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Monitor of Changes of Land Uses and Soil Characteristics at North West Area of Sinai Using Satellite Imagery, Egypt

T. M. H. Yossif[*] and G. M. Ebied
Dept. of Pedology, Water Resources and Desert Land Division, Desert Research Center, Cairo, Egypt

INFORMATION on changes in land use and soil characteristics due to either land degradation or reclamation in the form of maps and statistical data is very necessary for natural resources planning, management and utilization of land for agriculture production. The current study has been conducted at North West area of Sinai (El-Tina Plain), as a recent reclaimed area, bounded by long. 32^o 20` 00``E and 32$^o$ 33` 25``E and lat. 30^o 57` 15``N and 31$^o$ 04` 02``N, to monitor of changes that occurred in land uses over the period between 2000 and 2014 years by using the multitemporal analysis of satellite imagery and in some characteristics of the soil (soil salinity and ground water level) that hinder or reduce crop productivity. Landsat images, GIS, field work, laboratory analysis and previous studies data were used as the main sources of information to map land use, soil salinity and water table at the study area. The ETM+7, SPOT-xs and OLI 8 images were visually interpreted to produce different land use maps, each of them correspond to specific date. The area of each land use unit was measured in Arc-GIS software. Change detection has shown that the cultivated land area was increased by 10.5 % from about 18.8 % (7183.1 fed) in (2007) to 29.3 % (11189.4 fed) in the year (2014).Also, the area with fish farms has been increased to 43.2 % (16473.8 fed) and the land under reclamation decreased to 21% (8035.4 fed) in year 2014. Improvement trend in soil salinity was recorded in El-Tina plain soils due to reclamation process through 2006 – 2014 periods. However, an area of about 13311 fed showed a trend of degradation due to the rise of ground water level to < 50 cm from surface soil. The study is considered of vital importance for decision makers and for the management of natural resources in North West area of Sinai (El-Tina Plain).

Keywords: Land use, Soil salinity, Groundwater, Remote sensing, GIS, El-Tina Plain.

Sinai with its location and the variant natural resources is regarded as a strategic depth of Egypt and also as the main link to the eastern Arab countries. In spite of the remarkable vital advantages of Sinai, it has not been managed to be permanently prosperous for the whole country during the last three decades. After the elimination of terrorism in Sinai, a new awareness and appreciation have been remarkably grown in that a whole development regarding the economic, social, environmental and cultural structure aspects should take place to save the security of Egypt.

[*]Email: taheryossif@yahoo.com

Consequently, the government drew up a long-term plan; the main aim is the realization of the national utilization of the available water resources, mining new ores, establishment of industries, and cultivation near the sources of raw materials and also developing tourism.

El-Salam Canal project is one of the projects - including west and east of Suez Canal region - which need continuous monitoring in order to determine on the obstacles encountered and how to use the land for successful agricultural use. The differences in soil mapping units of El-Salam Canal project create variation in how to use the land for agriculture. As, the irrigation water in El-Salam canal passes either in the heavy clay soils affected by high ground water and high salinity or in loose sandy soils having rapid permeability. Soil resources of El-Salam Canal project were handled since 1981 among the agricultural development project, JICA (1981). A limited number of studies were conducted in the north western coast of Sinai (Dames & Moore, 1985, Abdel Rahman & Sadek, 1993, Schwarz-GTZ, 1993, El-Taweel *et al.*, 1997, Hola, 2000, Aly, 2004 and DRC staff, 2006).

El-Tina Plain is primarily a tidal mud-flat and salt marsh which is considered as a part of eastern side of ancient Nile Delta (Dames and Moore, 1985). It is irrigated with available water resources of El-Salam Canal which transports a mixture of Nile water and drainage water from Nile Delta region west of Suez Canal.

The most important factors affecting salinization and water logging of soils are the aridity of the climate, together with, the topography, hydrology of the terrain, and physio-chemical properties of the soil. In El-Tina Plain, salt water intrusion and submergence of the low lands by sea water cause the salinization of ground water and soils, respectively. The development of water-logged soils is mainly associated with low lands having bad physical properties and poor internal drainage conditions, (FAO, 1971). The installation of tile drainage increases the soil productivity in vast areas of the Nile Delta (ASRT, 1993).

Remotely sensed data, with its multi-temporal nature provide the mean to detect dynamic phenomena and to deduce information about objects (Townshend, 1992). Also, they have been employed for environmental study and monitoring since the conditions or phenomena studied often cover large area. The remote sensing data can be acquired under a variety of weather conditions, with various ground resolutions and different dates and wavelengths (Abdel Hady *et al.*, 1983 and Sadek *et al.*, 1993). The multi-application approaches have led to the better use of remote sensing data in natural resources inventory development, and management (Gad, 1988).

Land use is influenced by economic, cultural and land tenure factors at multiple scales. Land use refers to man's activities and the various uses which are carried on land. A serious problem for modeling land use change has been the lack of spatially detailed data. GIS and remote sensing have the potential to support such models, by providing data and analytical tools for the study of land use changes, (Manonmani and Suganya, 2010).

