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THE IMPACT THE IMPACT OF LAND DEGRADATION ON CULTURAL AND AGRO-BIO DIVERSITIES SOUTH BORG EL ARAB TOWN, ALEXANDRIA GOVERNORATE, EGYPT

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ABSTRACT

The study area is situated southwest of Alexandria Governorate and north of Al Nasr irrigation canal covering 23,242.10 hectares (ha) including Abu Mena archaeological site. Preserving such historical sites is essential for maintaining cultural and agro-bio diversities. The overall view of land cover features in the study area is dominated by intensive terrestrial irrigated agriculture under surface irrigation of dense water canals. These intertwined elements caused hydraulic pressure on soil substrata and the threat posed by waterlogging and salinization to the World Heritage site. Land units of piedmonts and pediplain have soils of finer textures (sandy clay loams) compared to coarser textures (sandy loams) in playa within the depressed basin. Hydro-physical investigations show a prominent pathway of water flow from the piedmonts and pediplain in upper ground. Their soils have lower hydraulic conductivity (0.3-2.9 cm h^{-1}) compared to more permeable soils (4.1-6.5 cm h^{-1}) within the depressed basin. A core effective area of 9,236.97 ha was delineated as the key source of seepage. Results show that drip irrigation achieves high drip irrigation water index being of less applied irrigation water than surface irrigation. Irrigation water rationalization performance index is averaged as 5,163 m $^3ha^{-1}$ for summer crops, while as 2,642 m^3ha^{-1} for winter crops. Saved water is estimated to be 72,094 m^3, if the proposed effective area is irrigated by drip irrigation system. The case is justifying the claim that implementation of drip irrigation provides a lasting solution to the rising water tables issue and a sustainable water conservation strategy for the gross cultivated area and Abu Mena heritage site.

KEYWORDS: Land cover, land deterioration, physiography, soils and archeology

INTRODUCTION

The ruins of Abu Mena archaeological site dating from the mid-7th century. After the construction and inauguration the Cathedral of Saint Mina, UNESCO decided in 1979 to include this site in the World Heritage List. The area was documented as one of Egypt's important historical sites (El-Aref, 2024). World Heritage Committee (2001) added Abu Mena Monastery in Egypt to the List of World Heritage in Danger as being surrounded by the rise of water table level that decreased the soil stability causing threats to the structural integrity of the monuments. Many walls and water wells were collapsed and the crypt of St. Mena had to be filled with sand. According to Ramadan (2011), some protection actions to counteract this phenomenon were decided by the Supreme Council of Antiquities. World Heritage Committee (2025) removed Abu Mena site from UNESCO's World Heritage in Danger list. According to Al-Ahram Daily Magazine (2025), this decision based on a project that was carried out by the Ministry of Tourism and Antiquities in collaboration with both the ministries of Water Resources and Irrigation and Agriculture and Land Reclamation as well as the Alexandria Governorate. This collaboration based on executing water trenches around the burial of St Abu Mena and around the site and pumping pipes to follow up the level of the groundwater inside each trench. The irrigation system for agricultural land around the archaeological area was converted to a drip irrigation system. Benedini and Cleere (2005) reported that the reclamation program of the agricultural development in the region had caused a rise in the water table during the previous decade. The case caused destruction of numerous cisterns in different parts and has led to the collapse of several overlying structures and underground cavities were opened in the north-western region of the town. The risk of collapse is including the crypt of Abu Mena with the tomb of the Saint with sand close them to the public. Morad and Abdel Latif (2017) found that the area between Borg El Arab and El Hammam, is recently subjected to intensive land reclamation projects to cultivate about 57000 feddans. During the last three decades since1985 to 2014, the depth to water level has risen up from about 20 m in 1985 to less than 5.0 m in 2014. Water seepage from the permeable soil is estimated by 4.125 x 106 m^3 y^{-1} due to the applied flood irrigation technique. Salem *et al*. (2015) reported that through the period from pre-reclamation in 1974 to post-reclamation in 2008, depth to groundwater in

1974 range from >51 m in the southwest to 33 m in the northeast, while in 2008 ranged between <1 m at Marmina Monastery to 11 m in the northeast at the periphery of the Mariut. The recharge area is related to the El Nasr Canal and its branches as the flow towards the central part of Abu Mina basin. Zaghloul *et al.* (2020) related these damages in archaeological site to the hydrological conditions as well as the inadequate excessive irrigation and poor drainage systems causing water table risen with salt accumulation in Abu Mena depression. The water-bearing formation is underlain by the Pliocene impervious sticky clay layer that prevents downward percolation of excess irrigation water. Shaaban (2001) also confirmed that water-bearing formation is underlain by the Pleistocene old deltaic deposits and the Pliocene impervious sticky clay layer prevent downward percolation of excess irrigation water leading to water logging and soil salinization. According to El-Sayed *et al*. (2012), groundwater level has risen about 35 m from 1960s to 2005 to be at 0.1 m below the ground surface. Since the year 1968, the cultivated land in west Al Nubaria area has significantly increased under uncontrolled surface irrigation causing water logging and soil salinization. Afify *et al.* (2025) considered that the submersion and waterlogging processes are the resultant of water intrusion frequencies by free water downwards the lands in a depressed area of playa. Araoz (2011) reported that historic preservation helps us to understand and appreciate our cultural heritage allowing us to learn from our history and creating a sense of place and community. By preserving historic sites, we can ensure that future generations have the opportunity to learn from and appreciate these important cultural resources as well as can be used for educational purposes encouraging the study of historic architecture. Stephenson (2023) considered the cultural heritage as a precious legacy that reflects shared humanity. Its preservation is essential for maintaining cultural diversity, fostering a sense of identity and passing down knowledge to future generations. So, the treasures of the past continue to inspire and enrich the present and the future. Afify *et al.* (2022) stated that denaturing the unique agrobiodiversity, the demographic and socio-economic features will be negatively affected. Also, the inherited glorious view of archaeological sites as well as their prestige and dignity will be dull, subdued, and distorted. This disturbance of the environmental balance requires an agricultural management of binding economic design not managed under temporary local vision. Changing surface irrigation to drip irrigation at Saint Mina in the Burj Al Arab area is profoundly underscored by the quantifiable dimension of water conservation, which save 30% to 40% of the water currently applied (Abdelkader. *et al.,* 2022). For the site itself, this conservation directly tackles the root cause of the deterioration by lowering water volume applied through drip systems, which significantly reduces excess infiltration (Guan *et al*., 2023). Lowering saline water table that is destroying Saint Mina archeological site can be realized by shifting surface irrigation to drip one in the farmlands surrounding Saint Mina site (Zhou *et al*., 2024 and FAO, 2021).

Practically, this conservation can be realized according to the initiative of the Central Bank of Egypt (2021) for developing field irrigation projects in Egypt. The implementation of laws that have been issued to protect Egyptian heritage is highly needed. The laws whose articles are directly referring to the protection of Egypt's cultural heritage with attention to the antiquities by regulating their management and preservation. These laws are Law No. 117 of 1983, which was amended by Law No. 3 in 2010 and Law No. 91 in 2018 (published in the Official Gazette of Egypt in 1983, 2010 and 2019).

The objective of this study is to define the reasons of land deterioration as related to water logging that is negatively affecting on the study area. Also to find effective solutions to overcome these reasons by avoiding an extra water logging. Improving the agricultural practices is the most active solution for protecting the environmental elements and Abu Mena archaeological site of cultural heritage as well as maximizing land and water uses. This objective can be more realized if based on an overall declaration concerning the problem that related to the natural environment and human practices. Accordingly, the cooperation between different entities when using land and water resources for agricultural management should integrates with antiquities and tourism interests. This cooperation creates a leap in the economic benefits keeping the demographic features within an integration that take into account the sustainability of their fully exploitation for different land utilizations of multi-purpose system.

