جمهورية مصر العربية
وزارة التعليم العالي والبحث العلمي
الهيئة القومية للاستشعار من البعد وعلوم الفضاء
National Authority for Remote Sensing and Space Sciences

http://www.narss.sci.eg

Monitoring of Soil Contamination Using Remote Sensing techniques

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Outlines

1. Introduction
2. Aims of The Study
3. Study Area
4. Material and Methods
5. Results
6. Conclusions

1 Introduction

- The issue of soil contamination is one of the most important subjects that interests decisionmakers all over the world
- The soils adjacent to the drains in Egypt suffer from increasing concentration of heavy metals, which negatively affects soil and crop quality
- Soil contamination by heavy metals consider as main environmental problem in the world, most of them have toxic effects on the plant and microorganisms in soil when permissible concentration levels are exceeded.
- Egypt has tried to increase its agricultural area through reclamation of desert land. This extension in agricultural land requires reuse of agricultural drainage water for irrigation due to Egypt face freshwater scarcely problem.

1 Introduction

- About 1 million Faddan in the Nile delta uses drainage water for irrigation. The increasing of heavy metal impact the balance of physical and chemical properties for instance; soil pH is a variable that influenced heavy metals adsorption, retention and movement.

- Remote sensing provide rich spectral, and generally spatially continuous information, that can be used for determining more detailed spectral properties of the soil properties, which could be applied for mapping and monitoring soil contamination.

2

Aims of The Study

(A) Produced spatial distribution maps for soil contamination.

(B) Produced Contamination Indices maps for soil contamination.

(C) Developed Multi- Linear regression (MLR) for relationships between reflectance data and soil contamination.

(D) Validate MLR of spectral reflectance data which detect heavy metal concentration in soil , plant and water properties using traditional method (ICPMS).

(E) Health risk assessment of heavy metals in agricultural areas.

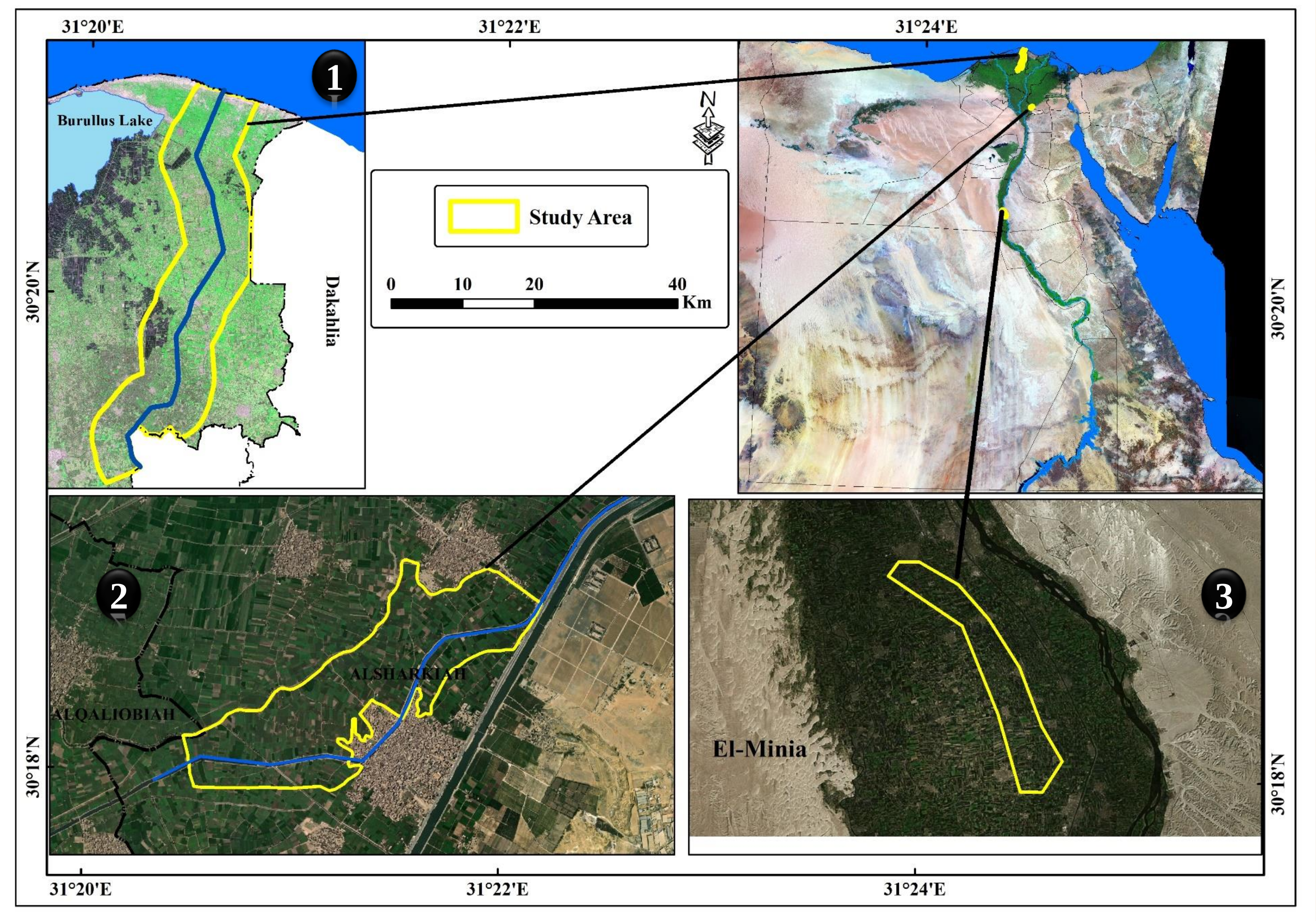
(F) Risk assessment map for heavy metals contamination in the study area.

3 Study Area

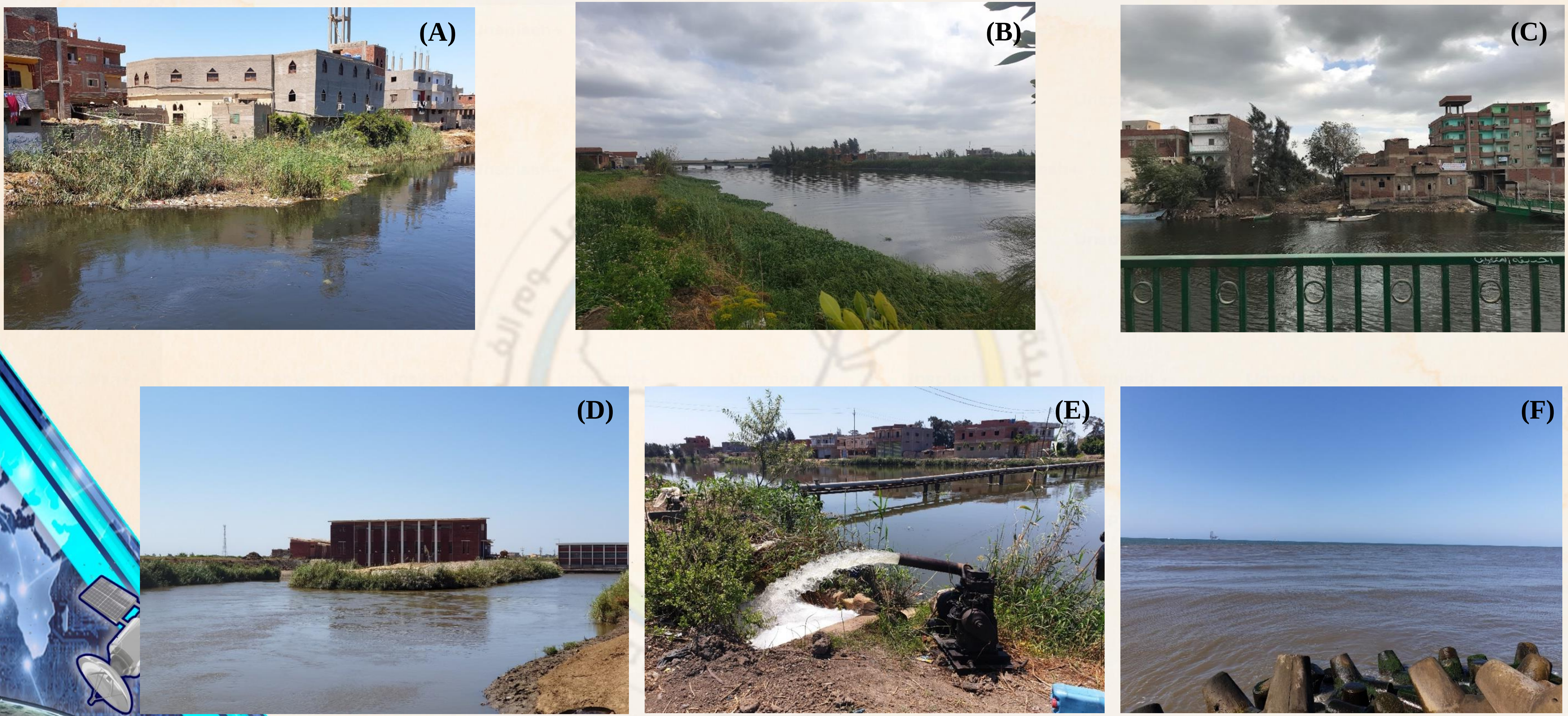
(1) Kitchener Drain

(2) Bahr Elbakr Drain

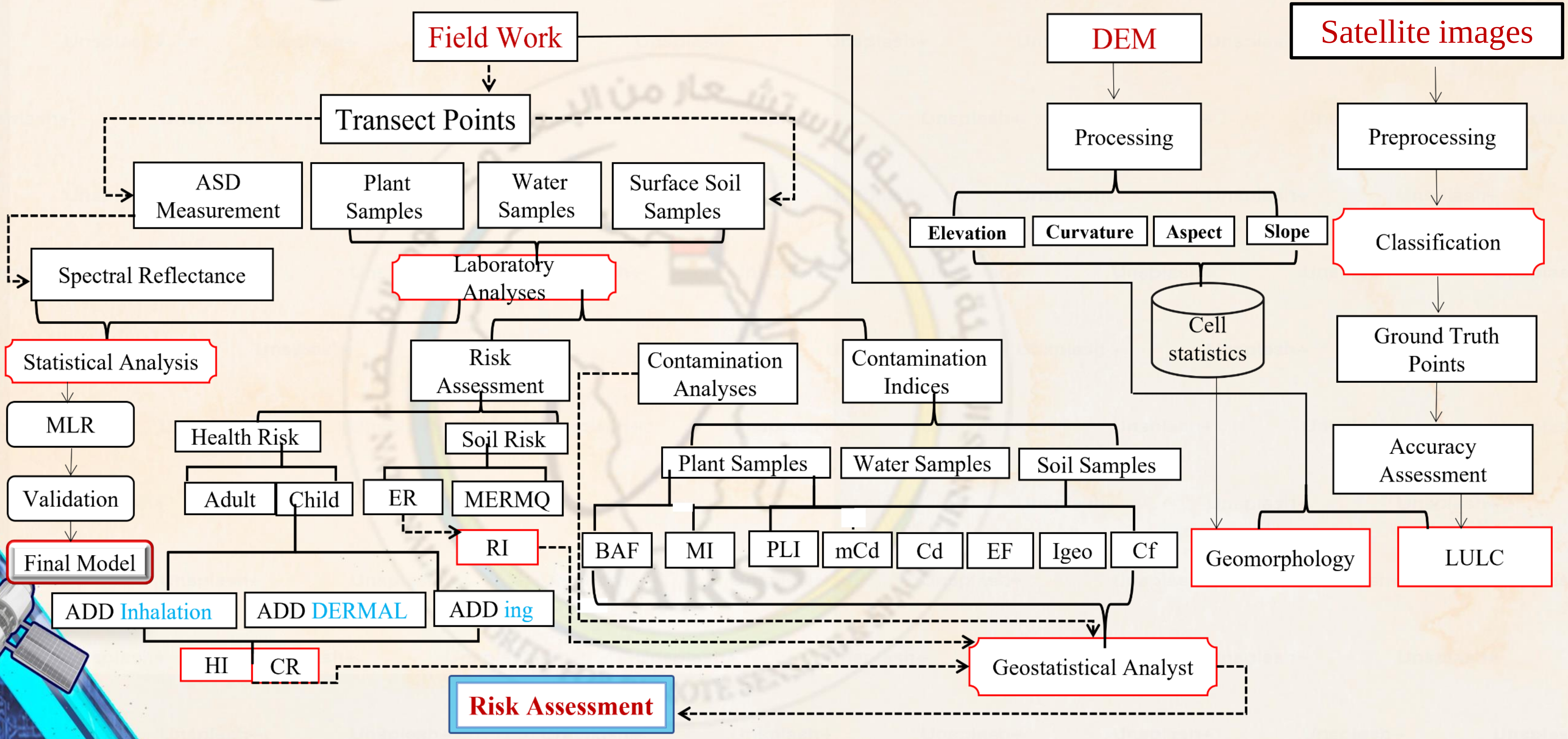
(3) El-Moheet Drain



Study Area (Kitchener Drain , Bahr Elbakr Drain , El-Moheet Drain


(A)
(B)
(C)
(D)
(E)
(F)

