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Monitoring Waterlogged Areas Using Thermal and Multi-Spectral Analysis, West Nubariya Region , Egypt

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THIS PAPER aims to monitoring waterlogged areas through linking terrain condition with ETM spectral characteristics images of West Delta in Egypt.

The agriculture development in the area is facing with human-induced degradation mainly waterlogging and salinity problems. Those are due to seepage from irrigation canals, inadequate drainage systems, conversion of pressurized irrigation system to surface-flooding irrigation, direct use of low quality drainage water in irrigation, and mixing drainage and wastewater with irrigation water system. The area is subjected to national extensive land improvement program throughout 1998 to 2004.

The study involves: - (1) Digital terrain analysis, (2) TM Analysis (Bands 1, 2, 3, 4, 5, 7 and 6), (3) field observations, (4) Test the relationship of the terrain condition with the different spectral classes, (5) Evaluate the effectiveness of the land improvement program throughout the temporal variability of the waterlogged areas. The materials used were topographic maps scales 1:50000, and Landsat 7 of ETM September 1997, December 1999, and December 2001.

The integrated land and watershed management system (ILWIS 3.2) has been used as the main software. The contour lines and ground control points of the topographic maps with 1000 meters grid system were used to create DTM using the geostatistical analyses. Physiographic mapping units was compiled from overlying and analyzing the classified DTM, slope aspect map, hills shadow map, geomorphologic information, ancillary information and geological map.

Multi-spectral image classification is used to extract thematic information from satellite images in a semi-automatic way. The thermal band was stretched to re-distributes values of an input map over a wider range of values in an output map.

The results show that terrain analysis is a powerful tool to identify the major physiographic mapping units. There is a good relationship between the physiographic mapping units and distribution of water logged areas. Also, there is a highly significant relationship between the two techniques of ETM analysis of using supervised maximum likelihood of the map list and thermal analysis of the band 6 of years 1997, 1999, and 2001 to determine the water logged areas. In general both techniques show that, there is dramatic increase in surface water; waterlogged area with shallow water, and waterlogged areas with poorly drained soils with high water table through 1997, 1999, and 2001. There is significant increase of the water logged areas in Sugar Beet and West Nubariya areas through 2001 due to the intensive flooding irrigation practices and the lack of appropriate drainage programs. The improvement of El-Bustan 1&2 is clear, due to the activities of Bustan Agricultural Development Project (1998-2004). The deterioration of some areas in Branch 20 and El-Bustan 3 reflects the recent intensive Banana cultivation.

Agriculture plays a major economic and social role in the development and welfare of the Arab Republic of Egypt. The loss of agricultural land as a result of urbanization has led the government to invest in a major land reclamation programme for the settlement of landless farmers and graduates. Nubariya district is considered to have scoped for the expansion of arable land as the Nile delta traditionally forms the old alluvial cultivable land. Sugar Beet, West Nubariya, Branch No. 20 and El Bustan areas (Old El-Bustan, zone I& II and zone III) are part of these new agricultural lands of the Western Delta reclaimed projects.

Land Degradation Assessment in Dry Lands (LADA, 2002), indicated that in Egypt there is 14,000 km^2 (1% of the total area) of hydromorphy condition. Waterlogging and salinity are universal problems of irrigated agriculture in arid and semi-arid regions. The risk of their occurrence has to be defined early in the planning, designing and construction processes of new areas (Bourrfa &Zimmer, 1994). Goossens (1994) concluded that the waterlogged soils in the western part of the newly reclaimed areas in the Baheira governorate in Egypt are created by a clay horizon below the aeolian sands impeding drainage. The use of satellite imagery has proved to be an excellent tool for monitoring of salinization and waterlogging. By the application of multi-temporal image analysis it is possible to estimate the loss of land due to waterlogging and by implementing a spatial growth model it is possible predict the expansion of waterlogging.

Geostatistical analysis was carried out at a two step procedure: (a) the calculation of the experimental semi-variogram and fitting a model; and (b) interpolation through ordinary Kriging, which uses the semi-variogram parameters (Stein, 1998). Ordinary Kriging takes into account both the structured and random characteristics of spatially distributed variables, thus providing tools for their description and optimal estimation.

Digital processing is increasingly used for identification and mapping of surface features. High spectral resolutions allow improving soil cartography, especially regarding the boundary precision of map unit delineation (Zinck, 1998). Norman *et al.* (1995) stated that temperature is a fundamental, thermodynamic quantity that is used to describe the state of matter and quantify the transport of heat. Yacoub (2003) and Abdel-Kader, *et al.* (2005), used the Maximum Likelihood classifier used to classify the colour composite of the satellite image after using the unsupervised classification to create the expected waterlogging areas. Howell *et al.* (1993) measured radiation components in both the short wave bands and long wave bands (thermal) in a bare clay loam soil. Travaglia *et al.* (1998) used Satellite Remote Sensing in exploring groundwater and locating the most suitable sites for drilling so that water can be tapped before it is lost.

Land improvement of West Nubariya (WN)

Bustan agricultural development project, Egypt (BADP) 1998-2004

The project aims to increase agricultural production and farm incomes and support the government's efforts to establish an economically viable and environmentally sustainable farming system for small holders on reclaimed desert land (New Land) in Bustan West Delta. This was achieved through more efficient irrigation systems to reduce waterlogging and waste of resources, the, improvement of extension services, training of small farmers and the wider availability of credit for essential on-farm investments. The project reactivates the existing Land Reclamation Training Centre at Mariut and establish two new 40 ha demonstration farms in the Bustan area.

The New Lands Agricultural Services Project. (NLASP) (306-EG) 1992-2000

The NLASP provided a coordinated area of agricultural support services in technology transfer, on-farm water management and credit to assist smallholder settlers in Egypt's reclaimed new lands in establishing sustainable and profitable farming systems. The project has provided many successful examples for providing assistance to new irrigation settlements in arid environments. A large training programme, plus demonstrations and excursions, have enabled the majority of farmers, whether traditional or graduates to come to grips with and address the difficult realities of farming and settling in the desert.

West Nubariya Rural Development Project (WNRDP) 2003-2007

The main activity aims at rationalizing the usage of available irrigation water and training the farmers to use and maintain the modern irrigation systems used in the new lands, which is totally different from the irrigation methods that they used to deal with in the old lands where they came from. The activity also focuses on encouraging the establishment of water users associations among beneficiaries.