MATERIALS AND METHODS

1-Description of the study area

The study area is situated about 50 km southwest of Alexandria Governorate, southeast of Borg El Arab town and north of Al Nasr irrigation canal covering 23,234.78 hectares (55,298.78 feddans). The study area is coordinated in the lower left corner as 30 ^{o} 45' 41.18" N and 29^{o} 34' 17.96"E, while in the upper left corner as 30 ° 52' 47.46" N and 29 ° 34' 17.9"-E. In the upper right corner, the coordinates are 30 ° 52' 48.01" N and 29 ° 45' 01.70"E, while in the lower right corner they are 30 ° 45' 41.80" N and 30 ° 52' 48.01"-N (figure 1). The study area includes Abu Mena archaeological site as Christian pilgrimage center in Late Antique in Egypt. The recent Christian monastery of Saint Mena was built up in north of the ancient site closing to the ruins of Abu Mena of tangible culture monuments and artifacts. This archaeological site is surrounding by rural villages within cultivated areas that are mostly managed under surface irrigation.

2-Manipulated remote sensing data

Selected multispectral bands were acquired by Sentinel-2 satellite in 2025 having spatial resolution of 10 meters as of green (0.560 µm), red (0.665 µm) and near infrared (0.842 µm). These data were geometrically corrected and projected as Universal Transverse Mercator, zone 36 Spheroid and Datum is WGS 84. Sub scene was produced to cover the study area using cartographic software ERDAS (2010).

3- Land cover delineation

Automated classification was carried out for performing land cover features into classes using unsupervised classification nodule. This algorithm of ERDAs-a (2010) is based on the natural groupings of pixels by the Iterative Self Organizing Data Analysis Technique (ISODATA). The linear features were buffered as polygons to be calculated as areas. The produced raster map was converted into vector one. Visual analysis was carried oud for revising the land cover boundaries and for drawing the map able passes of roads and water canal with the aid of the topographic maps (scales 1: 25000 and 1: 50000 updated by the Egyptian General Survey Authority in 2006. Land cover classes were defined according to the Land Cover Classification System (LCCS) that have proposed by Di Gregorio (2005).

4-Physiographic unit delineation

Visual interpretation of the physiographic units was delineated according to the proposed physiographic approach by Zinck and Valenzuela (1990) with the aid of produced automated unsupervised classification for recognizing the components of landscape features.

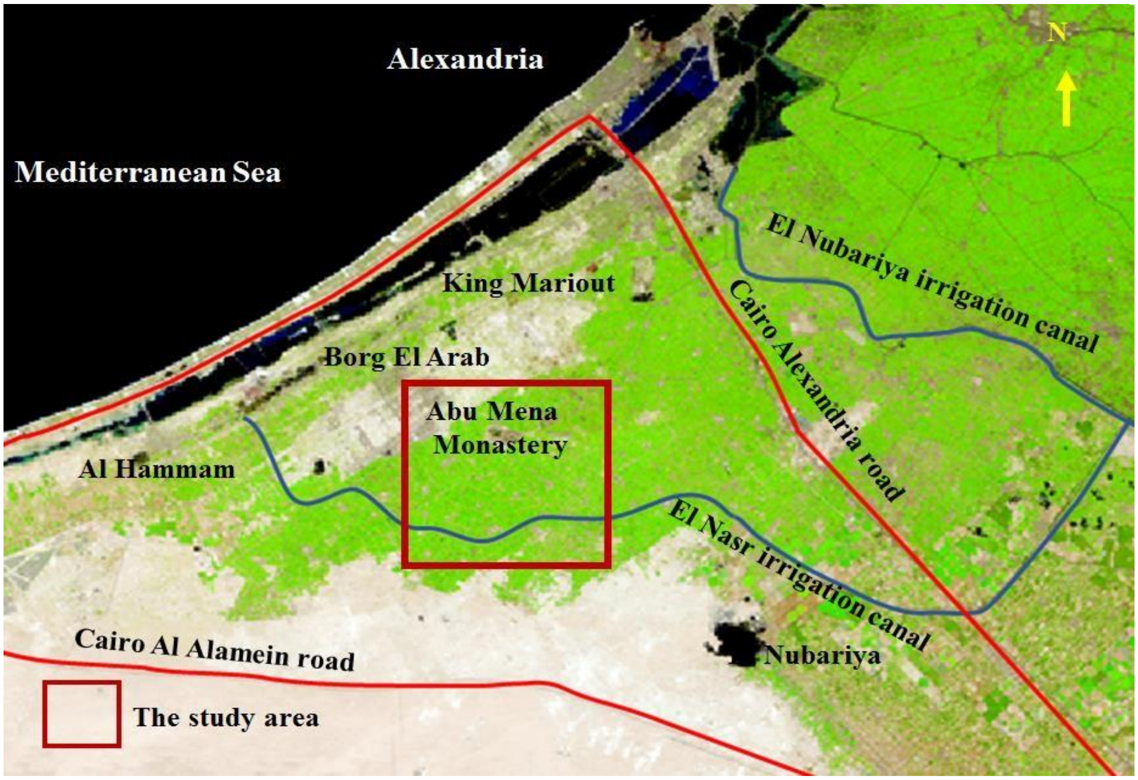

Figure 1 Location map of the study area allocated on sub seen of Sentinel 2 2025

5- Delineating the contour lines

Topographic maps (scale 1: 50,000) published by the Egyptian General Survey Authority in 2006 were used for tracing the contour lines and allocating the elevation levels. These maps were also used for naming the geographic features.

6-Ground truth

Ground truth was carried out to verify the efficiency of the delineated land units. Soil Survey Manual of USDA (2017) was followed to estimate the shapes and degrees of slopes, describing morphological attributes of the soil strata including depth, texture and gravel. The selected soil profiles were geographically located using the Global Positioning System (GPS). They were dug to a depth of 150 cm or to the hard pan or ground water table. Soil samples representing the soil strata were collected to be air dried and sieved from 2 mm mesh. The sites of soil profiles were assigned in (figure 2).

7-Laboratory analyses

According to Sparks *et al*. (2020), particle size distribution was determined. Carbonate contents were measured by the calciminer and gypsum contents were determined by precipitation with acetone according to Nelson

(1982). According to Carter and Gregrich (2007), soil pH was determined in soil past by pH meter. In soil paste extract and water table samples, salinity was determined as electrical conductivity (dSm^{-1}). Hydraulic conductivity was measured according to Hand book of USDA (2003).

8-Calculations of surface irrigation versus drip irrigation

Irrigation Water Applied (IWA) was calculated according FAO, (1998).

Water Rationalization Volume (WRV) in m^3 = (IWA for surface irrigation – IWA for drip irrigation).

Drip Irrigation Water Index (DIWI) was calculated as follow:

$$\mathbf{DIWI} = \frac{\text{IWA for drip system}}{\text{IWA for surface irrigation}} * 100$$

Irrigation Water Rationalization Performance Index **(**IWRPI**)** was calculated as follow:

$$\mathbf{IWRPI} = \frac{\text{amount of water rationlization}}{\text{IWA for surface irrigation}} \mathbf{* 100}$$

RESULTS AND DISCUSSION

1-The overall view of land cover attributes in the study area

The defined land cover features were delineated as either terrestrial vegetated areas of irrigated agriculture or non-vegetated areas that include terrestrial artificial surfaces and aquatic artificial ones. They are shown in Table 1, mapped in figure 2 and described as follows:

1-1-Terrestrial vegetated areas of irrigated agriculture.