The present study is a trial to monitor changes that occurred in land uses of period from 2000 to 2014 years by using satellite imageries and in some characteristics of the soil at North West area of Sinai. The multi temporal remotely sensed data - Enhanced Thematic Mapper (ETM 7), Operational Land imager (OLI 8) and SPOT xs images - are used and integrated to monitor the land uses of the area under investigation. Also, GIS, Field and laboratory studies are integrated in the present study to monitor soil salinity and groundwater level development through 8 years (2006 – 2014).

Materials and Methods

The study area is located in the north western corner of the Sinai peninsula, bounded by longitudes 32^o 20\` 00\`\`E and 32$^o$ 33\` 25\`\`E and latitudes 30^o 57\` 15\`\`N and 31$^o$ 04\` 02\`\`N, with a total area of about 42 thousands feddans (Fig. 1). Physiographically, the study area is originally a part of the eastern ancient Nile Delta. The topography is flat or almost flat with a very nearly level gradient slope in north and west direction. The elevation varies from 0 – 2 m a.s.l.. The soils consist mainly of a mud flat of young lacustrine and deltaic deposits which were mainly formed during Pleistocene and Holocene ages of the recent era as surficial flood sediments (EGPC- Conco Coral, 1987). Low sandy areas of slightly saline soils with minor elevation differences compared to the mud flat occurred.

To monitor changes in land uses and some characteristics of the soil, the GIS, the digital image processing techniques, the previous studies, field work and laboratory analyses are integrated.

Landsat 7 ETM+, SPOT xs and Landsat 8 OLI images dated in 2000, 2007, and 2014, respectively, were employed in this study, (Fig. 2-4 and Table 1). They were geometrically rectified and registered to the same projection namely, Universal Transverse Mercator WGS 1984 to lay them over each other. Also, they were processed in ERDAS Imagine 9.3 software and visually interpreted to asses and monitor the different land uses changes of the study area and generate land use maps, each of them correspond to a specific date. The delineation of different land use was done and the areas were measured by Arc GIS software 9.3.

TABLE 1. Characteristics of landsat imagery covering the study area

No	Path/k	Row/J	sensor	Acquisition Date	bands
1	176	38	Landsat 7 ETM+	2000	2, 4, 7
2	114	288	SPOT xs	2007	1.2.3
3	176	38	Landsat 8 OLI's	2014	3,5,7

(OLI): Operational Land Imager, (ETM): Enhanced Thematic Mapper,

The ground truth methodology followed in this work was done by choosing 85 homogeneous observation sites in surface characteristics to be observed during field visits. These sites demarcated on image, with the aid of the visual analysis of the satellite image dated in 2014 and locations of the previous soil profiles which were taken by DRC staff (2006), before visiting the study area. The GPS was used during the verification of the demarcated sites and to verify the delineated boundaries between land use units produced by visual interpretation of the Landsat images data.

