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Potentiality of a desert plain soil to irrigation in River Nile State-Sudan

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In this research GPS (Garmin-GPSmap276C) was used to locate the observation sites and explore potentiality of soils of the area east of Shendi town, Shendi Province-River Nile, State of Sudan which is about 12751 ha and comprises a flat to slightly undulating desert plain with low gravely ridges and low jebels in south western and north western parts for irrigated agriculture in terms of the suitability of the landscape and associated soils to the desired use. Map was prepared in the office with 500 m × 500 m grid, the soils were mapped at this intensity and soil lines were drawn to locate the soil profiles at approximately the centre of every delineation. Results revealed least one soil profile for every unit that has an 840 ha was described following FAO (2006) format for profile description and was sampled at different soil horizons. The profiles and auger observation samples were subjected to analysis for their chemical and physical properties. The chemical and physical characteristics was further used to fine tune the soil boundary lines, and for final classification and evaluation purposes for the intended land utilization types. Soil classification was done using USDA Soil Taxonomy (1999) and Keys to Soil Taxonomy (2010), while the evaluation was done following Kevie and Eltom (2004). Hence soil and suitability maps were the final product. Results of this study revealed that 22.9% of the soils of the area were moderately suitable, 69.6% are marginally suitable, 1.6% are currently unsuitable while 5.9% are permanently unsuitable for irrigated agriculture.

Key words: Potentiality, desert plain, River Nile, irrigation.

INTRODUCTION

This study was carried out to fulfil the main objectives which are: the characterization of soils and landscape; assessment of the suitability of the land for irrigated agriculture and to provide guidance to agronomists and irrigation engineers. The main landform is the desert plain. The area is flat, slightly sloping northeast towards Wadi Elhawad and very slightly sloping northwest. Except for low gravelly ridges and low jebels (hills) in south western corner of the project and the low very few scattered gravelly ridges the whole area can be seen as flat to slightly undulating desert plain.

The solid geology that underlies the unconsolidated mantle is of Precambrian Basement complex which crops out in the south western boundary, Cretaceous age represented by Nubian sandstone which is supposed to be the parent material for all the soils in the area and

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Table 1. Main climatic features of Shendi Meteorological Station, 2001-2010.

Climatic features	January	February	March	April	May	June	July	August	September	October	November	December
Maximum temperature (°C)	30	32	36	40	41	41	38	36	38	38	34	30
Minimum temperature (°C)	14	16	19	22	26	28	26	26	27	25	19	15
Precipitation (mm)	trace	trace	trace	0.2	1.8	4.2	20.7	39.3	9.2	2.2	0.0	0.0
Wind Direction (from the)	NE	NE	NE	NE	NE	SW	SW	SW	SW	NE	NE	NE

http://www.wunderground.com/history-2010.

quaternary age formations in the form of Nile alluvium and aeolian deposits (GRAS, 1988). The area lies within the desert plain landscape. Wind erosion is an important feature in the area where processes of deflation and deposition are active. In the southern parts close to the hills or Jebels, sand ripples are common features indicating a deflation process, whereas, to the north and north western parts deposition in the form of sand hummocks around the trees and tumam is common. The climate of area is the hot continental desert climate with annual rainfall of less than 200 mm and <0.5 wet months, the relative humidity is <40% and large diurnal and annual temperature range. The main activity is pastoralism and cultivation through irrigation (Walsh, 1990).

According to Adam (2002), the climate of the area is semi-desert, confirming earlier classification of the area as semi-desert by Kevie (1976). The summer months starts from April and end in September with rainfall in July and August and winter months from October to March. The cool winter in the region is an important factor when considering crop selection. Table 1 shows the main features of the climate of the area represented by Shendi Meteorological Station.

