective. Depending on the type of soil the operation requires between 30 and 50 labourers per hectare and as far as soil and water conservation is concerned this system is considerably superior to conventional ploughing but is not as effective as chemicals.

3.3.3.3. Tilth and timing of seedbed preparation:

With conventional land preparation the ease with which a good tilth may be obtained, and therefore the timing of the operation, is to a large extent dependent on soil type. For example good tilth is not easy to achieve in the black and red structured clays because they have a plastic consistency when wet and are hard and cloddy when dry. They can therefore only be satisfactorily worked over a narrow moisture range, usually in spring under rainfed conditions. The consistency of the brown humic soils is not as sensitive to moisture change and these soils can be worked at almost any time of the year. The final tilth preparation should be done only a day or two before planting. There is no need to prepare tilth deeper than 150 mm.

3.3.3.4. Trash management:

Soil type is one of many factors which influence the growth response of cane to a trash blanket. The soils which need the protection of a trash blanket most are the highly erodible, grey sandy loams on sloping ground. Experiments have shown that there is about a 6 ton yield response per hectare per annum to a trash blanket on these soils (Moberly, P. K. and McIntyre, R. K. 1983) which is less than the average response of 9 tons per hectare per annum obtained from a cross-section of soils (Thompson, G. D. 1977). Where burning is inevitable, the recommendation is that the burnt tops be scattered as they provide a layer of mulch which protects the soil. In experiments conducted in the field, it was shown that scattering the tops was about 60% as effective as a full trash blanket in increasing cane yields (Moberly, P. K. and McIntyre, R. K. 1983).

3.3.4. Harvesting of Sugarcane:

Harvesting and hauling sugarcane is massive task. Across Kenana, Assalaya, Sennar, New Halfa and Guneid schemes, sugarcane production is more than 7.5 million Tons and required hauling for 200 days of a year and distances ranging from 5 to 25 km to factory for each trip. Furthermore, harvesting and hauling efficiency is very important. Furthermore, harvesting and hauling efficiency is very important because sugar quality and content reduces over time taken between harvesting the sugarcane and getting it to the factory should be less than 16 hours. Consequently, sugarcane trucks management for hauling was very difficult, because they faced many managerial problems (Kheiralla A.F. *et al*.2008).

The harvesting season in Guneid scheme usually extends from about November to May (Abouna M.A., Ibrahim M.O., 2011). If it lasts longer it includes some of the wet summer months when there is the danger of infield traffic causing soil compaction. Maud, R.R. (1960) showed that the tendency of most sugar belt soils to become compacted is greatest when their moisture content is near field capacity. In Brazil, sugarcane can be harvested manually or mechanically. Almost all manually harvested sugarcane fields are burned before manual harvesting to reduce harvesting costs and labor, mechanically harvested sugarcane fields can be either burned or unburned (Jeongwoo *et al.,* 2012). The fraction of mechanically harvested fields that are unburned is rising along with the total share of fields that are unburned and it is expected that all mechanically harvested fields will be unburned in the near future (Macedo *et al.,* 2008).

3.3.5. The products after sugar milling:

Mill ash, mill mud and bagasse are produced during the sugar milling process. These products have usually been disposed off by distributing them on farm lands most often surrounding cane fields. Mill ash and mud are sometimes regarded as waste products, although they have long been recognized as having desirable properties as soil ameliorants and hence considered as source of plant nutrients. Traditionally, these by – products have been applied more often as soil ameliorant than as substitutes for commercial fertilizers. Their application has been made to improve the quality of salt affected soils, (Chapman, 1996).Cane growers use mill ash as a soil ameliorant for sodic soils. Applying mill ash and mill mud improves the structure, water holding capacity and aeration of the problematic soil (Chapman, 1996 and Kingston *et al.*, 1999).

3.3.5.1. Bugass

Are used in furnaces to produce the following:

1- Gas for industrial purposes.
2- Generation of electric power.
3- Production of solvents and other chemicals.
4- Paper pulp and pressed wood.
5- The production of organic fertilizer and animal fodder.

Abouna M. A. 2006, applied this material to the surface of the leveled soil, furrowed and then planted. However, the experiment should be continued in 2007/2008 by broadcasting materials on the plowed soil, before harrowing, leveling and furrowing and planting. This process increases the chance of making use of as much as possible of the soil amending materials.

3.3.5.2. Molasses:

It is currently produced in quantities too small to warrant further use. However, by-product output will increase continually with sugar production, and current cane conversion rates suggest annual molasses production will reach more than 300,000 metric tons. Efficient utilization of this by-product can contribute to increased profitability and viability of the sugar refinery sector, increased income for cane producers, and further development of the agro-industrial sector and seasonal off-farm employment opportunities (EL-Tohami, A, M, 1983).

Industrial uses for molasses:

Two potential applications for industrial use of molasses exist in the Sudan the production of alcohol and the incorporation of molasses into animal feed production. Alcohol would be used mainly for gasohol, since the market for alcohol in Sudan is small. The technology to produce alcohol is well known from extensive experience in other countries, such as Brazil and the United States. The animal feed industry is new in Sudan, but good results have been reported with feeding concentrates to dairy heifers at the Kuku Milk Plant, one of the largest milk production plants in Sudan. Molasses will allow a reduction in the carbohydrate portion of the ration since molasses is a partial substitute for sorghum, the main source of energy in the ration formula. Experimental results show that the cost of rations can be reduced by 25 percent per liter of milk for local consumers and the quality of meat exported can be improved considerably (EL-Tohami, A, M, 1983).

3.3.5.3. Alcohol Production:

About 200,000 tons of molasses is produced annually as a by-product of the sugar refining industry. The exportation of molasses is often unprofitable and unpredictable due to the cost of storage in both the sugar factories and the seaports, the frequent unavailability of gasoline for molasses transport, the high cost of internal transportation, the taxes and duties levied on exported molasses, and the continuous fluctuations in world prices of molasses (EL-Tohami, A, M, 1983).

3.3.6. Management Practices of sugarcane land:

Sugarcane cultivation, particularly when grown as a continuous monoculture, can contribute to soil degradation and yield decline (Henry 1995, Meyer 1995, Haynes and Hamilton, 1999). It is the use of intensive agricultural practices such as ripping and deep ploughing, over-fertilization, no recycling of organic residues, no legume breaks, uncontrolled field traffic that lead to soil compaction, which in general represents a threat to soils in tropical areas (Meyer and van Antwerpen 2001). Sugar production varies from year to year depending on the vagaries of climate but on average approximately 520,000 tones are produced annually. Though climate and edaphic factors are conductive to good sugarcane growth in Mauritius, the success of sugarcane production on the island can to a large extent be attributed to the adoption of good crop management practices (Ng Kee Kwong and Deville, 1987; 1992) including those that meet the nutrient needs of the crop.

Soil quality is a complex concept, involving a wide range of biological, chemical and physical variables. Haynes 1997, considers that soil quality can be broadly defined as, “the sustained capability of a soil to accept, store and recycle nutrients and water, maintain economic yields and maintain environmental quality.” Soil quality has been shown in studies in South Africa and elsewhere to be adversely affected by the wrong management practices. Dominy *et al* 2001, In his paper covering the of paired site survey of virgin and adjoining land, reductions in soil organic matter, increased acidification, compaction and sometimes increased salinity were all found in cultivated fields compared to the adjoining virgin sites.

Meyer *et al* 1996, carried out a review of soil degradation and management research under intensive sugarcane cropping, soil factors limiting yield potential that were identified for the grey soil group, were low intake rates due to crusting, soil loss through erosion, low available moisture capacity, soil organic matter loss, acidification and water logging during wet seasons. A number of ratoon management practices currently in use, such as inter row ripping, burning of crop residues at harvest, harvesting under wet conditions and using heavy infield transport, were found to be incompatible with the physical, chemical and biological properties of these soils.

Practices that conserve soil organic matter such as green manuring, minimum tillage, the use of organic nutrient carriers such as filter cake, chicken and cattle manure, and trashing of cane at harvest have greatly increased in the industry as there is a need to sustain the all important functions of the soil food web by maintaining soil humus. Fertilizer management is an important agronomic practice in sugarcane production. Sugarcane producers relay on field fertilizer trials, soil testing and foliar analysis to plan fertilizer programs (van Antwerpen *et al* 2003, and Kingston *et al* 2005).

Leaf analysis provides a picture of crop nutritional status at the time of sampling, while soil testing provides information about the continued supply of nutrients from the soil. For sugarcane leaf analysis, the top visible dewlap (TVD) leaf blade is sampled during the grand growth period (Evans 1956; Gascho and Elwali 1978; McCray *et al*., 2006). According to Holford (1968) yields of sugar cane is highly correlated with leaf nutrient status during the maximum growth period indicating that leaf analysis allows early detection of nutritional problems. Plant analysis could also be a useful tool for correcting plant nutrient deficiencies and imbalances (Baldock and Schulte, 1996), and optimize crop production (Walworth *et al*., 1986), through evaluation of fertilizer requirements.

