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LIMITATIONS AND IMPLICATIONS FOR EGYPTIAN SOIL SPATIAL DATA INFRASTRUCTURE

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ABSTRACT

The land master plan (LMP) of Egypt was issued in 1986, as a joint cooperation between the Egyptian Government represented by Ministry of development, new communities and land reclamation; and kingdom of the Netherlands, represented by Ministry of foreign affairs - directorate general for international cooperation. Euroconsult-Pacer consultants carried out the activities, based on the results of check-surveys of the high dam soil survey (FAO, 1965), and new reconnaissance and semi-detailed soil studies performed by General Authority for Rehabilitation Projects and Agricultural Development (GARPAD) in 1985. The LMP included maps for land capability, land management categories and soil units, at scales 1:250,000 (reconnaissance) and 1:50,000 (semi-detailed). The present study aimed to create a Spatial Data Infrastructure (SDI) in Geographic Information System (GIS) environment, for West Nubaria region, using 3 adjacent maps. Each map sheet was digitized separately, and processed to create the topology. Attribute data associated with each polygon included soil unit, land capability class, and land management categories. Up to this point, no limitations were encountered in building-up separate geodatabase. Problems started to occur when creating a seamless coverage for the three map sheets. The first and most important limitation was the inconsistency among the polygons boundaries at the edge of two map sheets. This represented a serious outcome, since each of the polygons

had different attributes. Edge matching failed at this point. Different processing techniques were elaborated (union and merging), and each method resulted in a different output, depending on which map is chosen first for the processing. None of the above mentioned techniques produced a satisfactory result. Another encountered limitation was the discrepancy in the calculated acreage of each mapping unit between the report and the GIS database. This might be attributed to methodology employed in measuring the 1986's areas using the planimeter, and the error associated with these measurements. Moreover, land capability classes were incompatible with the results obtained using recent software. The main implications for these limitations are

i) To apply the new techniques of Remote Sensing (RS) to map the different soil units, especially in vast desert and bare areas;

ii) To determine the location of soil observations by Global Positioning System (GPS); and

iii) To transfer all the gathered data into GIS environment for processing and manipulation.

Keywords: Digital land master plan, GIS, Land Evaluation, Remote sensing, Spatial Data Infrastructure (SDI).

INTRODUCTION

Soil surveys, soil maps, spatial soil information systems, and soil geographic databases, are all designed for fulfilling the requirements and demands of society for characterizing soils, which increased dramatically in the last decades (Mermut and Eswaran, 2000). Traditional soil survey is time consuming and expensive, new conventional surveys in the near future are very unlike, consequently methods exploiting existing information are becoming increasingly important (Nachtergale and van Ranst, 2002). In the recent digital era, spatial soil information systems (SSISs) are playing a more and more important role in this context (Lagacherie and McBratney, 2004; Rossiter, 2004). A key issue of applicability of SSISs is their accuracy. Essentially, the main practical aim of soil surveys and soil maps is prediction of soil attributes (Leenhardt et al., 1994). It simply means that certain soil feature is estimated for a whole region based on available soil data collected at localized sample points.

The traditional tool of this information extension is the classical soil map using soil mapping units. Crisp soil maps subdivide the region into disjunctive units in a way that within heterogeneity of soil properties is less than for the whole territory (Beckett and Webster, 1971). Numerous novel methods have been developed for producing more accurate soil maps; traditional crisp soil maps however are still extensively applied, since they offer the most easily interpretable results for the majority of users (Leenhardt et al., 1994). On the other hand accuracy of crisp soil maps can be increased in several ways: with the refinement of soil contours; with the subdivision of mapping units taking into consideration smaller unit within patch heterogeneities; and with the refinement of attribute information (more recent data, more precise measurement, up-to-date methodology, more appropriate classification etc.).

Digital soil mapping (DSM) integrates the recent developments in numerical soil mapping techniques with the knowledge on soil cover which has been accumulated by soil surveyors. A body of research work in geographical information science heralds the evolution from classical raster or vector GIS tools limited to the collection and storage of all kinds of spatial data, to more sophisticated systems able to represent more complex spatial models, and to embed spatial reasoning procedures such as inductive learning, or hierarchical reasoning. The development of DSM methods has been a growing activity for the past decades. DSM with the computational power integrated into modernized GIS packages provides new solutions for the improvement of SSISs (Pasztor and Szabo, 2006).

