International Journal of Science and Research (IJSR)
ISSN (Online): 2319-7064
Index Copernicus Value (2015): 78.96 | Impact Factor (2015): 6.391

Study of the Yield Differences in Sugarcane at Al Guneid Scheme as Related to Land Evaluation System in Sudan

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Abstract: ***Al Guneid sugar Scheme lies in Gezira State and located 120 km South East of Khartoum on the eastern bank of the Blue Nile near Rufaa, with an estimated area of 42,000 feddans (17640 hectares). It stretches from Al Hilallyia town at North, to Tambul at East and South of Rufaa city. The farming area included in the agricultural rotation amount to 37,500 feddans (15756 hectares). The scheme area comprises canals, irrigation pumps and villages. This scheme was specified for sugarcane production and it was consider as a pilot projects in cane production and sugar industry in Sudan. This study was carried to compare the results of the previous soil survey and land classification on Al Guneid scheme with long term yield figures. It is hoped that the conclusion will contribute in improving soil management. The scheme is divided into two main parts; Northern and Southern sections from which eight fields were selected for this study depending on the soil and land suitability maps. Yield data for 12 seasons from (2000-2013), was made available from the scheme records. Geographical Information System was used to determine the fields (canals) locations based on the soil and suitability maps. According to the previous soil surveys studies two different soil types (soil unit 14 and 17) have been identified and both classified as moderately suitable lands (S2) due to some physical limitation but without marked differences in their suitability for sugar cane production. However, in some statistical analysis of previous data it could be inferred that unit 14reflectedbetter soil properties than unit 17. In this study the use of the long term yield data beside utilization of the GIS it enables better evaluation of yield characteristics of the two units. The results of this study clearly confirmed that the sugar cane productivity in the fields which are located in soil unit 14 soil excels those in the soil unit 17 by 3.0 -6.0 tons/ feddan. The study also confirmed that there is a difference in the productivity per unit of land between the north and the south sections, where the production of similar soil units in south exceeds the north. The production differences of similar soils at north and south are most probably attributed to management differences. The study recommends the use of geographic information systems (GIS) when conducting land evaluation studies related to production since fields with specific soils and yields could be located easily.***

Keywords: Sugarcane, Yield Difference, Land Evaluation

1. Introduction

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, 2006). Al 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 Al 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 Al Guneid scheme; the land was cultivated by cotton (1955-1962), and the Sugar cane since then (Ali, M.A.1969).

Soils of the Al 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 Al 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).

The objectives of this study are to check the land evaluation of the Al 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) Comment on sugarcane yield relation to soil properties.
4) Advice on soil management practices.

2. Material and Methods

2.1 Materials

Soils of the Study Area

The Al 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 Al 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 montomorillonitic clay and the occurrence of enough wet and dry climatic periods.

Fields of the Study Area

The Al Guneid sugarcane scheme is divided into 25 fields named after major canals. The Eight fields selected in this study lie in two sections (The northern and southern section) and each section contains the two dominant soil units (soil units 14 and 17) as shown below (Table 5 and Figure 1).

1) 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.
2) 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 Al Guneid sugarcane scheme.

Table 5: Fields (Canals) of Al Guneid Sugarcane Scheme selected for the study

Sections	*Selected Fields (Canals names)*	
	Soil Unit17	*Soil Unit 14*
Northern Section	**1.** Abu Sugra	**3.** Jagogab
	2. Tamboul	**4.** ShikhAbdalla
Southern Section	**5.** Abu Sin	**7.** Alabbas
	6. Gad Alrub	**8.** Alganabia