3.3.7. The impacts of sugarcane production on the environment:

Given that large tracts of land are cropped to sugarcane, mostly as a monoculture, intensive use of agricultural chemicals such as fertilizer, herbicides and ripening materials, coupled with greater reliance on heavier mechanical harvesters and infield haulage equipment, it is not surprising that sugarcane production continues to raise concerns about environmental impact issues and sustainability. Sugarcane is listed as one of four crops to be investigated in terms of its impact on biodiversity as part of the IFC's Biodiversity Agricultural Commodities Program (BACP). It is also widely acknowledged that commercial agriculture has the potential to impose severe hydrological, soil degradation and biodiversity impacts on the natural environment (Clay 2004). According to Gopinathan and Sudhakaran (2009), a degraded environment truncates the set of livelihood strategies available to the poorest people and undermines economic growth, particularly where legislation is weak or inadequately enforced. Although many scientific papers have reported on the impacts of sugarcane production, separately on soil loss, soil degradation and water pollution, an excellent more recent publication by Cheesman (2004) has reviewed the work more holistically, in terms of the whole range of impacts, including biodiversity, water use and quality, soil quality and air quality. While the impacts of different practices are considered under each of the chapters in this manual, some selected examples of impacts and measures to mitigate these impacts are summarized below.

3.3.7.1 Biodiversity loss:

3.3.7.1.1. Loss of natural habitat:

The process by which natural ecosystems of endemic tropical and sub tropical plants are cleared and then replaced by artificial ones, such as sugarcane grown as a monoculture, has destroyed much of the natural flora, fauna and soil biota biodiversity , that formed part of the previous ecosystem. In terms of social impact , this loss in habitat in turn would have undermined the lives, livelihoods and cultures of peoples who previously used the ecosystems for hunting, gathering, grazing or shifting cultivation (Jan Meyer 2011).

3.3.7.1.2. Habitat fragmentation:

In Australia, Arthington *et al.* (1997), in a study on the potential impact of sugarcane production on riparian and freshwater environments, concluded that sugarcane cultivation may interfere with and modify the functional linkages between vegetated riparian zones, the surrounding land, streams, riverine flood plains and the adjacent marine environment. They highlighted three consequences of sugarcane production that have been particularly detrimental in coastal catchments as (i) extensive vegetation clearing of riparian zones of rivers and flood plain wetlands, (ii) soil erosion and stream sedimentation and (iii) contamination of water bodies with nutrients, pesticides and other discharges from diffuse sources. A report by Johnson *et al.* (1997) using a Geographic Information System (GIS) to compare the distribution of vegetation species between the 1960 and 1996, concluded that sugarcane lands have increased and that landscape diversity, integrity and quality of these ecosystems have declined.

3.3.7.1.3. The impacts of monoculture on diversity:

Sugarcane cultivation, particularly under continuous mono cropping, can have a serious impact on biodiversity by building up harmful species of organisms. The yield decline syndrome project in the Australian sugar industry was initially linked to a root pathogen called Pachymetrachaunorhiza. Cultivars that were found to be resistant to this pathogen led to yield increases of up to 40 % (Egan *et al.* 1984). Subsequent intensive studies highlighted the importance of a legume fallow, reduced tillage, green cane harvesting, and controlled infield traffic in improving soil health, especially in providing a balanced population of soil biota (Garside and Bell 2006).

3.3.7.2. Soil loss impacts:

Where planting and production practices take place under conditions of high rainfall and steep terrain, the potential for soil loss through erosion and loss of nutrients is high, as well as the loss of diverse communities of soil organisms, and material that is washed away into rivers to damage (Jan Meyer 2011).

3.3.7.3. Soil degradation:

The soil is a living, dynamic system made up of different mineral particles, organic matter and a extremely diverse community of living and interacting microorganisms that is referred to as the soil ecosystem or the soil food web. Soil not only provides mankind with food and renewable energy sources, but also produces living space and food for billions of microorganisms. Conservation of this ecosystem is seen as vital for maintaining the physical, chemical and biological integrity of the soil and the sustainable cultivation of sugar crops (Morgan (1986); Meyer and Wood (2000).

3.3.7.4. CO_2 sequestration:

Sugarcane's high efficiency in fixing CO_2 into carbohydrates for conversion into fuel has awakened the world's interest in the crop. Emerging data indicates that sugarcane could be the best crop for the production of renewable energy, which could reduce some effects of global warming caused by the use of fossil fuels (Buckeridge M., 2007). The impact of sugarcane on the environment might be reduced by adopting environmentally friendly agricultural practices such as the elimination of burning before harvest, modifying other practices for a reduction in diesel-driven transportation and a reduction in the use of oil-based fertilizers (Ometto A.R. *et al*., 2005).

3.3.7.5. Air quality impacts:

Impact of burning: The cultivation of cane can result in air pollution where the crop is burnt prior to harvesting. Many industries have established codes of burning practice to limit the nuisance value and danger o f smoke on highways (Jan Meyer 2011).

3.3.7.6. Agricultural impacts:

Environmental impacts of production practices can largely be reduced by the adoption of general good management practices. In the case of agriculture this might involve the adoption of alternative cultivation systems (e.g. Integrated or precision methods) that provide more efficient use of chemicals, and subsurface drip irrigation to save on water and chemicals such as N fertilizer. Many of the impacts of the cultivation of sugarcane are significantly influenced by local conditions, such as soil type and climatic factors, so appropriate planning as well as management is an important factor in the reduction of cultivation impacts. The challenge to the grower community is to protect biodiversity through the maintenance of natural habitat fragments within the farmed landscape, and the adoption of more diverse cropping systems that include legumes to break the monoculture of sugarcane. A number of good management practice guides are available such as the Australian cane-growers Code of Practice for Sustainable Cane Growing in Queensland (CANEGROWERS, 1998) and in South Africa, the South African Sugar Association's Manual of standards and guidelines for conservation and environmental management in the South African sugar industry (SASRI, 2002).

3.4. GIS applications in sugarcane studies:

Geographical Information Systems (GIS) comprise a computer-based program capable of acquiring, analyzing, managing geographical data and giving visual representation of the real world as output maps. Its ability to combine data from different sources with spatial reference has made it convenient for use (Masser, 1998). GIS in suitability analyses was rooted from the early 20th century by American landscape architects using hand drawn overlay techniques (Steinitz *et al.*, 1976) which preceded using computer software to generate digital maps presenting results from suitability modeling. Land use suitability modeling is one of the most important functions in GIS (Malczewski, 2004). Global positioning System (GPS) and GIS technology and linking it with related database, will help planners, decision makers and managers at all levels to manage diagnoses the exiting problems and find the solution in relatively short time with minimum cost and efforts through the use of GIS capabilities. GIS can provide farm managers with an effective method to visualize, manipulate, analyze and display spatial data, providing the backbone of a Precision Agriculture (PA) system (Ganawa, E. and Awad Allah, F.A.2010).

3.4.1. GIS capabilities:

Traditional techniques of generation of natural resources status is time consuming and expensive. The natural resources status include area, production, productivity of crops, irrigation facilities, rain fed area etc. this information can be generated using GIS and RS technology and would be cost effective and time saving (Sahu D. D. and Solanki R. M., 2008).

GIS in agriculture:

- Early season estimation of cropped area
- Monitoring crop condition
- Identification of crops and their estimation
- Crop yield modelling
- Cropping system/ crop rotation
- Crop water requirement estimation

- Detection of moisture stress in crops and quantification of its effects crop yield
- Command area management
- Food hazard mapping and flood monitoring
- Agricultural drought monitoring

Land use and soil:

- Mapping of land/ land cover
- Detection of change
- Identification of degraded lands/ soil erosion
- Mapping of soil erosion (Sahu D. D. and Solanki R. M.2008).

GIS has been used extensively for spatial analysis and land suitability as GIS functions could be employed for several forms of information including point, line and area. The system, therefore, possesses greater storage capacity for spatial information processed with identical standard. GIS also provides greater reliability with lesser time and cost compared with manual operation (Bera *et al*, 2002). The integrated information perform is highly useful especially when it is used to support decision-making towards farming activities (Ghaffari *et al*, 2000; Rasheed *et al*, 2003). Charuppat (2002) adopted GIS to develop models for land suitability evaluation and found that the system is highly effective for the above-mentioned task. GIS has played a major role in planning and management with its ability to manage substantive amounts of data (ESRI, 2012) and one of its most useful applications is suitability mapping of a given scenario (McHarg, 1969). Ecologists have mapped suitable locations for many habitats. Suitable land for agriculture has also been identified using GIS-aided suitability analyses (Paiboonsak S *et al.*, 2007). The ability of GIS to reclassify and overlay data to meet multiple requirements is very powerful and this has been applied to many fields like agriculture, urban planning, ecology and many more.

Evaluation of land suitability for sugarcane production using spatial information model developed by GIS has been regarded as highly effective method which could be adopted to provide the required information compared with conventional operation. The method not only minimizes the factors introduced into the analysis but also provides the steps reliable outcome through clear cut step of operation which could be updated. The output obtained could be used to back up decision-making on sugarcane production at provincial level. Apart from this, this method could also be adopted to examine land suitability of certain target areas (Paiboonsak S., *et al.*, 2007). The use of GIS in suitability analyses is on an increase and highly demandable (McHarg, 1969). A comparison between old methods of suitability classification and contemporary GIS, clearly showed GIS to be time saving technique that produces data with higher quality with possibilities of locating newer potential sites (Liengsakul *et al.*, 1993). GIS allows for a multi-criteria technique to be used to create suitability maps for specific uses. Malczewski (2006) utilized this approach with both boolean overlay and weighted linear combination in order to determine land use potentials.