The soil temperature and moisture regimes according to Wambeke (1982) are hyperthermic and aridic using Shendi climatic data. Previous ecological classifications in Sudan by Wickens (1990) classified the area as semi desert scrub and grassland on basement complex soils. The vegetation is very sparse and concentrated in sites where moisture is available in water courses (wadies and khors). The main vegetation types are: Salam (*Acacia ehrenbergiana*), Samar (*Acacia tortilis*), Hegleig (*Balanites aegyptiaca*), Tumam (*Panicum turgidum*) *and* Gaw (*Aristida funiculata*).Earlier studies on land evaluation underscore its importance in assessing land potentials for a specific purpose as well as understanding its optimal requirement. Land evaluation can be carried out to understand land potentials for a particular purpose at whatever scale (e.g. local, national, regional and even global). According to George (1997), studies

at the national scale may be useful in setting national priorities for development, whereas those targeted at the local level are useful for selecting specific projects for implementation. Land evaluation is applicable both in areas where there is strong competition between existing land uses in highly populated zones as well as in zones that are largely undeveloped. FAO (1983, 1995) noted that for assessing the suitability of soils for crop production, soil requirements of crops must be known and understood within the context of limitations imposed by land form and other features which do not form a part of the soil but may have a significant influence on use that can be made of the soil. A number of soil characteristics are directly related to crop yield and performance; beyond critical ranges, crops cannot be expected to yield satisfactorily unless special precautionary management measures are taken.

Soil suitability classifications are therefore based on knowledge of crop requirements, of prevailing soil conditions and of applied soil management. In other words, to the extent soil conditions match crop requirements under defined management and inputs (FAO, 1976).

MATERIALS AND METHODS

This research used GPS to locate the observation sites and explore potentiality of soils of the area east of Shendi town, Shendi Province-River Nile, State of Sudan which is about 12751 ha and comprises a flat to slightly undulating desert plain with low gravely ridges and low jebels in south western and north western parts for irrigated agriculture in terms of the suitability of the landscape and associated soils to the desired use. The climate is semi-desert with summer rains and cool winter; while the soil temperature and moisture regimes are hypethermic and aridic respectively. Field survey was located by GPS and adhered to a basic 0.5 km × 0.5 km grid. The intensity of field survey was one soil auger observation per 60 feddans.

Sample collection and classification and analysis

In all, 507 augers and 6 profile pits were made. At 125 auger sites, soil samples were collected from the 0.0 to 0.25, 0.25 to 0.50 m depths for pH, salinity (EC) and sodicity (SAR) screening. Five infiltration tests (double-ring infiltrometer method) were done at five locations with each test replicated thrice. A total of 33 soil samples were collected from the soil profile pits, profiles were described following FAO (2006) format for profile description, sampled at different soil horizons and classified according to the USDA Soil Taxonomy (1999) and Keys to Soil Taxonomy (2010). The profiles and auger observation samples were subjected to analysis for their chemical and physical properties following methods outlined by Page (1982) and Klute (1986). The chemical and physical properties were further used to fine tune the soil boundary lines,

Table 2. The main soil units.

Mapping unit	Soil name	Description
10	Eddamer	Deep to moderately deep soil, olive brown and/or dark greyish brown, sandy clay loam, non-calcareous,
20	Kelli	Moderately deep, reddish brown and/or dark yellowish brown, sandy clay loam, non-calcareous, the surface is covered by sand ripples or sand sheet and few gravels.
21	Kelli gravely	Moderately deep to shallow, reddish brown and/or yellowish brown, sandy clay loam, with gravels on the surface and embedded in the profile.
30	Infilled Wadi	Dark reddish brown, sandy or sandy loam soils with a thick mantle of sand hummocks around tumam and salam
M	Miscellaneous	Gravelly ridges

Table 3. Soil classification and correlation.

Order	Sub order	Great group	Sub-group	Family	Soil series	Phase
	Cambids	Haplocambids	Typic Haplocambids	Fine loamy, mixed, hyperthermic	Eddamer	
Aridisols	Argids	Haplargids	Typic Haplargids	Fine loamy over loamy skeletal, mixed, hyperthermic	Kelly	
	Argids	Haplargids	Typic Haplargids	Fine loamy, mixed, hyperthermic	Kelly	Gravely
Enttisols	Psamments	Torripsamments	Torripsamments	Sandy mixed, hyperthermic		

and for final classification and evaluation purposes for the intended land utilization types; hence soil and suitability maps were the final product.