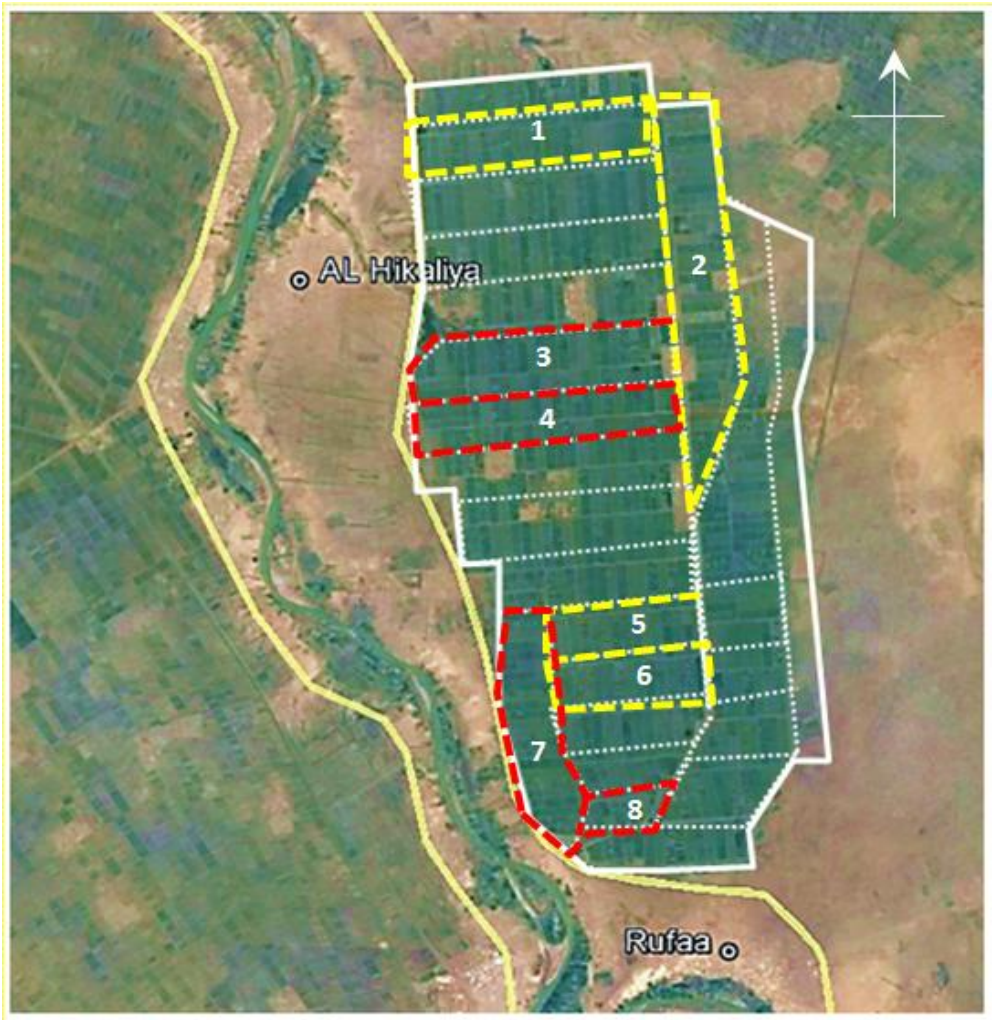

Figure 1: The Selected Fields (Canals)for the study at Al Al Guneid Sugar Scheme

Previous Documents

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

1) Study of Semi-detailed soil survey of Al Guneid sugarcane scheme and proposed extension, carried by Ali .M. A., Soil Survey Division, Wad Medani (1969).
2) Re- evaluation of Al Guneid scheme land potentials for sugarcane production. Idris, M. A. M, Soil survey administration, Wad Medani 1983.

The first soil survey (Ali, M.A. 1969) outlined the soil characteristics and classified the soils as IIp (moderately potential with soil physical limitations). The re_evaluation of the soil of Al Al Guneid according to the new land suitability system (Idris, M. A. M. 1983) and availability of reliable yield data, showed some soil variations but failed to link it either to differences in land classification classes or to differences in yield. The land was classed as S2p (moderately suitable with physical limitations).

GIS program

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

Remote Sensing Data and Soil Maps

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

3. Methods

Data Collection

The sugarcane yield data used in this study was collected from two sources; Al Guneid agriculture division and the Al Guneid sugarcane research station. GIS was employed to superimpose the fields map on soil map so as to enable selection of the field which are entirely located on specific one soil type. The data was collected in form of tables of yield data from the 2000-2013 seasons. The yield data from the selected fields was entered into GIS data base and linked with relevant fields.

Method of Analysis

The GIS was used to calculate the average and total yield of plant cane and 1st, 2nd, 3rd ratoons of the thirteen seasons for each of the eight selected fields. Manipulation and statistical analysis of the data was carried by GIS and MS office programs. Yields from fields on soil unit 17 were analyzed separately from those on soil unit 14 and eventually a comparison of the average yield from the two units was done. As well, it was possible to analyze and compare yields from same soil units in northern and southern sections.