These cultivated areas are mostly managed under surface irrigation of sequentially summer and winter herbaceous crops, which locally include permanent cultivation of trees covering 17,742.14 hectares (ha)

1-2-Terrestrial non-vegetated area

1-2-1 Consolidated bare areas

These areas include an intricate rugged land, which are attributed by consolidated surfaces in the north-western part of the study area covering 357.42 ha.

1-2-2- Unconsolidated bare areas locally cultivated

These land features are partly intersected with consolidated bare areas and are locally cultivated with scattered herbaceous crops on 1,117.98 ha

1-2-3- Artificial nonlinear surfaces

This land cover class include built up surfaces as buildings of urban settlements and administrative affairs covering 2,497.51 ha and Mari mina archeological site covering 417.42 ha. Also include the Monastery of Saint Mina with its annexes covering 43.41 and tombs over area of 23.92 ha.

1-2-4- Artificial linear surfaces

These linear surfaces represent a network of infrastructure including the main asphalted roads. They were buffered considering each of their width to be calculated as areas in polygons that cover 51.97ha.

1.2.5- Aquatic non-vegetated area (waterbodies)

This land cover features represent the artificial flowing water bodies in water channels. Their lines buffered and were calculated as polygons. These artificial water bodies were separated as main irrigation canals covering 414.88 ha and the main drainage canals covering 261.89ha.

Table 1 Land cover classes and their spatial distributions

Land cover classes	Area (ha)
Terrestrial vegetated areas	
Irrigated agriculture	17742.14
Terrestrial non-vegetated area	
Consolidated bare areas	357.42
Unconsolidated Bare areas locally cultivated	1117.98
Artificial nonlinear surfaces	
Setllements	2497.51
Archeologica site	417.42
Monastery of Saint Mina and its annexes.	43.41
Tombs	23.92
Artificial linear surfaces (main roads)	365.53
Aquatic non-vegetated area (waterbodies)	
Artificial waterbodies of main irrigation canals	414.88
Artificial waterbodies of main drainage canals	261.89
Total area	23,242.10 ha (55,316.20 feddans)

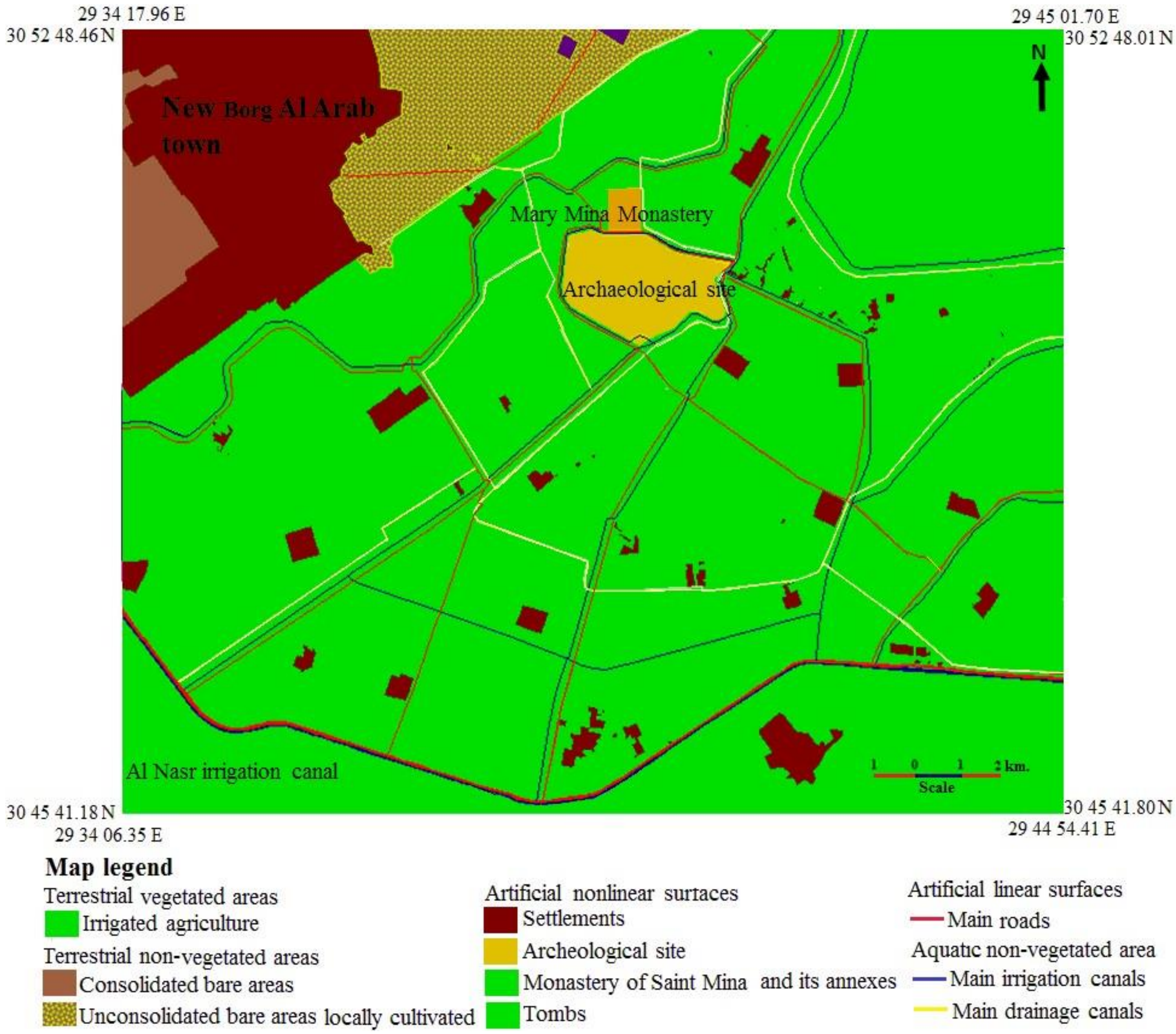

Figure 2. The geographic distribution of land cover classes in the study area

2-The assessment of land deterioration reasons.

For addressing the causes of damaging the archaeological site, the assessment of land deterioration extents was identified within the overall projection that include different resendable elements of land deterioration process as follows:

2-1-Descending slopes and water diversion

The cultivated areas and their water network of irrigation and drainage canals were situated in relatively high levels comparing to the archaeological site. Land deterioration in the archeological site and its outskirts have closed relationship to the geomorphological attributes in the study region as mainly extending at elevations from 30 to 65 meters a. s. l. The descending slope directions are northwards, eastwards and southwards diverting the flow of drainage water to the archaeological site in the low-lying area (figure 3).