Kheiralla A.F.; *et al,* (2008) used GIS in Guneid scheme for Vehicle Tracking System (VTS), it is an electronic device installed in a vehicle to enable the owner or a third party to track the vehicle's location. Most modern VTS use GPS modules for accurate location of the vehicle. Many systems also combine a communications component such as cellular or satellite transmitters (GSM/GPRS) to communicate the vehicle's location to a remote user. Vehicle information can be viewed on electronic maps via the Internet or specialized software.
Development of geo-spatial information technology in the later part of the 20th century has aided in the adoption of site specific management systems (SSMS) using remote sensing (RS), Global positioning system (GPS), and geographical information system (GIS). This approach is called PF or site specific management. It is a paradigm shift from convention management practice of soil and crop in consequence with spatial variability. It is a refinement of good whole field management, where management decisions are adjusted to suit variations in resource conditions. The goal of PF is to gather and analyze information about the variability of soil and crop conditions in order to maximize the efficiency of crop inputs within small areas of the farm field. To meet this efficiency goal the variability within the field must be controllable. Efficiency in the use of crop inputs means that fewer crop inputs such as fertilizer and chemicals will be used and placed where needed. The benefits from this efficiency will be both economical and environmental. Environmental costs are difficult to quantify in monetary terms. The reduction of soil and groundwater pollution from farming activities has a desirable benefit to the farmer and to society (Ganawa E., *et al*. 2008).

Sugar industries in Sudan play a big role in the Sudanese economy. It has received great attention and progress as show by presence of many governmental sugar factories. These factories include Guneid located 120 km south east of Khartoum in area 16800 ha, Sennar located 300 km south of Khartoum covering area 15120 ha and Assalaya located 280 km south of Khartoum covering area 18900 ha. Halfa located 400 km north east of Khartoum covering area 16800 ha. They are located in different areas in Sudan and run by the Sudanese sugar company (SSC). The total area utilized by the Sudanese sugar company is 67620 ha and average field of sugarcane per hectares about 87.61 Tons. Another large sugar factory owned by Kenana Sugar Company was located 250 km south Khartoum. The factory is the joint venture of Arab, Sudanese and foreign capital utilized an area of 42000 ha. Factory average cane per hectares is about 114 Tons/ ha (Ganawa E., *et al*. 2008).

CHAPTER FOUR
MATERIAL AND METHODS

4.1. Materials:

4.1.1 Soils of the study area

The Guneid two main mapping units suleimi clay (map symbol 17) and suleimi shallow melanic horizon (map symbol 14), they were separated on the basis of the presence and depth of the grey layer or melanic horizon (moisture color 10YR3/1 OR 3/2) irrespective of the sub group level (Entic or Typic Chromusters; soil survey staff, 1975). Mapping unit 14 (18000 feddan equivalent to 48% of the scheme area) has melanic horizon between 50-90 cm, while mapping unit 17 (19000 feddan equivalent to 52% of the scheme area) have melanic horizon below 90 cm. Fig (1) shows the Guneid soil map units and land capability all quoted from (Idris, 1990).

Analogous to the majority of the soils in the central clay plain of the Sudan, the soils of the scheme are developed in clayey alluvium. Like other Vertisols, their genesis and morphology indicate the enrichment of the parent material with montmorillonitic clay and the occurrence of enough wet and dry climatic periods.

4.1.2. **Fields of the Study Area:**

The Guneid sugarcane scheme is divided into 25 fields (Table 5) named after major canals; these fields are:

Table (5): The 25 Fields (canals) of Guneid sugarcane scheme:

Talha	Said	Abu Sugra	Wad alfadul	Ganomab
Jagogab	Sheikh abdallah	Zurug	higelieg	Adham
Abusin	Gad Elrub	Abushara	wad surur	Alabas
Alfirai	alganabia	Minor1	Minor2	Minor3
Minor5	Minor6	Minor7	Minor8	tambul

The eight canals selected in this study lie in two sections and each section contains the two dominant soil units (soil units 14 and 17) as shown below:

- The northern section: Includes 4 fields; Alabas and Al Ganabia canals located in soil unit 14, and Abu Sugra and Tambul canals located in soil unit 17.
- The southern section: Includes 4 fields; Jagogab and Shikh Abdallah) canals located in soil unit 14, and Gad Alrub and Abusin canals located in soil unit 17.

  Figure (5) shows the canals as located in the soil map of Guneid sugarcane scheme.

Figure (4): Guneid sugar scheme (Idris, 1990).

4.1.2. Previous Documents

Several reports have been reviewed to obtain data to assist with the compilation of this report. The most important are:

1- Yield data of sugarcane in Guneid scheme: Here was using the yield data of sugarcane in the scheme at the 13^{th} years late; from 2000 – 2013, was collected with literature on the scheme area.
2- Semi-detailed soil survey of Guneid sugarcane scheme and proposed extension, carried by Ali .M. A., Soil Survey Division, Wad Medani (1969).

3- Re- evaluation of Guneid scheme land potentials for sugarcane production. Idris, M. A. M, Soil survey administration, Wad Medani 1983.

4.1.3. GIS program:

The Geographic Information System Program (Arc map version 9.3) with all its tools.

4.1.4. Remote Sensing Data:

Satellite image and maps about the scheme, the semi detailed soil survey map of 1969 (Ali 1969).

4.2. Methods:

4.2.1. Data Collection:

The sugarcane yield data used in this study was collected from many sources; Guneid agriculture division, the Guneid sugarcane research station.

4.2.2. Method of analysis:

The data was collected in form of tables of yield data from the 2000-2013 seasons. The data was used to calculate the average and total yield of plant cane and 1^{st}, 2^{nd}, 3^{rd} ratoons of the each season.

The map data was analyzed by using geographic information system (GIS) program; It is a program used to analyze the databases and use the map units and correlate them to the sugarcane yield.

The Guneid sugar scheme is comprised of 25 canals, select 8 canals to perform the units. Cane field were randomly selected according to crop categories; mainly plant cane fields, first and second ratoons. The work was concerned on these three crop categories, because they represent 90% of the total area under harvest seasonally.

4.2.3. Land classification in Al Guneid Sugar Scheme:

4.2.3.1. Land suitability classification system

Re- evaluation of Guneid scheme land potentials for sugarcane production adopted the new Land suitability classification system which replaced the former land capability system (Idris, M. A. M, Soil survey administration, Wad Medani 1990, and Ali .M. A., Soil Survey Division, Wad Medani 1969). Land suitability evaluation is the process of assessing the suitability of land for specific kinds of use. These may be major kinds of land use, such as rainfed agriculture, irrigated agriculture, livestock production, etc.; or land utilization types described in more detail. The evaluation of the land in this study area for the production of some irrigated crops adapted to the area, involves the identification of a number of relevant land qualities expected to affect the productivity of some selected crops. These land qualities include moisture availability, chemical fertility, and seedling establishment, possibility for mechanization, topography, soil drainability, salinity, sodicity, adverse physical properties, soil depth and erosion. These land qualities were used to assess the land potentialities for irrigated agriculture in the study area assuming that moderate to high capital inputs together with moderate to high levels of management will be adapted.

4.2.3.2. Kinds of land suitability classification:

The distinction should be made between current suitability and potential suitability and in both classifications suitability classes may be expressed in either qualitative or quantitative terms, depending on whether exact economic data on benefits and inputs are available. The current land suitability classification either classifies land for its present use, without considering major improvements, or classifies land for other kinds of land use, provided that inputs do not differ very much from the present use in their impact on the land. The potential land suitability classifies land for a defined kind of land use after major improvements of the land have been carried out.

4.2.3.3. Categories of the system

The system uses well defined hierarchical subdivision into orders, classes, subclasses and units. The four categories with decreasing generalization are:

- Orders; reflecting kinds of suitability (suitable or not suitable).
- Classes; reflecting degrees of suitability within orders.
- Subclasses; reflecting kinds of limitations and including improvement requirements within classes.
- Units; reflecting minor differences in production capacity and or in management requirements within subclasses.

Table (6) : Categories of land suitability classification

Category				
Order		***Class***	***Subclass***	***Unit***
S Suitable	**Highly** suitable	**S1**	**S2m**	S2e-1*
	Moderately suitable	**S2** →	**S2e***	S2e-2*
	Marginally suitable	**S3**	**S2me**	
N Not suitable	**Conditionally** suitable	**N1** →	**N1m**	
	Permanently Not suitable	**N2**	**N1e**	

4.2.3.3.1. The land suitability orders

Order S - Suitable land

Land on which sustain use in the defined manner is expected to yield benefits that will justify the required capital and recurrent inputs, without causing unacceptable risks to land resources on the site or on adjacent areas.

Order N – Unsuitable land

Land having characteristics which prevent its sustained use in the defined manner because of an unacceptable level of recurrent or development inputs required.

4.2.3.3.1. The land suitability classes

Land suitability classes are subdivision of land suitability orders. Three classes are recognized in the suitable order and two in the unsuitable order. Each class groups lands with similar production capacity within a certain range expressed qualitatively or quantitatively for the type of land use.

Class 1 – Highly suitable land

The Land which is expected to be highly productive for the defined use and yields high benefits, amply justifying the required capital and recurrent inputs. There are no significant limitations that will reduce crop yields or increase recurrent costs for production and conservation.

Class 2 - Moderately suitable land

Land which is expected to be moderately productive for the defined use and yields moderate benefits, which are sufficiently high to justify the required capital and recurrent inputs. There are moderately severe limitations likely to reduce crop yields and/or increase recurrent costs for production and conservation.