Area studies

The total studied area covers about 265,910 Hectares cover five main areas, which are Sugar Beet, West Nubariya, Branch No. 20 and El-Bustan areas (Old El-Bustan, and zone I& II), and New EL-Bustan zone III. It represents one of the newly reclaimed areas in the west of the Nile delta. The location map of the study area is shown in Fig. 1. The area has a Mediterranean climate, characterized by rainy winter and prolonged hot and dry summer. The maximum monthly temperature is 30.3° in August and the minimum temperature is 6.3° in January. The annual rainfall is low (104 mm) and the relative humidity ranges between 59% and 81%, within an average of 69%. In summer the north wind comes from the Mediterranean Sea bringing moisture with it and during the period of February to July the Khamaseen wind, coming from the southwest direction, from the vast area of Western Desert, prevails. Soil moisture regime is Torric and the Soil temperature regime is Hyperthermic.

Material and Methods

Materials

1- Ten topographic maps of the area sheets NH35-K5b "Alam Musaylikh", NH35L-5d "El Hammam", NH35-L6a "Alam al Jataa", NH35L-6b "Jabal Khashm al Qaud", NH35L-6c "Burj al Arab", NH36-I4a "Jabal Na'um" , NH36-I4a "El-Nubariyyah", NH36-I4b Jabal Na'um, NH36-I4c "Abu al-Matamir", and NH36-I4d, "Hawsh Isa" scale 1:50,000 produced by the Egyptian general survey authority (EGSA, 1996). Geological map of Egypt at, sheet NH36NW Cairo scale 1: 500,000 printed in Germany1988, with cooperation of the Egyptian General Petroleum Corporation (EGPC, 1988).

2- Satellite images ETM of August 1997, December 1999, and December 2001, bands 1, 2, 3, 4, 5, 6, and 7.

Methodology

The integrated land and watershed management system ILWIS 3.2 (2003), has been used as a GIS package software.

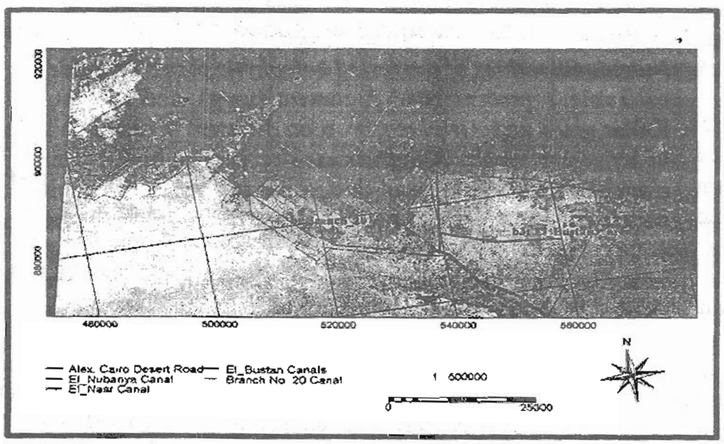

Fig. 1. Location of the study area.

Terrain analysis

The contour lines and ground control points of the topographic maps of the studied area, scale 1:50,000 (1996) with 1000 meters intervals were used to create DTM. The DTM was created using the geostatistical analyses of the final contour point's map of the studied area. Due to computer's memory and software capacity the area was divided into 4 sub areas before processing and glue map afterward. The semi-variogram is defined as a spatial dependence function of the distance between locations in the observation space. The histogram operation was used to determine the classes' intervals of the DTM value map. The slicing operation was used to obtain the boundaries of the geomorphic mapping units. Physiographic mapping units were compiled from overlying and analyzing the classified DTM, slope aspect map, hills shadow map, geomorphologic information, and geological map. Also the ancillary information and existed soil maps information were used to compile the physiographic mapping units.

TM analysis

1.*Map projection:* A projection defines the relation between the map coordinates (X, Y) and the geographic coordinate's latitude and longitude (Lat, Lon). The map projection of the topographic map was used as base maps. Map projection: Transeverse Mercator, with Datum: Old Egyptian 1907, Central Meridian: 31E, Origin Latitude: 30N, False Easting: 615000 m, and False Northing: 810000 m.

2.*Optimum Index Factor (OIF):* The Optimum Index Factor (OIF) is a statistic value that can be used to select the optimum combination of three bands in a satellite image with which you want to create a color composite. The optimum combination of bands out of all possible 3-band combinations is the one with the highest amount of 'information' (= highest sum of standard deviations), with the least amount of duplication (lowest correlation among band pairs).

3. *Supervised maximum likelihood classification using informative bands:* Multi-spectral image classification is used to extract thematic information from satellite images in a semi-automatic way. The main purpose to use color composite image are the ability to classify the visual interpretation of the image and help to define the classes of the slicing single band. The process of the supervised classification methods are divided into two phases: a training phase, where the user trains the computer, by assigning for a limited number of pixels to what classes they belong in this particular image, followed by the decision making phase, where the computer assigns a class label to all (other) image pixels, by looking for each pixel to which of the trained classes this pixel is most similar.

4. *Thermal band analysis using linear stretching and slicing operations* :The thermal band was stretched to re-distributes values of an input map over a wider range of values in an output map. The stretch operation produces a new output

map with stretched values slicing classifies the values of a raster map. Ranges of values of the input map are grouped together into one output class. A domain Group should be created beforehand; it lists the upper boundaries of the groups and the group names.

Field work/ancillary data

At representative sites, the different spectral classes were assessed and soil samples were taken. The physical and chemical analysis of the representive soil observations were show in Table 1 & 2. The classes primarily defined based on mainly field observations and verified with the soil map, geologic map, some soil physio-chemical properties, reports, and general land use maps, for both thermal and multi-spectral analysis. A class domain consists of a list of class definitions for the image classification content 12 classes are used for the both thermal band and multi-spectral analysis (Table 3).

TABLE 1. The physical analysis of the representive observation points.

Mapping Unit	Sample No.	Depth cm	Sand %	Silt %	Clay %	Texture Class	$CaCO_3$ %
Hi111	P38	0-30	71.40	10.40	18.20	Sandy Loam	24.31
		30-60	76.60	10.40	13.00	Sandy Loam	28.36
		60-150	81.80	5.20	13.00	Sandy Loam	20.26
Hi112	P19	0-30	74.00	10.40	15.60	Sandy Loam	21.27
		30-60	71.40	15.60	13.00	Sandy Loam	22.29
		60-150	71.40	15.60	13.00	Sandy Loam	16.82
Hi113	P9	0-30	82.00	7.70	10.30	Loamy Sand	21.27
		30-60	74.00	7.80	18.20	Sandy Loam.	22.29
		60-150	63.60	13.00	23.40	Sandy Clay Loam.	16.82
Hi114	P45	0-30	76.80	7.70	15.40	Sandy Loam	13.57
		30-60	70.10	10.40	18.20	Sandy Loam	23.30
		60-150	66.20	10.40	23.40	Sandy Clay Loam	14.18
Va111	P1	0-30	65.80	21.00	13.20	Sandy Loam.	19.25
		30-60	71.10	7.90	21.00	Sandy Clay Loam	14.18
		60-150	58.40	15.60	26.00	Sandy Clay Loam	14.18
Va112	P8	0-30	76.80	7.70	15.40	Sandy Loam.	18.64
		30-60	71.20	7.80	20.90	Sandy Clay Loam	22.29
		60-150	58.40	15.60	26.00	Sandy Clay Loam	24.31
PL111	P48	0-25	91.5	6.7	1.8	Sandy	4.2
		25-60	90.5	6.7	2.8	Sandy	7.5
		60-150	89.3	8.1	2.6	Sandy	7.5
PL112	P29	0-20	92.5	5.9	1.6	Sandy	4.2
		20-60	91.5	6.7	1.8	Sandy	7.5
		60-150	90.2	8.1	1.7	Sand	7.5

TABLE 1.Contd.