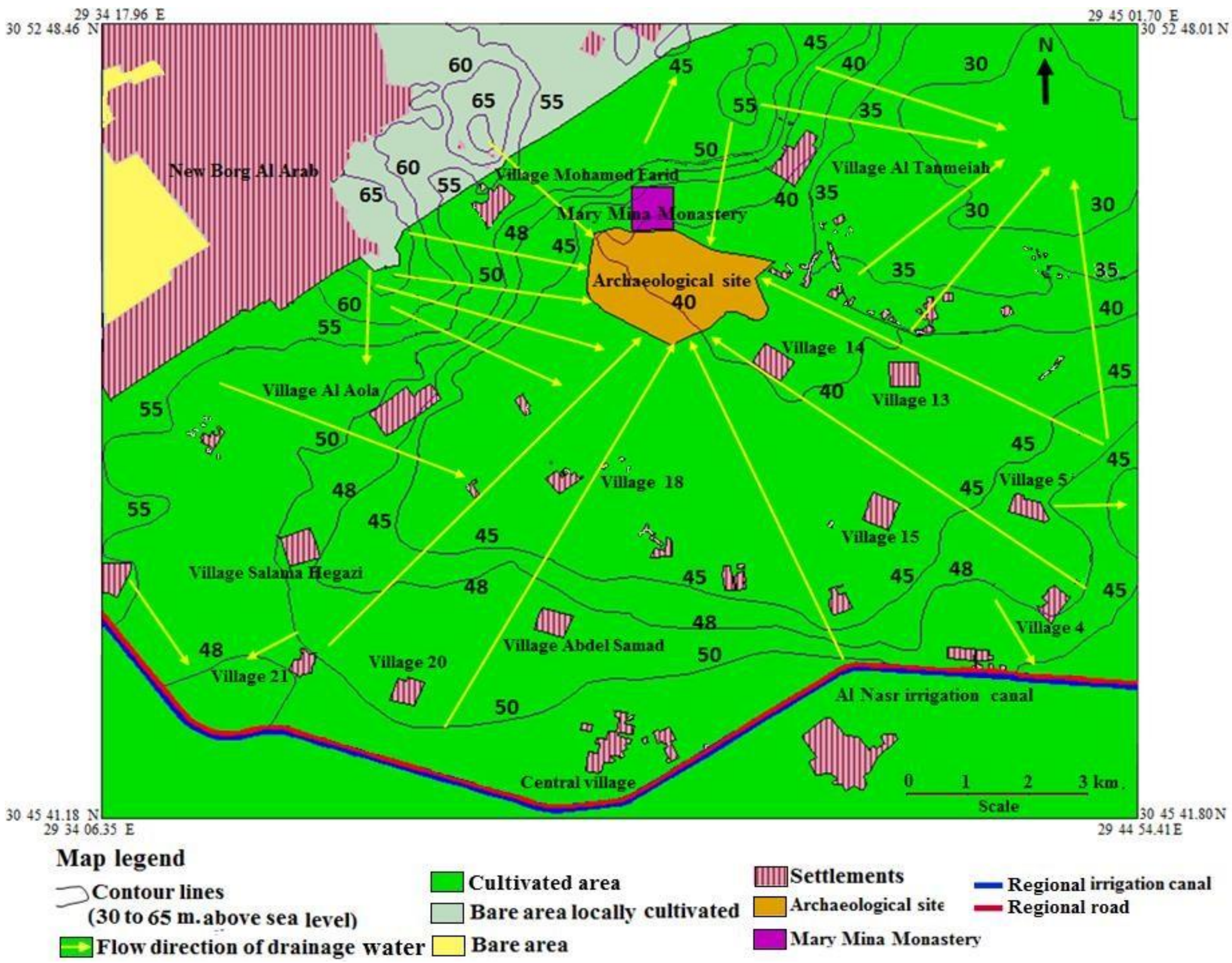

Figure 3. The flow directions of drained water in the study area

2-2- Surface irrigation practices using dense water canals

According to Afify *et al.* (2019), intensive cultivation intertwined with over use of irrigation water in a closed system initiates waterlogging and consequently extensive patches is salinized This land degradation resulting in a negative impact on the demographic features and high level of agrobiodiversity is seriously to be threatening as a clearly dawned problem. In the current study area, intensive cultivation expansion is mostly managed under surface irrigation that receive water from Al-Nasr irrigation canal. Drainable water as an excess of the plant's water requirements resulting in hydraulic pressure that directed to the soil substrata pushing the subsurface water towards areas of less elevations. The water intrudes to the archaeological site resulting in rising the water table level that damage the site's buildings threatening a world heritage site. For managing this surface irrigation, a dense network of irrigation and drainage water canals was designed. In figure 4, this network of water canal was projected northwards from Al-Nasr irrigation canal considering that the beginning of the problem is aligning the canal's path heading north and converting the negative impact to the archeological sites. In this water network huge quantities of water flow create rather enormous hydraulic pressure at damaged lining sites in bottoms and sides of these water canals. This high density of water channels on large area causes a waste of water resources and does not achieve the approach of maximizing the unity use of land and water within a region under arid climate and condition of water scarcity. The case takes away other areas of promising land for agricultural land use that can be to be utilized.

2-3-Physiographic-soil attributes

2-3-1-Piedmonts of sloping shallow soils to hard pan

These piedmonts developed on the foot slopes at the most of higher elevations in the northwestern marginal part of the study area covering1, 591.64 ha with sloping surfaces of shallow soil with depths less than 50 cm from the soil surface. Soil profile is dominated by sandy clay loams with salinity range from 9.1 to 10.9 dSm^{-1} and Ph. range from 8.6 to 8.9. Calcium carbonate contents range from 298.8 to 400.7 g kg^{-1} soil and gypsum contends range from 101.5 to 160.4 g kg^{-1} soil. Hydraulic conductivity ranges from 0.3 to 2.4 cm h^{-1} (soil profiles 1 and 2).