Class 3 - Marginally suitable land

Land which is expected to have low productivity for the defined use and yields benefits that are just high enough to justify the recurrent costs and capital inputs. There are limitations which in aggregate are sufficiently severe to reduce crop yields and/or increase recurrent costs for production and conservation.

Class N1 -Currently unsuitable land

Land with very severe limitations which are at present cannot be economically corrected and which prevent successful sustained use in the defined manner.

Class N2 - Permanently unsuitable land

Land with very severe limitations preventing any possibility of successful use of the land for agricultural production.

4.2.3.3.3. The land suitability subclasses

Subclasses are subdivisions of the classes reflecting the kinds of the major limitations to profitable land use which determine the class level. It also reflects the general direction of the required improvements and so distinguishes land that differs in nature of their management requirements. Subclasses are indicated by one to three lower case letters with economic significance following the class symbol e.g. Order: S; Class: S2; Subclass: S2t. No subclasses are recognized in class S1 and class N2.

4.2.3.3.4. The land suitability units

The suitability units are subdivisions of the subclasses and used in detailed studies to distinguish lands with minor differences in production capacity which may or may not be accompanied by different management requirements. The land suitability units may also be used to subdivide lands of class S1 within which no subclasses are recognized.

The suitability units are indicated by Arabic numbers between brackets, e.g.S2f (2). The units were not applied in Guneid because of the lack of determining management data.

CHAPTER FIVE
RESULTS AND DISCUSSIONS

Table (7): Fields (Canals) areas (feddans) at Northern and Southern Sections of Guneid scheme according to soil unit (14):

Section	Field (Canal)	Field Area (feddans)	Area in Soil Unit 14	
			Area /fed.	%
Northern	**Jogogap**	2085.00	1570.00	75.30
	Sheikh Abdallah	2240.00	1485.00	66.29
Southern	**Alabas**	2204.50	2204.50	100.00
	Gianabia	379.00	379.00	100.00
Total Fields Areas		6908.50	5638.50	-
Average % area at Soil Unit 14				81.6

Table (8): Fields (Canals) areas (feddan) at Northern and Southern Sections of Guneid scheme according to soil unit (17):

Section	Field (Canal)	Total Area Feddans	Area in Soil Unit 17	
			Area /fed.	%
Northern	**Abu Sugra**	2158.00	1548.00	71.73
	Tambul	2704.00	1885.00	69.71
Southern	**Gad Elrub**	1350.00	1325.00	98.15
	Abu Sin	1529.00	1364.00	89.21
Total Fields Areas		7741.00	6122.00	-
Average % area at Soil Unit 17				82.19

Tables (7, 8) showed the eight fields (Canals) in the two sections of the scheme (Northern and Southern) that lie within the two soil map units 14 and 17. The tables showed the total area of each field and as well its size within each of the two soil unit expressed as total area (feddans) and percentage. Figure (5) showed the map of the fields within the two soil units. These selected eight fields are largely dominantly by either of the two soil units as shown in the two tables (more than 80% dominance of either of the two soil units).

For soil unit 14, two Fields (canals) selected at the Northern section (Jagogab and Sheikh Abdallah), and (Alabas and Ganabia) at Southern section. For unit 17, two canals were selected (Abu Sugra and Tambul) at Northern section, and (Gad Alrub and Abusin) at the Southern section.

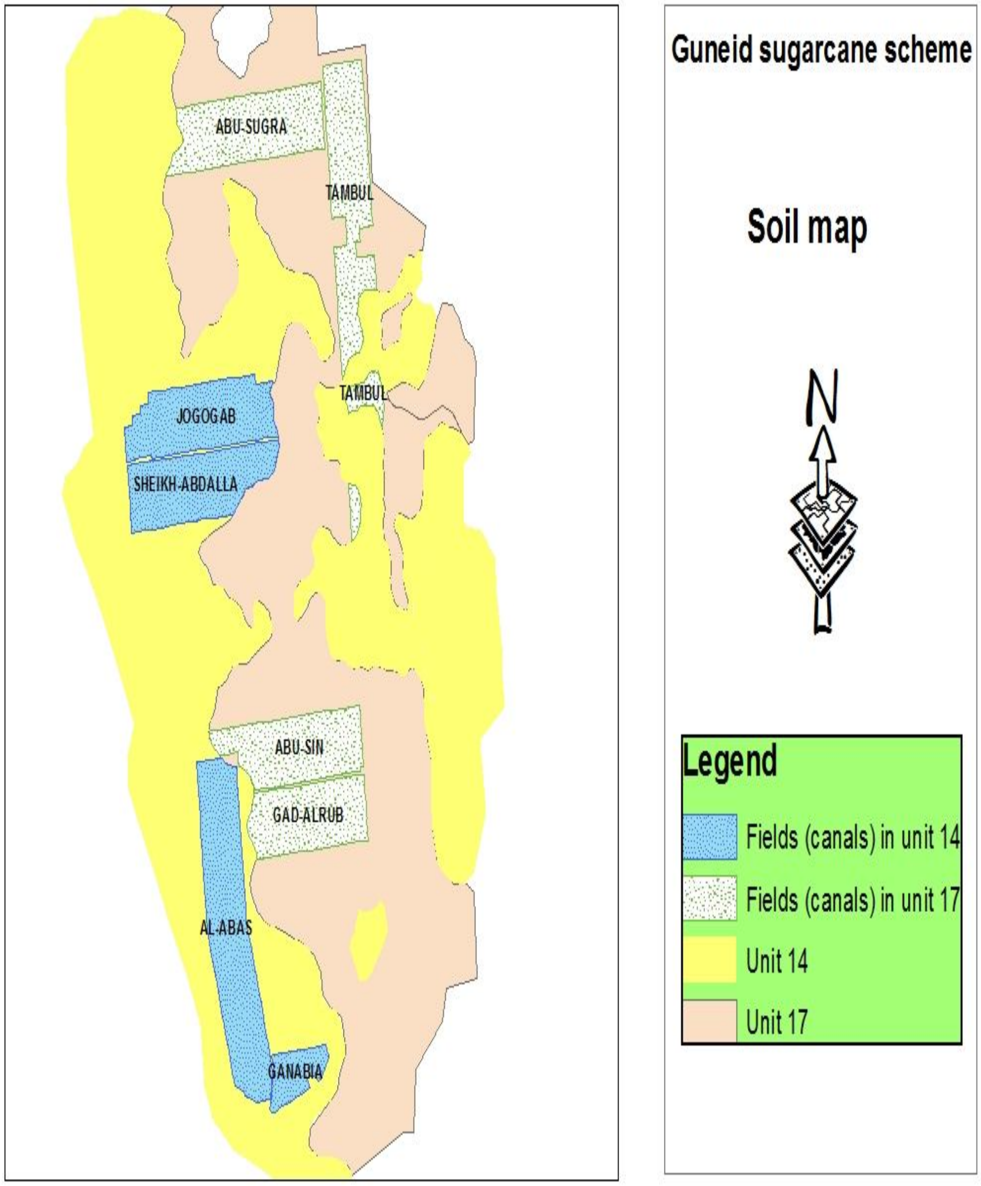

Figure (5): The Map of the Eight Fields (canals) as superimposed on the soil map of Guneid sugarcane scheme.

The Tables (9), (10) and the figures (6), (7), (8) and (9) were summarized from Tables 12-35 included in Appendix 1. These tables showed the average of plant cane, 1st ratoon, 2nd ratoon and 3rd ratoon+ other yield of the 2 main section of the scheme during the period from 2000 – 2013(13 years). As shown in the tables, the southern section is high in yield when compared with the other section; this is for all cane categories and for the consecutive seasons. The season 2009/2010 was excluded because of the lack of yield data for ratoons, the study base on the other 12 seasons from (2000/2001 – 2012/2013).

Table (9): The Average yield of plant cane and ratoons in different canal at soil unit 14 and 17 of Guneid scheme (2000 – 2013) at the Northern Section:

Soil Unit	**Soil Unit 14 (Jagogab + Sheikh Abdallah)**				**Soil Unit 17 (Abu Sugra + Tambul)**			
season	**Plant cane**	**1st ratoon**	**2nd ratoon**	**3rd ratoon/ other**	**Plant cane**	**1st ratoon**	**2nd ratoon**	**3rd ratoon/ other**
2000/2001	44.07	38.95	34.67	32.81	42.41	37.22	33.47	31.12
2001/2002	62.60	47.61	39.52	34.58	53.42	46.36	37.31	66.68
2002/2003	53.37	44.34	34.75	28.27	50.93	41.06	33.18	26.78
2003/2004	62.43	42.81	37.77	37.00	51.34	41.71	36.00	31.74
2004/2005	59.01	45.62	38.34	33.54	53.81	44.48	31.93	31.98
2005/2006	54.73	41.73	35.64	35.25	49.16	40.49	31.67	35.10
2006/2007	58.18	45.08	44.52	35.69	53.52	41.23	33.75	30.42
2007/2008	55.82	40.74	37.38	31.04	45.78	39.80	31.63	38.24
2008/2009	58.22	44.86	34.55	30.32	45.66	39.76	30.40	33.99
2010/2011	56.50	46.44	37.43	36.37	52.86	39.14	31.26	37.97
2011/2012	56.24	44.64	38.09	33.02	50.59	42.84	33.99	30.00
2012/2013	51.99	43.75	32.65	32.37	45.96	38.05	29.33	41.64
Average	***56.09***	***43.88***	***37.10***	***33.35***	***49.62***	***41.01***	***32.82***	***36.30***

Figure (6) and (7) below show the histograms of sugar cane yield (plant cane and ratoons) at the northern section indicating that unit 14 clearly achieved higher yields (average 56.09 ton/fed) than soil unit 17 (average 49.62 ton/fed) particularly for plant cane (Table 10 show the figures). At both soil units and as expected the ratoons gave lower yields than plant cane but nevertheless the average ratoons yields are still higher at soil unit 14 than 17 despite the minor differences between them.