Mapping Unit	Sample No.	Depth cm	Sand %	Silt %	Clay %	Texture Class	$CaCO_3$ %
PL113	P36	0-25	91.8	6.6	1.6	Sandy	6.6
		25-60	90.5	7.9	1.6	Sandy	6.6
		60-150	89.3	8.9	1.8	Sandy	7.0
PL114	P41	0-25	94.2	4.1	1.7	Sandy	7.5
		25-60	92.4	5.5	2.1	Sandy	7.5
		60-150	91.1	7.4	1.5	Sandy	7.9
PL211	P10	0-25	93.50	4.10	2.40	Sandy	7.9
		25-60	93.4	4.60	2.00	Sandy	8.3
		60-150	86.6	7.60	5.80	Loamy Sand	10.4
PL212	P28	0-25	93.60	4.40	2.00	Sandy	7.0
		25-60	93.40	4.40	2.20	Sandy	9.1
		60-150	93.30	4.70	2.00	Sandy	9.1
Pl311	P32	0-30	71.40	10.40	18.20	Sandy Loam	24.31
		30-60	76.60	10.40	13.00	Sandy Loam	28.36
		60-150	81.80	5.20	13.00	Sandy Loam	20.26
PL411	P25	0-20	80.6	14.4	5.0	Loamy Sand	6.6
		20-60	77.9	16.5	5.6	Loamy Sand	7.6
		60-150	71.7	20.4	7.9	Sandy Loam	7.9
PL511	P43	0-25	77.39	17.64	4.97	Loamy Sand	8.3
		25-60	69.81	23.28	6.91	Sandy Loam	9.9
		60-85	64.26	27.76	7.98	Sandy Loam	16.8
PL511	P15	0-15	68.19	23.28	8.53	Sandy Loam	7.5
		15-45	60.48	30.54	8.98	Sandy Loam	9.5
PL611	P17	0-30	65.80	21.00	13.20	Sandy Loam	19.25
		30-60	71.10	7.90	21.00	Sandy Clay Loam	14.18
		60-150	58.40	15.60	26.00	Sandy Clay Loam	14.18
PL612	P22	0-30	76.80	7.70	15.40	Sandy Loam	18.64
		30-60	71.20	7.80	20.90	Sandy Clay Loam	22.29
		60-150	58.40	15.60	26.00	Sandy Clay Loam	24.31
PL711	P47	0-25	96.7	2.3	1.0	Sandy	8.3
		25-60	95.4	3.4	1.2	Sandy	8.3
		60-150	94.2	4.3	1.5	Sandy	10.8
PL712	P34	0-30	76.80	7.70	15.40	Sandy Loam	18.64
		30-60	71.20	7.80	20.90	S.C.L	22.29
		60-150	58.40	15.60	26.00	S.C.L.	24.31

TABLE 2. The chemical analysis of the representive observation points.

Mapping Unit	Profile No.	Depth cm	pH	EC dS/m	Cations (meq/L)				Anions(meq/L)		
					Ca^{2+}	Mg^{2+}	$Na+$	K^{+}	HCO^{3-}	Cl^{-}	SO_4^{2-}
Hi111	P38	0-30	7.90	4.88	22.09	6.20	19.20	1.96	3.50	37.59	9.11
		30-60	7.52	4.15	21.30	4.78	14.76	1.68	3.38	34.38	4.20
		60-150	8.00	2.34	11.59	2.70	8.30	1.35	2.30	17.68	3.50
Hi112	P19	0-30	7.41	3.16	14.30	3.64	17.14	4.51	26.94	7.07	29.10
		30-60	7.65	4.61	20.86	5.31	25.00	6.57	39.30	10.31	20.10
		60-150	7.48	5.21	23.58	6.01	28.26	7.43	44.42	11.65	27.90
Hi113	P9	0-30	7.26	2.87	15.99	3.31	9.50	1.32	3.50	20.30	5.50
		30-60	7.42	1.12	5.52	1.15	4.42	0.65	2.30	7.53	1.50
		60-150	7.51	0.95	5.30	1.10	4.15	0.62	2.00	7.32	1.30
Hi114	P45	0-30	8.50	3.14	15.42	5.63	9.35	1.92	3.20	21.66	7.10
		30-60	8.42	2.78	13.68	3.20	10.20	1.65	3.10	18.96	6.50
		60-150	7.94	2.41	11.36	2.78	9.58	1.44	2.34	16.92	5.36
Va111	P1	0-30	7.70	0.87	3.93	1.00	2.75	1.24	1.85	4.93	2.10
		30-60	7.50	0.73	3.20	0.85	2.98	0.85	1.26	4.26	2.30
		60-150	7.51	0.44	2.32	1.14	1.20	0.17	1.01	2.50	1.30
Va112	P8	0-30	7.85	0.87	3.53	1.30	3.11	0.92	1.90	4.70	2.30
		30-60	7.87	0.56	2.89	1.23	1.50	0.75	0.54	3.48	1.70
		60-150	7.38	0.45	2.30	1.10	1.20	0.19	0.31	2.65	1.89
PL111	P48	0-25	8.01	0.55	2.73	1.14	0.1	1.86	1.5	2.63	1.70
		25-60	7.91	0.48	2.65	1.15	0.1	1.09	1.5	1.79	1.70
		60-150	7.95	0.49	2.73	1.11	0.1	1.16	1.5	1.99	1.61
PL112	P29	0-20	8.01	0.45	2.21	1.00	0.1	1.33	1.0	2.50	1.14
		20-60	8.00	0.47	2.05	1.19	0.1	1.50	1.0	2.13	1.71
		60-150	8.03	0.56	2.91	1.21	0.1	1.72	1.0	2.03	2.91
PL113	P36	0-25	7.77	0.99	5.14	2.44	0.1	2.61	2.4	6.04	1.85
		25-60	8.39	2.10	9.21	4.14	0.2	8.3	3.0	15.44	3.41
		60-150	8.38	6.14	35.13	13.35	0.2	14.2	3.0	42.12	17.76
PL114	P41	0-25	8.21	0.64	2.58	1.48	0.1	2.5	2.0	3.00	1.66
		25-60	8.28	1.04	6.16	2.45	0.1	2.5	2.0	5.45	3.76
PL211	P10	60-150	8.29	1.15	6.15	2.88	0.15	2.90	3.0	5.20	3.88
		0-25	8.09	0.63	3.12	1.68	0.1	2.5	1.5	3.65	2.25
		25-60	8.14	1.85	8.55	3.79	0.1	7.0	2.5	10.65	6.29
PL212	P28	60-150	8.17	2.11	9.06	4.11	0.2	8.5	2.5	15.20	4.17
		0-25	8.08	0.66	3.01	1.48	0.1	2.4	1.5	3.48	2.01
		25-60	8.25	0.98	5.93	1.66	0.1	2.5	2.0	4.26	3.93
Pl311	P32	60-150	8.25	1.23	7.06	3.11	0.2	2.5	2.0	8.46	2.41
		0-30	7.90	4.88	22.09	6.20	19.20	1.96	3.50	37.59	9.11
		30-60	7.52	4.15	21.30	4.78	14.76	1.68	3.38	34.38	4.20
		60-150	8.00	2.34	11.59	2.70	8.30	1.35	2.30	17.68	3.50