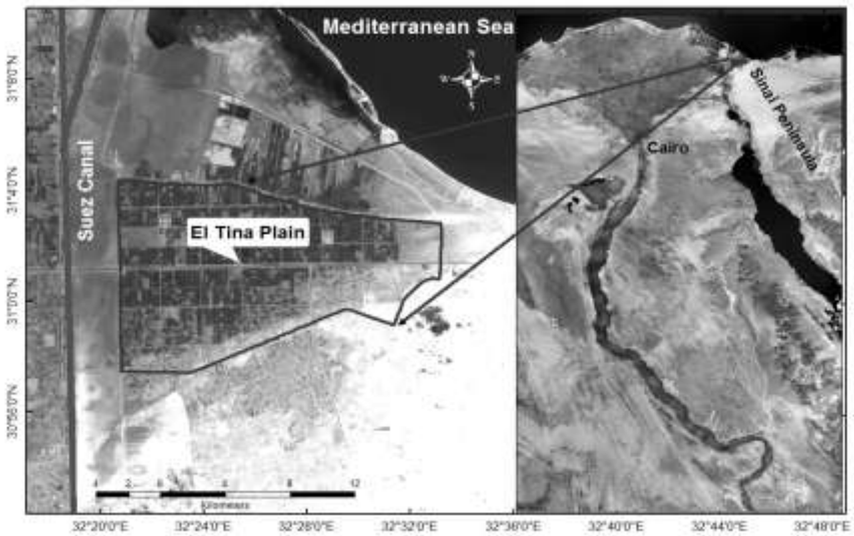

Fig.1. Location map of the study area- El-Tina Plain in Sinai Peninsula

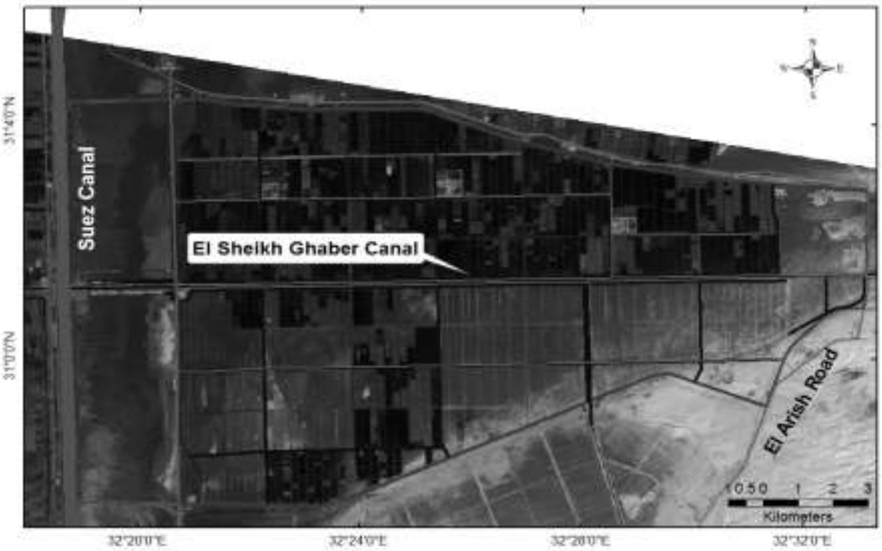

Fig.2. Landsat 7 ETM+image acquired in2000 (bands 7,4,2) of the study area

Fig.3. SPOT xs image acquired in 2007 (bands 3,2,1) of the study area

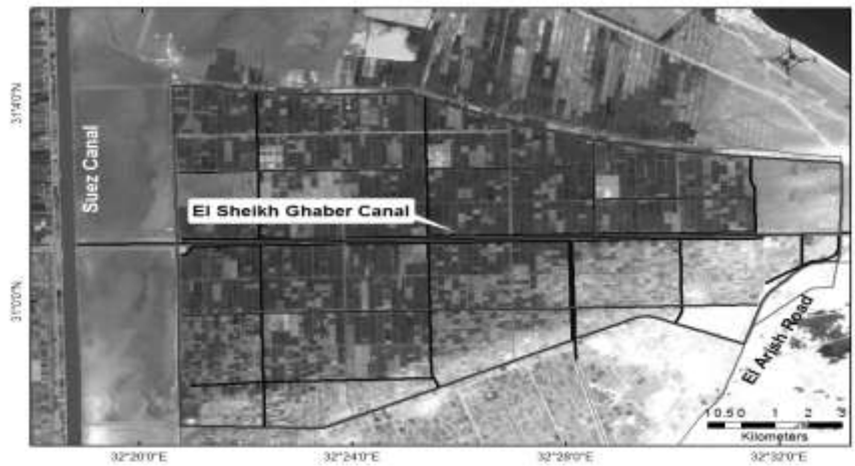

Fig.4. Landsat 8 OLI image acquired in 2014 (bands 7,5,3) of the study area

Soil salinity data of 219 sites of soil profiles recorded by DRC staff (2006) were integrated together in the present study to classify the study area into six soil salinity mapping unit shown in Fig. 9 and stored as database attribute for different mapping units by using GIS capabilities. In the year 2014, eighty nine soil profiles and the depth of groundwater table from surface were tested to investigate salinity status (Fig. 5 and Table 2). The investigation sites were selected depend on the same previous locations as those given by DRC staff, (2006). The coordinate of locations were registered and imported to GIS software as point map. In each investigation point, the soil profiles are sampled for laboratory analyses and depth of ground water level is measured. The electrical conductivity (EC) of extract from 1:2.5 soils: water mixtures was measured according to US Salinity Laboratory staff (2004) and recalculated according to Sys *et al*. (1991b). The analyses data were stored as attributes for the point map.

Inverse distance weighted average interpolation method of the spatial analysis function in Arc GIS software (ESRI, 2010) was used to establish the soil salinity and ground water depth maps of the study area. Crossing capability between maps of different dates was also used to monitor of changes in the studied characteristics. Digital Elevation Models (DEM) of soil and ground water level were employed in this study. Regarding statistical analysis for the determined data, SPSS 21.1 software program was used.

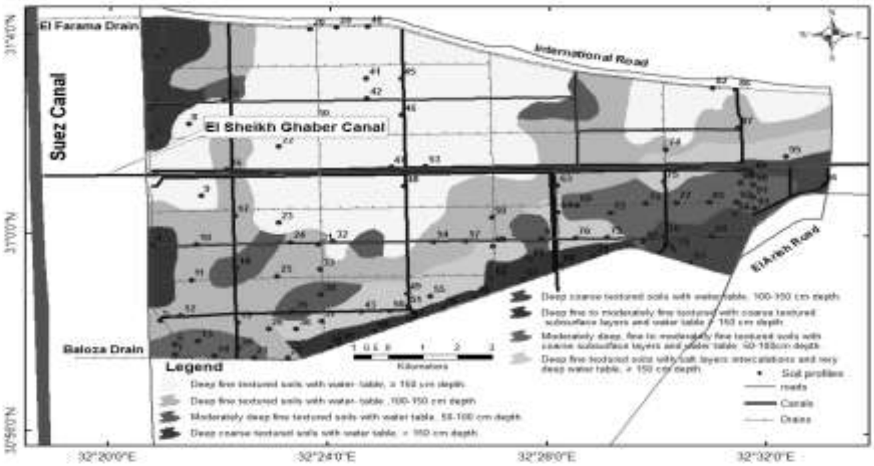

Fig. 5. Soil mapping units and location of the studied soil profiles of the study area (after desert research center staff, 2006)

TABLE 2. Soil types and its areas in the study location (after DRC staff 2006)