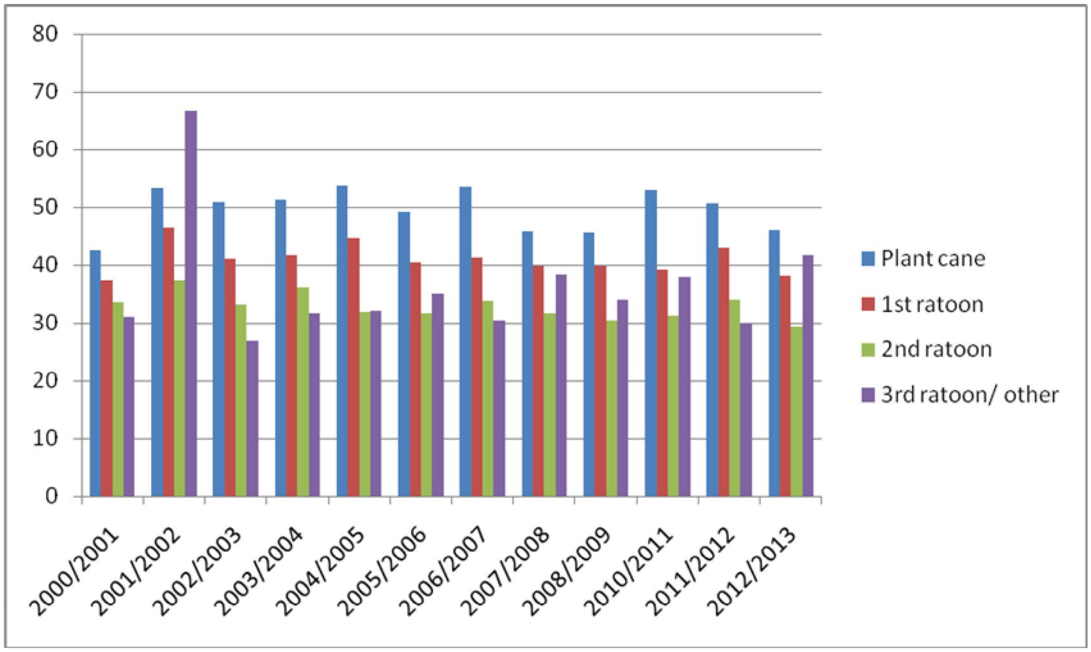

Figure (6): The average yield of plant cane and ratoons in different canal at **Northern** Section of Guneid scheme (2000 – 2013) for soil unit 17.

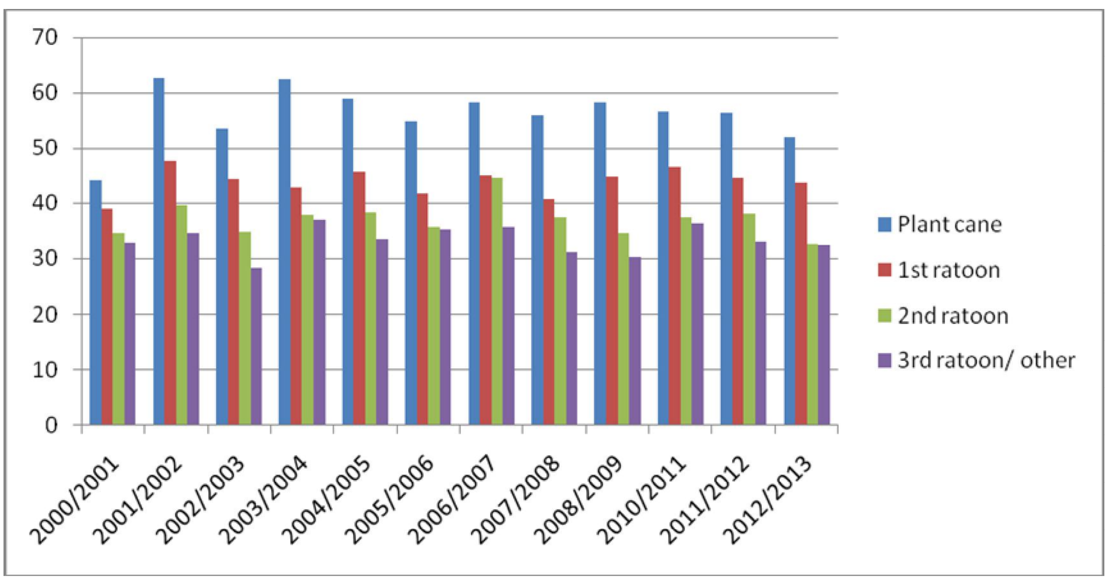

Figure (7): The average yield of plant cane and ratoons in different canal at **Northern** Section of Guneid scheme (2000 – 2013) for soil unit 14.

Table (10): The Average yield of plant cane and ratoons in different canal at soil unit 14 and 17 at Guneid scheme (2000 – 2013) at the Southern Section

Soil unit	Unit 14 (Alabas + Gianabia)				Unit 17 (Gad Elrub + Abu sin)			
Season	**Plant cane**	**1st ratoon**	**2nd ratoon**	**3rd ratoon/ other**	**Plant cane**	**1st ratoon**	**2nd ratoon**	**3rd ratoon/ other**
2000/2001	44.78	36.45	35.39	32.39	41.78	38.55	33.67	27.37
2001/2002	57.97	48.12	40.54	37.95	56.72	45.42	41.74	33.24
2002/2003	61.54	41.89	32.86	32.06	49.59	43.18	34.25	27.52
2003/2004	62.43	42.81	37.77	37.00	62.81	44.46	37.37	31.92
2004/2005	62.17	49.08	41.79	28.60	57.06	42.22	39.12	28.46
2005/2006	55.31	44.89	38.93	34.06	52.25	48.36	40.30	32.04
2006/2007	62.01	46.00	36.53	36.21	56.62	51.03	34.86	37.69
2007/2008	63.30	46.48	39.69	39.43	53.79	50.13	39.44	36.55
2008/2009	58.09	43.37	39.00	35.90	60.91	40.55	38.46	32.69
2010/2011	55.48	45.85	39.23	37.10	54.15	49.63	34.22	32.77
2011/2012	56.52	45.02	36.80	36.63	50.42	43.74	39.24	34.78
2012/2013	50.11	43.92	36.80	29.79	53.44	44.54	40.15	37.13
Average	***57.47***	***44.49***	***37.94***	***34.76***	***54.12***	***45.15***	***37.73***	***32.68***

Figure (8) and (9) below show the histograms of sugar cane yield (plant cane and ratoons) at the southern section indicating that unit 14 clearly achieved higher yields (average 57.47 ton/fed) than soil unit 17 (average 54.12 ton/fed) particularly for plant cane (Table 11 show the figures). At both soil units and as expected the ratoons gave lower yields than plant cane but nevertheless the average ratoons yields are still higher at soil unit 14 than 17 despite the minor differences between them.

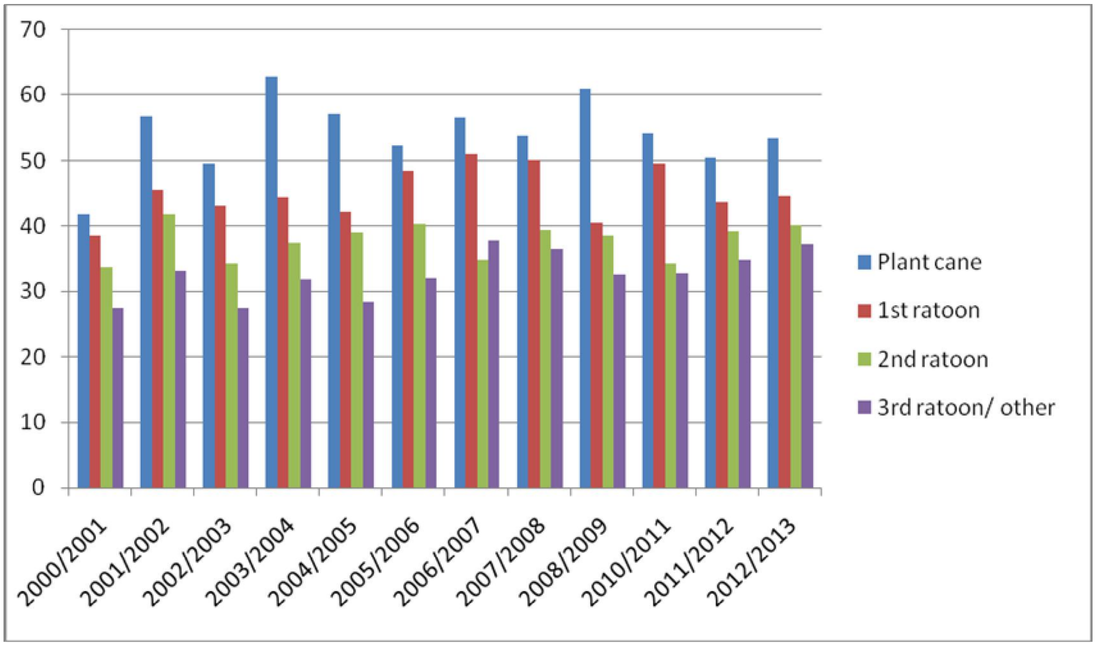

Figure (8): The average yield of plant cane and ratoons in different canal at **southern** of Guneid scheme (2000 – 2013) for soil unit 17.