Sample identification and evaluation

Two orders (Ardidsos and Entisols) and three main suborders of soils are identified: Argids Cambids and Psamments. The Argids (brown soils) covered about 23%, the Cambids (red soils) about 70%, and Psamments about 7%. Land suitability assessment follows the Framework for Land Evaluation adapted for Sudan by Kevie and Eltom (2004). It is based on the analysis of a number of sites and soil characteristics matched against the requirements of the intended land use, termed land utilization types (LUT). The proposed agricultural development plan is intended for both surface and pressure irrigation systems. The land suitability has two orders: Suitable (S) with highly (S1), moderately (S2) and marginally (S3) suitable classes; and unsuitable (N) with currently (N1) and permanently (N2) unsuitable classes.

RESULTS AND DISCUSSION

The whole area lies within the desert landscape, so the soils were categorized into three main groups namely, the brown soils, the red soils and soils of infilled wadis. The brown soils surface is always covered with gravel and sand sheet, mostly devoid of any vegetation, except in some low lying patches as resembled by Eddamer soil series, while the red soils (Kelli soil series, Kelli gravely phase and miscellaneous landtype) are soils of gravelly ridges, covered by gravel and sand ripples and sometimes the gravels are embedded in the soil column and finally the soil of Infilled wadis are covered by thick mantle of sand hummocks around *Panicum tugidum* and *Acacia ehrenbergiana*.Three main soil units were identified with one phase and one miscellaneous land type associated with them (Table 2). Mostly all soils properties along with their chemical and physical properties were considered to classify the soils using USDA system of classification (USDA, 1999; Keys to Soil Taxonomy, 2010). The soils were then correlated with the established soil series in LWRC as shown in Table 3.

The brown soils are flat or slightly convex, devoid of any vegetation. The surface is covered in some places with fine calcium carbonate concretions, while the red soils occupy a relatively high position in the pediment plain. The soil surface is flat with sand ripples and few quartz gravel. On the other hand, the soils of infilled wadi are characterized by a thick cover of wind blown sand. It has a dense vegetation cover of tumam (*P. turgidum)*, salam (*A. ehrenbergiana)* and higleig (*Balanites aegyptiaca*) trapping the blowing sands. The brown soils are deep, moderately drained while the red are moderately deep and moderately well drained. All soils are non-saline and non-sodic with ECe of less than 4 dS/m and ESP of less than 15, although previous studies reported saline and sodic spots in adjacent areas (Fadul, 1990). The infilled wadi and the miscellaneous land type are not recommended for agricultural use; although the infilled wadi soils could be used, it is advised that they be left as barrier to trap the moving sands.

A minimum of 2.0 m soil depth is required for areas where there is salinization or risk of salinization to allow for leaching or drainage if needed which is not the case here as all soils are non-saline.

Surface irrigation requires gently smooth sloping deep medium and fine textured soils, so gravely and coarse textured soils with infiltration rates above 60 mm/h are not suitable, unless very short furrows or very short basins are used, which is not desirable, this indicates that all soils here are not suitable for surface irrigation Table 4

Table 4. Infiltration rate for all soil units.

Profile number	Soil unit	Soil texture	IR (cm/h)
GP01	10		6.80
GP02	20		18.30
GP03	20		7.00
GP04	21		8.56
GP06	10		6.50

Table 5. Available water content per soil unit.

AWC class	Average	Range of average values	Range of average for mapping units	Mapping units	Suitability for irrigation
High	182	> 170			All types
Moderate	139	131 – 170	130-137	10	All types
Low	116	90 – 130	91-123	20-21	Sprinkler. Marginal for Gravity, Drip
Very low	74	< 90			Not suitable

Sandy and steep sloping soils of up to 20% slopes can be used for sprinkler irrigation, hence soils suitable for sprinkler irrigation are not suitable for surface, while the reverse is true.

Drip or micro-sprinklers are restricted to small areas where high value crops, that is, fruits, flowers and vegetables are grown. There is less hazard of rising water table or salt mobilization compared to other irrigation forms. It can not be used in sandy or very gravelly soils.

Of particular importance to the choice of irrigation system are hydraulic conductivity, infiltration rate and available water holding capacity, and they should be considered.

Table 4 show the infiltration rate (IR) for the soils of the area and the results show that the infiltration rate is above 6.0 cm/h, hence the soils are increasingly marginal for successful gravity irrigation, regarding the hydraulic conductivity, the permeability is rapid having values more than 0.3 m/day (Landon, 1991).