4 Material and Methods



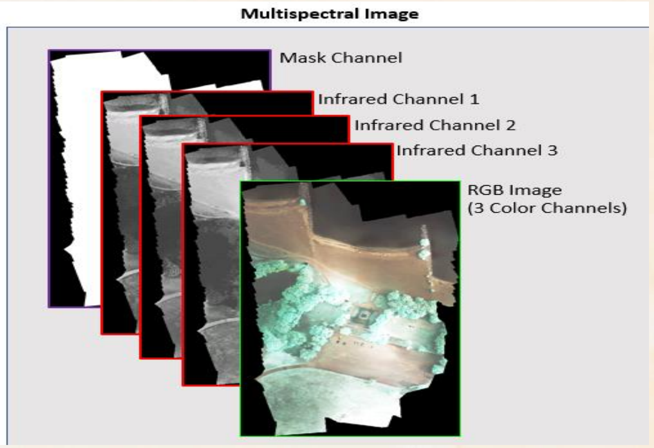
Flowchart diagram show the steps of the research work

Material and Methods

4

- Remote Sensing Data

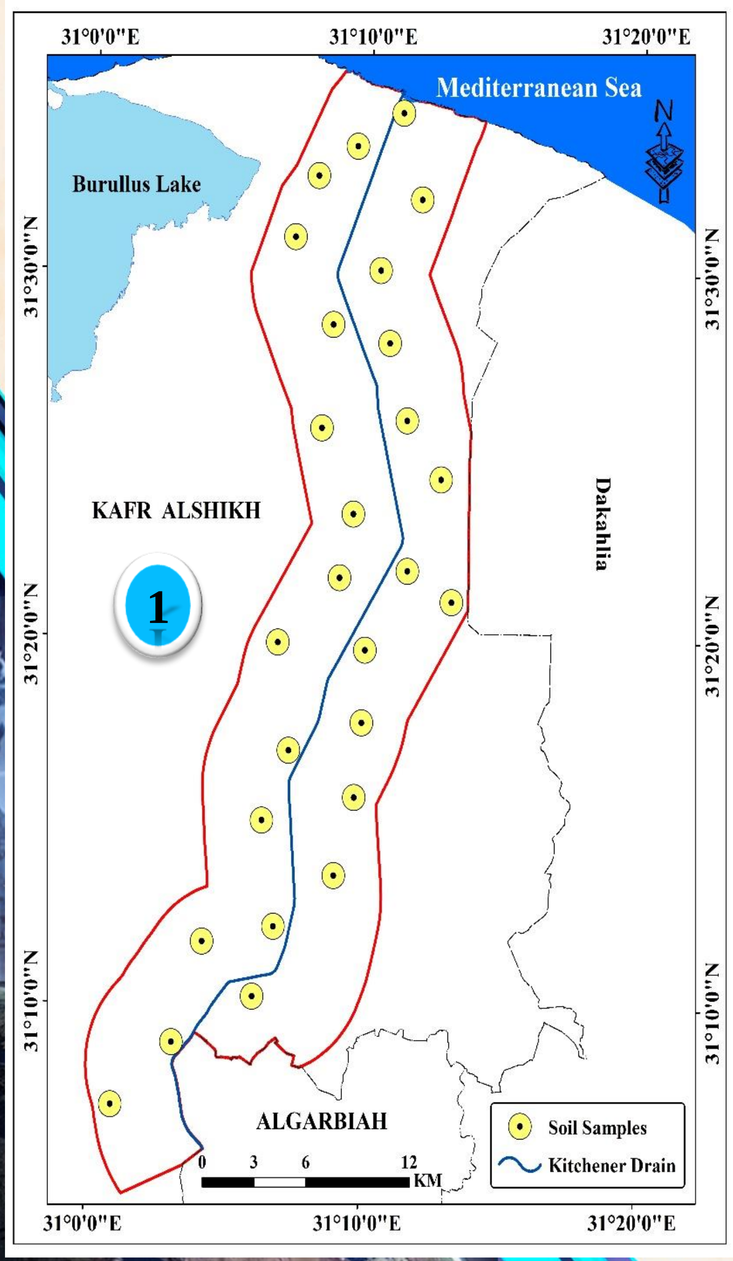
- Multispectral data (Sentinel 2 satellite images)
- Spectroscopic data (ASD Spector-radiometer)
- Digital Elevation Model (DEM) (ALOS PALSAR 12.5 m)

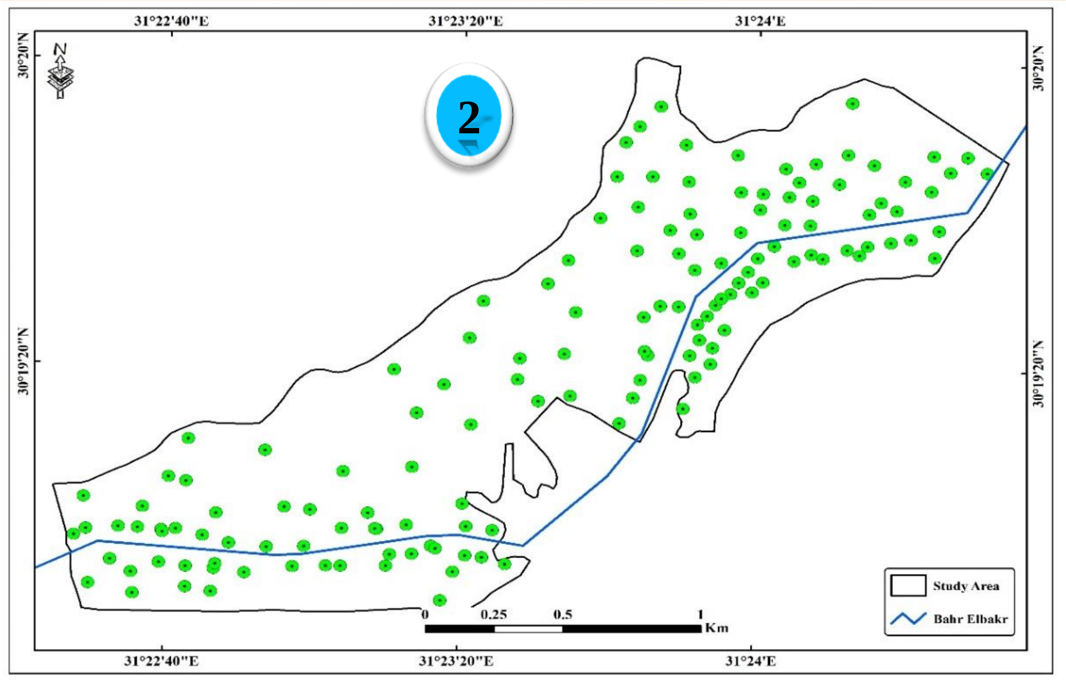


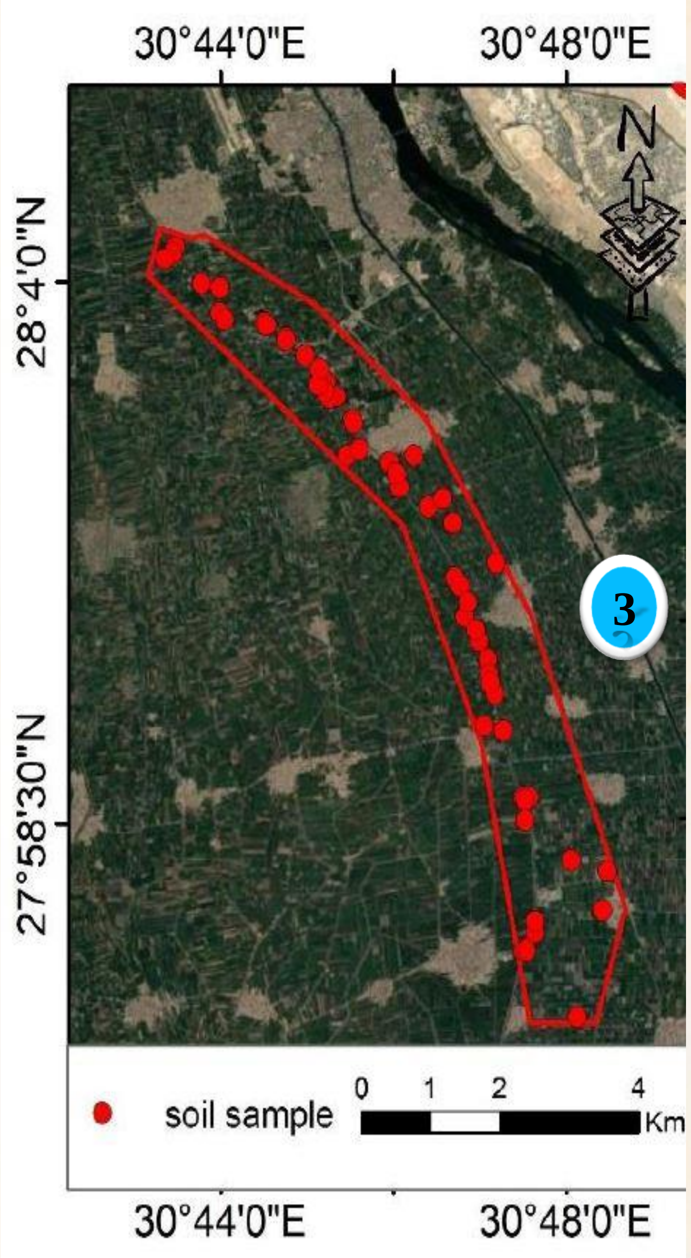
- Laboratory Analysis

- Soil samples analyses (Texture, Ec, pH, OM, Ni , Mn , As, Cd, Cu, Pb, Zn, Co and Fe
- Plants samples analysis (Ni , Mn , As, Cd, Cu, Pb, Zn, Co and Fe)