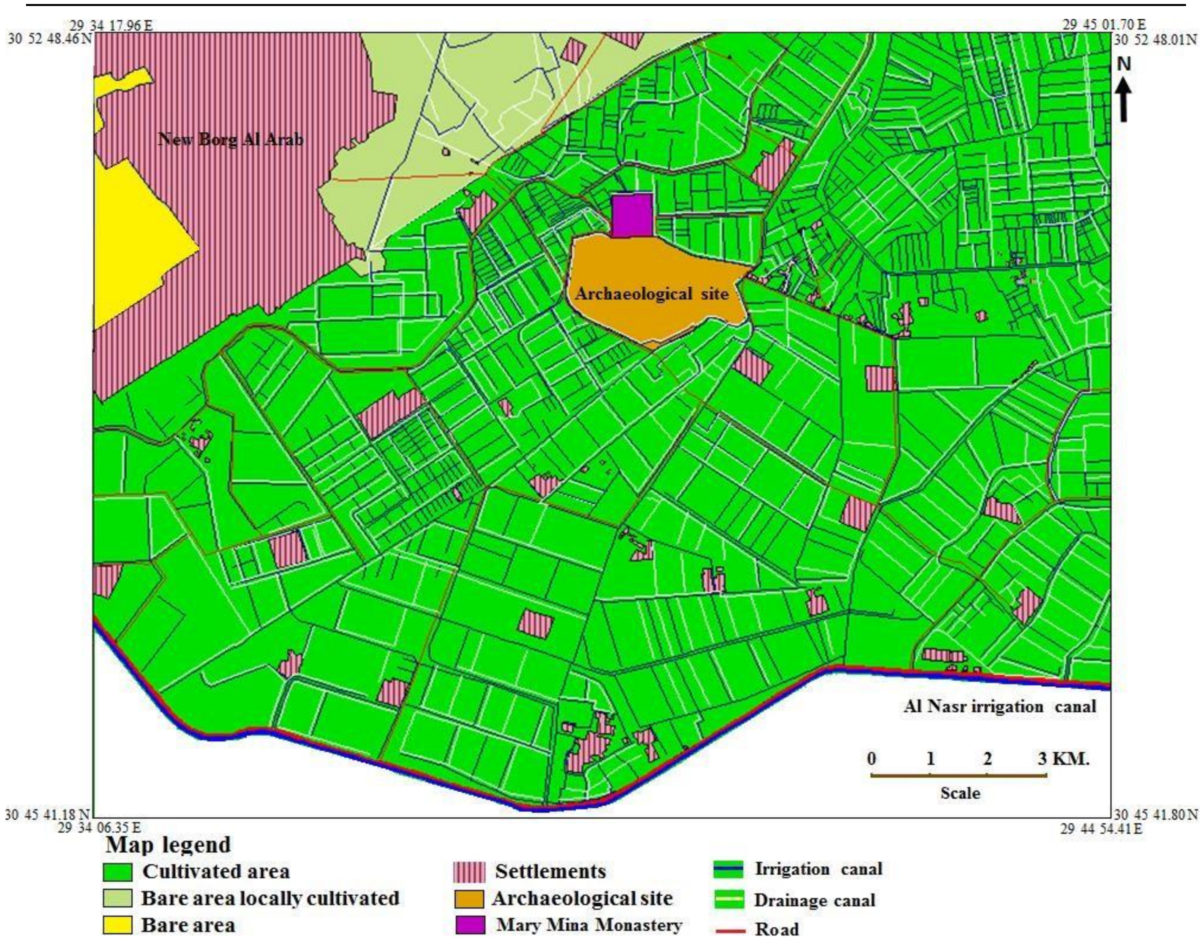

Figure 4 Intensive cultivation within high density of water channels

2-3-2-Pediplain of deep to moderately deep soils to hard pan

Pediplain develops under an arid climate during pediplanation processes that mainly acts by physical weathering. This pediplain occurred at relatively high elevations covering 2782.10 ha with gently sloping surfaces of moderately deep soils (depths from 85 to 95 cm from the soil surface). Soil strata are dominated by sandy clay loams with salinity from 4.0 to 7.3 dSm^{-1} and Ph. range from 7.9 to 8.6. Calcium carbonate contents range from 240 to 354 g kg^{-1} soil and gypsum contends range from 80.3 to 150.4 g kg^{-1} soil. Hydraulic conductivity ranges from 0.6 to 2.8 cm h^{1} (soil profiles 3 and 4).

2-3-3-Pediplain of slightly sloping deep soils to hard pan

This pediplain occurred at relatively high elevations covering 5267.24 ha with gently sloping surfaces of deep soils with depths from 135 to 140 cm from the soil surface. Soil profile is dominated by sandy clay loams with salinity range from 3.6 to 7.8 dSm^{-1} and pH range from 7.9 to 8.9. Calcium carbonate contents range from 70.5 to 171.1 g kg^{-1} soil and gypsum contends range from 23 to 90.1 g kg^{-1} soil. Hydraulic conductivity ranges from 0.3 to 2.9 cm h^{-1} (soil profiles 5 and 6).

2-3-4-Playa of almost flat deep soils to water table

This playa occurred at relatively low elevations covering 5,624.61 ha with almost flat surfaces. The soils are dominated by the texture of sandy loams with salinity range from 4.6 to 8.6 dSm^{-1} and pH range from 7.3 to 8.4. Calcium carbonate contents range from 90.0 to 150. 5 g kg^{-1} soil and gypsum contend range from 19 to 24.2 g kg^{-1} soil. Hydraulic conductivity ranges from 4.1 to 6.1 cm h^{-1}. The soils have been affected by the drainage water intrusion. The internal free water is deep and persistent with water table at 105 cm from the surface with salinity of 8.6 dSm^{-1} (soil profiles 7).

2-3-5-Playa of flat moderately deep soils to water table

This playa occurred at the most lowest elevations covering 2,233.73 ha with flat surface surrounding the archeological site. These soils are dominated by sandy loams with salinity range from 7.9 to 9.6 dSm^{-1}. and pH range from 7.9 to 9.1. Calcium carbonate contents range from 52.2 to 92.0 5 g kg^{-1} soil and gypsum contends range from 27.8 to 44.6 g kg^{-1} soil. The soils have been affected by the drainage water intrusion resulting in moderately deep internal free water and persistent with water table from 70 to 80 cm from the surface with salinity range from of 10.2 dSm^{-1}.

Soil data cleared that the land units of piedmonts and pediplain have finer soils textures compared to the coarser soil texture of playa in the depressed basin. Piedmonts and pediplain have less soil hydraulic conductivity range from 0.3 to 2.9 cm h^{-1} comparing with those in the depressed basin that range from 4.1 to 6.5 cm h^{-1}. In piedmonts and pediplain in relatively high elevations, the drained water stagnates over their hard pan then seeped via the descending slopes to the depressed basin of playa. Within this basin drained water moves horizontally within more permeable soil sub strata resulting in drainage water intrusion to the surrounding area of the archeological site. Accordingly, this archeological site in the lowest level is negatively affected by water logging and salinization process According to Atwia *et al*. (2013) this basin is geologically defined as Mina basin underlined by water-bearing sediments are mainly gravelly sand. Significant rises in aquifer heads and changes in the flow system have occurred in response to man-made artificial surface water canals (e.g. Bahig and El-Nasr canals).

Table 3 Physical and chemical attributes of the soils in the study area

Physiographic unit	Profile No.	Depth (cm)	pH	ECe (dS/m	Gravel (vv)	Particle size distribution			Modified Texture class	Calcium carbonate (g/kg)	Gypsum (g/kg)	*K* (cm/h)
						Sand (%)	Silt (%)	Clay (%)				
Piedmonts of sloping shallow soils to hard pan	1	0-30	8.8	8.90	25	70.1	10.85	19.05	GSL	400.7	160.4	1.6
		30-45	8.9	10.9	30	56.13	12.29	31.58	GSCL	396.2	110.3	0,4
		45-						hard pan				
	2	0-20	8.8	9.7	25	58.14	11.18	30.68	GSCL	455	167.9	0.3
		20-50	8.6	9.1	20	70.1	12.85	17.05	GSL	298	101.5	2.4
		50-						hard pan				
Pediplain of slightly sloping moderately deep soils to hard pan	3	0-50	8.3	5.1	10	69.1	13.75	17.15	SGSL	354	150.4	1.1
		50-70	8.3	7.2	10	67.1	12.75	20.15	SGSCL	346	80.3	0.8
		70-						hard pan				
	4	0-25	8.4	4.3	20	60.14	9.18	30.68	GSCL	300.0	130.4	0.6
		25-60	7.9	3.2	15	70.1	12.85	17.05	GSL	270	101	2.8
		60-95	8.6	6.2	10	70.03	9.24	20.73	SGSCL	240	90	0.7
		95-						hard pan				
Pediplain of slightly sloping deep soils to hard pan	5	0-30	8.2	3.6	5	59.19	11.13	29.68	SCL	114	90.1	0.3
		30-50	8.9	4.1	10	61.36	10.08	28.56	SCL	156.8	47.2	0.4
		50-75	8.1	5.1	10	58.34	10.08	31.58	SGSCL	171.1	61.3	0.5
		70 140	7.9	4.3	5	68.12	11.93	19.95	GSL	90.8	40.22	2.9
		140						hard pan				
	6	0-250	8.4	4.9	-	56.14	12.38	31.48	SCL	170.7	23.0	0.3
		25-50	8.1	4.4	-	71.1	10.85	18.05	SL	111.3	27.8	2.7
		50-75	8.3	6.9	-	58.14	11.19	30.67	SCL	70.5	32.4	0.5
		70 135	7.9	7.8	-	72.1	12.85	15.05	SL		44.1	2.2
		135						hard pan				
Playa of almost flat deep soils to water table	7	0-30	7.3	4.9	-	68.68	13.10	18.22	SL	150.5	24.2	4.1
		30-50	8.4	4.6	5	83.18	6.48	10.34	LS	90.0	12.2	6.1
		50-70	7.9	6.9	5	69.52	12.53	17.95	SL	112.2	9.0	4.4
		70 105	8.1	7.8								
		105-		8.6					Water table			
Playa of flat moderately deep soils to water table	8	0-30	7.9	7.9	-	68.68	13.10	18.22	SL	92.0	34.0	5.2
		30-50	8.1	8.0	-	69.68	11.30	19.02	SL	89.40	28.2	4.7
		50-70	7.3	9.6	-	69.52	12.53	17.95	SL	52.2	30.0	4.9
		70		9.4					Water table			
	9	0-25	7.8	8.1	-	79.76	10.12	10.12	SL	50.9	44.6	5.3
		25-60	8.0	8.3	-	76.69	9.91	13.40	SL	65.3	32.9	5.1
		60-80	7.4	9.1	-	82.18	8.47	9.35	LS	53.9	27.8	6.5
		80		10.2					Water table			