Application of Land suitability classification system

Re-evaluation of Al Guneid scheme land suitability for sugarcane production adopted the new Land suitability classification system (Idris, M. A. 1990) which replaced the former land capability system (Ali .M. A., 1969). The previous 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 the selected crops. The land qualities include moisture availability, chemical fertility, and seedling establishment, possibility for mechanization, topography, soil drainability, salinity, sodicity and adverse physical properties. 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. Both soil units were classified as moderately suitable for the adapted crops with soil physical limitations (S2p).

4. Results and Discussions

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

Section	Field (Canals)	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 Al Guneid scheme according to soil unit (17):

Section	Field (Canals)	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

Table (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.

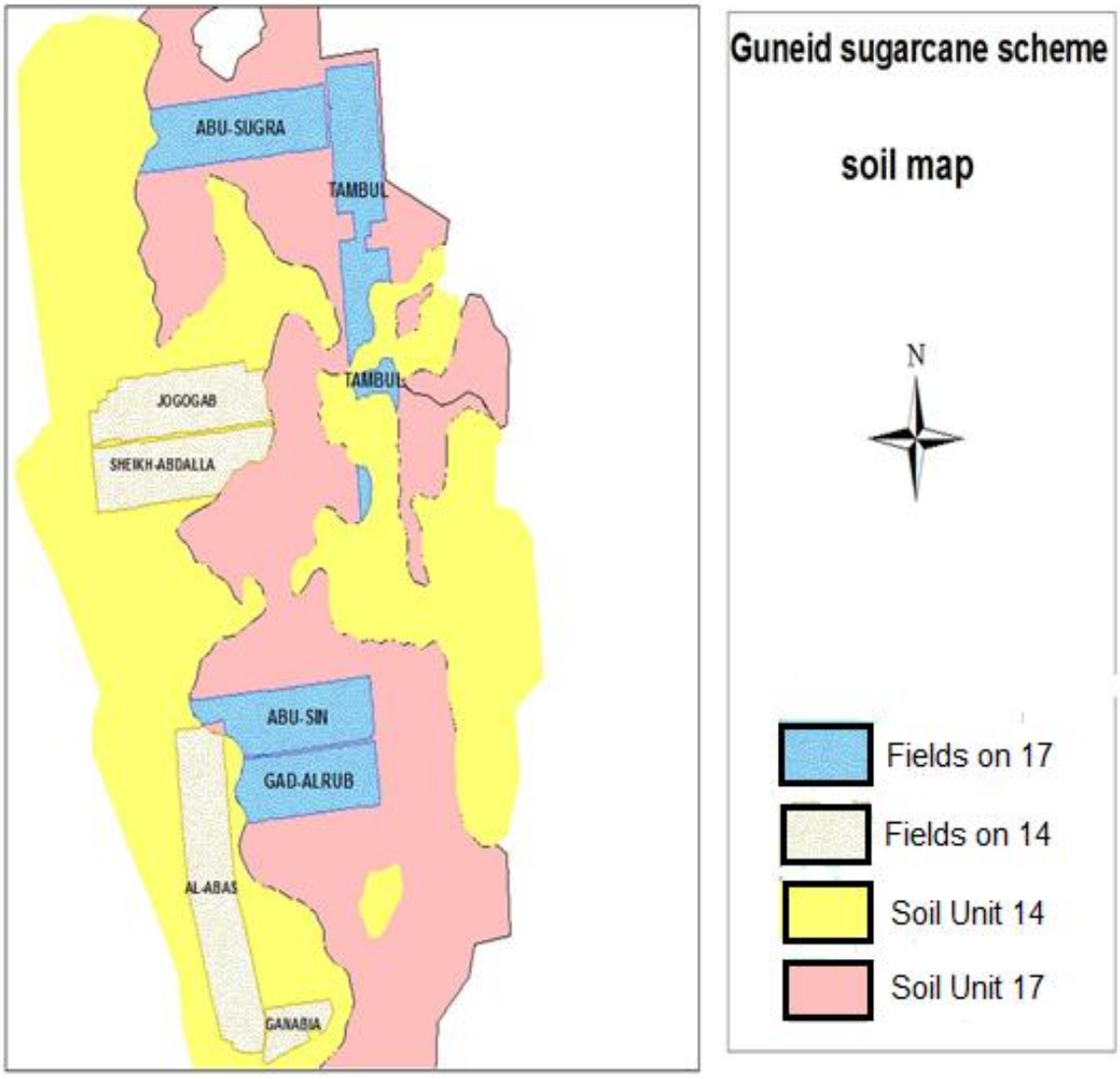

Figure 5: The Map of the Eight Fields (canals) as superimposed on the soil map of Al Guneid sugarcane scheme.