The available water capacity (AWC) according to soil units is shown in Table 5. Given that in desert zones where there is little accumulation of organic matter and where soil structures tend to be weakly developed, AWC is primarily related to soil texture. This varies considerably within and between soils so there is a corresponding variability of AWC as evidenced by the disparity between minimum and maximum values per soil unit. Based on all the survey data arranged per soil unit the following classification of AWC has been derived Table 5.

Sandy and coarse loamy soils that have low or very low AWCs are marginally suitable or unsuitable for gravity irrigation. It is to be remembered that not all of the soil AWC is readily available to plants. Readily available water content was not measured, but a rule-of-thumb is that it is about half to two-thirds of the total AWC (Landon, 1991).

The relevant land qualities that should be considered in analysis for irrigated agriculture in general have been listed by Kevie and Eltom (2004). The limits of suitability for each land quality have been followed in this study but with necessary adaptations to cater for the different requirements of surface and pressure irrigation as Land Utilization Type (LUT). Table 6 sets out the minimum requirements to separate suitable from non-suitable land under different irrigation regimes. For land to be suitable, all the criteria must be met.

None of the soils of survey area is highly suitable (class S1) for the LUTs being considered. Most of these soils are flat land and are suited to both surface and sprinkler irrigation and can sustain a wide range of crops. They are at best suited as class S2.

The coarse-textures, soil depth and/or topography are the main parameters that can reduce productivity and/or increase production costs and thereby downgrade land to classes S3, N1 or N2. Such land anyway is unsuitable for surface irrigation. Coarse soils demand more irrigation and sloping land may limit the options for pressure irrigation systems or affect their efficiency.

By comparing the soil and site characteristics against the aforementioned suitability criteria we have recognized four main categories of land suitability suborders, S2, S3, N1 and N2. These are defined in Table 7 and shown in Figures 1 and 2. Suitability subclasses are defined by the relevant *limitation* to use, where d = soil depth limitation, g = gravel limitation, m = soil moisture limitation (low AWC and/or high infiltration rate due to coarse soil texture and/or many gravels), t = topographic limitation and e= wind erosion limitation. These limitations may

Table 6. Measured land and soil characteristics; minimum value to establish land suitability for irrigated agriculture.

Characteristics	Surface	Sprinkler	Drip
Landform	Any except jebel, kerib, khor, floodplain		
Topography	Flat – gently undulating, long smooth slopes	Flat to rolling but excluding badlands	Flat to undulating but excluding badlands
Slope	< 3%	< 20% [1]	< 8%
Erosion	Exclude severe; that is, > 50% of area with one or more of dunes; hummocks > 0.4 m; gullies > 0.5 m deep		
Flooding	Exclude floodplain land inundated annually by main rivers		
Soil depth	> 2.0 m	> 2.0 m[2]	> 1.0 m
Sandy / gravel cover	< 0.15 m	n/a	n/a
Topsoil (0 - 0.25 m) stone, gravel	< 40% volume		
Topsoil (0 - 0.25 m) texture	Loamy or clayey (that is, not sandy, not gravely (>15%) loamy)	Any	Loamy or clayey (that is, not sandy, not gravely (>15%) loamy)
Infiltration rate[3]	1 – 60 mm/h	> 1 mm/h	> 1 mm/h
AWC, top m	> 90 mm	> 50 mm	> 90 mm
Permeability rate	> 8 mm/h (0.2 m/day)		
Soil drainage class	Any except very poor (and poor if drainage is not feasible)		
Water-table depth	> 3.0 m (or >1.0 m if drainage is feasible)		
Cation exchange capacity	> 8.0 $cmol^{(+)}$ kg^{-1} (or < 8 if extra fertilization is feasible)		
pH, top m	< 9.0 (or > 9.0 if associated with sodicity where reclamation is feasible)		
EC, top m	< 16 (or > 16 if reclamation is feasible) dS/m		< 4 dS/m
ESP / SAR, top m	< 35; < 50 for Vertisols (or higher if reclamation is feasible)		< 15

i) Based on criteria for centre-pivot irrigation. Other sprinkler systems are restricted to slopes < 15%.
ii) 1.5 m with proven well-managed centre-pivot irrigation and no evidence or risk of rising water-table or salinisation.
iii) Italicised parameters are measured from soil profile analyses or site tests. Non-italicised parameters derive from soil auger survey. Soil depth is measured from auger and profile pit.