Remote Sensing (RS) can provide valuable and timely information about natural resources and environment, which are very important for sustainable developments. Geographic Information Systems (GIS) provide indispensable tools for decision-makers. Both RS and GIS techniques are considered very important geometric tools, which are fully utilized in the developed countries. However, in the developing countries, the utilization of such advanced technologies differs from one country to another due to one or more of the following reasons; a) lack of tools and infrastructure, b) inadequate training, c) lack of coordination between aid agencies, d) too much emphasis on technology push rather than on application, e) restrictions and regulations, and f) lack of basic information and maps (Arafat 2003).

The benefits from using RS and GIS technology depend on the level of success of its application for solving a concrete task. In general, these benefits can be divided into four categories such as scientific, technological, methodological, and economic efficiency (Badarch, 1990). The scientific efficiency of remotely sensed data also includes obtaining new facts for corroboration and quantitative clarification of previously known, qualitatively studied data. Technological efficiency means increasing of the work productivity (mainly the most expensive field job), making norms for fieldwork and speeding up of natural resources mapping, reducing the fieldwork volume, shortening the time necessary for territorial surveys and reducing the number of personnel engaged in natural resources surveys. Methodological efficiency means increasing the accuracy and detail of spatial research of natural resources and also of observing widespread and dynamic processes and phenomena. Finally, economic efficiency of remote sensing data applications to natural resources can be expressed both directly (in the reduction of the cost of mapping) and indirectly (by an increase in the quality, reliability, detail, and information of the results).

The integration of image data into GIS is one of those great ideas whose time has come. Furthermore, remote sensing is often the most cost-effective source of information for updating a GIS and it is a valuable source of current land use/land cover data. Remote sensing techniques has been utilized successfully in certain areas of application, including agriculture and related fields, especially in the developed countries were agricultural patterns are well defined and methodologies developed. The areas of applications in agriculture have been the identification or classification of crops, inventory of crop acreage, forecasting of crop yield, soil survey, design and operation of irrigation projects, and assessment of flood damage. Soil has an easily distinguishable characteristic reflectance pattern in the visible, near-infrared and mid-infrared wavelengths. The characteristic of soil reflectance pattern is easily distinguishable from green vegetation. Economic efficiency of remote sensing data applications can be expressed both directly as reduction of the cost and indirectly by an increase in the quality, reliability, and details of information. Remotely sensed data, when complemented by existing and supporting GIS, could improve management decision in agriculture for the next millennium (Syam, and Jusoff 1999).

MATERIALS AND METHODS

Datasets

Soil maps from land master plan:

Three soil units map sheets were used in this study to characterize the soil of West Nubaria region at scale 1:250000. The first one (the right) was covered by 2 seamless sheets having 22 soil units (map, 1 and table, 1) which describe each soil units and its area measured by land master plan team. The second soil units map (the left) describes the soil units and their areas (map, 2 and table, 2).

Satellite image:

Landsat MSS satellite image acquired in May 1985 (path176 and raw 38) was geometrically corrected (RMSE of 0.31) to match the same coordinates of the land master plan maps. The image was visually enhancement applying liner stretch histogram manipulation (Research Systems Inc., 2003).

GIS Data input:

The three LMP map sheets (soil units) were digitized and georeferenced in UTM using TerraSoft GIS software (Digital Resource System, 1991) having Helemert 1906 ellipsoid, and old Egyptian 1906 horizontal datum. The edges between map sheets were matched to form a seamless datasets, and then merged into one map sheet.

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Table (1): Description of the soil units for the right map of the study area.