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 Al 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 56.09ton/fed) than soil unit 17 (average 49.62ton/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. The difference between unit 14 and unit 17 in yield for plant cane, 1st and 2nd ratoons is 6.47, 2,87 and 4.28 ton/ feddan respectively with an average difference of 4.54 ton/ feddan. In this respect, the range in yield difference is between 3 – 6 tons/ feddan.

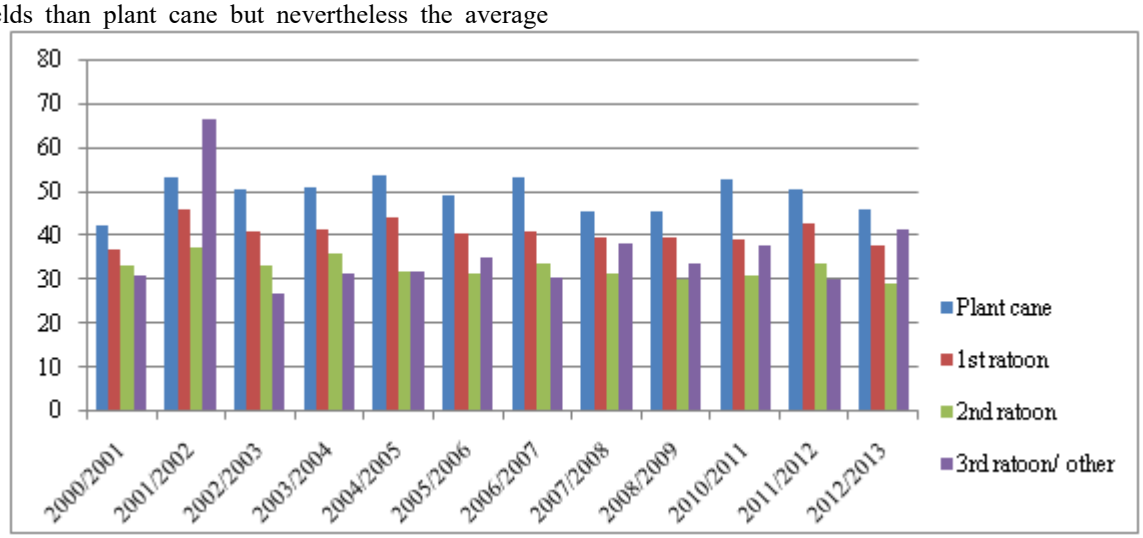

Figure 6: The average yield of plant cane and ratoons in different canal at **Northern** Section of Al Guneid scheme (2000 – 2013) for soil unit 17.

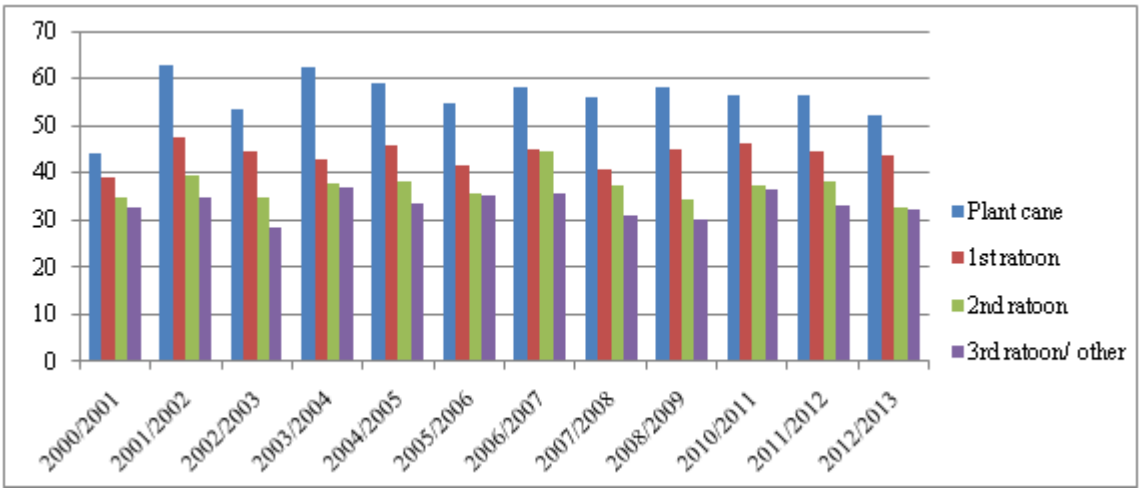

Figure 7: The average yield of plant cane and ratoons in different canal at **Northern** Section of Al Guneid scheme (2000 – 2013) for soil unit 14