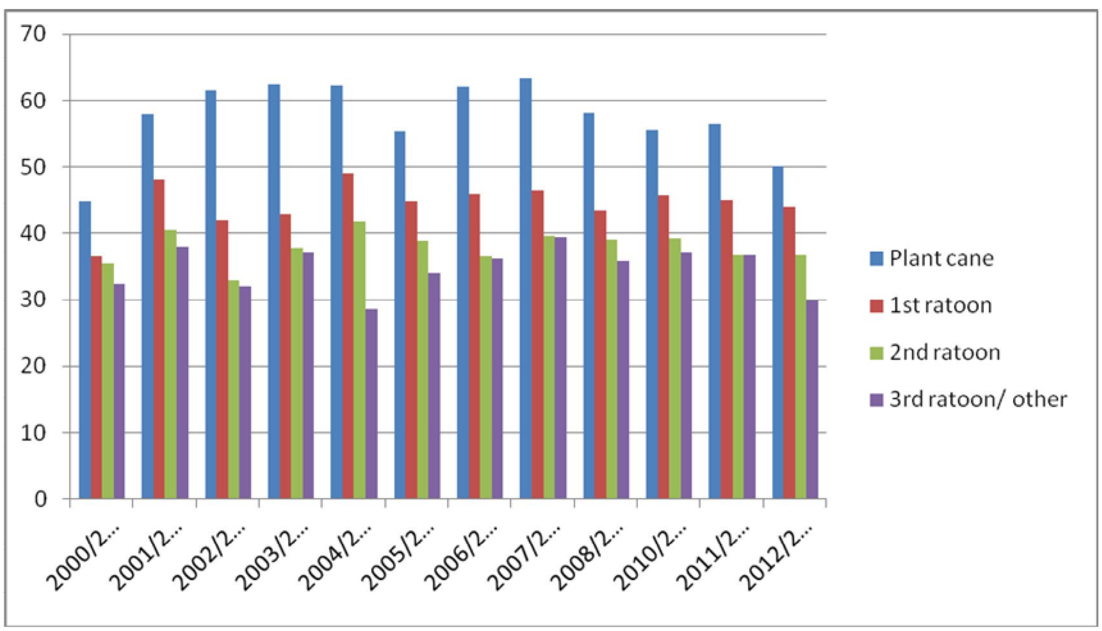

Figure (9): The average yield of plant cane and ratoons in different canal at **southern** of Guneid scheme (2000 – 2013) for soil unit 14.

Table (11): The Average yield of Sugar plants (ton/fed) of canal at different section of Guneid scheme for 12 seasons for soil unit 14 and 17.

SOIL UNITS	SECTIONS (Fields)	AVERAGE YIELD (ton/ feddan)				
		Plant Cane	1st Ratoon	2nd Ratoon	3rd Ratoon	Total
14	**NORTHERN** (Jagogab + Sheikh Abdallah)	56.09	43.88	37.1	33.35	170.4
	SOUTHERN (Alabas + Gianabia)	57.47	44.49	37.94	34.74	174.6
	Average	**56.78**	**44.185**	**37.52**	**34.05**	**172.5**
17	**NORTHERN** (Abu Sugra +Tambul)	49.62	41.01	32.82	36.2	159.7
	SOUTHERN (Gad Elrub + Abu sin)	54.12	45.15	37.73	32.68	169.7
	Average	**51.87**	**43.08**	**35.28**	**34.44**	**164.7**

Table (11) show the average yields of plant cane and all ratoons for soil units 14 and 17 at the northern and southern sections at Guneid sugar scheme. The average and total yields in table 10 have reflected clear variations between soil unit 14 and 17. Soil unit 14 has yielded a total of 170.4 in the northern section and 174.6 ton/ feddan in the southern section (Average 172.5). Soil unit 17 has yielded a total of 159.7 in the northern section and 169.7 ton/ feddan in the southern section (Average 164.7).

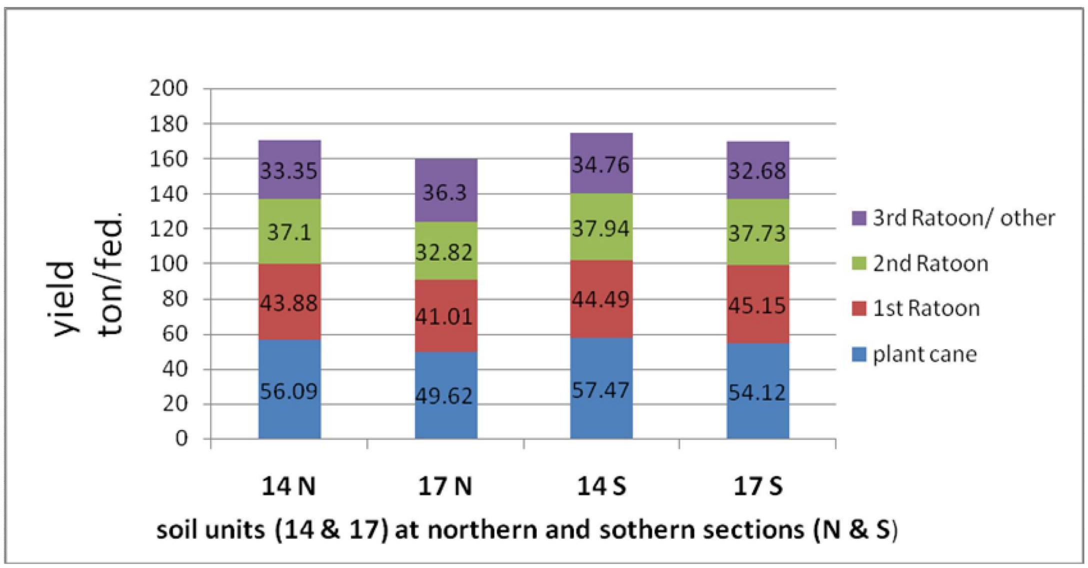

Figure (10): The Average yield of plant cane and ratoons (ton/fed) in different canal at northern and southern section of Guneid scheme for 12 seasons for soil unit 14 and 17.

Although soil unit 14 produced better yields than soil unit 17 in both sections of the Guneid Sugar Scheme and this is most probably due to soil differences but nevertheless the yield of both units in southern section is higher than northern section. This could be attributed to differences in management practices at the two sections. Evidence of differences in management practices at the two sections was expressed by some farm managers who confirmed the outstanding management efforts at southern section.

The quantitative soil data synthesis produced in the last land evaluation study at Guneid scheme (Idris, 1990) in the Table (4) deals with the quantitative paired comparisons between mapping units 14 and 17 in terms of soil analysis. The comparisons present the relative advantages (a) or disadvantages (d) of mapping unit 17 over mapping unit 14 as shown in column c. As well, significance tests of difference between variance of means of soil map units 14 and 17 have been conducted using the F-test. It present 30 soil parameters including the bulk density which is equal in both units and this leaves only 29 parameters that have differences between the two units.

The table presents soil unit 17 with 19 disadvantages and present unit 14 with 17 advantages. That is means Unit 14 has more advantages over 17, but these facts were overlooked in the table of the previous study and concluded that soil unit 17 is better than 14. According to this table, it is considered in this study soil unit 14 reflects better qualities for sugar cane production than soil unit 17. The long term sugar cane yield data used in this study proved that soil unit 14 performed better than 17. It seems that the better soil moisture qualities and related characteristics (WHC, AWC, and Permeability) in soil unit 14 improved its productivity performance as reflected in the yield data.

CHAPTER SIX
CONCLUSIONS AND RECOMMENDATIONS

6.1 CONCLUSIONS

1. The study has clearly demonstrated that the soil differences already outlined in previous studies have been assessed and considered in this study. The use of improved techniques (GIS) enabled specifying certain fields to specific soil map units. This process revealed considerable differences in sugar cane yield between the two soil units.

2. The previous land evaluation study as a complementary part of an updated soil survey revealed some soil differences between the two identified soil units but failed to clarify and show the yield differences. This could easily be explained by the generalized yield data used and the improper correlations and attributes being used. It seems that the yield data was taken from fields with more than one soil type and correlated to one soil. Accordingly this procedure have masked yield differences between soils and failed to explain yield differences in the scheme

3. The application of GIS techniques has allowed the selection of specific fields that lie entirely on one soil types. This procedure has facilitated relating specific yield data to specific soil types and hence the performance of each soil types could be assessed.
   In this regard, the yields obtained from soil unit 14 in both sections are higher than from soil unit 17.

4. The previous soil survey studies have characterized the soils of the Guneid and separated two soil map units (14 and 17) with considerable difference in soil analytical data. The previous analytical results for the two soil units indicated that of out of the 30 parameters listed, the two soil types are similar in one soil property. The quantitative data produced have indicated that soil map unit 17 has more disadvantageous soil properties than soil unit 14 and hence it has affected its yield performance which was figured out in this study.

5. Yield variations between soil types is largely attributed to differences in soil properties, but differences in yield within similar soil types could mostly be explained by management differences. The confirmed proper management practices in the southern section explain the low yields obtained in northern section by similar soil units.