Soil types	feddan	%
Deep fine textured soils with water- table, ≥ 150 cm depth.	16596.7	40.1
Deep fine textured soils with water- table ,100-150 cm depth	11321	27.3
Moderately deep fine textured soils with water table, 50-100 cm depth.	2166	5.28
Deep coarse textured soils with water table, > 150 cm depth.	1828	4.42
Deep coarse textured soils with water table, 100-150 cm depth.	2166	5.23
Deep fine to moderately fine textured with coarse textured subsurface layers and water table > 150 cm depth.	2869.3	6.93
Moderately deep, fine to moderately fine textured soils with coarse subsurface layers and water table, 50-100cm depth.	2672	6.46
Deep fine textured soils with salt layers intercalations and very deep water table, ≥ 150 cm depth.	1772	4.28
Total	41391	100 %

Results and Discussion

Monitoring of land use

Visual image interpretation was utilized to classify the images into different land use units. Results indicated that the study area was utilized in different land uses and the major changes in land use occurred over the period from 2000 to 2014. Eight land uses units were recognized and mapped namely;

A- Cultivated land
B- Land under reclamation
C- Barren and unused land (salt affected soils)
D- Fish ponds
E- Villages
F- Main roads
G- Main canals
H- Main drains

The differentiation among the different land uses was based on image characteristics. The relatively high reflection of the barren land in all used bands, and the extremely low reflection of the lands covered by shallow water due to leaching processes in band 7 were the main criteria followed to differ between them. Also, the no-reflection of the land covered with deep water that is used as fish ponds in all used bands of landsat and the very low reflection of soils under reclamation by leaching processes were the main criteria followed to differentiate among them. The reflection of ETM band 4 and OLI band 5, also, provided useful information on cultivated land and moisture condition of soil surface. The photo pattern and shape elements are considered the most striking criteria in characterizing the infrastructure - villages, main roads, and main canals and drains - at the study area.

The distribution of land use maps prepared for the years 2000, 2007 and 2014 are shown in Fig. 6 - 8, respectively. They show the continuous increase in both cultivated lands and fish farms. The latter land use was the main use during 2014, especially in the extremely saline soils, and was located in the northern side of main canal. Parts of the cultivated lands were used for growing field crops, such as sugar beet and rice.

The Spatial distribution areas of the different land use types were calculated and the obtained data were presented in Table 3. Data revealed that the area of the Barren and unused land (salt affected soils), about 21673.6 fed in the year 2000 was reduced, due to reclamation process, to 4956.6 fed and 2487.4 fed in the years 2007 and 2014 respectively. These lands become productive and are used for two types of land use units namely; cultivated land and fish farms. About 2.8 % of the areas are occupied by fish farms during 2007 and about 43.2 % of the areas are occupied by fish farms during 2014. The area occupied by the agriculture was increased from about 18.8 % (7183.1 fed) in (2007) to 29.3 % (11189.4 fed) in the year (2014). This is due to shifting of land under reclamation to fish farms. As a result, the study area is not used in agricultural production according to the El-Salam canal project plan. Thus, it should be searching about the reasons that the area became unexploited in agricultural production.