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

Soil unit	*Unit 14 (Alabas + Ganabia)*				*Unit 17 (Gad Alrub + 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 57.47ton/fed) than soil unit 17 (average 54.12ton/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.

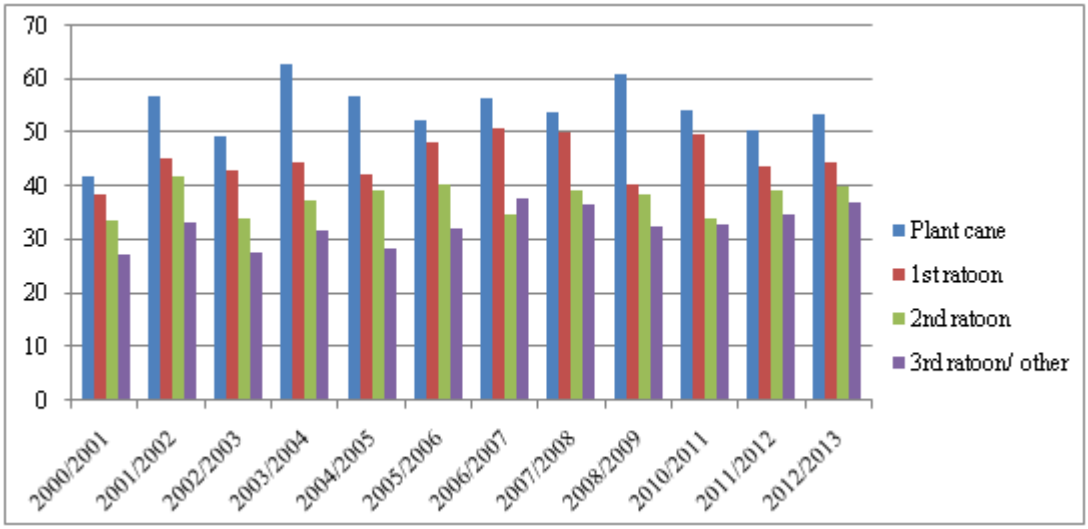

Figure 8: The average yield of plant cane and ratoons in different canal at **southern** of Al Guneid scheme (2000 – 2013) for soil unit 17.