Code -right units	Physiographic units	Soil mapping description	Area calculated fed	Area LMP fed
DB/6	Windblown deposits	Loose sand soils of undulating to rolling medium and high dunes, partly of barkhan or longtudinal types	50576.693	52080
DB11/4		Coarse sandy loam to clay loam soils or subsoils between isolated high dunes or low dunes to 50% of the area	45327.019	44640
DR/3			566.919	
DR23/3		Loose sand soils of predominantly low ripple dunes, groundwater below 2.50m	15773.666	20683
DS/4		Loose sand soils of medium and low dunes	67696.076	65918
DS11/6			23477.727	
DS12/6		Loamy sand soils, partly with rocky crust between low and medium dunes covering 40-50% of the area	52114.453	52080
DS25/6		Predominantly medium to high dunes	44026.581	36902
DS9/3		Gravelly sand soils or susoils between low dunes to 30-40% of the area	5936.508	5950
DU11/3		Loose sand soils of undifferientiated sheets of windblown sand predominantly moderately deep over clay loam subsoil	1916.111	3720
DU18/4		As Du11, with CaCO3 cemented layer partly with coarse sandy loam-clay loam subsoil	49550.772	50249
DU26/3		Wet saline/alkali windblown sand soils, groundwater at less than 1m	7004.33	11160
EG/4	Deltaic stage of various river terraces	Predominantly gravelly sand soils nearly level, slightly loamy to less than 20cm depth	26355.016	23361
EG12/21/3		As EG, partly reddish loamy soils between sand sheets locally with rocky crust in the surface	4000.509	5200
EG14/20/4		As EG, with small and thin sheets of windblown sand with gypsiferous (clay) loam subsoils and rocky crust on the surface	25078.878	26486
EG14/4		As EG, with locally sandy soils with gypsiferous (clay) loam subsoils and rocky crust on the surface	14249.391	14880
EG20/3		As EG, with small and thin sheets of windblown sand	422.003	446
EG21/4		As EG, with wide and thick sheets of windblown sand	948.378	446
FO5/4	outwash plains	Gravelly sand with terrace remnants	4329.008	2426
M/6	Miscellaneous land types		121090.034	104904
MN10/4			486.489	
NG/4	Wadi El-Natrun complex	Gypsiferous coarse sand soils, gravelly surface	63117.076	60710
NG/6			767.987	
NG20/4		As NG, with small and thin sheets of sand	9203.823	8928
NG22/6		As NG, sloping severely gullied	13324.958	12796

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Table (1) Cont.: Description of the soil units for the right map of the study area.

Code -right units	Physiographic units	Soil mapping description	Area calculated fed	Area LMP fed
NN/4	Wadi El-Natrun complex	As NN, predominantly gravelly coarse sandy soils	18473.518	18897
NN10/4		As NN, predominantly gravelly coarse sandy soils	9704.183	10118
NN20/4		As NN, with small and thin sheets of windblown sand	26827.223	23064
NN22/6		As NN, sloping severely gullied	10197.422	8928
NP/6		Nearly level, gypsiferous sandy and shaly soils, predominantly with rocky crust	2196.525	7440
NX/6		Complex of coarse and fine sand soils partly gravelly, loamy gypsiferous; locally silty clay subsoil or plateau remnants	38435.676	39878
PI20/3	Plains	Very deep coarse sandy loam soils with thin sheets and sand	13272.213	12796
PM4/20/6		Very deep silty clay loam soils with few and thin sheets of windblown sand, partly shallow over rock, or rock in surface	23632.11	23064
RA/6	River terraces	Predominantly undulating relief, gravel soils with reddish subsoils	32353.751	28718
RA1/6		As RA, nearly flat	29937.471	31545
RA2/6		As RA, severely eroded	971.945	1488
RA22/6		As RA, sloping, severely gullied	4124.612	5952
RA28/6		As RA, strongly undulating to rolling	20489.216	19939
RB/6		As RA	37321.517	11904
RB14/4		As RB, with gypsiferous/saline clay subsoil, partly with rocky crust in the surface	2328.412	4464
RB17/4		As RB, nearly level	4202.719	4464
RB20/6		As RB, with small and thin sheets of windblown sand	1190.261	744
RB22/6		Sloping, severely gullied	13214.565	5750
RB28/6		As RB, strongly undulating to rolling	18171.195	22320
RB7/4		As RB, loamy to about 20 - 50 cm depth	10013.723	10416
RC/6			4475.783	6738
RC1/6		Nearly level	2282.563	4313
RC22/6		Sloping, severely gullied	709.942	1168
W	Water		5030.218	

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Table (2): Description of the soil units for the left map of the study area.