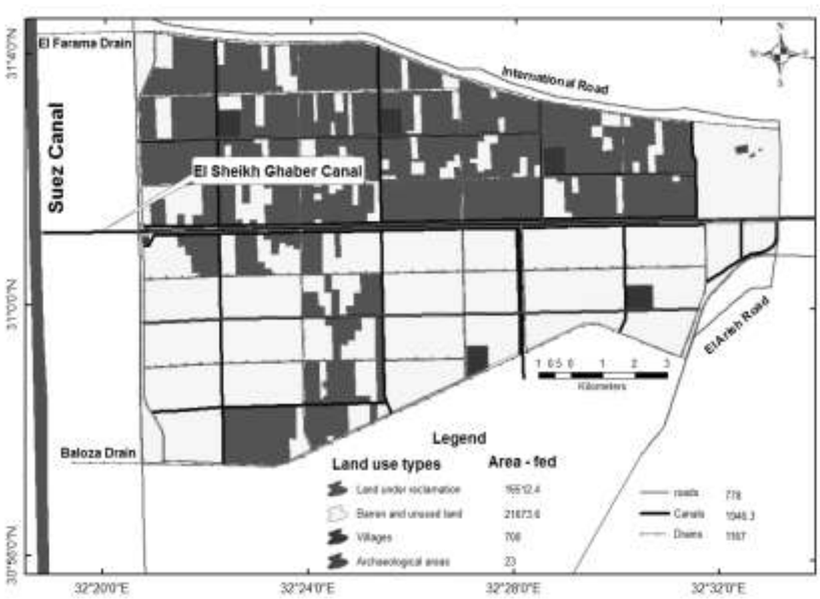

Fig.6. Land use map for the year 2000 based on landsat 7 ETM+ data

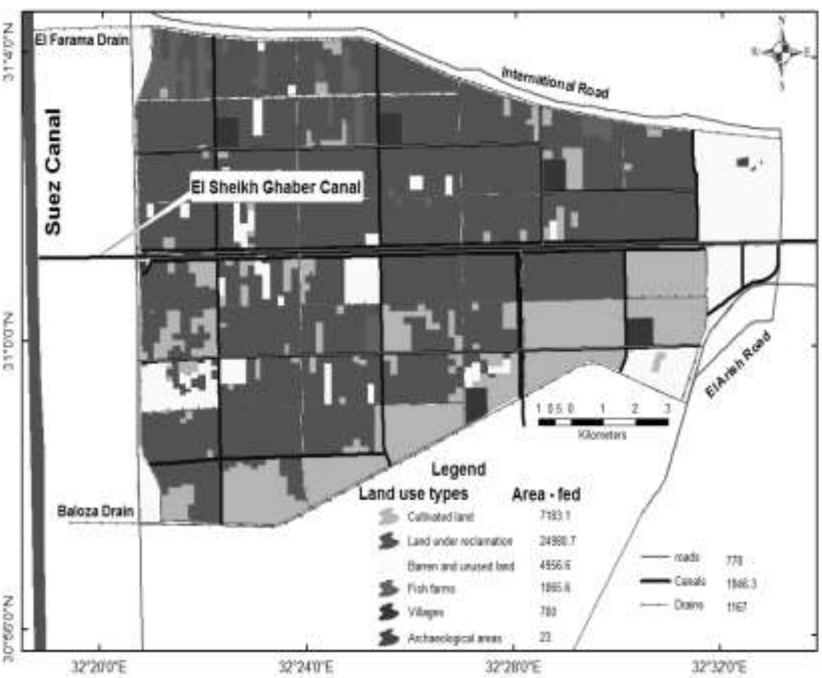

Fig.7. Land use map for the year 2007 based on SPOT XS data.

TABLE 3. The main land uses types and its areas in the study area at different time

Land use types	Area in 2000		Area in 2007		Area in 2014		Difference (2007- 2014) in %
	(fed.)	%	(fed.)	%	(fed.)	%	
Cultivated land	nil		7183.1	18.8	11189.4	29.3	+10.5
Land under reclamation	16512.4	43.3	24980.7	65.4	8035.4	21	-44.4
Barren and unused land	21673.6	56.7	4956.6	13	2487.4	6.5	-6.5
Fish farms	nil		1065.6	2.8	16473.8	43.2	+40.4
Total of Land use types without infrastructure	38186 (fed.)						
Villages	700 (fed.)						
Main road	778 (fed.)						
Main canals	1946.3 (fed.)						
Main drains	1167 (fed.)						
Archaeological areas	23 (fed.)						
Total of the study area	42800.3 (fed.)						

Monitoring of soil salinity

Remote sensing data provide valuable information on the surface features such as extent of cultivated land or water logging. However, the subsoil characteristics could be determined after field observation and soil analysis. Since agriculture in Egypt, as many other countries in the arid and semi-arid regions, is suffering from salinization of the soil. It was stated that a decline of 30 % of the soil productivity is attributed to this unfavorable process (FAO, 1975). Also, El-Taweel *et al.* (1997), Hola (2000), Aly (2004) and DRC staff (2006) pointed out that the area under investigation is considered salt affected soils.

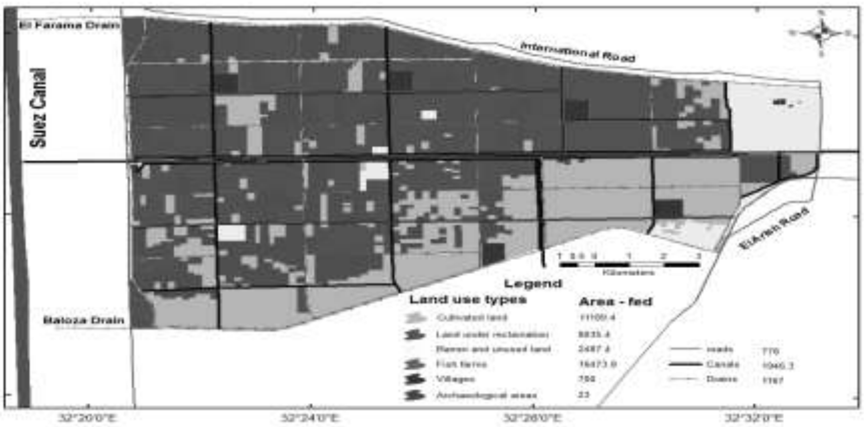

Fig.8. Land use map for the year 2014 based landsat 8 OLI data

Soil salinity of year 2006

According to DRC staff 2006, (Fig. 9 and Table 4) the areas of saline soils with salinity values (> 4 dS/m) reached 36325.9 fed, whereas soils of strongly to extremely saline (> 16 dS/m) reached 31203.4 fed. They are mainly located at the northern side of El-Sheikh Ghaber Canal where poor drainage conditions, shallow to moderate deep saline ground water, salt sea water intrusion and clayey soils with low permeability occurred. In the south and south east of the study area, soils are slightly to moderately saline (EC 4 - 16 dS/m) because the soils exhibit lighter textural classes due to sand encroachment from the sand sheets and dunes occurred in the south and south east of the area. Areas, beside Farama main drain north of the study area, the high soil salinity values are enriched mainly through evaporation from the capillary rise of saline water table and salt sea water intrusion. It is expected that, leaching process, gypsum application, establishing of drains, and lowering down the ground water depth will improve salinity and drainage conditions in the area.

Soil salinity of year 2014

As shown in Fig.10 and Table 4 a clear improvement in soil salinity condition is achieved. The total saline area with salinity values > 4 dS/m reduced to 30933.3 fed; with note that this area includes fish farms with an area of about 16473.8 fed. Also, the high salinity values > 16 dS/m were not recorded. The highest salinity values (10 – 16 dS/m) were recorded in the area beside the Farama main drain at the extreme north part of the study area, which may indicate the needs for drainage improvement in the area.