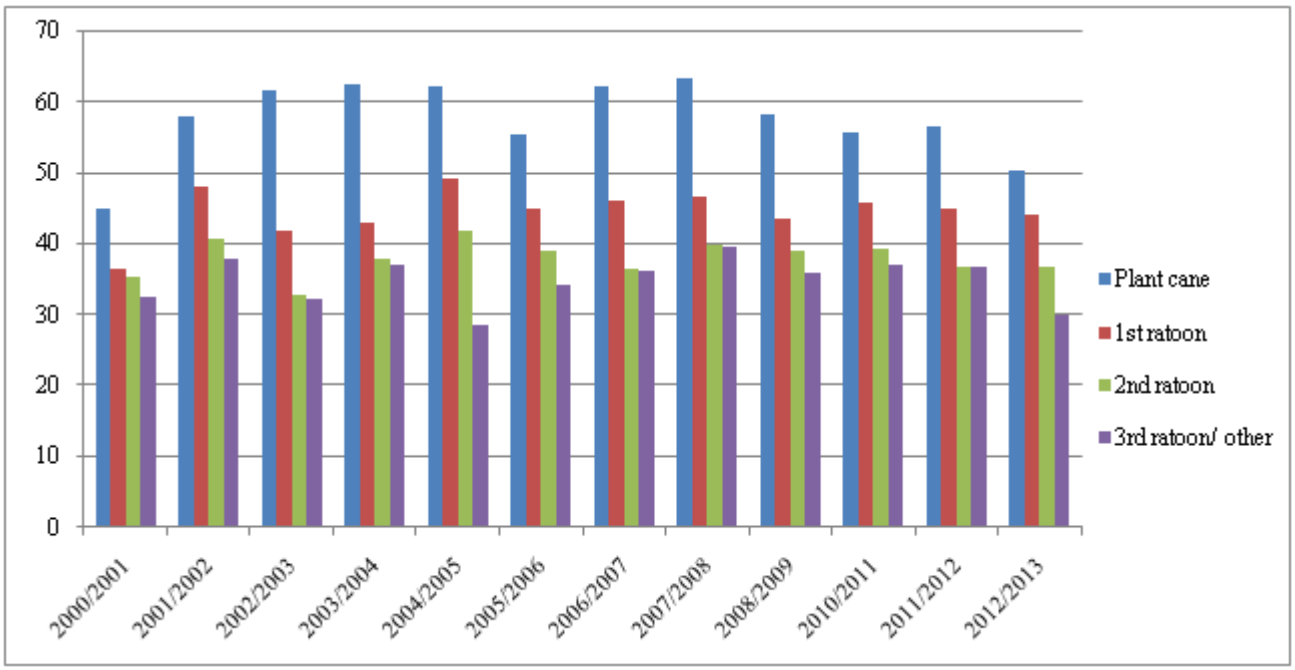

Figure 9: The average yield of plant cane and ratoons in different canal at **southern** of Al Guneid scheme (2000 – 2013) for soil unit 14.

Table 11: The Average yield of Sugar plants (ton/fed) of canal atdifferent section of Al 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 + Ganabia)	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 Alrub + 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 Al 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).

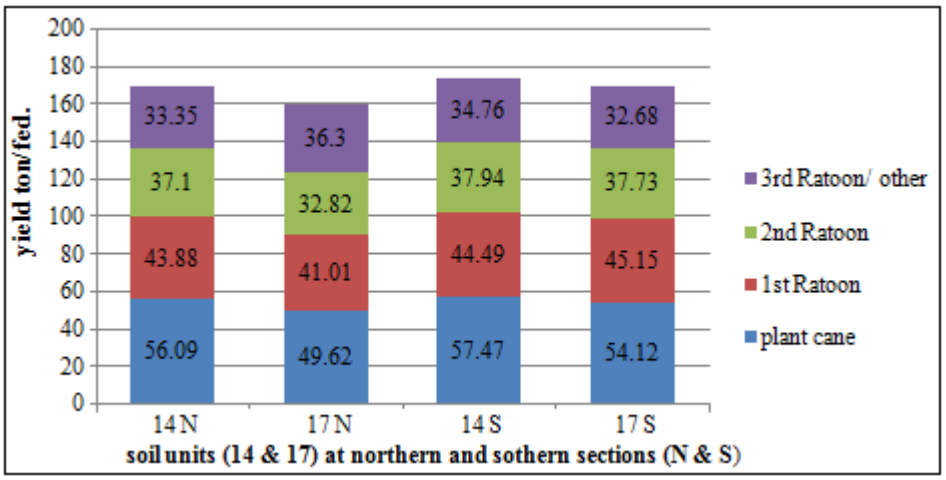

Figure 10: The Average yield of plant cane and ratoons (ton/fed) in different canal at northern and southern section of Al Guneid scheme for 12 seasons for soil unit 14 and 17

Although soil unit 14 produced better yields than soil unit 17 in both sections of the Al 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 Al 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.

5. 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 first previous soil survey study have characterized the soils of the Al Guneid and separated two soil map units. The quantitative data produced in the subsequent land evaluation study have indicated that soil map unit 17 has more disadvantageous soil properties than soil unit 14 and hence it should have affected its yield performance but the study failed to clarify and show the yield differences. 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) 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.
5) It seems that at the initial stages of land use planning at Al 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.

6) 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.
7) This study suggests that soil map unit 14 should be classified as S1 and unit 17 as S2p.This is according to the marked differences in their sugar cane yields (3.0–6.0 ton/feddan) and the figured soil limitations in unit 17 (i.e. WHC, AWC and permeability). It seems from the topographic location and the advantageous soil characteristics that soil map unit 14 is mainly located within the lower terrace whereas soil map unit 17 is mostly occupying slightly higher position of the upper terrace.

6. 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 Al Guneid Scheme administrations to help improve sugar cane production and reduce yield variations in both sections. As well, more research is needed at Al 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 Al Guneid Sugar scheme to support indoor research programs in providing recommendations on proper land management practices

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