Code – left Units	Physiographic units	Soil mapping description	Area calculated fed	Area LMP Fed.
F/6	Intermediate areas	Fans covered with unconsolidated materials and stones	32630.184	25200
G1/3		Predominantly sandy to sandy loam soils, having a calcic horizon, slightly dissected	159085.978	251640
G2/6		As G1, but with also gypsic horizon, gently undulating	32008.676	40400
G3/4		Predominantly gravelly sand to loamy sand soils, gently undulating	183704.942	140066
G4/6		Pediments predominantly covered with consolidated crust and stones	111403.697	87600
K1/6		Depression bottoms covered with consolidated crust and stones	6564.045	5400
K2/6		Depression bottoms covered locally with sand sheets over unconsolidated mixed materials	39303.304	41566
L1/6	Miscellaneous land types	Ridges covered with unconsolidated mixed materials	11915.163	9300
L2/6		Ridges covered locally with sand sheets over crust fragments and stones	12376.166	10800
P/6	Wadi El-Natrun system	Predominantly gravelly sand to loamy sand soils with dense drainage pattern	132327.54	134000
R/6	Miscellaneous land types	Buttes, with consoilidated surface	7164.061	4200
S1/4	Sand deposit system	Gravelly pavement with predominantly gravelly sand to sandy soils	474150.257	539200
S1/6			1848.557	
S2/6		Dune fields, deep coarse sand	34711.115	32166
S3/6		Self dunes, deep coarse sand	15748.903	15800
S4/6		Barchan dunes, deep coarse sand	80676.307	59300
T1/2A	Table land	Silty clay loam soils	53377.447	54400
T2/6		Deep sand soil with locally rock outcrops	93691.015	98860
T3/6		Rocky plateau covered locally with thin sand layer	197489.465	219366
T4/6		Predominantly rocky plateau	43859.668	29700
T5/6		Plateau covered predominantly with consolidated crust and stones	121104.379	150300
T6/6			17021.372	21000

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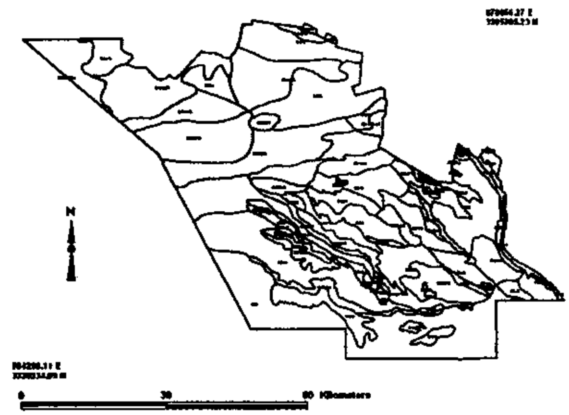
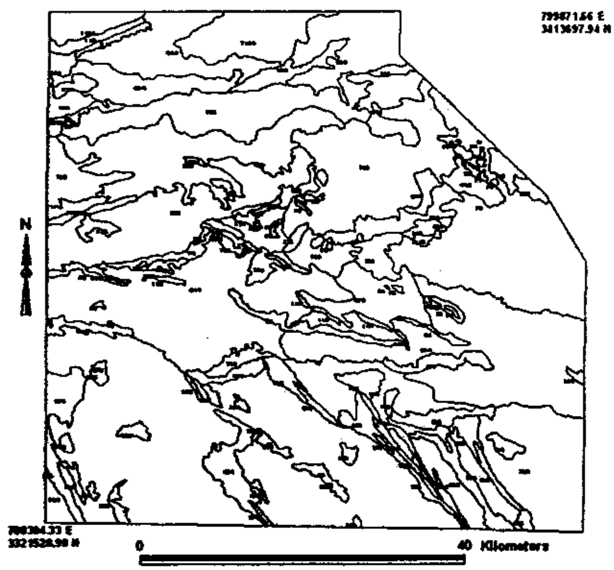


Map (1): Soil units of the right map of the study area.



Map (2): Soil units of the left maps of the study area.

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RESULTS AND DISCUSSION

Area inconsistency:

GIS data showed that there are area differences in soil units which were calculated from the LMP maps with those measured by GIS. These differences resulted from the method of measuring the area in 1985, which depends on field and manual datasets and now which depends on satellite images and GIS. The planimeter is less accurate than those of GIS method, knowing that the error of digitizing is less than 0.003. Tables (1) and (2) indicate that some units had increased in their areas, while others were decreased, for both right and left soil units maps, respectively.

Minimum mappable areas:

Since the LMP maps were at 1:250,000 scale, so the minimum mappable area should at least 250 hectares. This condition was not met since, may small polygons were included, having areas less than that. To overcome this problem, the small polygons were combined into the larger polygons containing them. This was resulted in increasing the areas of those large polygons.

Matching the two soil units maps:

The left map and the right map were merged for the sake of creating seamless soil unit coverage. When doing so, the process indicated that the boundaries of the two map sheets does not match (map 3), regardless of which one was on top of the other. This created a problem to be solved. The solution came from remote sensing, as the landsat MSS image of the same date was available. By overlaying the map on the satellite image (map 4), it was clear that the boundaries of the units on the margin of the two maps needed adjustment. The process for adjusting the boundaries included deleting the boundaries and performing union operation to merge the same units together. The final output was a clean seamless soil unit map covering most of the West Nubaria region (map 5).