4 Material and Methods







(1) Kitchener Drain

(2) Bahr Elbakr Drain

(3) El-Moheet Drain

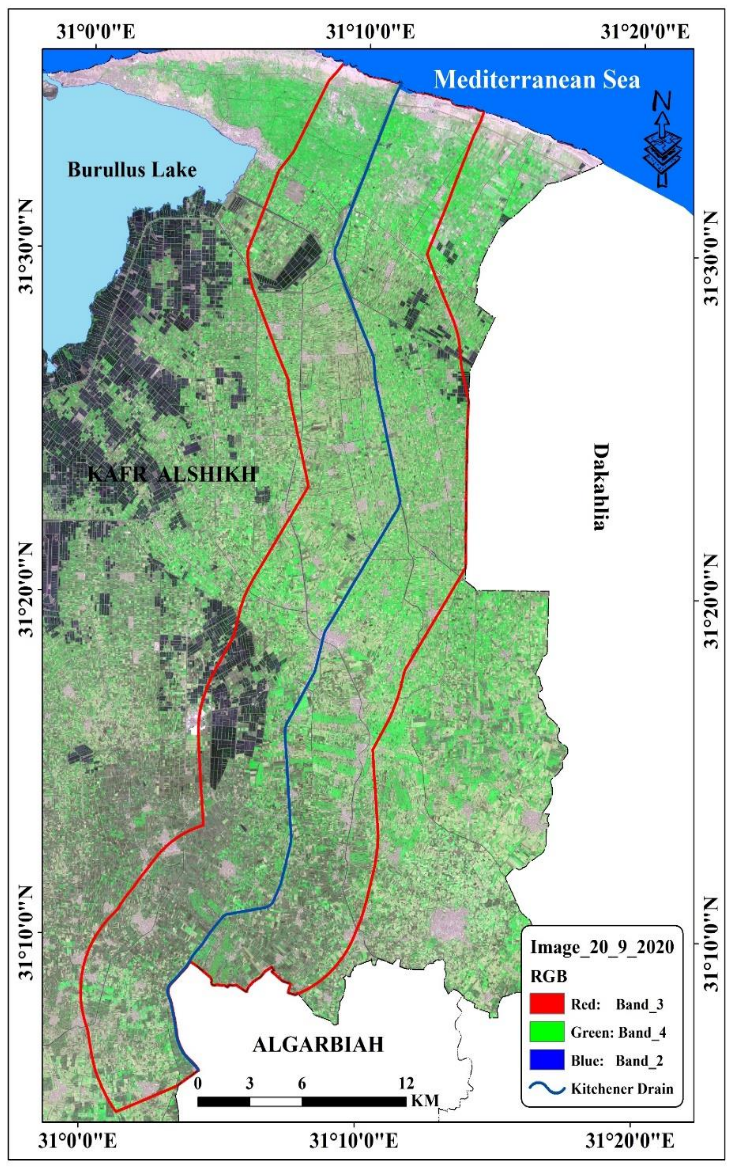
Spatial Distribution of Transect Points

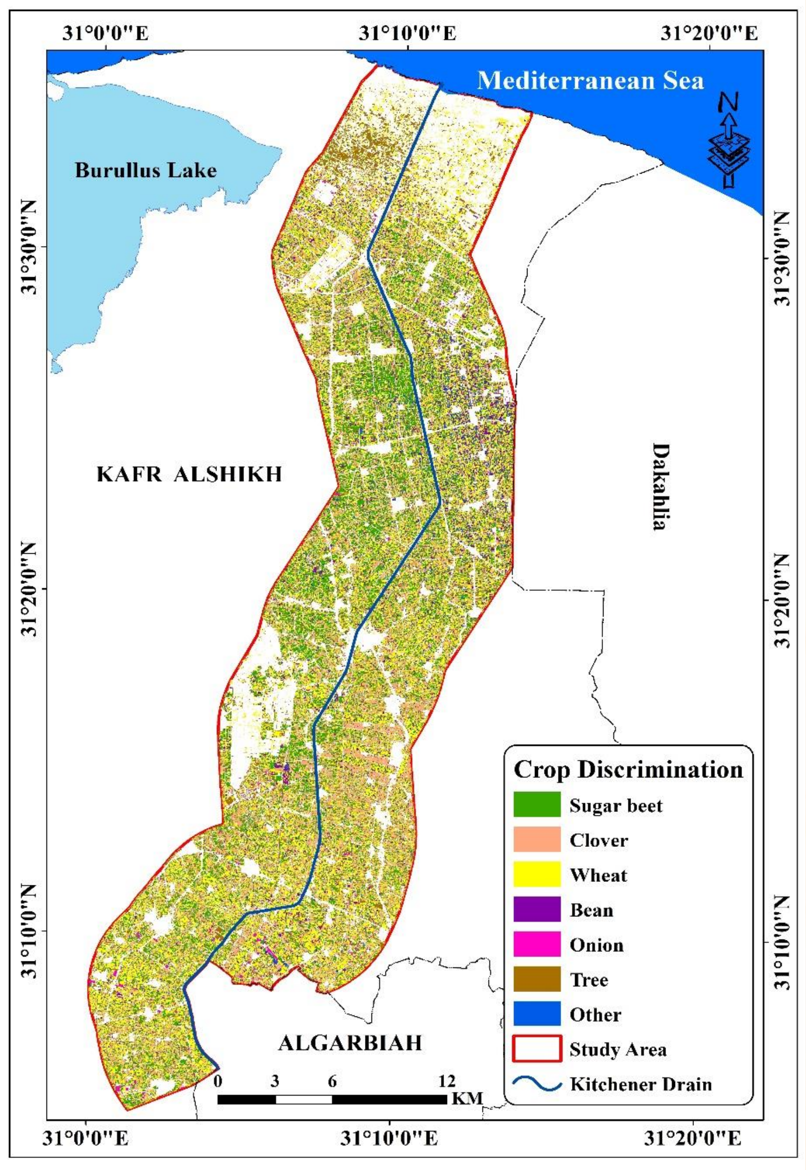
5

Results

1. Crop Discrimination

Crop Discrimination 2021





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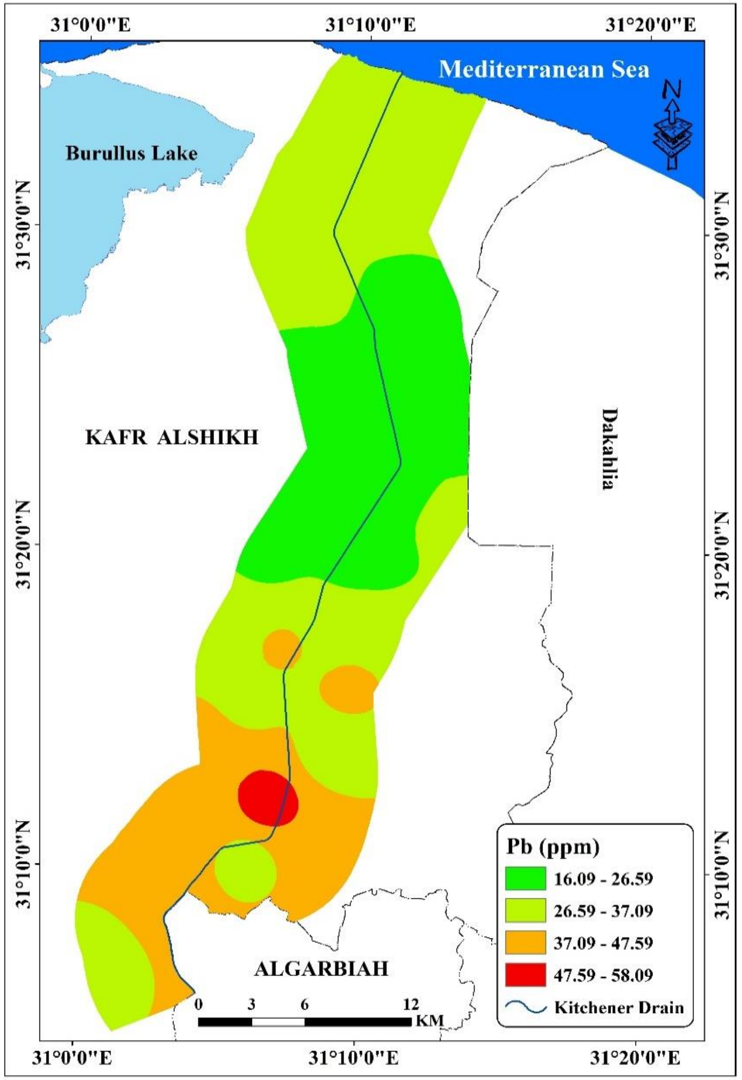
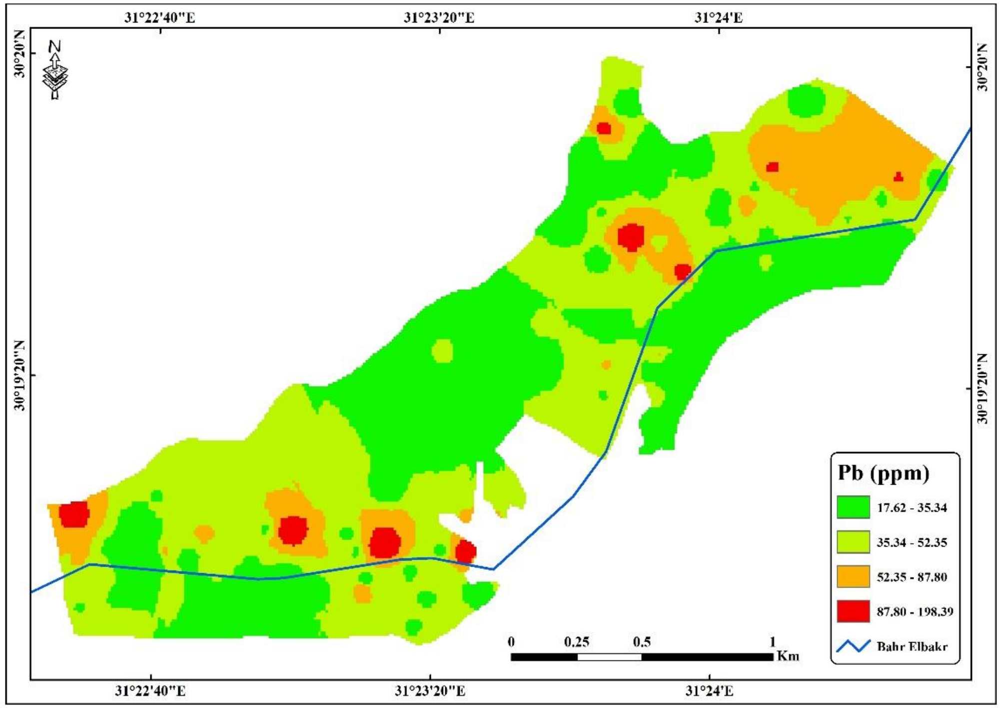
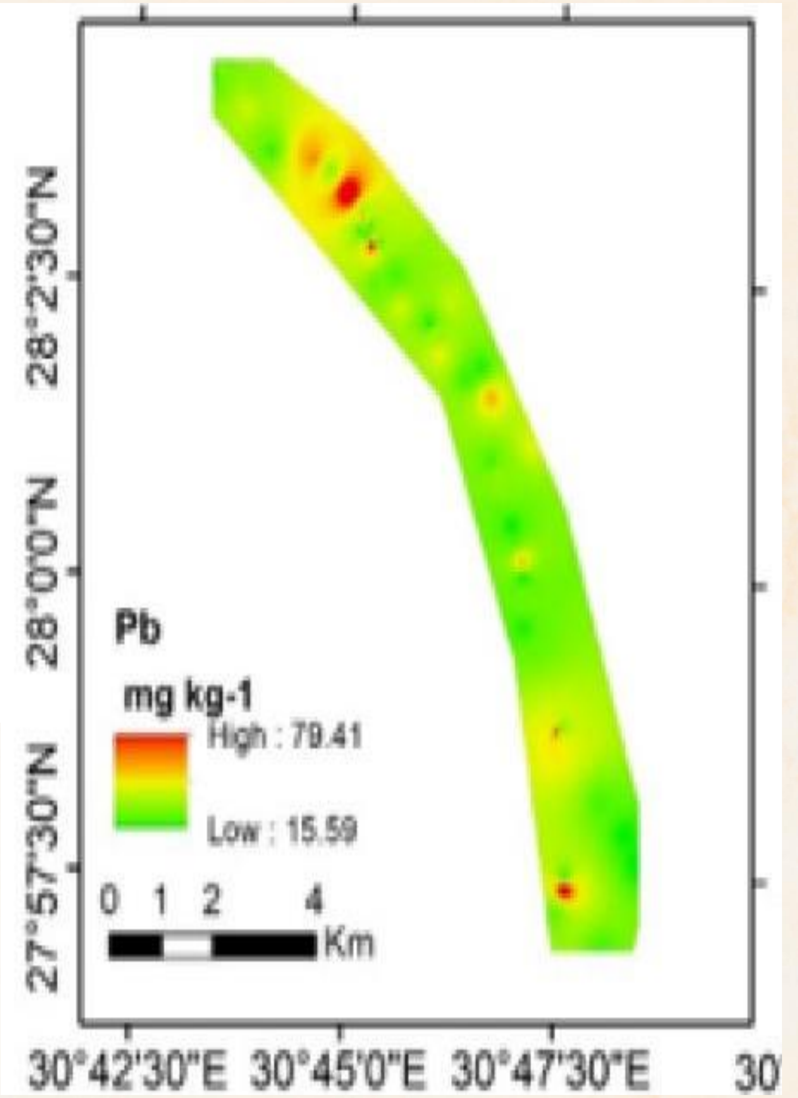
5