Salinity monitoring between 2006 – 2014 periods

Using crossing capability of the spatial analysis function in Arc GIS software (ESRI, 2010), the raster salinity maps were crossed together to monitor the salinity development in the area under investigation, (Fig. 11). The improved salinity conditions areas to salinity values (< 4 dS/m) reached 5388.3 fed. The main improvement area was a belt of about 3 km width located in the extreme south part of the study area, north of Baloza drain. An area of about 11205 fed showed an improvement in its high salinity values to 4 – 8 dS/m. Another improved area with salinity values 8 – 16 dS/m appeared north of El-Sheikh Ghaber Canal in the form of spots with an area of about 3252.9 fed. The improvement is attributed mainly to the applied drainage networks system and continues leaching process. However, there are areas of about 16473.7 fed of land shifting from land under reclamation to fish farms.

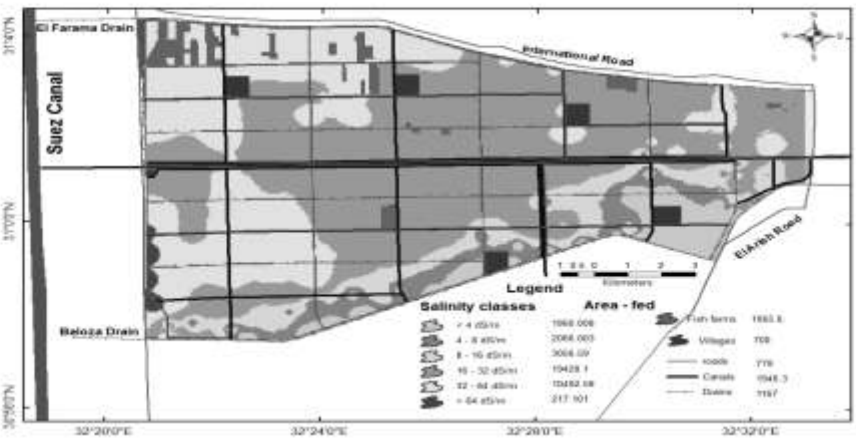

Fig. 9. Soil salinity map of year 2006.

TABLE 4. Soil salinity classes and its areas in the study area at different time

Classes	Area in 2006 (fed.)	Area in 2006 %	Area in 2014 (fed.)	Area in 2014 %	Difference (2006- 2014) in %
Soils with salinity values < 4 dS/m	1860.008	4.9	7252.58	19.0	14.1
Soils with salinity values 4 - 8 dS/m	2066.003	5.4	11206.73	29.3	23.9
Soils with salinity values 8 - 16 dS/m	3056.59	8.0	3252.83	8.5	0.5
Soils with salinity values 16 - 32 dS/m	19428.1	50.9	0	0.0	-50.9
Soils with salinity values 32 - 64 dS/m	10492.58	27.5	0	0.0	-27.5
Soils with salinity values > 64 dS/m	217.101	0.6	0	0.0	-0.6
Fish farms	1065.6	2.8	16473.8	43.1	40.4
Total of soil without infrastructure	38186 (fed.)				
Villages	700 (fed.)				0
Main road	778 (fed.)				0
Main canals	1946.3 (fed.)				0
Main drains	1167 (fed.)				0
Archaeological areas	23 (fed.)				0
Total of the study area	42800.3 (fed.)				

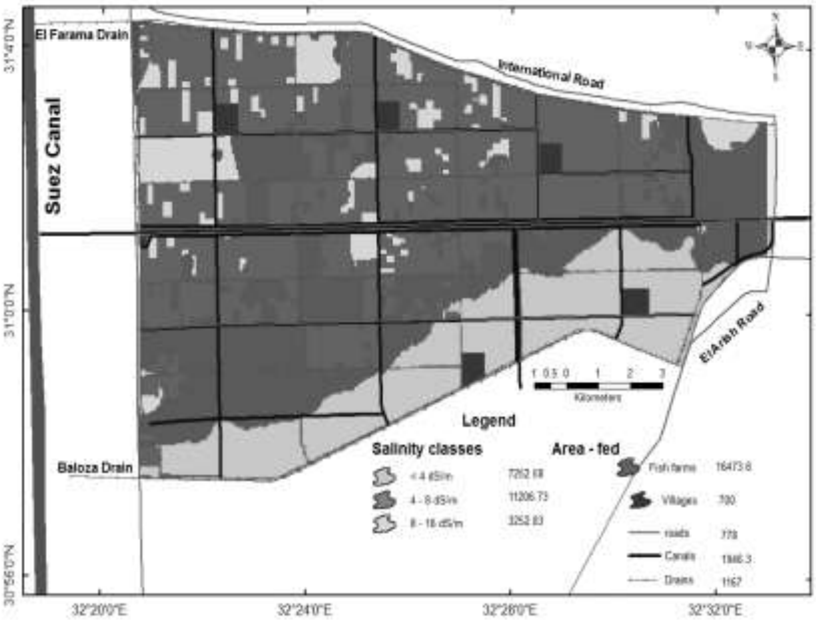

Fig. 10. Soil salinity map of year 2014

Fig. 11. Soil salinity monitoring map between 2006-2014 period

Also, application of cross tabulation technique (Table 5) among soil salinity classes in 2006 and 2014, revealed that the area of free and very slightly saline soils with salinity values < 4 dS/m has increased from 1864.3 to 7252.58 fed. The areas having soil salinity values ranging from 4 to 8 dS/m have increased from 2070.8 fed in 2006 to 11206.73 in 2014. An area of about 30109 fed having soil salinity values > 16 dS/m in 2006 has improved under reclamation as salinity values became less than 16 dS/m (13635.19 fed) and other land has shifted to fish farm (16473.81 fed) in 2014. The latter land use appeared in image of 2014.