Table 7. Land suitability classification.

Land suitability		Area (ha)	%
Suitable land			
Moderately suitable land			
S2def	Moderately severe limitations for the proposed uses and management. The land is flat or almost flat. Soils are deep to moderately deep. The main limitation being gravel, soil depth and wind erosion (MU10)	2923	22.9
Marginally suitable land			
S3dgm	Severe limitations due to shallow soil depth, gravel and moisture deficiency (MU 20&21)	8870	69.6
Unsuitable land			
Currently not suitable			
N1edm	Very severe limitations due to severe wind erosion , sandy soil texture and moisture deficiency. This land should be left as shelter belt to trap the creeping sands. (MU30)	202	1.6
Permanently not suitable			
N2	Gravely ridges (MU-Miscellaneous)	756	5.9
Total		12751	100

lower the profitability of the LUT being considered and/or may demand particular management, but they are surmountable as part of adapted farming practices.

Normal farming practices would be expected to cope with calcareous soils and somewhat gravely soils. Rough micro topography would be smoothed and surface stones

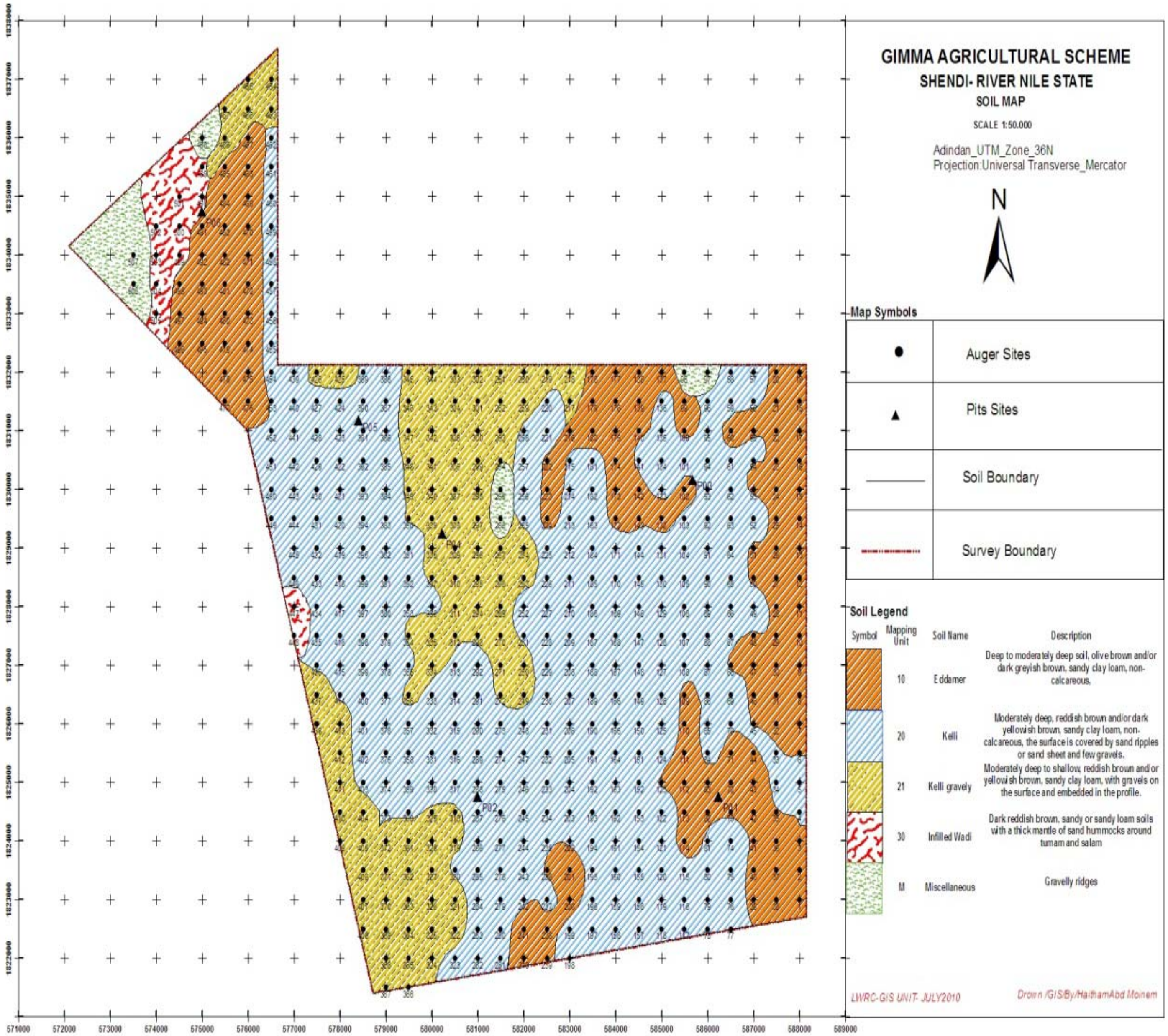

Figure 1. Soil map.

scraped away during land preparation, albeit with an increased cost.

Limitations and remedies

The main limitations in the study area are: shallow soil depth, erosion hazards, low soil fertility, high gravel content and moisture deficiency. The major remedies are:

i) Addition of fertilizers.
ii) Wind breaks and shelter belts for protection from wind erosion.
iii) Scraping of surface gravel and leveling.
iv) Addition of organic manure as a fertilizer and amendment.

Conclusions

The study thus revealed that
i) 23% of the total area is moderately suitable for irrigated agriculture.
ii) 70% of the total area is marginally suitable for irrigated