TABLE 2. Contd.

Mapping Unit	Profile No.	Depth cm	pH	EC dS/m	Cations (meq/L)				Anions(meq/L)		
					Ca^{2+}	Mg^{2+}	Na+	K^{+}	HCO^{3-}	Cl^{-}	SO_4^{2-}
PL411	P25	0-20	8.04	1.66	8.92	3.52	0.1	4.5	2.5	8.92	5.62
		20-60	8.21	2.76	18.68	4.45	0.2	6.5	3.0	18.9	7.93
		60-150	8.26	2.76	18.65	4.46	0.2	6.5	3.0	19.1	7.71
PL511	P43	0-25	7.79	4.11	22.12	7.88	0.2	11.6	3.0	30.5	8.30
		25-60	8.23	6.54	36.18	16.52	0.3	14.5	4.5	48.24	14.76
		60-85	8.29	9.55	56.12	24.04	0.3	18.5	4.5	76.13	18.33
PL511	P15	0-15	8.34	19.2	121.2	31.82	2.53	71.03	3.5	127.5	95.56
		15-45	8.29	32.8	134.3	43.75	3.5	225.2	5.0	235.5	166.2
PL611	P17	0-30	7.70	0.87	3.93	1.00	2.75	1.24	1.85	4.93	2.10
		30-60	7.50	0.73	3.20	0.85	2.98	0.85	1.26	4.26	2.30
		60-150	7.51	0.44	2.32	1.14	1.20	0.17	1.01	2.50	1.30
PL612	P22	0-30	7.38	0.45	2.30	1.10	1.20	0.19	0.31	2.65	1.89
		30-60	7.87	0.56	2.89	1.23	1.50	0.75	0.54	3.48	1.70
		60-150	7.85	0.87	3.53	1.30	3.11	0.92	1.90	4.70	2.30
PL711	P47	0-25	8.38	0.80	3.02	1.68	0.1	3.5	1.5	3.55	3.25
		25-60	8.35	0.80	3.52	2.95	0.1	2.5	2.0	4.20	2.87
		60-150	8.01	0.96	4.93	2.25	0.1	2.5	1.5	5.1	3.18
PL712	P34	0-25	8.09	0.56	2.71	1.23	0.1	2.51	1.90	4.70	2.30
		25-60	8.11	0.49	2.63	1.01	0.1	2.0	0.54	3.48	1.70
		60-150	8.02	0.51	2.69	1.11	0.1	2.0	0.31	2.65	1.89

TABLE 3. Class definitions for the both single and multi-spectral analysis.

Class No.	Class Name*	Class No.	Class Name
C1	Surface water	C7	Mixed crops 1 & crops 2
C2	Waterlogged area with shallow water	C8	Crops 1
C3	Waterlogged area with poorly drained soils, high water table	C9	Crops 2
C4	Crop 3 new generation	C10	mainly sandy soil
C5	Mainly fruit trees	C11	soil mixed with limestone and sand)
C6	Fruit trees mixed with some crops	C12	Soil mainly Limestone

The classes definition is modified from Goossens *et al.* (2003).

TABLE 4. The DTM model parameters of the four point maps and their goodness of fitting.

Point map	Models	Parameters			Goodness of fitting semi-variogram (R^2)
		Nugget	Sill or slope	Range	
Sub map 1	Spherical	0.0	690	45,000	0.850
Sub map 2	Spherical	0.0	1420	33,000	0.828
Sub map 3	Power	0.0	0.01	1.2	0.910
Sub map 4	Power	0.0	0.0588	1.0	0.870

Temporal and spatial change detection of waterlogged soils

For the hole test area and sub areas using map calculation and crossing operations (c1) Surface deep water , (c2) Waterlogged area with shallow water and (c3) Waterlogged area with poorly drained soils were calculated and compared.

Results and Discussions

Terrain units

Semi-variogram

In total 8,194 contour point's covers ten topographic maps were digitized. Due to the computer memory and the software capacity for calculating the contour value's map, the total contour points map was divided into four sub maps 1, 2, 3, and 4 (2399, 1271, 2090, and 2434 points respectively) and calculate the value map of each one, then glue them again. The contour points were ranged between -23 to 200 meters ASL (Above Sea Level) and the average was 62 meters ASL. The standard deviation was 51 m ASL. Using the ILWIS 3.2 facility, the dependent output tables of the four point maps will be defined, and calculated. Five models were tested to select the most fitted model of each sub point map (see Table 4).

Ordinary kriging

The parameters of the best fitting model were used to calculate the interpolation of the four sub contour value maps as the following definition:

- Map Kriging Ordinary (Sub map 1, sub area, Spherical (0.0, 690, 45000), 50000, 1, 8, 14, average, 0.0, 1000).
- Map Kriging Ordinary (Sub map 2, sub area, Spherical (0.0, 1420, 33000), 45000, 1, 8, 14, average, 0.0, 1000).
- Map Kriging Ordinary (Sub map 3, sub area, Power (0.0, 0.013, 1.2), 60000, 1, 8, 14, average, 0.0, 1000).
- Map Kriging Ordinary (Sub map 4, sub area, Power (0.0, 0.0588, 1.0), 55000, 1, 8, 14, average, 0.0, 1000).

The result of the raster error maps were 6.2, 8.5, 3.4, 7.3 m ASL respectively, with average of 6.3 m ASL. Notes: the big difference between the estimated error of Kriging and the standard deviation of the contour points map (51 m ASL.).