CONCLUSION

The paper addressed the role of NSDI as a framework for recognizing the different land mapping units with the assistance of remote sensing as a background tool for accurate verification of the

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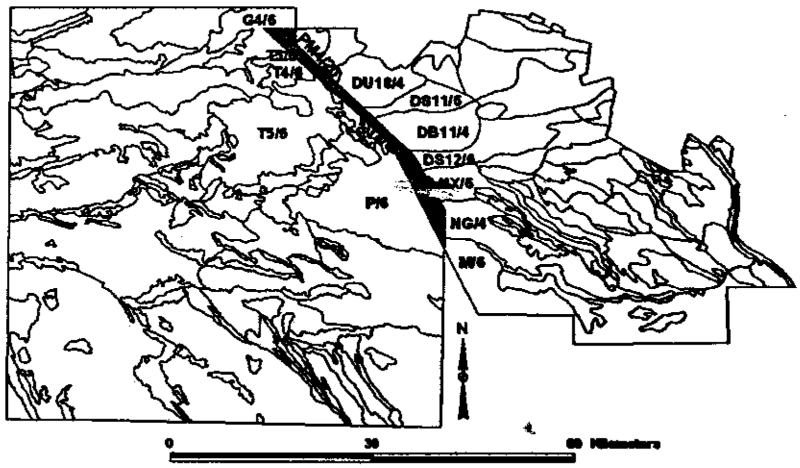
consistency of the land mapping units. Digital Mapping technology is knowledge-based, and the use of GIS and RS technologies helped bring a spatial perspective to environmental phenomena, allowing the visualization of relevant environmental information to correct the problem.



Map (3): Merging the right and left soil units maps

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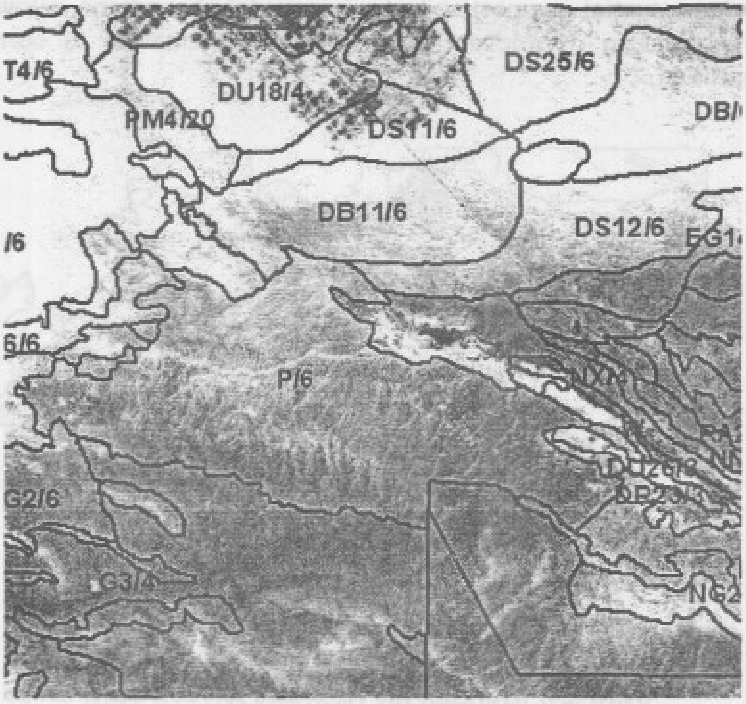

Map (4): Overlay of map on satellite image after correction.

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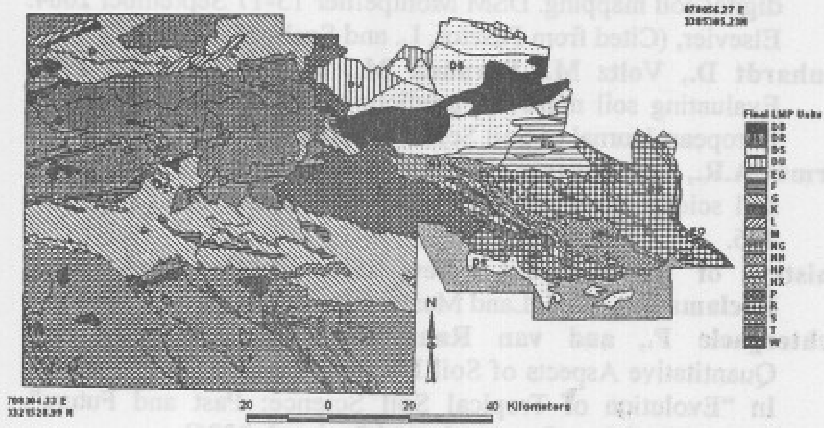

Map (5): Matching right and left soil units maps after correction.