6. It seems that at the initial stages of land use planning at Guneid Scheme the designing and distribution of the fields was done according canals and did not

consider soil differences within fields as shown on soil map of the scheme. If this was considered then most probably field should have one soil type and this could have improved the soil management practices.

7. It is considered in this study that soil unit 14 reflects better qualities for sugar cane production than soil unit 17. The long term sugar cane yield data used in this study proved that soil unit 14 performed better than 17. It seems that the better soil moisture qualities and related characteristics (WHC, AWC, and Permeability) in soil unit 14 improved its productivity performance as reflected in the yield data and in the previous soil analytical data..

6.2. RECOMMENDATIONS:

1. Studies and research on land productivity assessment based on soil factor should pay much attention to the relevant yield data. Long term yield data should always be produced for specific soils so as to assess their performance. Generalized yield data coming from many soils usually conceals soil differences and will not help in recommending proper management practices.

2. Awareness and guidance programs on the importance of soil differences in relation to productivity and management practices should be initiated for farm managers and farmers based. Improving management practices based on land qualities is essential for sustainable production. Available soil maps and land evaluation studies should be utilized for such purposes.

3. Periodic monitoring of soil health, land qualities and yield performance using remote sensing and GIS technique is vital in all sections of the scheme to ensure efficient management practices. Some essential soil properties like bulk density, permeability, porosity, soil fertility and organic matter content often show considerable variations with time and need to be maintained at adequate levels.

4. Research programs on land management questions should be encourages and supported by the Guneid Scheme administrations to help improve sugar cane production and reduce yield variations in both sections, particularly in Southern section where the yield is low due to management factor. As well, more research is needed at Guneid Sugar Scheme to verify the determining soil factors in relation to sugar cane production.

5. Soil testing, soil analysis equipment, GPS and GIS facilities are prerequisite at Guneid Sugar scheme to support indoor research programs in providing recommendations on proper land management practices

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APPENDICES

Appendix 1

Average yield of Sugarcane for 12 seasons

At (Guneid Sugarcane Scheme)

Table (12): Average yield of plant cane and ratoons in different canal at Northern and Southern Sections of Guneid scheme (2000 – 2001) for soil unit 14:

Section	NO	MINOR	Plant Cane	1st Ratoon	2nd Ratoon	3rd Ratoon + other
Northern	**1**	**Jogogap**	46.97	40.89	36.85	31.82
	2	**Shikh Abdalla**	41.17	37.01	32.49	33.81
	Average yield		*44.07*	*38.95*	*34.67*	*32.81*
Southern	**3**	**Alabas**	47.19	36.94	34.81	32.83
	4	**Gianabia**	42.37	49.40	35.97	31.96
	Average yield		*44.78*	*36.45*	*35.39*	*32.39*

Table (13): Average yield of plant cane and ratoons in different canal at Northern and Southern Sections of Guneid scheme (2000 – 2001) for soil unit17:

Section	NO	MINOR	Plant Cane	1st Ratoon	2nd Ratoon	3rd Ratoon + other
Northern	**5**	**Abu Sugra**	40.57	37.55	31.43	31.77
	6	**Tambul**	44.26	36.90	35.51	30.47
	Average yield		*42.41*	*37.22*	*33.47*	*31.12*
Southern	**7**	**Gad Elrub**	46.31	39.84	34.07	25.60
	8	**Abu Sin**	49.52	37.26	33.28	29.15
	Average yield		*41.78*	*38.55*	*33.67*	*27.37*

Table (14): Average yield of plant cane and ratoons in different canal at Northern and Southern Sections of Guneid scheme (2001 – 2002) for soil unit 14:

Section	NO	Minor	Plant Cane	1st Ratoon	2nd Ratoon	3rd Ratoon + other
Northern	**1**	**Jogogap**	67.06	52.18	42.46	35.69
	2	**Shikh Abdalla**	58.15	43.05	36.58	33.47
	Average yield		*62.60*	*47.61*	*39.52*	*34.58*
Southern	**3**	**Alabas**	58.17	45.22	40.71	35.68
	4	**Gianabia**	57.78	51.02	40.37	40.23
	Average yield		*57.97*	*48.12*	*40.54*	*37.95*

Table (15): Average yield of plant cane and ratoons in different canal at Northern and Southern Sections of Guneid scheme (2001 – 2002) for soil unit 17:

Section	NO	MINOR	Plant Cane	1st Ratoon	2nd Ratoon	3rd Ratoon + other
Northern	**5**	**Abu sugra**	51.45	46.07	35.27	33.77
	6	**Tambul**	55.39	46.65	39.35	32.91
	Average yield		*53.42*	*46.36*	*37.31*	*66.68*
Southern	**7**	**Gad Elrub**	57.07	40.46	37.62	32.83
	8	**Abusin**	56.37	50.39	45.87	33.65
	Average yield		*56.72*	*45.42*	*41.74*	*33.24*

Table (16): Average yield of plant cane and ratoons in different canal at north and south of Guneid scheme (2002 – 2003) for soil unit 14:

Section	NO	MINOR	Plant Cane	1st Ratoon	2nd Ratoon	3rd Ratoon + other
Northern	**1**	**Jogogap**	50.73	48.31	37.71	32.47
	2	**Shikh Abdalla**	56.03	40.37	31.80	24.08
	Average yield		*53.37*	*44.34*	*34.75*	*28.27*
Southern	**3**	**Alabas**	59.80	45.73	33.00	-
	4	**Gianabia**	63.29	38.06	32.73	32.06
	Average yield		*61.54*	*41.89*	*32.86*	*32.06*

Table (17): Average yield of plant cane and ratoons in different canal at Northern and Southern Sections of Guneid scheme (2002 – 2003) for soil unit 17:

Section	NO	Minor	Plant Cane	1st Ratoon	2nd Ratoon	3rd Ratoon + other
Northern	**5**	**Abu Sugra**	49.87	39.65	31.95	-
	6	**Tambul**	52.00	42.48	34.41	26.78
	Average yield		*50.93*	*41.06*	*33.18*	*26.78*
Southern	**7**	**Gad Elrub**	49.70	41.52	32.36	-
	8	**Abu Sin**	49.48	44.85	36.14	27.52
	Average yield		*49.59*	*43.18*	*34.25*	*27.52*

Table (18): Average yield of plant cane and ratoons in different canal at Northern and Southern Sections of Guneid scheme (2003 – 2004) for soil unit 14:

Section	NO	Minor	Plant Cane	1st Ratoon	2nd Ratoon	3rd Ratoon + other
Northern	**1**	**Jogogap**	54.74	44.81	40.63	36.21
	2	**Shikh Abdalla**	53.53	45.56	38.81	-
	Average yield		*54.13*	*45.18*	*39.72*	*36.21*
Southern	**3**	**Alabas**	62.45	42.72	40.30	38.76
	4	**Gianabia**	62.41	42.91	35.10	35.25
	Average yield		*62.43*	*42.81*	*37.77*	*37.00*

Table (19): Average yield of plant cane and ratoons in different canal at Northern and Southern Sections of Guneid scheme (2003 – 2004) for soil unit 17:

Section	NO	Minor	Plant Cane	1st Ratoon	2nd Ratoon	3rd Ratoon + other
Northern	**5**	**Abu Sugra**	47.40	42.12	34.94	-
	6	**Tambul**	55.28	41.31	37.06	31.74
	Average yield		*51.34*	*41.71*	*36.00*	*31.74*
Southern	**7**	**Gad Elrub**	62.19	44.60	35.92	-
	8	**Abu Sin**	63.43	44.33	38.83	31.92
	Average yield		*62.81*	*44.465*	*37.375*	*31.92*

Table (20): Average yield of plant cane and ratoons in different canal at Northern and Southern Sections of Guneid scheme (2004 – 2005) for soil unit 14:

Section	NO	Minor	Plant Cane	1st Ratoon	2nd Ratoon	3rd Ratoon + other
Northern	**1**	**Jogogap**	57.92	48.24	38.52	35.10
	2	**Shikh Abdalla**	60.10	43.00	38.17	31.99
	Average yield		*59.01*	*45.62*	*38.34*	*33.54*
Southern	**3**	**Alabas**	59.64	47.42	41.38	29.69
	4	**Gianabia**	64.71	50.78	42.20	27.52
	Average yield		*62.17*	*49.08*	*41.79*	*28.60*

Table (21): Average yield of plant cane and ratoons in different canal at Northern and Southern Sections of Guneid scheme (2004 – 2005) for soil unit 17:

Section	NO	Minor	Plant Cane	1st Ratoon	2nd Ratoon	3rd Ratoon + other
Northern	**5**	**Abu Sugra**	53.20	47.33	32.86	29.47
	6	**Tambul**	54.42	41.63	31.00	34.49
	Average yield		*53.81*	*44.48*	*31.93*	*31.98*
Southern	**7**	**Gad Elrub**	56.65	43.61	44.03	-
	8	**Abu Sin**	57.47	40.83	34.22	28.46
	Average yield		*57.06*	*42.22*	*39.12*	*28.46*

Table (22): Average yield of plant cane and ratoons in different canal at Northern and Southern Sections of Guneid scheme (2005 – 2006) for soil unit 14:

Section	NO	Minor	Plant Cane	1st Ratoon	2nd Ratoon	3rd Ratoon + other
Northern	**1**	**Jogogap**	55.92	42.38	37.24	35.98
	2	**Shikh Abdalla**	53.55	41.09	34.05	34.53
	Average yield		*54.73*	*41.73*	*35.64*	*35.25*
Southern	**3**	**Alabas**	56.98	44.33	34.96	31.89
	4	**Gianabia**	53.64	45.46	42.90	36.23
	Average yield		*55.31*	*44.89*	*38.93*	*34.06*