Physiographic mapping units

The DTM value map was used to delineate the boundaries of the physiographic mapping units after using the histograms operation. Using the slicing operation with the interval values, we can transfer the DTM value map to a classified map. The landscape was classified as coastal plain, elongated hills, mean valley, and plain of Maryout tableland. The main relief types were Maryout, extensive ridge, depression, series of terraces, elongated sand dunes, flat areas covered by thick and thin sand sheet and Knop. The physiographic mapping unit's legend was shown in Fig. 2 and Table 5.

TABLE 5. The physiographic mapping units legend.

Environmental deposits	Landscape	Relief	Lithology	Landform	Unit	Area in	
						Hectares	%
Marine deposits	Elongated hills	Extensive ridge	Pliocene formation	Summit	HI111	755	0.28
				Back slope	HI112	590	0.70
				Foot slope	HI113	24142	9.07
				Toe slope	HI114	11570	4.35
	Mena valley	Depression		Outer	Va111	10383	3.50
				Inner	Va112	6385	2.40
Colluvial deposits	Plain of Maryout Tableland	Elongated sand dune	Pliocene Miocene formation	Summit	PI111	645	0.24
				Back slope	PI112	3140	1.18
				Foot slope	PI113	7284	2.74
				Toe slope	PI114	41060	15.43
		Flat		Thick sand sheet	PI211	93945	35.31
				Thin sand sheet	PI212	30022	11.28
Colluvial Aeolian deposits		Knop		Knop	PI411	3009	1.13
		Depression		Depression	PI511	6790	2.55
		Terraces		Terrace 1	PI611	20450	7.69
				Terrace 2	PI612	2776	1.04
Colluvial deposits		Pyramid sand dune		Top	PI711	664	0.25
				Foot slope	PI712	2300	0.86

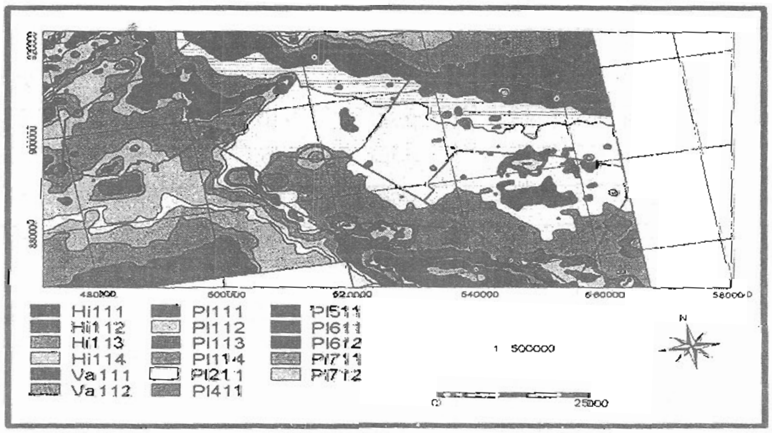

Fig. 2. The physiographic mapping units of the study area.

Multi-spectral and thermal spectral units

The OIF values are calculated and show in the Table 6. The combination of bands tmb1, tmb3, tmb5 and tmb7 is the best statistical choice to create a color composite of year 1997, 1999 and 2001.

TABLE 6. The summations and the standard deviations of the ETM of 1997, 1999, and 2001.

Bands	Year 1997		Year 1999		Year 2001	
	SUM	St.D	SUM	St.D	SUM	St.D
Band 1	1173	44.25	887	44.68	556	44.49
Band 2	888	26.54	577	29.67	242	19.72
Band 3	1445	44.34	963	44.87	411	44.69
Band 4	830	26.97	399	26.06	182	23.81
Band 5	1147	44.47	833	44.48	524	44.27
Band 7	1389	44.13	849	44.35	531	44.75

The result of using supervised maximum likelihood of the map list and thermal analysis of the band 6 of years 1997, 1999, and 2001 is shows in Table 7 & 8. In general the both techniques show that, there is dramatic increased in C1: surface water, C2: waterlogged area with shallow water, and C3: waterlogged area with poorly drained soils with high water table of the three images.

TABLE 7. The results of using maximum likelihood of ETM of 1997, 1999 & 2001.

Classes	Maximum likelyhood to map list					
	1997		1999		2001	
	Hectars	%	Hectars	%	Hectars	%
c1	154	0.06	240	0.09	2234	0.81
c2	2158	0.78	4284	1.56	9869	3.59
c3	10258	3.73	12125	4.41	25034	9.10
c4	22506	8.17	24687	8.97	36485	13.26
c5	26460	9.61	26404	9.59	34304	12.46
c6	48099	17.47	47567	17.28	33090	12.02
c7	26596	9.66	25358	9.21	32807	11.92
c8	30114	10.94	30066	10.92	31580	11.47
c9	35809	13.01	32973	11.98	25973	9.44
c10	48354	17.56	48372	17.57	18095	6.57
c11	20248	7.35	19636	7.13	23914	8.69
c12	4585	1.67	3529	1.28	1856	0.67
Total	275341	100.00	275241	100.00	275241	100.00

TABLE 8. The results of using slicing operation of the band 6 of 1997, 1999 & 2001.

Classes	Slicing operation to Band 6								
	Values	1997		Values	1999		Values	2001	
	Range	Hectars	%	Range	Hectars	%	Range	Hectars	%
c1	0 - 45	95	0.03	0 - 45	265	0.10	0 - 5	2453	0.89
c2	45 - 68	1598	0.58	45 - 71	4532	1.65	5 - 14	10153	3.69
c3	68 - 79	10490	3.81	71 - 83	13509	4.91	14 - 28	26193	9.51
c4	79 - 96	18982	6.90	83 - 101	25223	9.16	28 - 43	37248	13.53
c5	96 - 108	24880	9.04	101 - 112	25840	9.39	43 - 57	35910	13.04
c6	109 - 119	49255	17.90	112 - 123	46512	16.90	57 - 71	34637	12.58
c7	119 - 136	26176	9.51	123 - 143	26774	9.73	71 - 85	33071	12.01
c8	136 - 153	29677	10.78	143 - 161	29616	10.76	85 - 99	30075	10.92
c9	153 - 170	36602	13.30	161 - 177	34917	12.69	99 - 113	24249	8.81
c10	170 - 181	48730	17.70	177 - 188	47261	17.17	113 - 128	17947	6.52
c11	181 - 193	22971	8.35	188 - 205	17644	6.41	128 - 184	22373	8.13
c12	193 - 255	5785	2.10	205 - 255	3148	1.14	184 - 255	1032	0.37
Total		275241	100.00		275241	100.00		275341	100.00

The results of using maximum likelihood of map list and slicing of thermal band of year 2001 are shown in Fig. 3.The correlation test using SPSS software indicates that there is highly significant relationship between the two techniques of ETM analysis of using supervised maximum likelihood of the map list and thermal analysis of the band 6 of years 1997, 1999, and 2001 to determine the water logged areas. The results of correlation between the two techniques for each year are very high significant at the 0.01 level (2-tailed); year 1997 (0.996**), year1999 (0.997**) and year 2001 (0.996**).