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الملخص العربي

المعوقات والتحديات للبنية التحتية الرقمية للأراضي المصرية

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يهدف هذا البحث إلى إنشاء البنية التحتية الرقمية للأراضي المصرية عن طريق إدخال الخرائط إلى قاعدة البيانات الجغرافية وعمل خريطة موحدة للمناطق المتجاورة. وقد تم اختيار خريطتين من خرائط المخطط الرئيسي للأراضي، وقوبل البحث ببعض المعوقات التي تمثلت في عدم تطابق حدود الوحدات الموجودة على الإطار المشترك للخريطتين، مما استلزم استخدام صور الأقمار الصناعية لمحاولة تصحيح هذه التجاوزات. تم تصميم وإنتاج المخطط الرئيسي للأراضي في جمهورية مصر العربية عام ١٩٨٦ وهو عبارة عن ثمرة التعاون الدولي بين كلا من الحكومة المصرية ممثلة في وزارة التعمير والمجتمعات العمرانية الجديدة واستصلاح الأراضي والمملكة الهولندية ممثلة في وزارة الخارجية واعتمد أساسا على نتائج حصر أراضي مشروع السد العالي الذي تم عام ١٩٦٥ونتائج الحصر الاستكشافي والنصف التفصيلي للأراضي الذي تم بواسطة الهيئة العامة لاستصلاح الأراضي عام ١٩٨٥. يشتمل المخطط الرئيسي للأراضي في مصر على العديد من الخرائط ومنها خرائط القدرة الإنتاجية للأراضي وخرائط إدارة الموارد الأرضية وخرائط الوحدات الأرضية المختلفة بمقاييس رسم مختلفة تتراوح من الاستكشافي (١:٢٥٠٠٠٠) والنصف تفصيلية (١:٥٠٠٠٠). وتهدف هذه الدراسة إلى بناء قاعدة معلومات رقمية للبنية التحتية لقطاع غرب النوبارية داخل بيئة نظم المعلومات الجغرافية ولتحقيق هذا الهدف تم عمل مسح وإدخال لعدد ٣ خرائط منفصلة تغطى منطقة الدراسة تشتمل على الوحدات الأرضية المختلفة الموجودة بالمنطقة وكذلك وحدات قدرة الأرض الإنتاجية وأيضا وحدات إدارة الموارد الأرضية وحتى هذه النقطة لا توجد أي معوقات ولكن ظهرت المعوقات عندما تم دمج حدود هذه الخرائط الثلاثة معا (Edge matching) حيث وجد اختلاف في حدود الوحدات وعدم توافق حدود الوحدات (Polygons boundaries) فى الخرائط مع بعضها البعض مع استخدام تقنيات مختلفة (Merging and Union features) لعمل عملية دمج الخرائط مع بعضها البعض ولكنها لم تصلح سواء كانت إحدى الخرائط أعلى الأخرى أو العكس كذلك وجد أن المساحات المحسوبة عام ١٩٨٦ باستخدام (Planimeter) لكل وحدة من الوحدات مختلفة عن تلك التي تم حسابها بواسطة نظم المعلومات الجغرافية كذلك تم العثور على وحدات صغيرة المساحة (اقل من ٢٥٠ هكتار) داخل الوحدات الأساسية وهذه لا تصلح في أنواع الحصر الاستكشافي. وكانت التحديات الأساسية هي:

١- استخدام التقنيات الحديثة وخاصة تقنيات الاستشعار عن بعد واستخدام صور الأقمار الصناعية لتحديد حدود الوحدات المختلفة وخاصة في الأراضي الصحراوية الغير منزرعة.
٢- لابد من تحديد مواقع اخذ العينات بدقة متناهية وذلك باستخدام Global Positioning System (GPS).
٣- وإدخال كل هذه البيانات والمعلومات إلى نظم المعلومات الجغرافية للحصول على نتائج صحيحة ودقيقة.