Table (23): Average yield of plant cane and ratoons in different canal at Northern and Southern Sections of Guneid scheme (2005 – 2006) for soil unit 17:

Section	NO	Minor	Plant Cane	1st Ratoon	2nd Ratoon	3rd Ratoon + other
Northern	**5**	**Abu Sugra**	50.29	41.93	32.25	31.74
	6	**Tambul**	48.03	39.06	31.09	38.47
	Average yield		*49.16*	*40.49*	*31.67*	*35.10*
Southern	**7**	**Gad Elrub**	49.54	46.84	36.21	32.66
	8	**Abu Sin**	54.96	49.89	44.39	31.42
	Average yield		*52.25*	*48.36*	*40.30*	*32.04*

Table (24): Average yield of plant cane and ratoons in different canal at Northern and Southern Sections of Guneid scheme (2006 – 2007) for soil unit 14:

Section	NO	Minor	Plant Cane	1st Ratoon	2nd Ratoon	3rd Ratoon + other
Northern	**1**	**Jogogap**	60.15	48.62	40.33	35.69
	2	**Shikh Abdalla**	56.22	41.54	38.71	-
	Average yield		*58.18*	*45.08*	*44.52*	*35.69*
Southern	**3**	**Alabas**	62.66	41.91	38.78	37.88
	4	**Gianabia**	61.37	50.10	34.29	34.54
	Average yield		*62.01*	*46.00*	*36.53*	*36.21*

Table (25): Average yield of plant cane and ratoons in different canal at Northern and Southern Sections of Guneid scheme (2006 – 2007) for soil unit 17:

Section	NO	Minor	Plant Cane	1st Ratoon	2nd Ratoon	3rd Ratoon + other
Northern	**5**	**Abu Sugra**	54.21	43.63	33.76	27.77
	6	**Tambul**	52.83	38.83	33.75	33.08
	Average yield		*53.52*	*41.23*	*33.75*	*30.42*
Southern	**7**	**Gad Elrub**	58.62	50.97	33.38	35.22
	8	**Abu Sin**	54.62	51.10	36.35	40.17
	Average yield		*56.62*	*51.03*	*34.86*	*37.69*

Table (26): Average yield of plant cane and ratoons in different canal at Northern and Southern Sections of Guneid scheme (2007 – 2008) for soil unit 14:

Section	NO	Minor	Plant Cane	1st Ratoon	2nd Ratoon	3rd Ratoon + other
Northern	**1**	**Jogogap**	56.84	38.30	39.11	31.41
	2	**Shikh Abdalla**	54.81	43.19	35.66	30.68
	Average yield		*55.82*	*40.74*	*37.38*	*31.04*
Southern	**3**	**Alabas**	61.98	50.80	37.66	38.25
	4	**Gianabia**	64.63	42.17	41.73	40.62
	Average yield		*63.30*	*46.48*	*39.69*	*39.43*

Table (27): Average yield of plant cane and ratoons in different canal at Northern and Southern Sections of Guneid scheme (2007 – 2008) for soil unit 17:

Section	NO	Minor	Plant Cane	1st Ratoon	2nd Ratoon	3rd Ratoon + other
Northern	**5**	**Abu Sugra**	46.47	40.53	34.61	29.20
	6	**Tambul**	45.10	39.07	28.66	47.29
	Average yield		*45.78*	*39.80*	*31.63*	*38.24*
Southern	**7**	**Gad Elrub**	54.16	51.67	40.07	36.55
	8	**Abu Sin**	53.42	48.60	38.82	-
	Average yield		*53.79*	*50.13*	*39.445*	*36.55*

Table (28): Average yield of plant cane and ratoons in different canal at Northern and Southern Sections of Guneid scheme (2008 – 2009) for soil unit 14:

Section	NO	Minor	Plant Cane	1st Ratoon	2nd Ratoon	3rd Ratoon + other
Northern	**1**	**Jogogap**	61.33	48.10	36.93	30.73
	2	**Shikh Abdalla**	55.11	41.63	32.18	29.92
	Average yield		*58.22*	*44.86*	*34.55*	*30.32*
Southern	**3**	**Alabas**	56.32	49.93	42.23	35.56
	4	**Gianabia**	59.87	36.82	35.77	36.25
	Average yield		*58.09*	*43.37*	*39.00*	*35.90*

Table (29): Average yield of plant cane and ratoons in different canal at Northern and Southern Sections of Guneid scheme (2008 – 2009) for soil unit 17:

Section	NO	Minor	Plant Cane	1st Ratoon	2nd Ratoon	3rd Ratoon + other
Northern	**5**	**Abu Sugra**	45.96	41.50	32.87	28.86
	6	**Tambul**	45.37	38.03	27.94	39.12
	Average yield		*45.66*	*39.76*	*30.40*	*33.99*
Southern	**7**	**Gad Elrub**	58.66	39.31	38.90	32.38
	8	**Abu Sin**	63.16	41.79	38.03	33.00
	Average yield		*60.91*	*40.55*	*38.46*	*32.69*

Table (30): Average yield of plant cane and ratoons in different canal at Northern and Southern Sections of Guneid scheme (2010 – 2011) for soil unit 14:

Section	NO	Minor	Plant Cane	1st Ratoon	2nd Ratoon	3rd Ratoon + other
Northern	**1**	**Jogogap**	55.71	48.42	39.89	33.77
	2	**Shikh Abdalla**	57.29	44.47	34.98	38.97
	Average yield		*56.50*	*46.44*	*37.43*	*36.37*
Southern	**3**	**Alabas**	56.12	45.81	39.83	35.58
	4	**Gianabia**	54.84	45.89	43.18	38.63
	Average yield		*55.48*	*45.85*	*39.23*	*37.10*

Table (31): Average yield of plant cane and ratoons in different canal at Northern and Southern Sections of Guneid scheme (2010 – 2011) for soil unit 17:

Section	NO	Minor	Plant Cane	1st Ratoon	2nd Ratoon	3rd Ratoon + other
Northern	**5**	**Abu Sugra**	54.55	38.16	32.27	-
	6	**Tambul**	51.18	40.12	30.25	37.97
	Average yield		*52.86*	*39.14*	*31.26*	*37.97*
Southern	**7**	**Gad Elrub**	53.18	47.75	34.30	30.76
	8	**Abu Sin**	55.13	51.51	34.15	34.79
	Average yield		*54.15*	*49.63*	*34.22*	*32.77*

Table (32): Average yield of plant cane and ratoons in different canal at Northern and Southern Sections of Guneid scheme (2011 – 2012) for soil unit 14:

Section	NO	Minor	Plant Cane	1st Ratoon	2nd Ratoon	3rd Ratoon + other
Northern	**1**	**Jogogap**	56.78	43.41	37.44	35.07
	2	**Shikh Abdalla**	55.70	45.88	38.74	30.98
	Average yield		*56.24*	*44.64*	*38.09*	*33.02*
Southern	**3**	**Alabas**	58.64	45.30	36.29	36.06
	4	**Gianabia**	54.40	44.75	37.32	37.21
	Average yield		*56.52*	*45.02*	*36.80*	*36.63*

Table (33): Average yield of plant cane and ratoons in different canal at Northern and Southern Sections of Guneid scheme (2011 – 2012) for soil unit 17:

Section	NO	Minor	Plant Cane	1st Ratoon	2nd Ratoon	3rd Ratoon + other
Northern	**5**	**Abu Sugra**	52.22	44.09	37.82	28.73
	6	**Tambul**	48.96	41.60	30.17	31.27
	Average yield		*50.59*	*42.84*	*33.99*	*30.00*
Southern	**7**	**Gad Elrub**	51.54	45.22	40.51	40.51
	8	**Abu Sin**	49.30	42.27	37.97	29.05
	Average yield		*50.42*	*43.74*	*39.24*	*34.78*

Table (34): Average yield of plant cane and ratoons in different canal at Northern and Southern Sections of Guneid scheme (2012 – 2013) for soil unit 14:

Section	NO	Minor	Plant Cane	1st Ratoon	2nd Ratoon	3rd Ratoon + other
Northern	**1**	**Jogogap**	53.98	43.82	33.04	29.04
	2	**Shikh Abdalla**	50.00	43.69	32.26	35.71
	Average yield		*51.99*	*43.75*	*32.65*	*32.37*
Southern	**3**	**Alabas**	52.47	47.02	36.17	30.58
	4	**Gianabia**	47.75	40.82	37.44	29.00
	Average yield		*50.11*	*43.92*	*36.80*	*29.79*

Table (35): Average yield of plant cane and ratoons in different canal at Northern and Southern Sections of Guneid scheme (2012 – 2013) for soil unit 17:

Section	NO	Minor	Plant Cane	1st Ratoon	2nd Ratoon	3rd Ratoon + other
Northern	**5**	**Abu Sugra**	49.18	39.95	31.43	-
	6	**Tambul**	42.75	36.16	27.24	41.64
	Average yield		*45.96*	*38.05*	*29.33*	*41.64*
Southern	**7**	**Gad Elrub**	53.72	45.88	40.22	33.59
	8	**Abu Sin**	53.17	43.21	40.08	30.68
	Average yield		*53.44*	*44.54*	*40.15*	*37.13*