Results

2. Soil Contamination

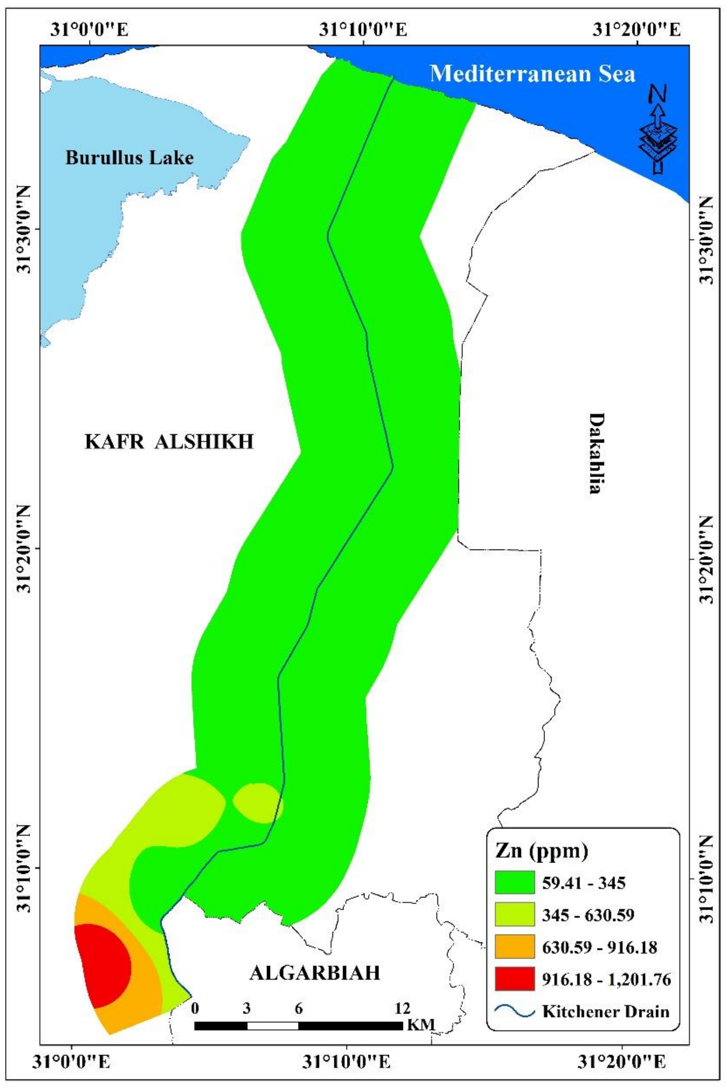


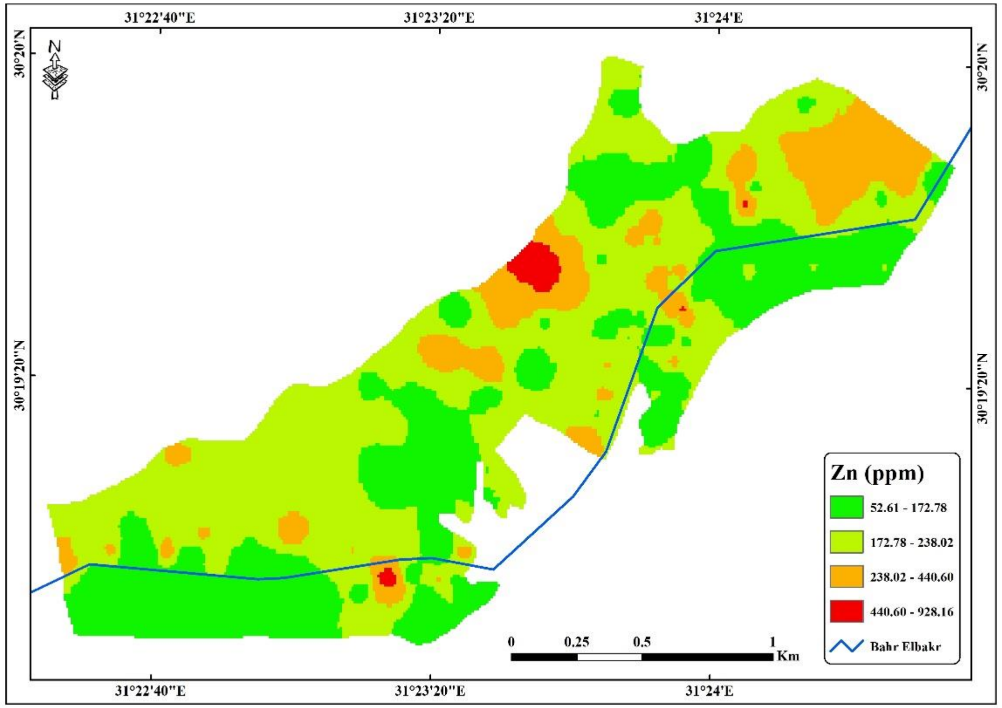


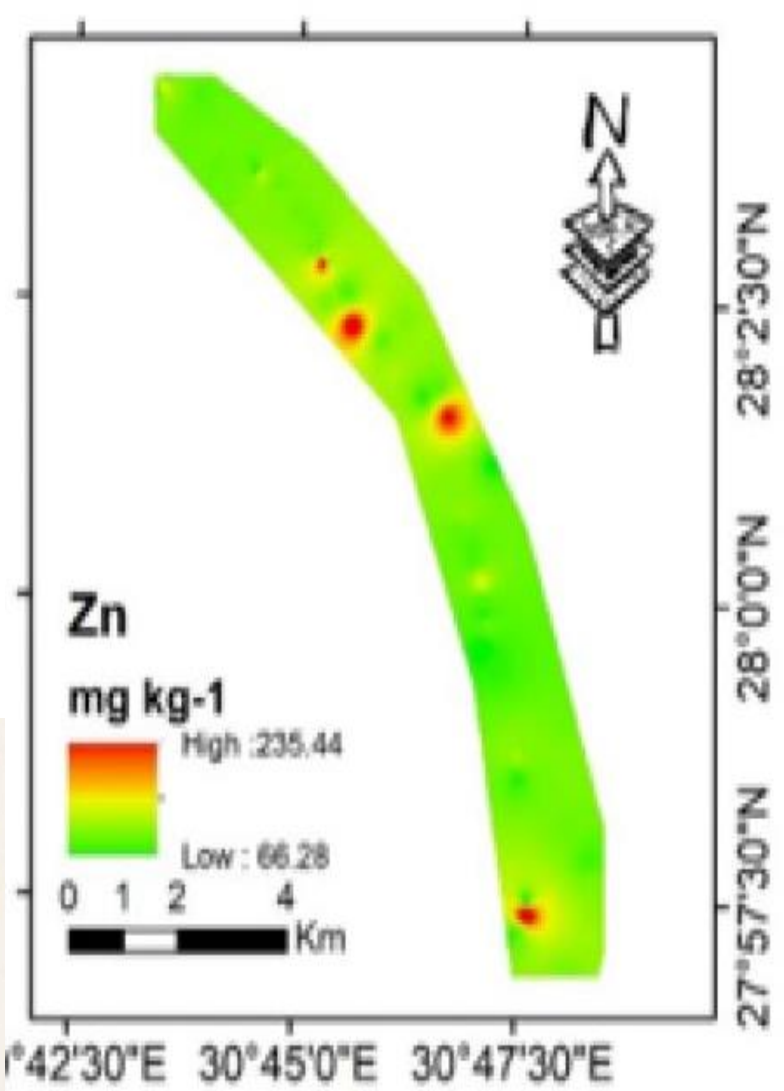


Spatial distribution of heavy metals total concentrations of Pb

2. Soil Contamination





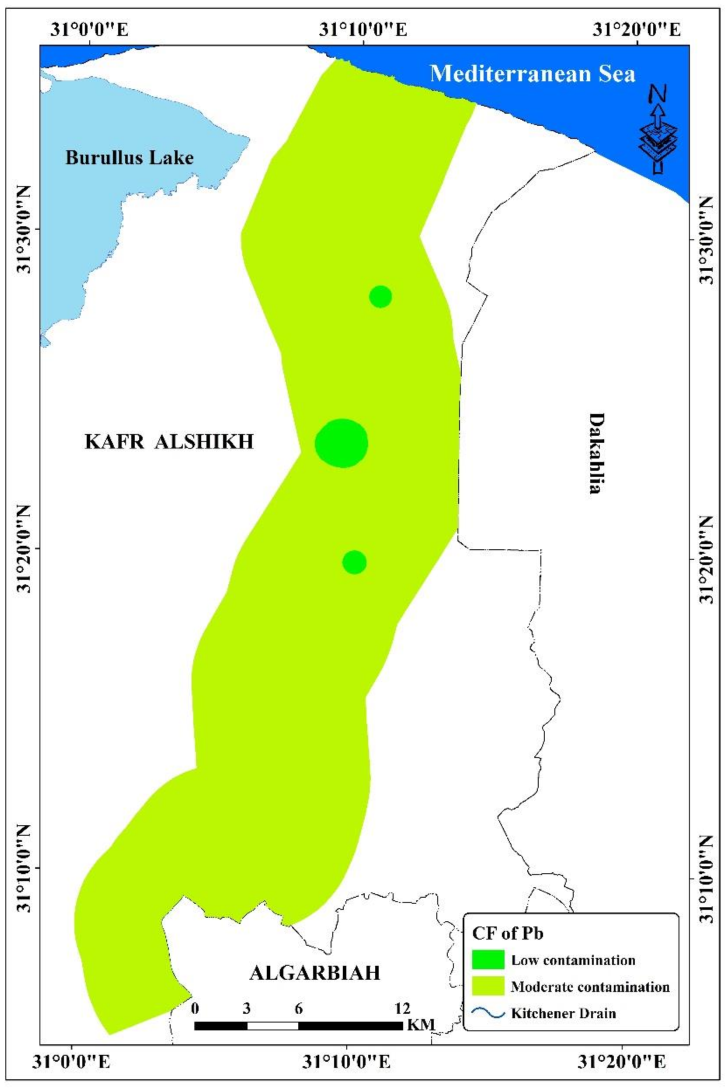


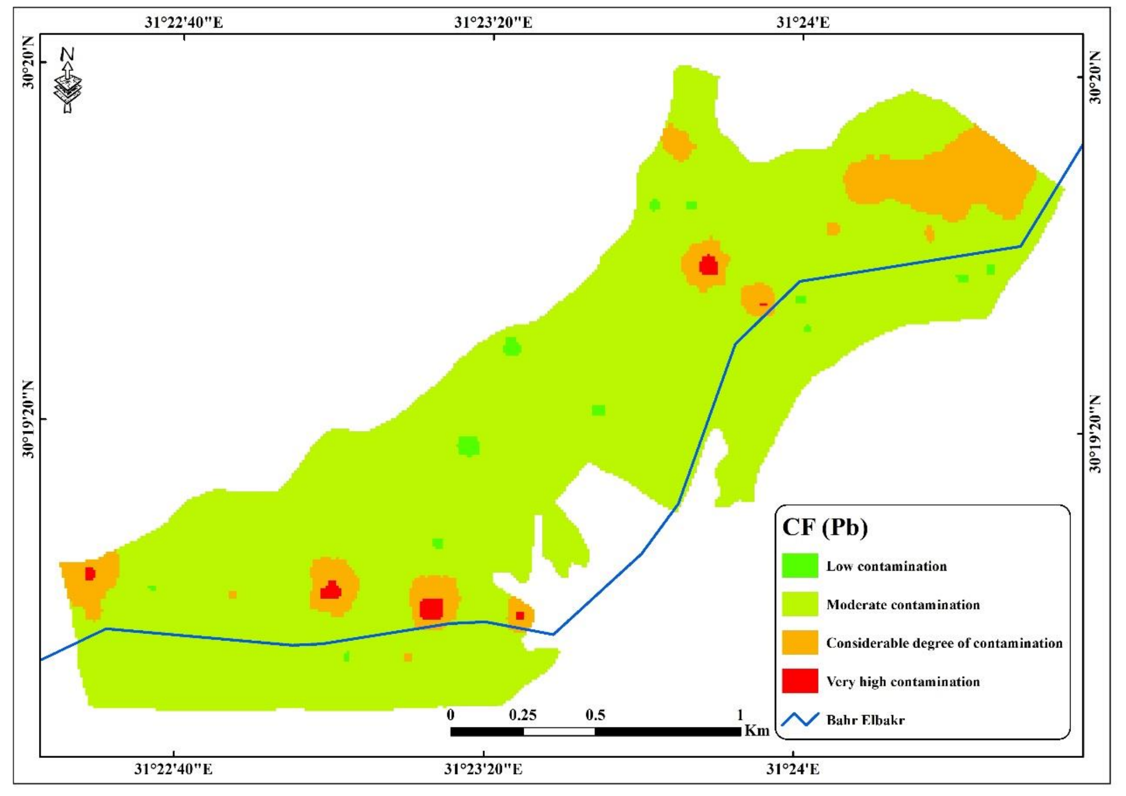
Spatial distribution of heavy metals total concentrations of Zn

Results

3. Soil Contamination Indices

1. Individual indices





Contamination factor Distribution of Pb

(A) Contamination factor (Cf)

This index enables the assessment of soil contamination, taking into account the content of heavy metal from the surface of the soil and values of pre-industrial reference levels given by Hankinson (1980) Cf is calculated by the following formula:

$$C_f = \frac{C_m}{C_{p-i}}$$

Results

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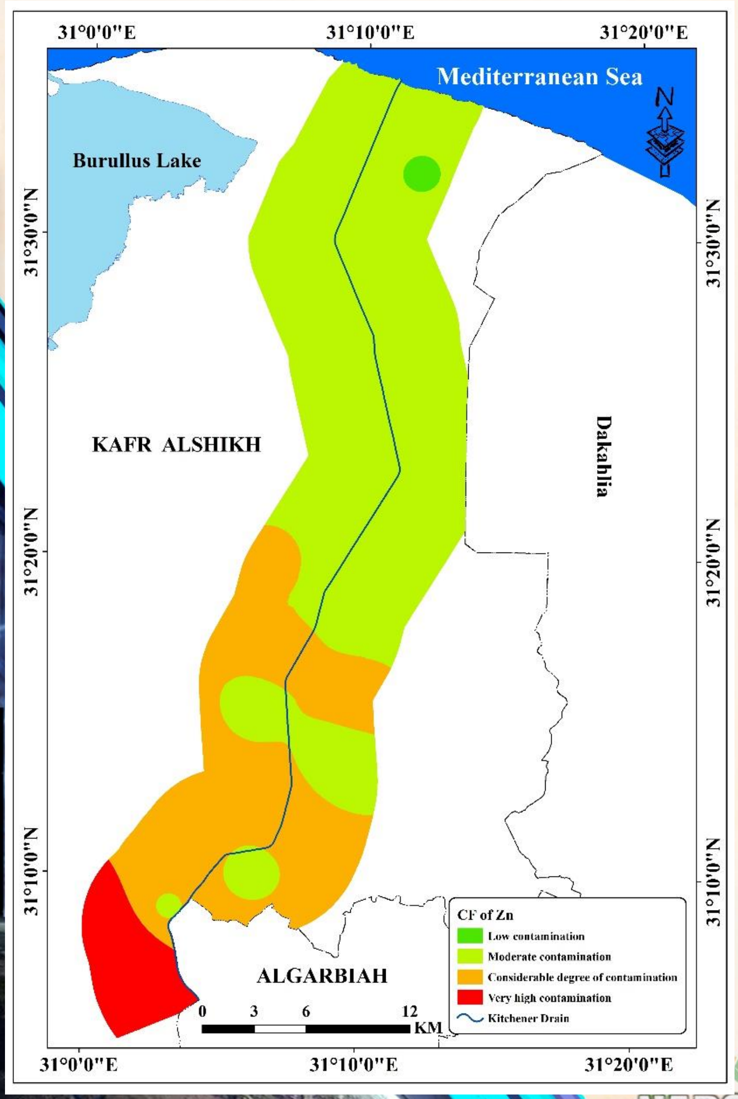