ECe = electrical conductivity, dS/m = decisiemens per meter ; pH= soil reaction ; vv = volume of void-space, SG= slightly gravelly; G=gravelly; SCL=sandy clay loam; SL= sandy loam; LS= loamy sand, *K* =Hydraulic conductivity (cm/h)

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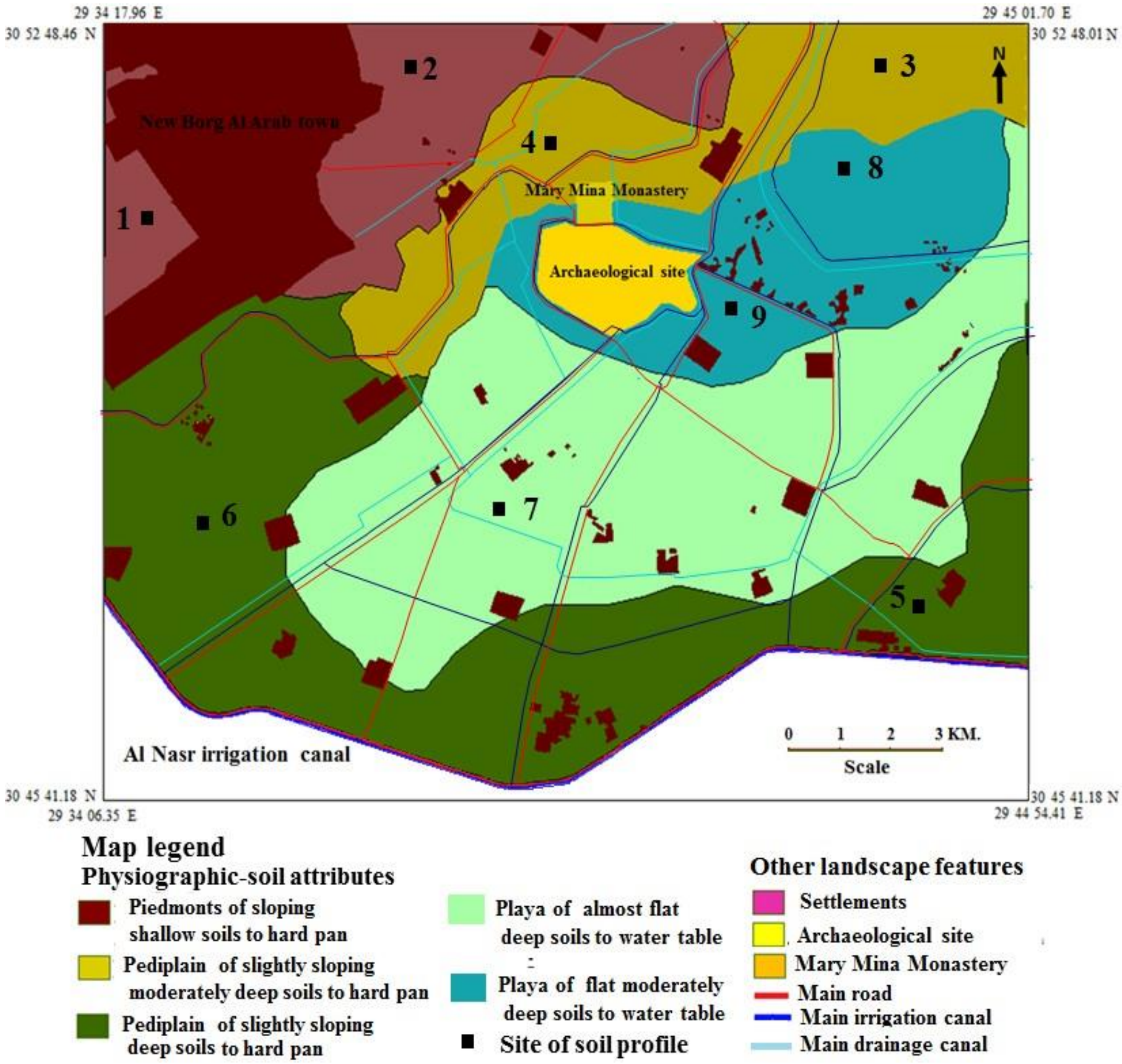

Figure 5 Physiographic features in the study area

2-4-Annual rainfalls (secondary reason)

The study area is characterized by xeric moisture regime as being within the southern part of the coastal zone. According to the Central Laboratory for Agricultural Climate (2017), the area receives an annual precipitation ranging from 100–140 mm per year. This precipitation is a secondary reason for causing surface runoff that accumulates in the depressed areas percolating the caves.

3-Overcoming the reasons of land degradation

The approach of this study based on managed plan of conserving Abu Mena World Heritage property to be done by comprehensive and collective vision concerning the site itself and its situation in the open outskirts within the agricultural land use. The dynamic changes of the environmental factors should be monitored following a long-term master plan. The idea of lowering the water table realize a temporal solution for minimizing the rise of water table but overcoming the main reasons of land deterioration is highly required to be as follows:

3-1-Delineating the effective area for deterioration impact

Based on the flow directions of drained water as shown in figure 4, the most effective area that convert the rising water table to archaeological site was delineated. The gross area of this effective one was totally calculated as 10,653.42 ha. The area Includes or bordered by nominated villages as Al Aola , Abd al- Basit Abd al- Salamad, Al Tanmeiah, Central village, Mohamed Farid, Salama Hegazi and villages numbers 4, 5, 13, 14 , 15, 16, 17, 18 and 20 (figure 6).