Relationship between physiographic mapping units and ETM analysis

The results of crossing the physiographic mapping units with the results of (c1, c2 & c3) using supervised maximum likelihood of the map list and thermal analysis of the band 6 of years 1997, 1999, and 2001 are shown in Tables 9 & 10. The results show that the first three classes not exist in the high and sloping areas (Summit, Back Slope, and Knop areas). It is dominant in the almost flat areas (Foot Slope, Toe Slope, Depression and Flat areas, Fig. 4).

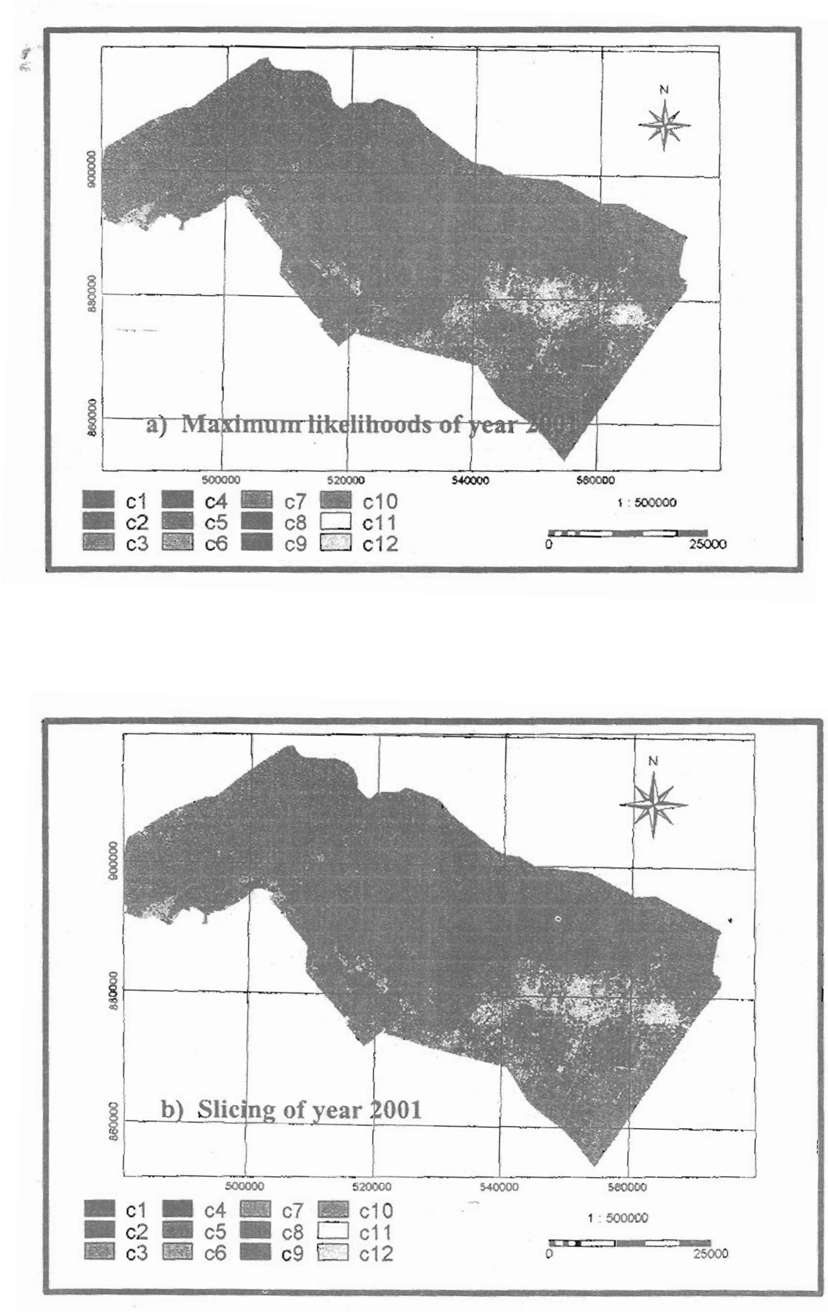

Fig. 3. The results of ETM analysis of year 2001.

TABLE 9. The results of crossing physiographic mapping units with the results of using maximum likelihood of ETM of 1997, 1999 & 2001.

mapping	area in	mxlkh_1997 in hectars				mxlkh_1999 in hectars				mxlkh_2001 in hectars			
units	hectars	c1	c2	c3	Total	c1	c2	c3	Total	c1	c2	c3	Total
Hi111	755												
Hi112	590												
Hi113	24142			258	258		21	669	690	612	1798	3212	5622
Hi114	11570	29	243	168	440	33	506	846	1385	1222	4688	7867	13777
Va111	10383	19	190	583	792	26	589	1201	1816	56	224	1645	1925
Va112	6385		156	165	321		162	602	764	39	204	764	1007
Pl111	645												
Pl112	3140												
Pl113	7284			78	78			105	105		25	122	147
Pl114	41060		163	589	752		324	485	809	53	521	1391	1965
Pl211	93945		229	2658	2887		650	2201	2851	69	633	3454	4156
Pl212	30022		340	2842	3182		621	2211	2832	129	1107	4034	5270
Pl411	3009												
Pl511	6790	78	65	308	451	138	474	1979	2591	13	102	387	502
Pl611	20450	11	617	1854	2482	22	700	1611	2333	22	213	745	980
Pl612	2776	17	145	605	767	21	154	144	319	19	354	1414	1787
Pl711	664												
Pl712	2300		10	149	159		82	72	154				
Total	265910	154	2158	10258	12570	240	4284	12125	16649	2234	9869	25034	37138