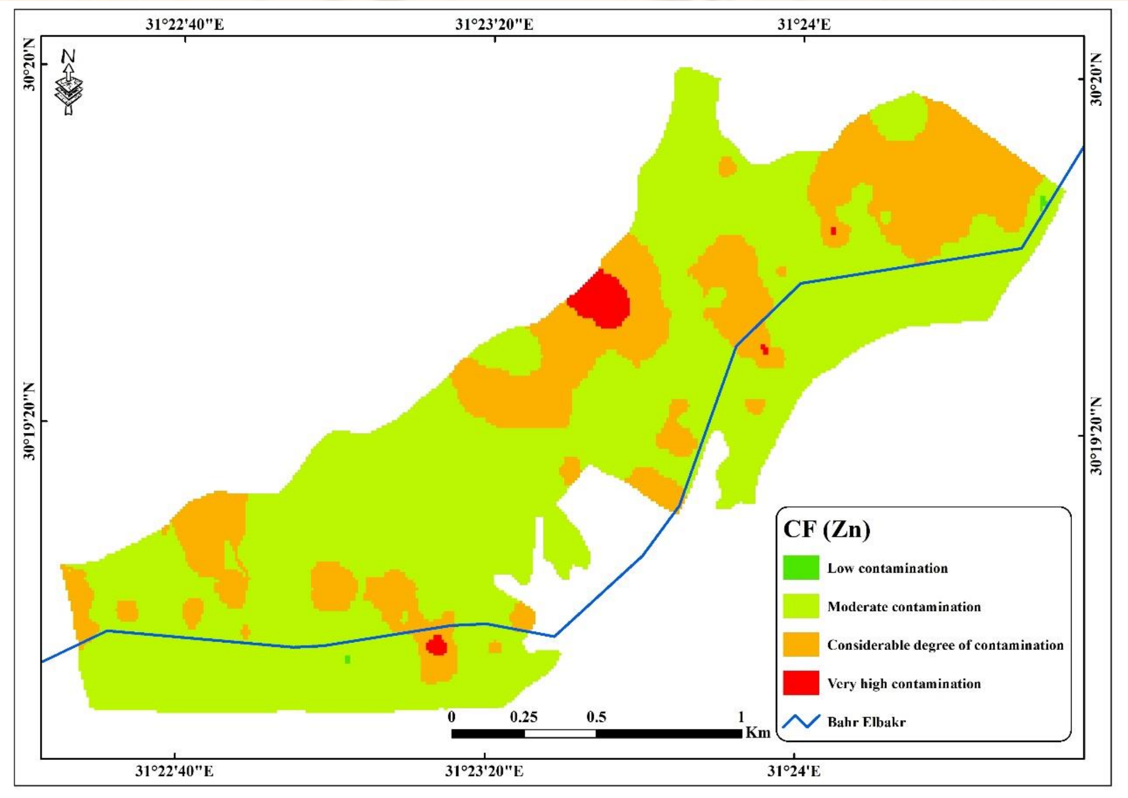

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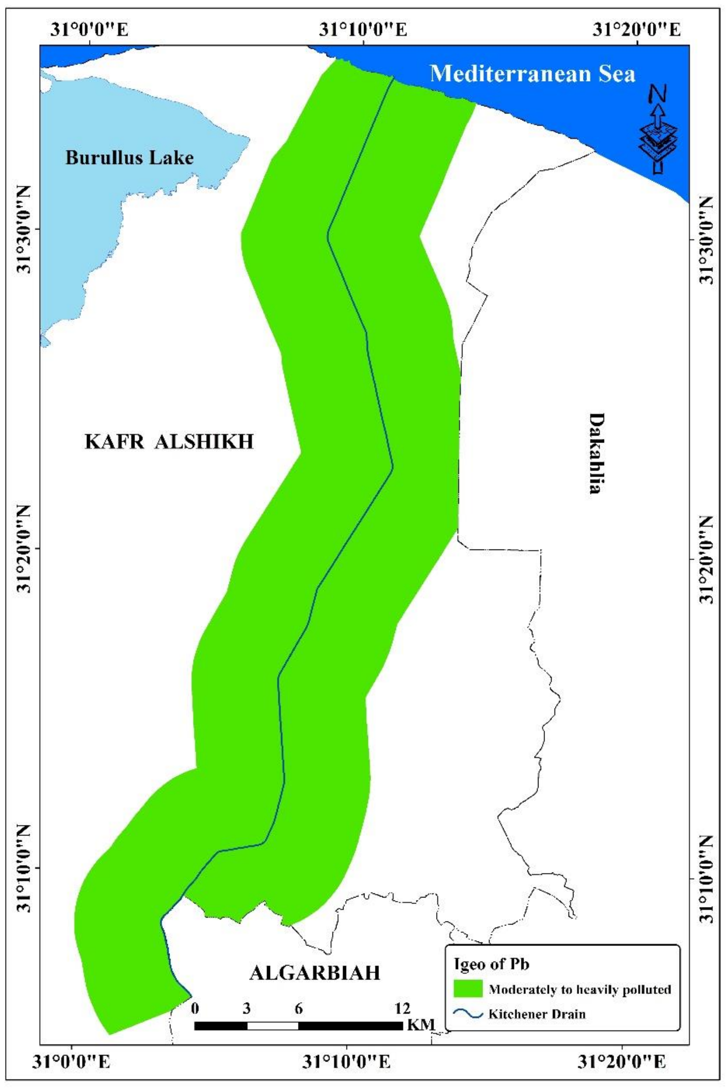

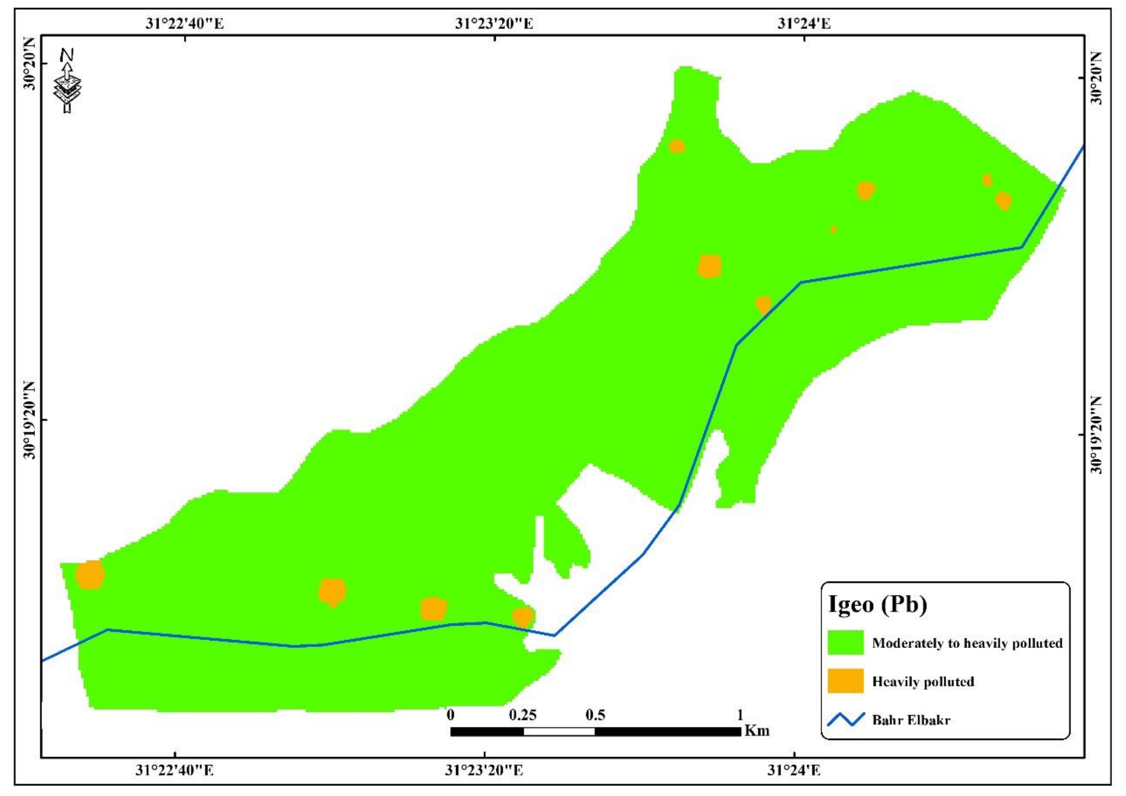

Contamination factor Distribution of Pb

(B) Geoaccumulation Index (Igeo)

An index of geo-accumulation (Igeo) was originally defined by Muller (1979), in order to determine and define metal contamination in sediments, by comparing current concentrations with pre-industrial levels.

Igeo = Log2 (Cn/1.5Bn)

5

Results

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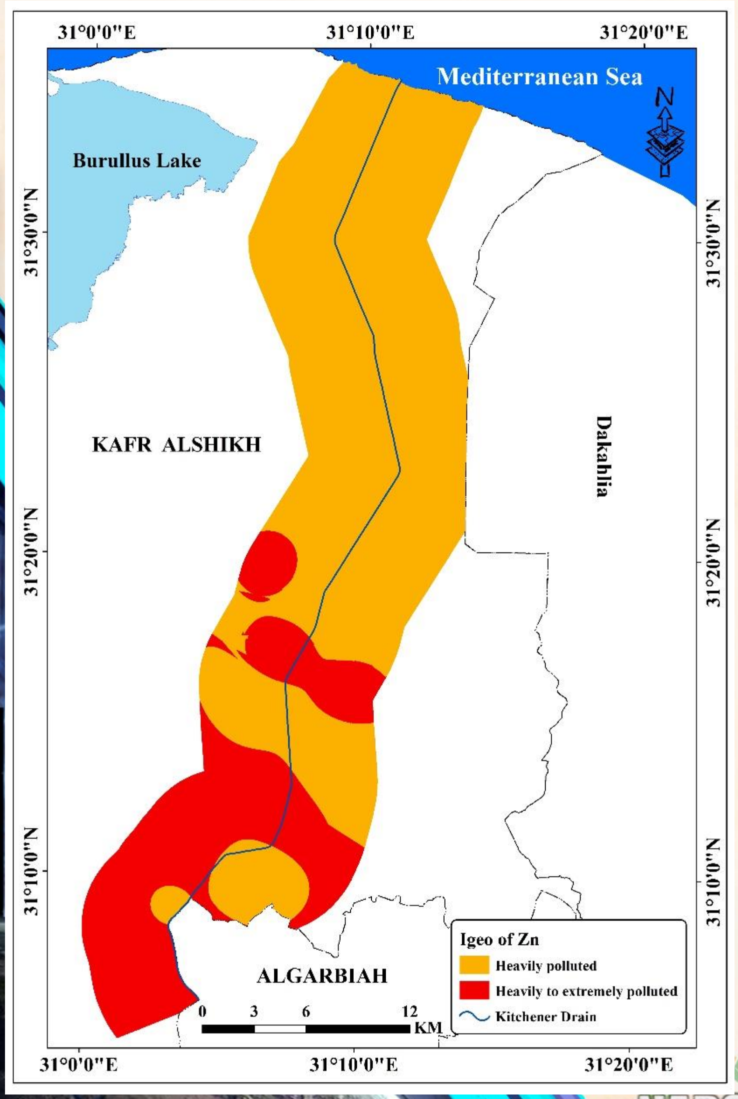
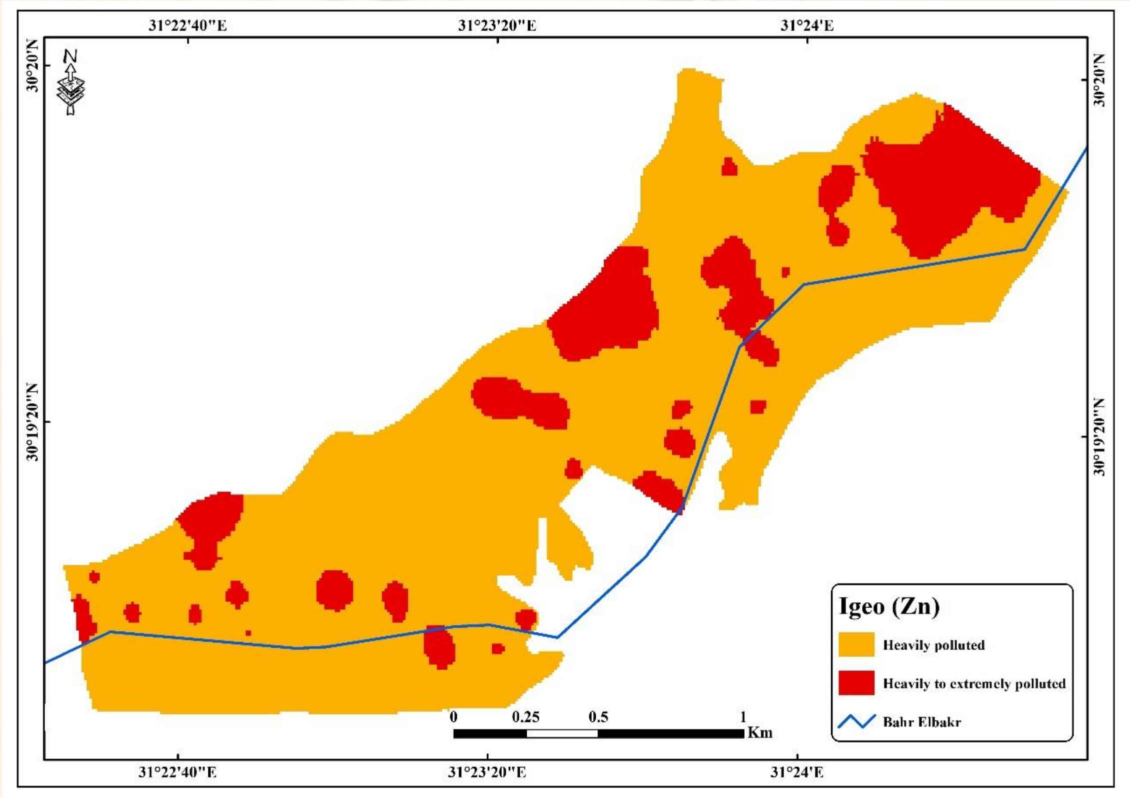
1. Individual indices