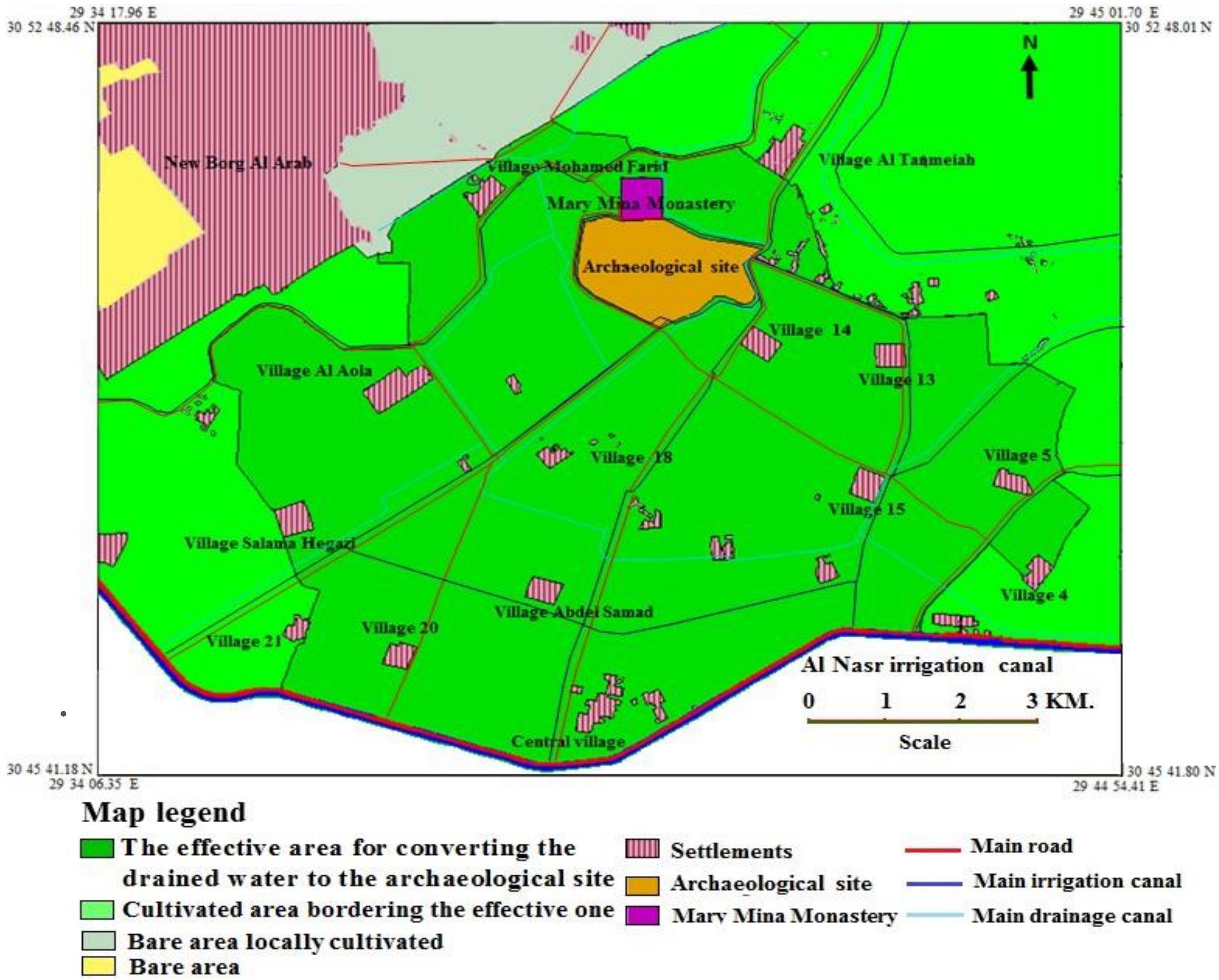

Figure 6 The effective area for converting the drained water to the archaeological site

3-2-Changing the irrigation system in the delineated effective area

Changing surface irrigation system to the drip one can be economically and practically done in the effective area that convert the drained water to archaeological site. The total area of this effective one (figure 6) was modified by erasing the non-cultivated land of the artificial nonlinear features and linear ones of main roads and main water canals. The gross area was estimated as 9,236.97ha (figure 7). This area still including secondary narrow water channels and secondary narrow roads. The net area will be practically realized when the drip irrigation system is implemented as the secondary narrow water channels will be replaced by other adapted water network to the drip irrigation system and when the secondary narrow roads will be out of the design.

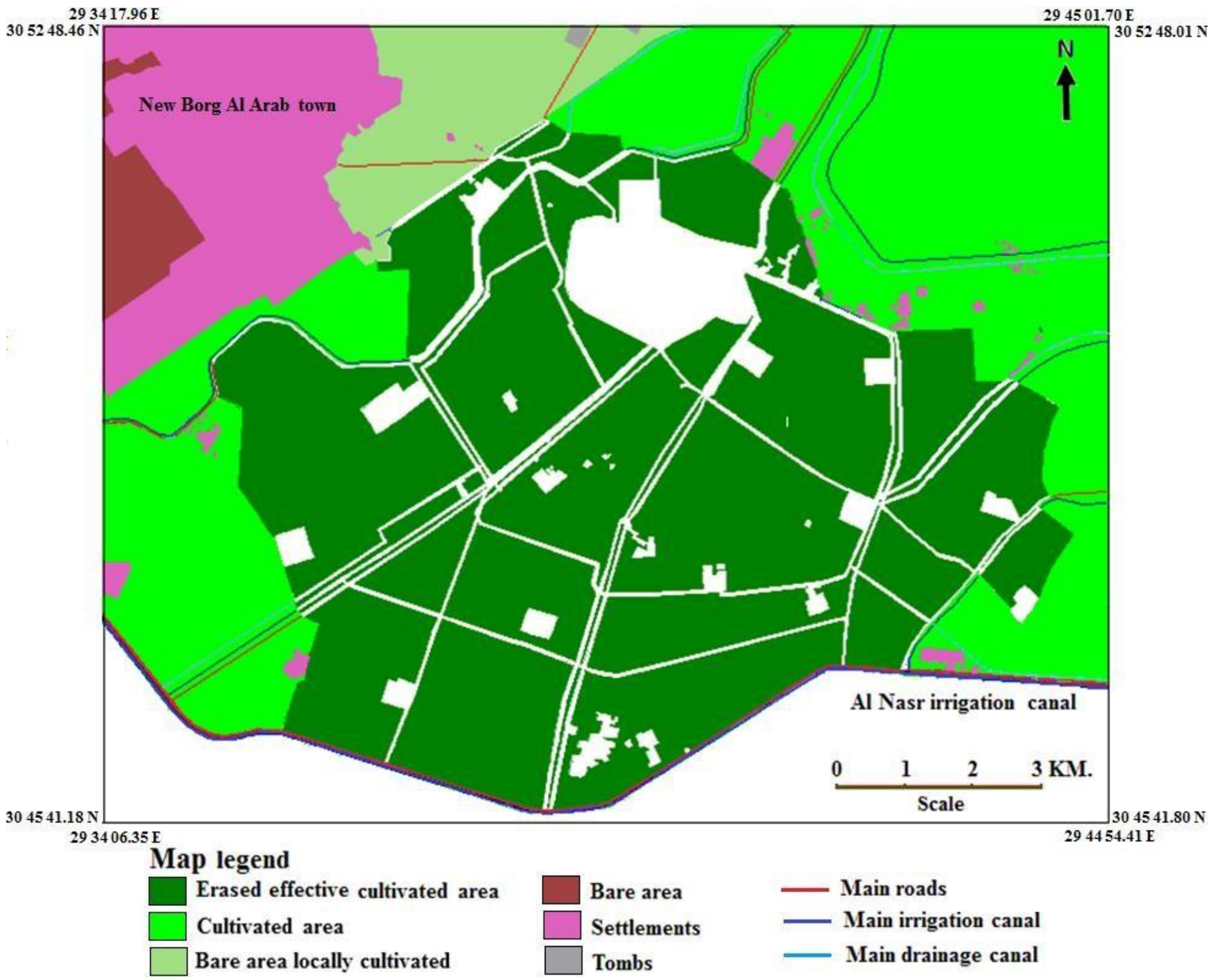

Figure 7 Extracted gross area to be managed under drip irrigation system

3-3-Maximizing the use of drip irrigation with certain cropping patterns

In addition that drip irrigation is highly required for preventing water infiltration, saving water in a region of arid climate is also important to select certain crops to be cultivated. These crops should be more compatible and productive with that irrigation system and the natural environment elements. Also to be compatible with the interest of owners and producers considering their accumulated agronomical skinless. A list of selected crops that are traditionally grown in the study region are shown in Table 3. To clarify the importance of changing the surface irrigation system to drip system, comparative mathematical evidence has been implemented as follows:

3-3-1- Evaluating surface irrigation system versus drip irrigation one: The surface irrigation system represents watering crops involves higher water volumes due to distribution losses. Tables 3 and 4 show that the average water application under surface irrigation is 11,735 m^3 ha^{-1} for summer crops and 6,108 m^3 ha^{-1} for winter crops. The results confirmed the advantages of applying drip irrigation system as follows**:**

3-3- 1- 1- Water Rationalization Volume:

Water rationalization which expresses the difference between amount of irrigation water under surface system and drip one is the absolute volume of water rationalized per hectare as a result of changing from a surface irrigation system to a drip one. Table 3 and 4 show that the water rationalizations are significant for both summer and winter crops. The average of saving water is 5,163 m^3 ha^{-1} summer crops while is 2,642 m^3 ha^{-1} for winter crops.