TABLE 10. The results of crossing physiographic mapping units with the results of using slicing operation of the band 6 of 1997, 1999 & 2001

mapping	area in	b6_1997 in hectars				b6_1999 in hectars				b6_2001 in hectars			
units	hectars	c1	c2	c3	Total	c1	c2	c3	Total	c1	c2	c3	Total
Hi111	755												
Hi112	590												
Hi113	24143			478	478		27	653	680	545	1855	3279	5679
Hi114	11570	23	104	259	386	25	525	819	1369	1431	4809	7979	14219
Va111	10383	21	124	594	739	30	625	1142	1797	48	367	2125	2540
Va112	6384		151	111	262		146	539	685	42	309	1512	1863
Pl111	644												
Pl112	3139												
Pl113	7284			61	61			95	95		19	136	155
Pl114	41060		156	572	728		236	469	705	47	530	1246	1823
Pl211	93945		212	2690	2902		625	2247	2872	62	665	3426	4153
Pl212	30022		304	2818	3122		743	2425	3168	174	1027	3655	4856
Pl411	3008												
Pl511	6790	45	140	232	417	151	625	1997	2773	18	89	311	417
Pl611	20450		344	1987	2331	29	726	1596	2351	32	161	700	894
Pl612	2726	6	63	545	614	30	175	1452	1657	54	320	1825	2199
Pl711	664												
Pl712	2300			142	142		80	76	155				
Total	265857	95	1598	10490	12183	265	4532	13509	18306	2453	10153	26193	38799

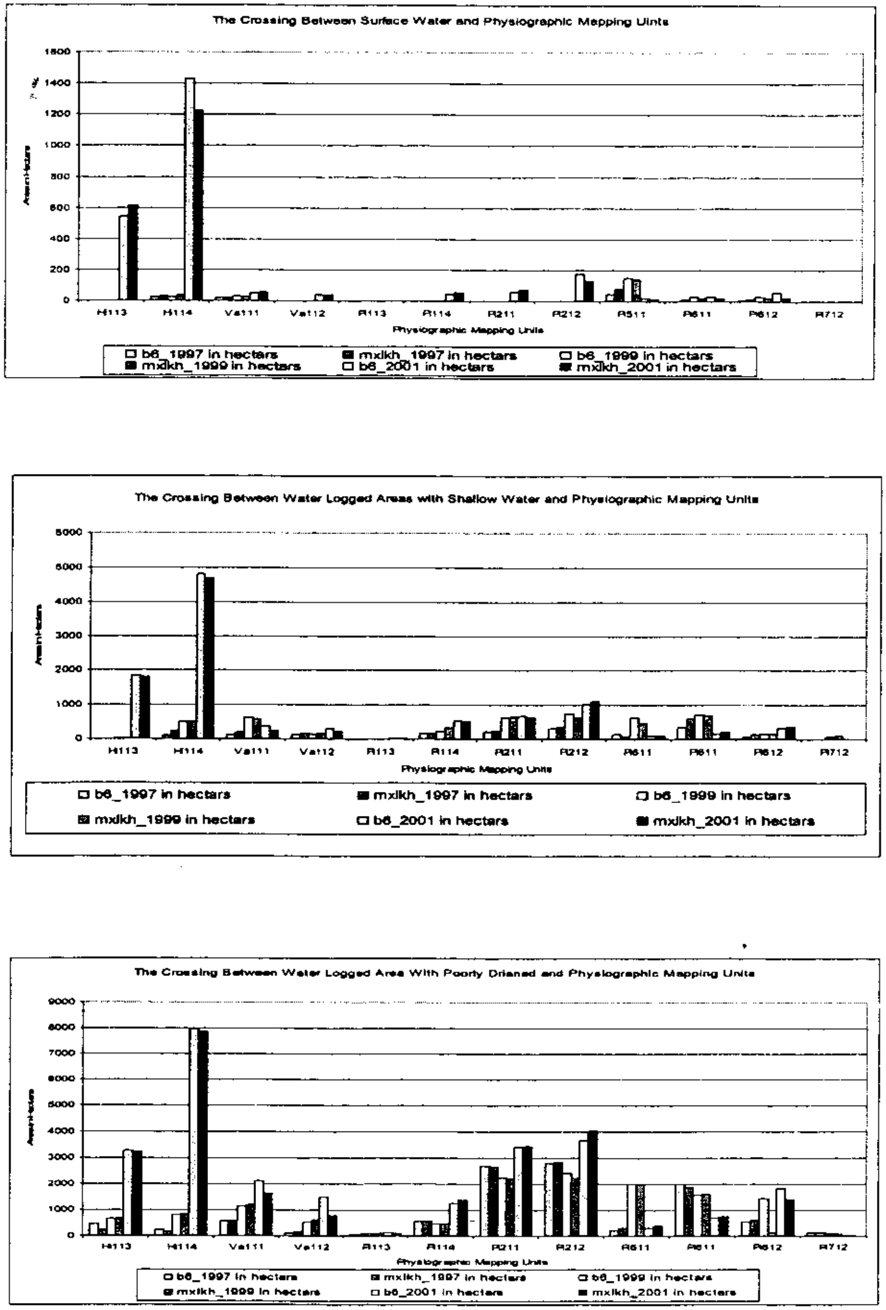

Fig. 4. The results of crossing physiographic mapping units with ETM classification.

The results of ANOVA of the three classes, images classification of year1997, 1999 and 2001 are presented in Table 11. In this analysis, the probability (P) value of the F-test shows that the probability of the random distribution of the water logging areas with shallow water (c2), and the water logging areas with poorly drained soils (c3) of the images classification of years 1997, 1999, and 2001 were very highly significant at level 0.05. The surface water (c1) of the three years were not significant at level 0.05. The classes (c1&c2) were differentiated group of the physiographic mapping units and class C1was not differentiated group.

TABLE 11. The ANOVA results of the classification of the three years.

Type		Sum of Squares	df	Mean Square	F	F_Table	Sig.
C1	Between Groups	2643832	18	146824	1.88	2.13	.072
	Within Groups	2105804	27	77992			
	Total	4752336	45				
C2	Between Groups	26434566	18	1468587	2.57	2.04	.000
	Within Groups	29125264	51	571084			
	Total	55559830	69				
C3	Between Groups	109911708	18	6106206	3.83	2.02	.000
	Within Groups	92525237	58	1595263			
	Total	202436945	76				

The sub areas

The changes of the first three classes for each sub area of the studied area is shows in Table 12 using the crossing operation between the sub-areas map with the results (c1, c2 & c3) of using supervised maximum likelihood of the map list and thermal analysis of the band 6 of years 1997, 1999, and 2001. The data shows that there is significant increase of the water logged areas in Sugar Beet and West Nubariya areas through 2001 due to the intensive flooding irrigation practices and the lack of appropriate drainage programs. The improvement of El-Bustan 1&2 is clear, due to the activities of Bustan Agricultural Development Project (1998-2004). The deterioration of some areas in Branch 20 and El-Bustan 3 reflects the recent intensive Banana cultivation (Fig. 5).

Conclusion

There is a highly significant relationship between the two techniques of ETM analysis of using supervised maximum likelihood of the map list and thermal analysis of the band 6 of years 1997, 1999, and 2001 to determine the water logged areas.

Terrain analysis is a powerful tool to identify the major physiographic mapping units. There is a good relationship between the Physiographic mapping units and distribution of water logged areas.