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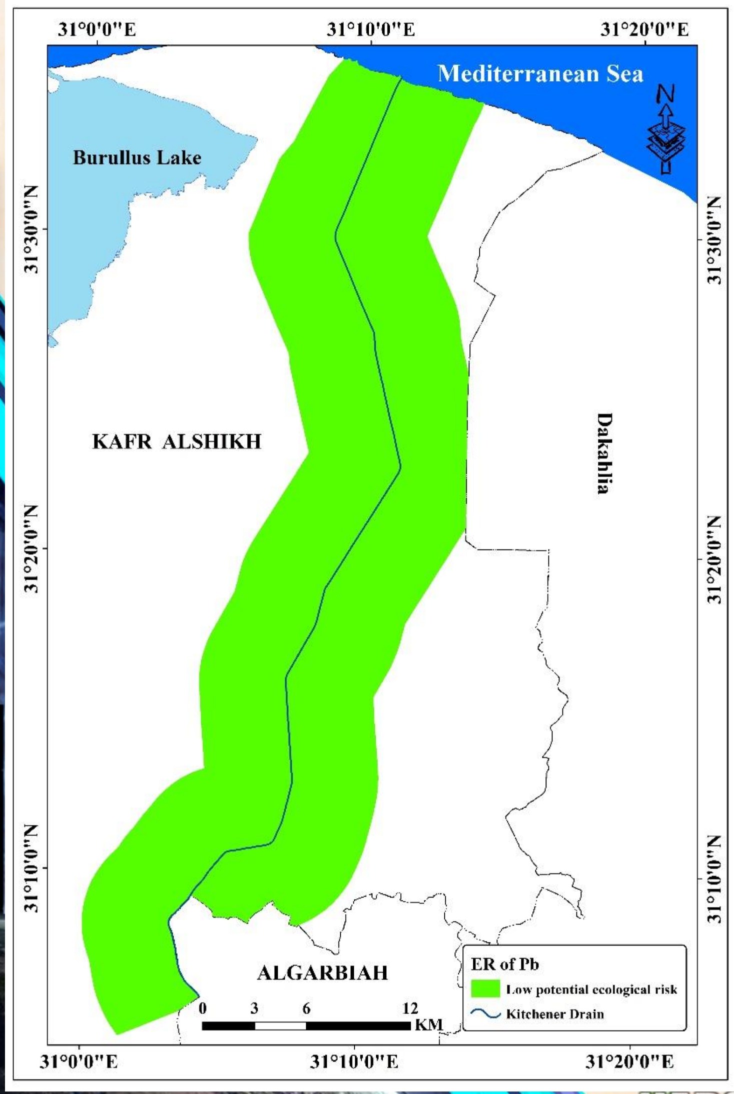
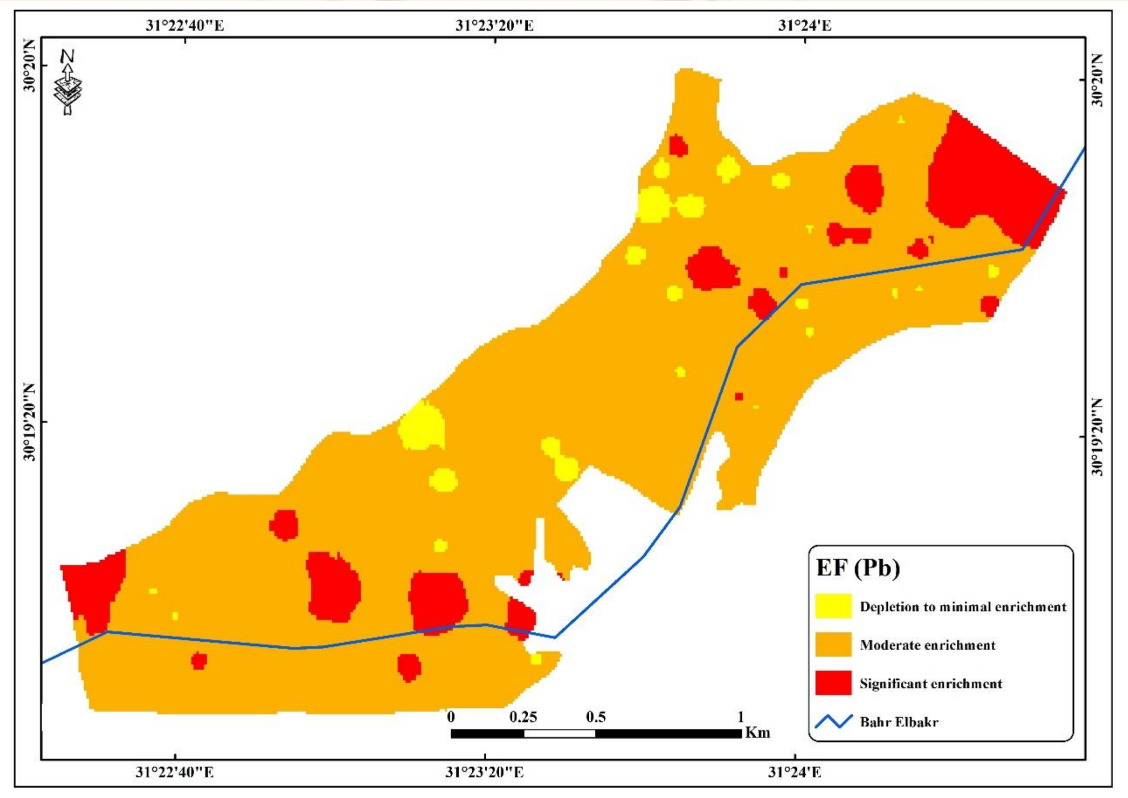




Enrichment factor Distribution of Pb

(C) Enrichment factor (EF)

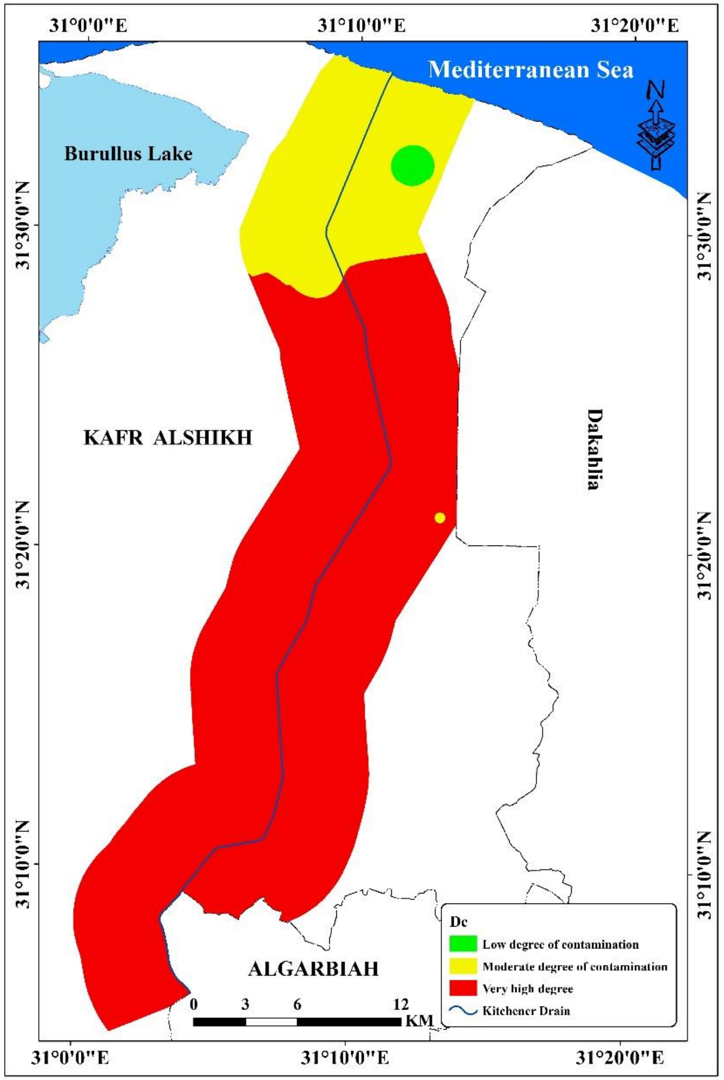
EF is a measure of the possible impact of anthropogenic activity on the concentration of heavy metals in soil. To identify the expected impact of anthropogenesis on the heavy metal concentrations in the soil, EF is calculated using the following formula:

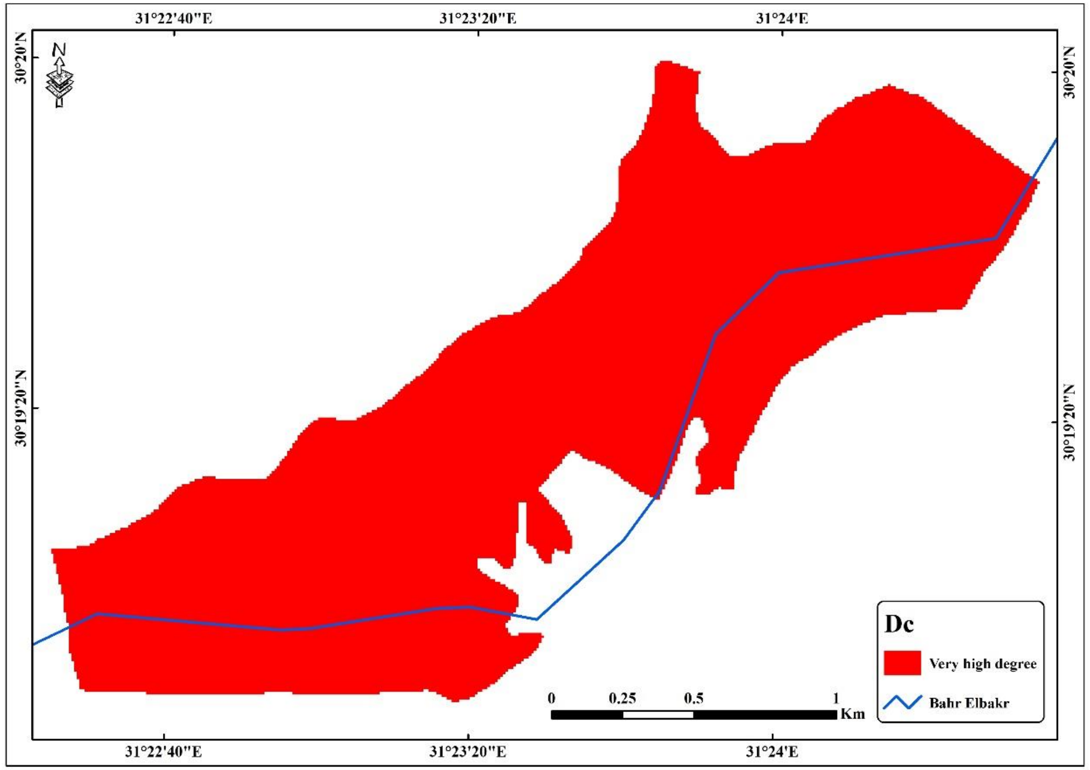
EF= (M/Fe) sample / (M/Fe) background

5 Results

3. Soil Contamination Indices

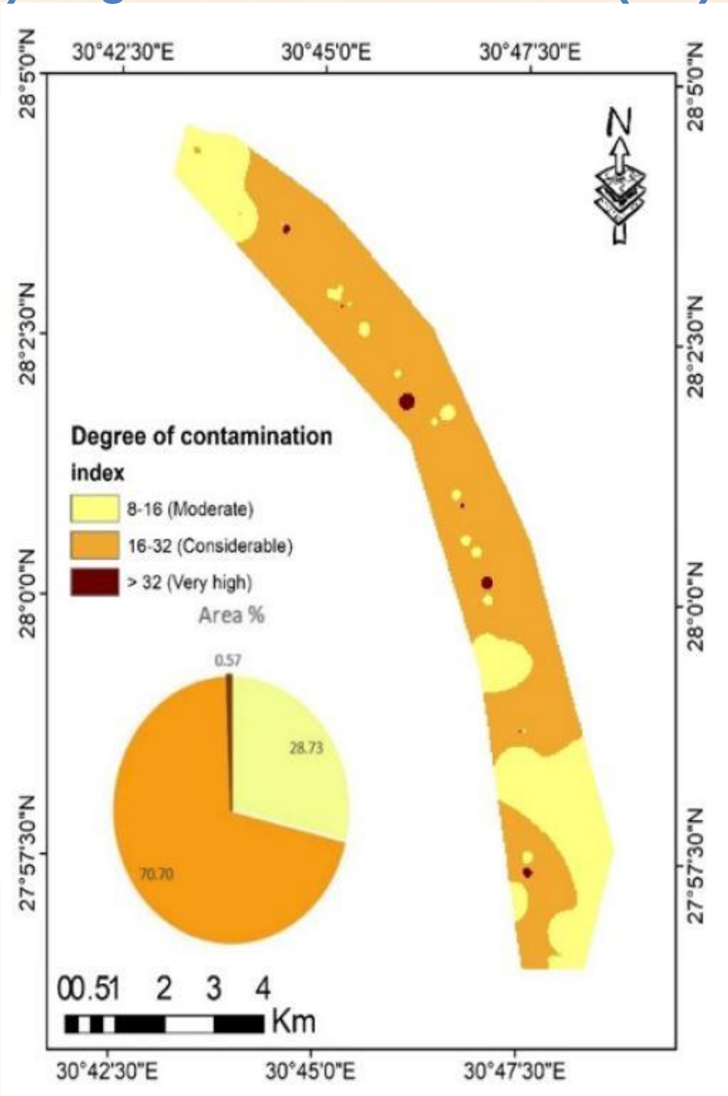
2. Complex indices





Distribution of Degree of contamination

(A) Degree of contamination (DC)