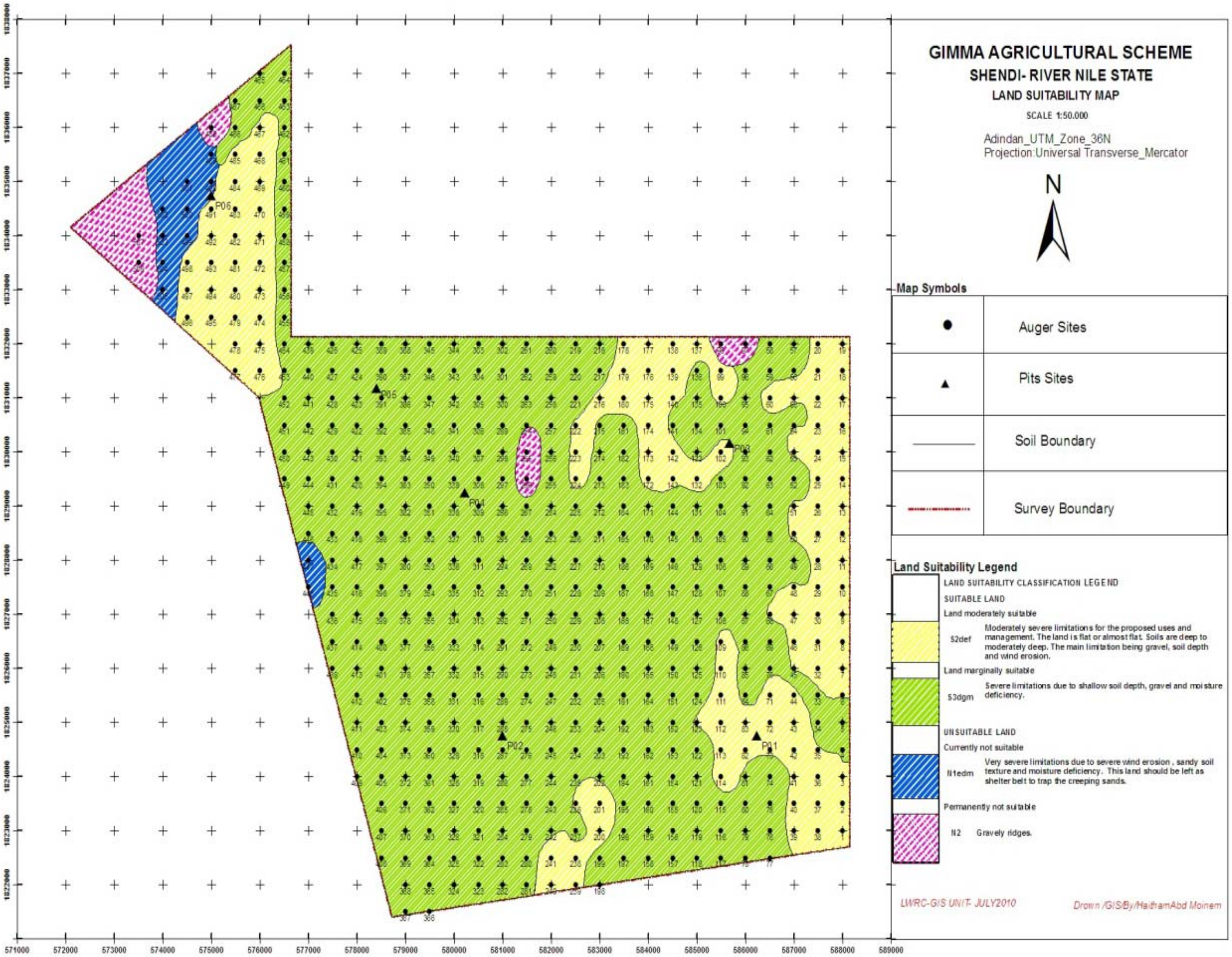

Figure 2. Land suitability map.

agriculture.

iii) 1% of the total area is currently unsuitable for irrigated agriculture.

iv) 6% of the total area is permanently unsuitable for irrigated agriculture.

Therefore, as infiltration rate is above 6.0 cm/h, the soils are increasingly marginal for successful gravity irrigation; also regarding the hydraulic conductivity, the permeability is rapid having values more than 0.3 m/day.

REFERENCES

Adam HS (2002). Agrometeorology. 2nd editin. Gezira university printing and publishing house.

FAO (1976). A Framework for Land Evaluation. FAO Soil Bulletin P. 32. Rome

FAO (1983). Guidelines: Land Evaluation for Rainfed Agriculture. FAO soil Bulletin, FAO, Rome P. 52.

FAO (1995). Planning for sustainable use of land resources: Towards a new approach. FAO Land and Water Bulletin, Rome P. 2.

FAO (2006). Guidelines for soil profile description. Rome, Italy.

Fadul HM (1990). Detailed soil survey and land evaluation of the AAAID proposed seed production project. Shendi District, Nile State.SSA report No.138. Soil Survey Administration, Wad Medani, Sudan.PMid:2152447

GRAS (1988). Geological atlas of the Republic of the Sudan, scale 1:1,000,000, Geological Research Authority of Sudan, Khartoum.