In general both techniques show that, there is a dramatic increase in surface water; waterlogged area with shallow water, and waterlogged area with poorly drained soils and high water table through 1997, 1999 and 2001.

The experience of the analyst plays important roles to obtain good results of thermal and multi-spectral analysis. Understanding the algorithm and the functionality of the 2D-feature spaces and statistical separability analysis help to get high correlation between thermal and multi-spectral analysis.

TABLE 12. The results of crossing sub areas with ETM analysis.

Sub Areas	Classes	b6-1997	Mxlkh 1997	b6-1999	Mxlkh 1999	b6-2001	Mxlkh 2001
Sugar Beet Areas	c1	33	36	74	52	2005	1896
	c2	37	41	988	666	6703	6234
	c3	791	646	4223	4154	10731	96.40
West Nubariya Areas	c1	62	67	159	126	400	303
	c2	995	1125	2230	2153	2699	2728
	c3	5099	5145	5593	4533	12055	10950
Branch No.20 Areas	c1						
	c2	60	23	60	68	151	236
	c3	306	250	401	359	966	1104
El-Bustan 1&2 with Old Bustan	c1		51	32	62	48	35
	c2	506	969	1254	1396	346	319
	c3	4212	4201	3223	2988	1293	1277
	c1						
El-Bustan3 Areas	c2					254	352
	c3	82	16	69	91	1148	2064
Total of C1of each year		95	154	265	240	2453	2234
Total of C2of each year		1598	2158	4532	4284	10153	9869
Total of C3of each year		10490	10258	13509	12125	26193	25034
Total		12183	12570	18307	16649	38798	37137

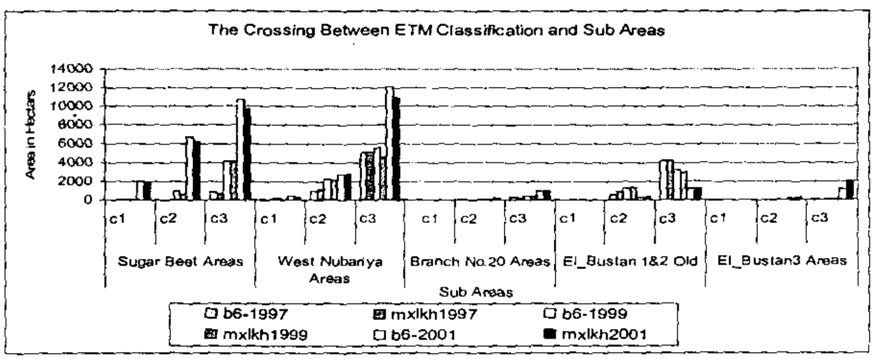

Fig. 5. The results of crossing sub areas with the images classification.

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تتبع مناطق الغدق بأستخدام تحليل الأطياف الموجيـــة المتعـــددة والحرارية- غرب الدلتا - مصر

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يهدف هذا البحث الى تتبع مناطق الغدق من خلال الربط بين حالة الأرض مع خواص الأطياف الموجية للصور الفضائية غرب الدلتا بمصر. حيث تواجة التنمية الزراعية بالمنطقة مشاكل تدهور الأراضى من حيث الغدق و الملوحة. و ذلك نتيجة التسرب من قنوات الرى و عدم كفاية انظمة الصرف و تحويل الرى الى الرى بالغمر و كذلك الى الأستخدام المباشر لمياه الصرف فى الرى و خلط الصرف الزراعى و الصحى مع نظام مياه الرى. و علية قد تم وضع هذه المناطق تحت برنامج مشروع تحسين قومى فى الفترة من عام ١٩٩٨ الى ٢٠٠٤ .

تمت هذه الدراسة كالآتـــى :- (١) تحليل النموذج الرقمى لسطح الأرض (٢) تحليل الأطياف الموجية لصور الأقمار الفضائية ETM (٣) الزيارة الميدانية (٤) اختبار العلاقة بين حالة الأرض مع اقسام تفسير الأطياف الموجية (٥) تقييم كفاءة برنامج تحسين الأرض خلال التغير الحادث فى مناطق الغدق. تم استخدم الخرائط الطبوغرافية بمقياس رسم ١:٥٠٠٠٠ و كذلك صور الأقمار الفضائية سبتمبر ١٩٩٧ و ديسمبر ١٩٩٩ و ديسمبر ٢٠٠١ .

تم استخدم برنامج ILWIS 3.2 كمصدر رئيسى لأجراء عمليات التحليل. كما تم رسم خطوط الكنتور وتوقيع نقاط الأرتفاع الطبوغرافية على نظام شبكى بمسافات بينية ١٠٠٠ متر و استخدمت لأنتاج النموذج الرقمى لسطح الأرض بأستخدام طرق الأحصاء المكانية. و تم انتاج الوحدات الفيزيوجرافية الخرائطية من تحليل و جمع و تقسيم النموذج الرقمى لسطح الأرض و الأستعانة بالمعلومات الثانوية و الخرائط الجيولوجية المتاحة. تبع ذلك تقسيم الأطياف الموجية المتعددة للصور الفضائية لأستخلاص خرائط معلوماتية. كما تم تقسيم الأطياف الموجية الحرارية و اعادة توزيع قيمها على مدى عريض من القيم.

اظهرت النتائج أن تحليل النموذج الرقمى لسطح الأرض أداه قوية لتحديد الوحدات الفيزيوجرافية الخرائطية الأساسية. و ان هناك علاقة جيدة بين الوحدات الفزيوجرافية الخرائطية و توزيع مناطق الغدق. و أن هناك علاقة معنوية عالية بين طريقتى تحليل صور الاقمارالفضائية لاعوام ١٩٩٧ و ١٩٩٩ و ٢٠٠١ لتحديد مناطق الغدق. وكما اظهر التحليل الكامل الطيفى المتعدد و الحرارى زيادة معنوية فى مناطق الماء السطحى و مناطق الغدق و مناطق الأراضى سيئة الصرف خلال ١٩٩٧ و ١٩٩٩ و ٢٠٠١ . و أن زيادة مناطق الغدق فى مناطق بنجر السكر و غرب النوبارية خلال سنة ٢٠٠١ كان نتيجة استخدام الرى بالغمر الكثيف و عدم كفاءة برنامج تحسين الصرف. كما حدث انخفاض فى مساحات مناطق الغدق فى مناطق البستان ١ ، ٢ نتيجة نشاط مشروع التنمية الزراعية بالبستان فى الفترة من ١٩٩٨ الى ٢٠٠٤ فى مقابل زيادة مساحات التدهور فى بعض المناطق مثل فرع ٢٠ و البستان ٣ نتيجة لتكثيف زراعات الموز.