TABLE 5. Cross tabulation between soil salinity classes and its area by fed in 2006 (columns) and 2014 (rows)

Classes	< 4 dS/m	4 - 8 dS/m	8 - 16 dS/m	16 - 32 dS/m	32 - 64 dS/m	> 64 dS/m	Fish farm	Total
< 4 dS/m	1864.3	2063.0	2331.1	960.4	33.8	0	0	7252.58
4 - 8 dS/m	0	1.7	680.1	6719.0	3639.3	138.8	27.8	11206.73
8 - 16 dS/m	0	0	0	1260.4	1778.2	30.4	183.9	3252.83
Fish farm	0	0	51.7	10467.0	5033.5	48.3	867.2	16473.81
Total	1864.3	2070.8	3062.9	19406.8	10484.8	217.4	1078.9	38186

Groundwater table and soil salinity

The depth of groundwater level is shown in Fig. 12. The resultant groundwater depth map indicated clearly that soils located in the northern parts of El-Sheikh Ghaber Canal are generally the most suffering areas from shallow groundwater. The groundwater depth map shows an area of 13311 fed, north of El-Sheikh Ghaber Canal, possessing water level shallower than 50 cm which clearly match with the results for land use in fish farms of that area. As indicated in Fig. 12 and 13; the groundwater depth varied from 20 cm to 175 cm below soil surface with an average 87 cm below soil surface. The comparison of the digital elevation models of both of soil surface (DEM) and the groundwater depth (GW DEM) indicated that the groundwater level is not running in a harmony with the soil elevation values (Fig. 13) due to the densely established fish farms. To substantiate the relationship between the spatial variability of soil salinity values with depth of ground water table and soil elevation, simple correlation coefficient are computed. The obtained coefficients indicate that the soil salinity is significant positively correlated with depth of ground water ($r = 0.736$) and in significant correlation with soil elevation ($r = 0.0141$). That means a very complex relationship that needs to be tested with more detailed studies to clarify the contribution rule of the different characteristics on soil salinity.