Results

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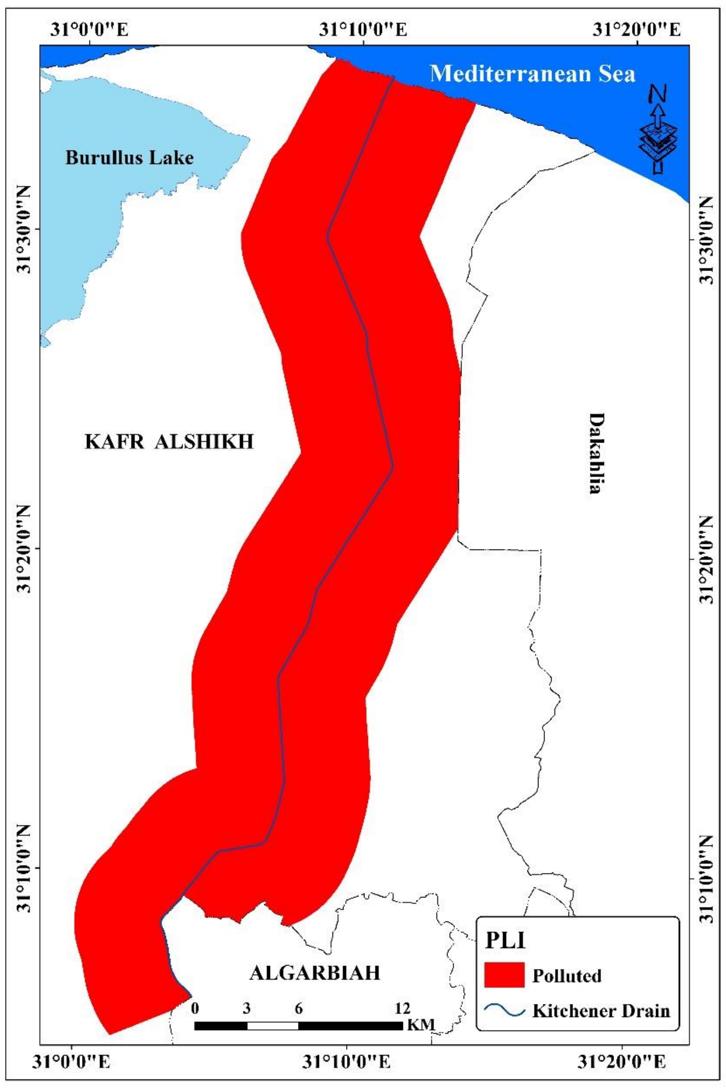
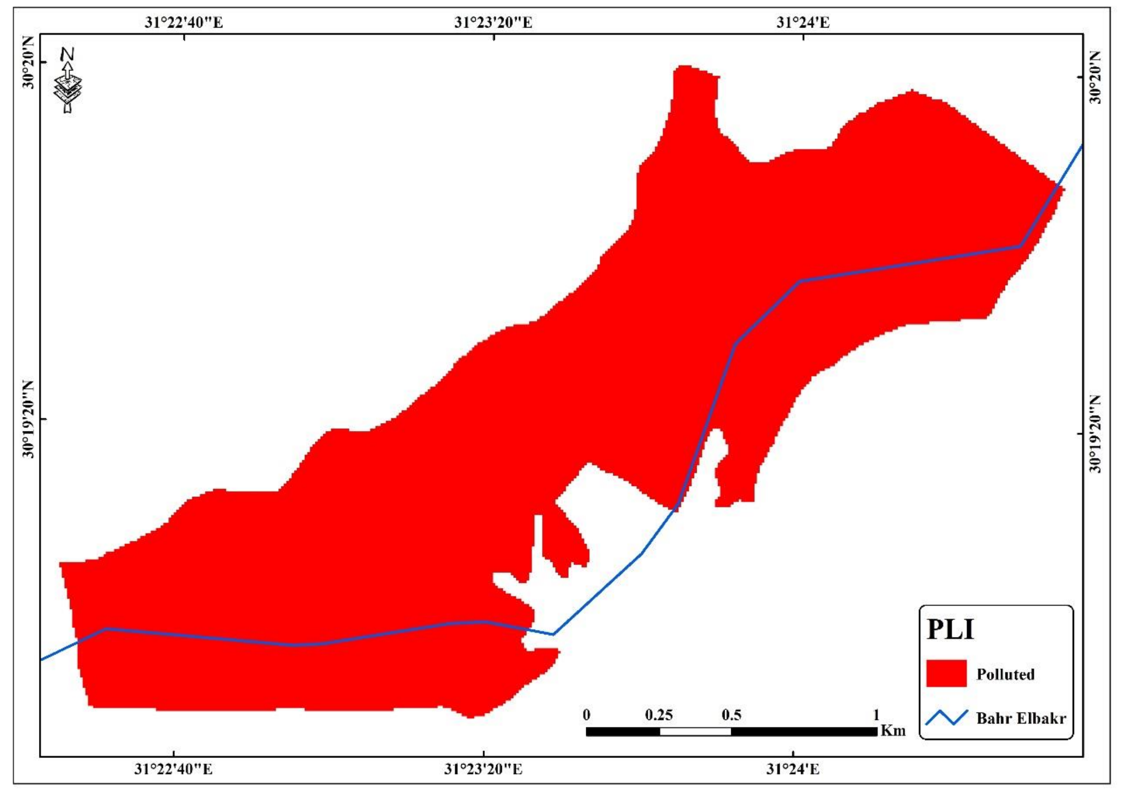




Distribution of Pollution Load Index

(B) Pollution Load Index (PLI)

This index provides an easy way to prove the deterioration of the soil conditions as a result of the accumulation of heavy metals Varol (2011) The index is calculated according to the formula:

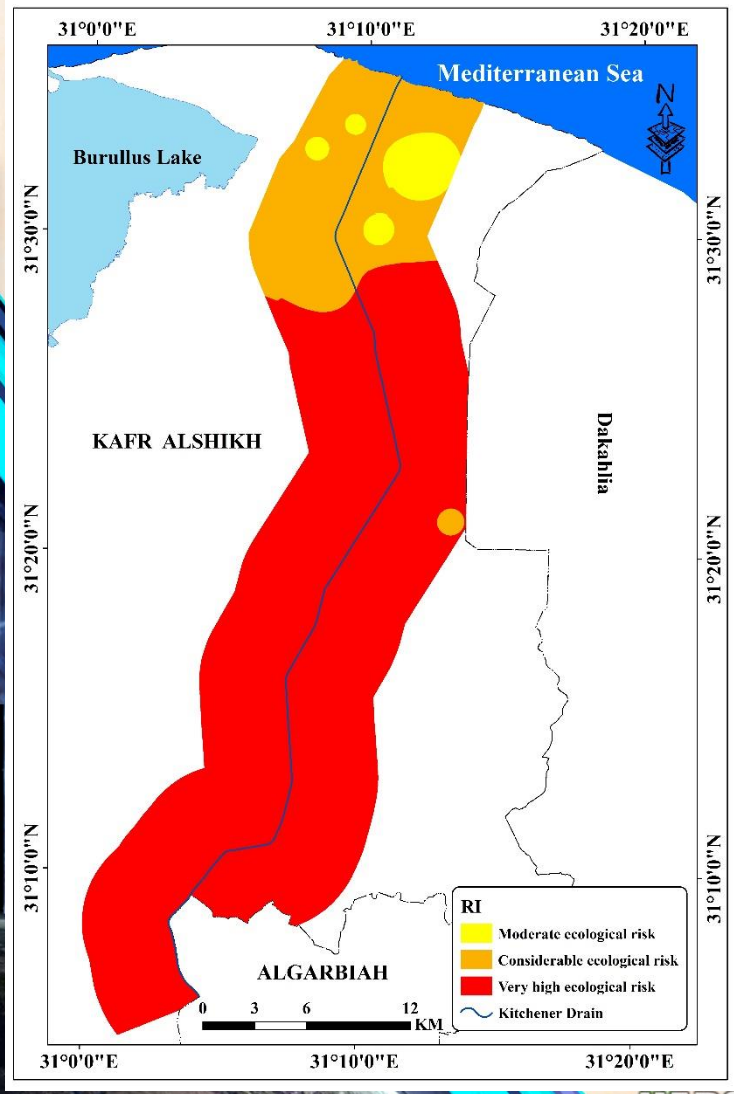
$$PLI = \sqrt[n]{PI_1 \times PI_2 \times PI_3 \times \ldots . PI_n}$$

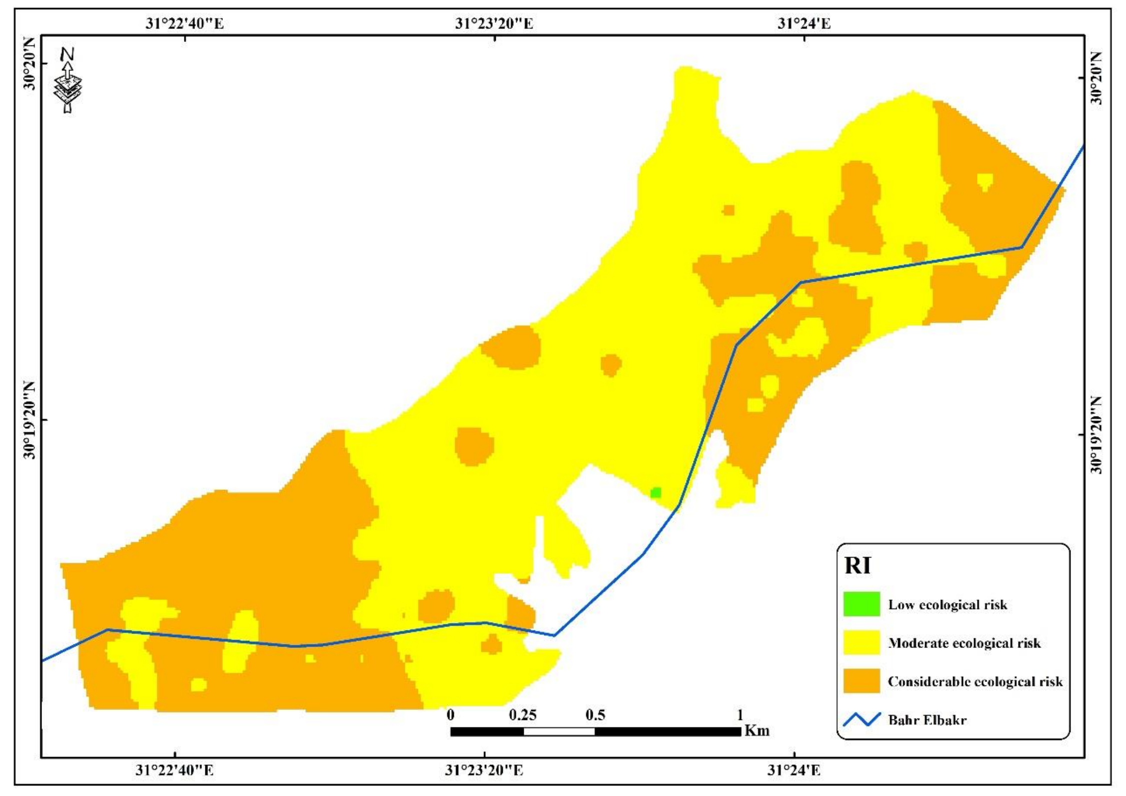
5 Results

4. Risk Assessment

1.Soil Risk Assessment

(A) Potential Ecological Risk Index (RI)





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2. Human Health Risk Assessment

- **Non cancer effect evaluation**

There are three paths by which humans may be subjected to heavy metals: ingestion, inhalation, and dermal contact. The average daily intake (ADI) of metals in soil is calculated according to the successive equations:

$$ADD\ ing = C*IRing*EF*ED*SAF / BW*AT$$

$$ADD\ dermal = C*SA*ABS*EF*ED*SAF / BW*AT$$

$$ADD\ inhalation = C*IRinh*EF*ED*CF / PEF*BW*AT$$

- **Non-carcinogenic Risk Assessment**

A method proposed by the US Environmental Protection Agency was used to assess the potential health risk related to the non-carcinogenic impacts of metals on soils. The hazard quotient (HQ) was calculated as the ratio of the ADI and the reference dose (RFD) for a given metal. $HQ = ADI / RfD$

2. Human Health Risk Assessment

Cancer Effect Evaluation

For carcinogens, the risks are estimated as the incremental possibility of each person developing cancer over a lifetime as a result of exposure to the potential carcinogen. The equation for calculating the excess lifetime cancer risk is: **Cancer risk = ΣADI * CSF**

CR less than 1×10^{-6} is considered as insignificant, and the cancer risk can be neglected, while an CR above 1×10^{-4} is considered as harmful and the cancer risk is troublesome