3-3- 1- 2- Drip Irrigation Water Index (DIWI)

DIWI is a ratio of irrigation water applied using drip system to surface irrigation system. Drip irrigation demonstrates higher values as an average for most crops to be 57% for summer crops and 56% for winter ones achieving a very high level of DIWI (approximately. 57%).

3-3- 1- 3- Irrigation Water Rationalization Performance Index (IWRPI)

The IWRPI is a metric comparison that quantifies the theoretical water efficiency of drip irrigation relative to traditional surface irrigation. IWRPI divided into three categories based on DIWI: When DIWI is less than 50%, this confirms that drip irrigation has a lower theoretical water requirement. When DIWI equal to 50%, this means that both systems are assumed to have the same water requirement. If DIWI is more than 50%, the planned water allocation for the drip system less than that allocates for the surface system.

DIWI and IWRPI are complementary indices when used in tandem provide a robust framework for water management. This two-pronged analytical approach enables data-driven decision-making, enhances accountability, and ultimately drives meaningful progress toward agricultural water sustainability.

Table 3. Irrigation Water Applied (IWA), Water Rationalization Volume (WRV), Drip Irrigation Water Index (DIWI), and Irrigation Water Rationalization Performance Index (IWRPI) for summer crops

Crop	IWA (m^3 /ha)		WRV ($m^3\ ha^{-1}$)	DIWI %	IWRPI %
	Surface system	Drip system			
Maize	10147	5682	4465	56	44
Tomatoes	6546	3666	2880	56	44
Water melon	10484	5871	4613	56	44
Cantaloupe	7140	3998	3142	56	44
Zucchini	7229	4048	3181	56	44
Artichoke (seeds)	17821	9980	7841	56	44
Sesame	10333	5786	4547	56	44
Grapes	16805	9411	7394	56	44
Pears	14780	8277	6503	56	44
Olives	16065	8996	7069	56	44
Average per ha	11735	6572	5163	56	44
Average per feddan	5014	2742	2169		

** Hectare = 2.38 feddans

Table 4. Irrigation Water Applied (IWA), Water Rationalization Volume (WRV), Drip Irrigation Water Index (DIWI), and Irrigation Water Rationalization Performance Index (IWRPI) for winter crops

Crop	IWA (m3 /ha)		WRV ($m^3\ ha^{-1}$)	DIWI %	IWRPI %
	Surface system	Drip system			
Sugar beet	6723	3735	2988	56	44
Vaba beans	4321	2401	1920	56	44
Cabbage	6693	3937	2756	59	41
Broccoli	6528	3841	2687	59	41
Tomatoes	6546	3637	2909	56	44
Potatoes	5835	3242	2593	56	44
Average per ha	6108	3466	2642	57	43
Average per feddan	2566	1456	1110		

** Hectare = 2.38 feddans

Changing the surface irrigation system to a drip irrigation one lead to many advantages. Drip irrigation system delivers water directly to the root zone of plants, which in turn minimize losses reducing the amount of needed water and agricultural water withdrawal. The agricultural services will be improved with a relative increase in areas that are occupied by the current intensive water canals raising the value of the production unit in relation to the quantities of irrigation water.

By changing the surface irrigation system to drip irrigation, renewable energy becomes part of the solution expanding the agricultural management system to include land, water, and energy. As the dense water canals will mostly be removed, big stations that generate high-cost traditional energy for pumping water will be replaced by limited units for generating clean energy of low coast. According to El-Bably and Abd Elhafez (2019), status quo requires implement Water - Food - Energy – Ecosystem approach is effective and sustainable solutions to the problem of water scarcity and drought for maximizing utilization of natural resources in Egypt of water scarce, food deficient and intensive energy. The integration of the policy concerning Water - Food - Energy WFE nexus through a set of measures considering climate change will provide integrated solutions and to mitigate nexus-related risks management and implement integrated planning that builds synergies across the three sectors and reduces trade-offs.

The necessity of benefiting from the Central Bank's initiative launched in November 2020 (Central Bank of Egypt 2020), which offers the advantage of interest-free financing for modern irrigation systems, as part of the national campaign adopted by the Egyptian state to address water challenges

4 Recommendations

-It is important to take into account the factors that cause the environmental changes as mainly related to the conversion of drained water via descending slopes to an area without natural drainage outlets.

-The changes of the environmental factors should be monitored following a long-term master plan. The idea of lowering the underground water around the archeological is realize a halting of rising the water table. Parallel with these beneficial efforts, taking into account the multiple reasons for land deterioration is required

-Changing the surface irrigation system to drip irrigation one is important to prevent the flow of agricultural drainage water towards the archaeological site and to overcome further deterioration. Also, for maximizing the optimum use of water with minimum losses.

- Continued cooperation between relevant government institutions in Egypt and UNSCO of UN is of considerable benefit in overcoming this problem. Providing technical advice and funding to facilitate the achievement is increasing the value of the water and land unit production as well as protecting the cultural and agro-bio diversities.

-Expanding the agricultural management system to be food, land, water, and energy nexus as the dense water canals will mostly be removed. Big stations that generate high-cost traditional energy for pumping water will be replaced by limited units for generating clean energy of low coast.

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الملخص العربى

تأثير تدهور الأراضي على التنوعات الثقافية والزراعية الحيوية جنوب مدينة برج العرب، محافظة الإسكندرية، مصر

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تقع منطقة الدراسة جنوب غرب محافظة الإسكندرية وشمال ترعة النصر للري وتغطي مساحة ٢٣٢٤٢,١٠ هكتارًا، بما في ذلك موقع أبو مينا الأثري. ويعتبر الحفاظ على هذا الموقع التاريخى أمرًا مهما للحفاظ على التنوع الثقافي والزراعي الحيوي. وتبين الملامح االشاملة لخصائص الغطاء الأرضي في منطقة الدراسة ان غالبيتها هى زراعة مروية مكثفة تحت الري السطحي باستخدام قنوات مائية كثيفة مما تسبب فى احداث ضغطا هيدروليكيا على طبقات التربة،التحتية والتأير سلبا على محيط منطقة التراث العالمي بتشبع طبقاتها بالمياه وتملحها. تتميز وحدات الأراضى على المنحدرات وفى سهول التجوبة بتربة ذات قوام انعم (طمي رملي طيني) مقارنةً بالقوام الأكثر خشونة (طمي رملي) في البلايا داخل الحوض المنخفض وبناء على التفسيرات الهيدروفيزيائية فان مسار تدفق المياه يتجه من هذه المنحدرات وسهول التجوبة فى الارتفاعات الاعلى وذات توصيلا هيدروليكيا أقل (٠,٣–٢,٩ سم / ساعة) مقارنة بالتربة الأكثر نفاذية (٤,١–٦,٥ سم / ساعة) داخل الحوض المنخفض. تم تحديد المنطقة الاكثر فاعلية فى انسياب مياه الصرف الى المنطقة الاثرية

وتبلغ مساحتها ٩٢٣٦,٩٧ هكتارًا. كما بينت النتائج أن الري بالتنقيط يحقق مؤشر مياه مرتفع للري ، وذلك بسبب استخدام كمية أقل من المياه مقارنة بالري السطحي. وتقدر إجمالى المياه المتوفرة بحوالى ٧٢٠٩٤ متر مكعب داخل المنطقة المنزرعة المحددة لتغيير نظام الرى مما يؤكد بأن تطبيق الري بالتنقيط يوفر حلاً دائمًا لمشكلة ارتفاع منسوب المياه ويحقق استراتيجية مستدامة لترشيد استخدام المياه والحفاظ على موقع أبو مينا التراثي والتنوع الحيوى الزراعى وذلك باستمرار التعاون بين الجهات المعنية فى مصر ومنظمة اليونسكو بالامم المتحدة من خلال المشورة الفنية والتمويل الذى يعتبر أمرا بالغ الأهمية .