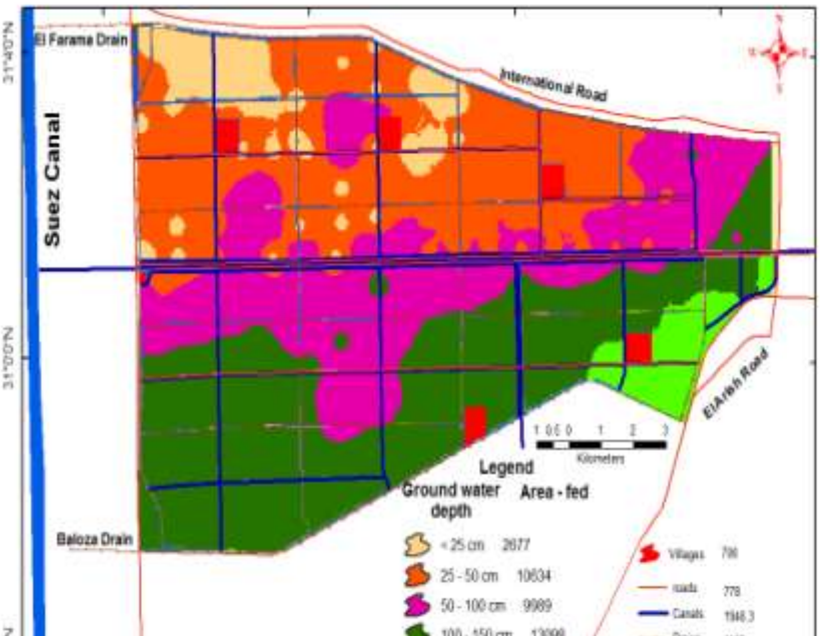

Fig.12. Groundwater depth map 2014

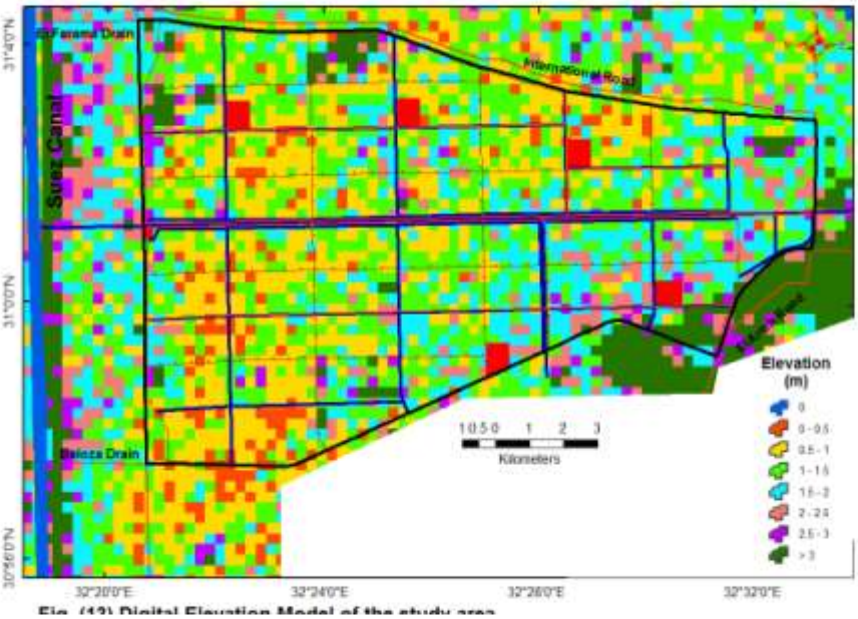

Fig.13. Digital Elevation Model of the study area

Conclusion

This study concluded that the integration between satellite remote sensing based land use mapping to monitor changes of land use and soil characteristics at El-Tina Plain area is very effective. The high resolution satellite data such as SPOT data and Landsat ETM and OLI are good source to provide valuable information about the changes in land use. The measurement of areas of the different land use mapping units illustrates clearly the changes in land characteristics in a vast area. Consequently, statistical information about land reclamation activities, soil improvement processes, and soil degradation problems could be obtained. Improvement trend in soil salinity was recorded in El-Tina Plain soils as a part from El-Salam Canal project. The study recommends continuous monitoring of land use, soil salinity and groundwater level to make the suitable intervention needed to prevent deterioration of soil resources.

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رصد التغيرات فى استخدامات وصفات الاراضى لمنطقة شمال غرب سيناء باستخدام بيانات الأقمار الصناعية - مصر

طاهر مصطفى حامد يوسف و جيهان محمد عبيد عبدالمولى
قسم البيدولوجى – شعبة مصادر المياه والاراضى الصحراوية - مركز بحوث الصحراء – القاهرة – مصر.

يعتبر تتبع التغيرات فى استخدامات وصفات الأراضى الناتجة عن عمليات الاستصلاح أو سوء الاستخدام وأعطاء معلومات عن تلك التغيرات فى صورة خرائط وبيانات احصائية هام جدا لعمليات التخطيط المستقبلية وادارة استراتيجية للموارد الطبيعية واستغلال الأراضى فى الانتاج الزراعى. لذلك أجريت الدراسة الحالية بهدف رصد التغيرات التى حدثت فى استخدامات الأراضى فى احد مشروعات الاستصلاح بمنطقة سهل الطينة – شمال غرب شبه جزيرة سيناء باستخدام تحليل معلومات الاقمار الصناعية فى الفترة بين عام 2000 وحتى 2014. وكذلك رصد التغيرات فى بعض خواص الأراضى (ملوحة التربة ومستوى الماء الأرضى) التى تقلل من الانتاج الزراعى. واعتمدت الدراسة الحالية على استخدام صور الاقمار الصناعية ونظم المعلومات الجغرافية والدراسات الحقلية والمعملية كمصدر اساسى للمعلومات فى رسم خرائط استخدامات الاراضى وملوحة التربة ومستوى الماء الأرضى ، وبالاعتماد على التفسير البصرى لصور الاقمار الصناعية المحسنة الملتقطة فى سنوات 2000 ، 2007 ، 2014 وكذلك بيانات الحصر الميدانى للأراضى أمكن التعرف على وحدات استخدامات الأراضى بالمنطقة ورسم خرائط الاستخدامات وفق كل زمن التقاط الصورة الفضائية وقد قيست مساحة الوحدات المعبرة عن الاستخدامات المختلفة فى سنوات الدراسة باستخدام برنامج Arc – GIS 9.3 ، وأظهرت الدراسة أن مساحة الأرض المنزرعة قد زادت بمقدار 10.5 % حيث قدرت المساحة المنزرعة بحوالى 18.8 % (7183.1 فدان) فى عام 2007 وقد زادت الى 29.3 % (11189.4 فدان) فى عام 2014 من المساحة الكلية لمنطقة الدراسة ، كذلك مساحة المزارع السمكية زادت لتصل الى 42.2 % بينما مساحة الاراضى تحت الأستصلاح قلت الى 21 % من المساحة الكلية فى عام 2014. هذا وقد تم دراسة ملوحة التربة ومستوى الماء الأرضى بالتفصيل وقورنت البيانات بالدراسات السابقة التى تمت بواسطة مركز بحوث الصحراء فى عام 2006 وقد اظهرت الدراسة تحسن فى قيم ملوحة الاراضى وذلك بسبب عمليات الاستصلاح خلال الفترة بين 2006 – 2014 ، الا ان مساحة قدرها 13311 فدان تدهورت بسبب ارتفاع مستوى الماء الأرضى الى اقل من 50 سم من سطح التربة . هذا وتعتبر الدراسة ذات أهمية حيوية لمتخذى القرار لادارة الموارد الطبيعية فى احد مشروعات الاستصلاح بمنطقة سهل الطينة – شمال غرب شبه جزيرة سيناء.