Kevie WV, Eltom OA (2004). Manual for land suitability classification for agriculture with particular reference to Sudan, LWRC, Wad Medani, Sudan.

Kevie WV (1976). Climatic zones in the Sudan. Bulletin Soil Survey Administration, Wad Medani, Sudan P. 27.

Klute A (ed) (1986). Methods of Soil Analysis.Part1-physical and mineralogical methods (2nd edition). American Soc. Agron. Agronomy monograph Madfison, Wisconsin 9(1).

Landon JR (1991). Booker tropical soil manual. longman scientific and Technical, NY, USA.

Page AL (ed) (1982). Methods of Soil Analysis.Part2-chemical and microbiological properties. (2nd edition). American Soc. Agron.

Agronomy monograph Madison, Wisconsin 9(2).
USDA (1999). Soil Taxonomy. Agric. Handbook No.436.NCRS, Washington, DC.USA
USDA (2010). Keys to Soil Taxonomy. 11th ed. USA.
Walsh RPD (1990). Climate, hydrology and water resources In: Craig, G.M Ed); The Agriculture of The Sudan. Oxford University Press, London.UK.
Wambeke A (1982). Africa soil moisture and temperature regimes. SMSS Tech Monograph, Washington D.C. USA.PMid:7074118
Wickens GE (1990). Natural vegetation In: Craig, GM Ed); The Agriculture of The Sudan. Oxford University Press, London.UK.
http://www.wunderground.com/history-2010