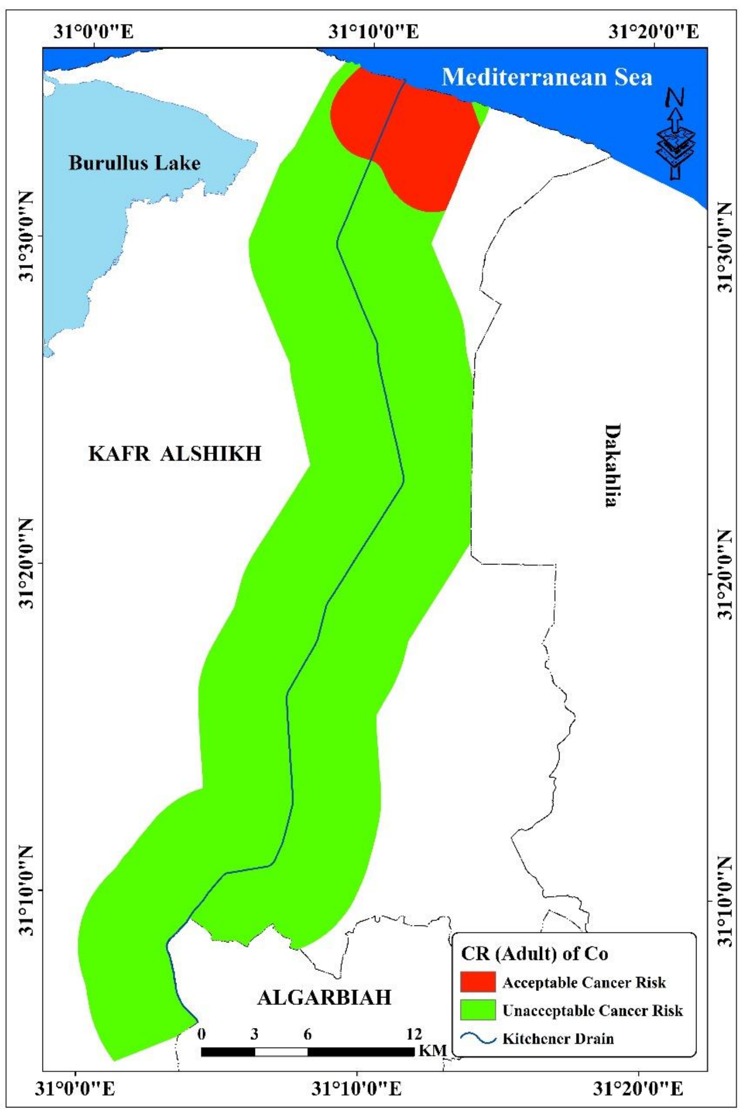
Results

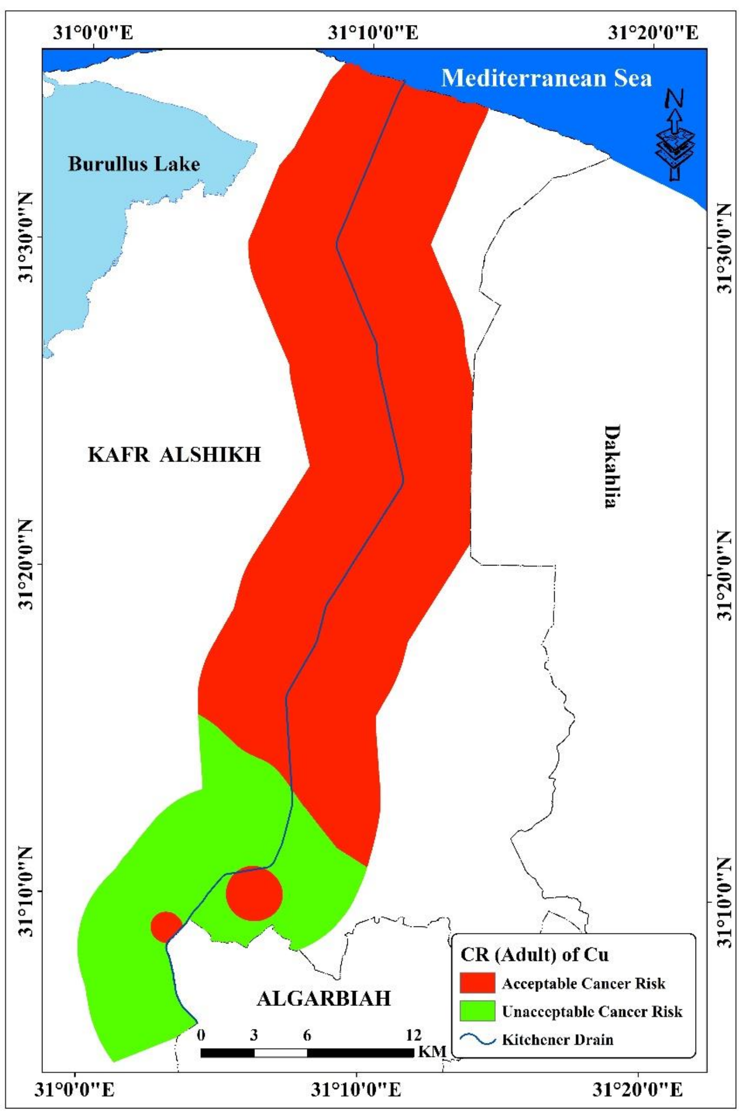
5

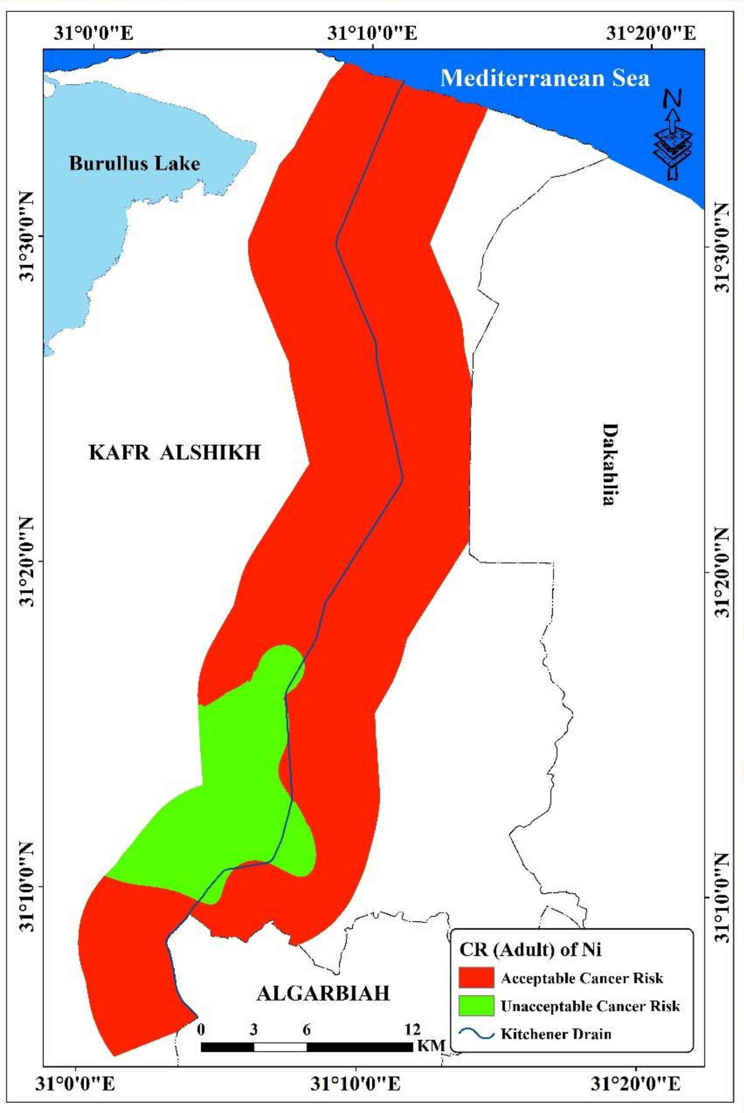
4. Risk Assessment

2.Human Health Risk Assessment

(A) Cancer Effect Evaluation (CR)







Cancer Effect Evaluation Distribution of Co , Cu and Ni

5. Statistical Analysis

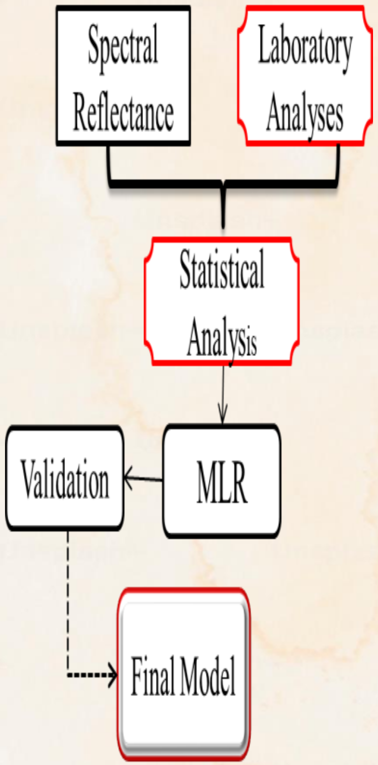
Results

- **Multi Linear Regression (MLR)**

The simplest way to express a relationship between variables is Multi-linear relationship. The Multi-linear expression is as follows:

$$Y = a + b1X1 + b2\,X\,2 + \ldots\ldots\ldots\ldots + bn\,X\,n$$

Where, Y is the plant or Soil properties explained by wave lengths X1, X2 and Xn, is intercept b1, b2 and a are the regression coefficients and a are the regression coefficients, The relationship should be tested for the following: ANOVA statistic and Collinearity test.



- **Validation of MLR Model**

The validation prediction models were used 40 % from spectral and soil samples were not used in the calibration process were used to validate the prediction equations using correlation coefficient.

5. Statistical Analysis

5

Results

Kitchener drain

Soil Spectroscopic data

Models have been extracted by MLR

Soil			
Parameter	**Wavelength**	**Model**	**R^2**
Ni	W_395,W_591,W_484	115.037+1499.838*W_395+1349.429*W_591-2756.482*W_484	**0.743**
Mn	W_1000,W_1001	713.573+12082.959*W_1000-11725.194*W_1001	**0.807**
Cu	W_1000,W_950,W_674	82.694+7397*W_1000-8048.655*W_950+886.567*W_674	**0.768**
Zn	W_2475,W_2475,W_397	92.754+58153.446*W_2499-56043.950*W_2475+876.081*W_397	**0.858**
Pb	W_999,W_1049	29.813+629.312*W_999-590.882*W_1049	**0.708**
Co	W_395,W_407,W_1000, W_2207	15.852+398.725*W_395-513.308*W_407+346.659*W_1000-226.858*W_2207	**0.659**
Cd	W_395,W_795,W_429,W_2357	4.183+304.539*W_395+265.963*W_795-467.583*W_429-123.021*W_2357	**0.876**
Fe	W_414,W_411	165255.096-21444168.2*W_414+22135263.48*W_411	**0.578**
As	W_999,W_971,W_1267, W_514	204.545+2470.672*W_999-1302.028*W_971-852.456*W_1267-302.291*W_514	**0.837**

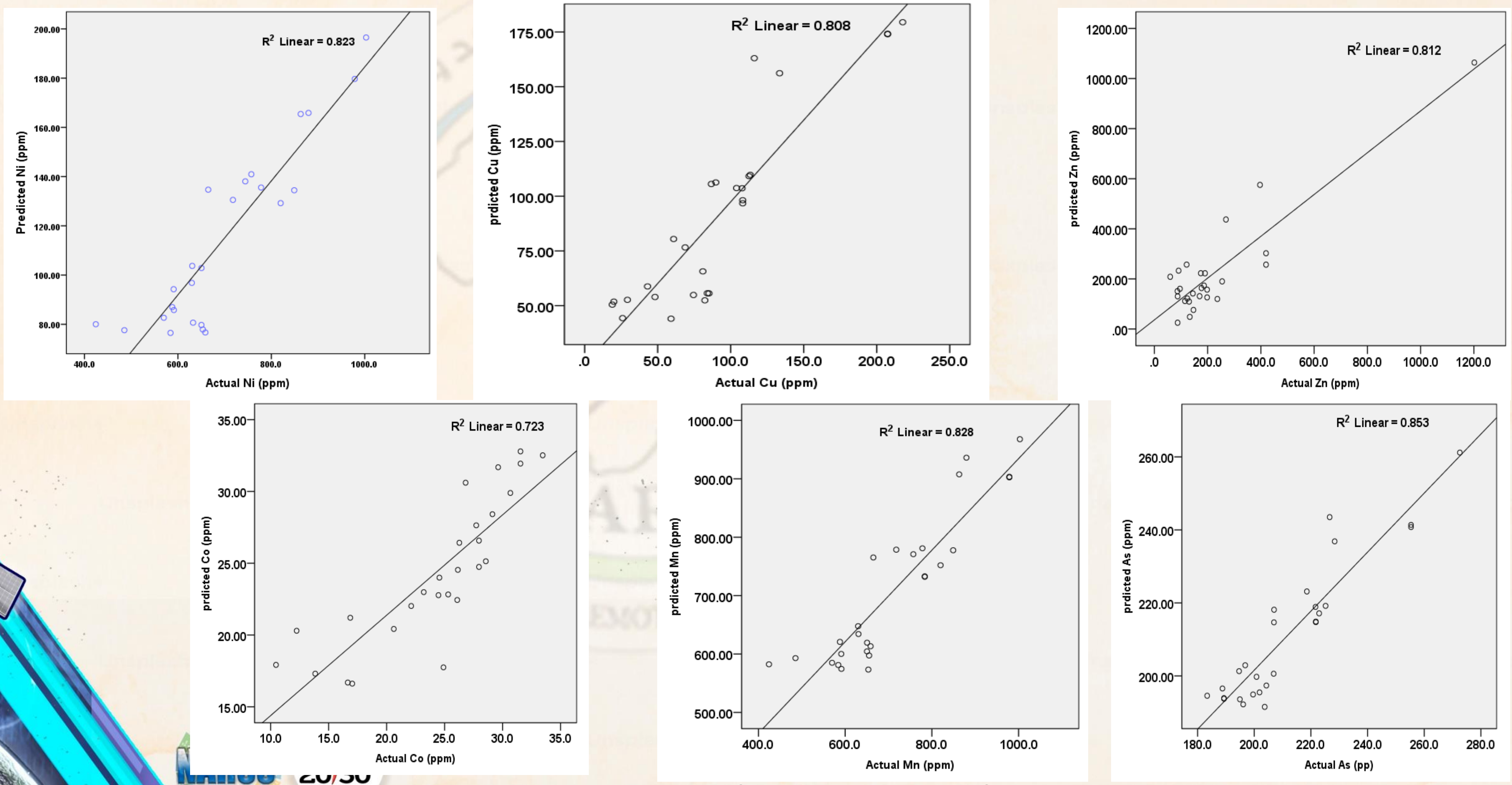
5. Statistical Analysis

5

Results

Kitchener drain

Soil Spectroscopic data



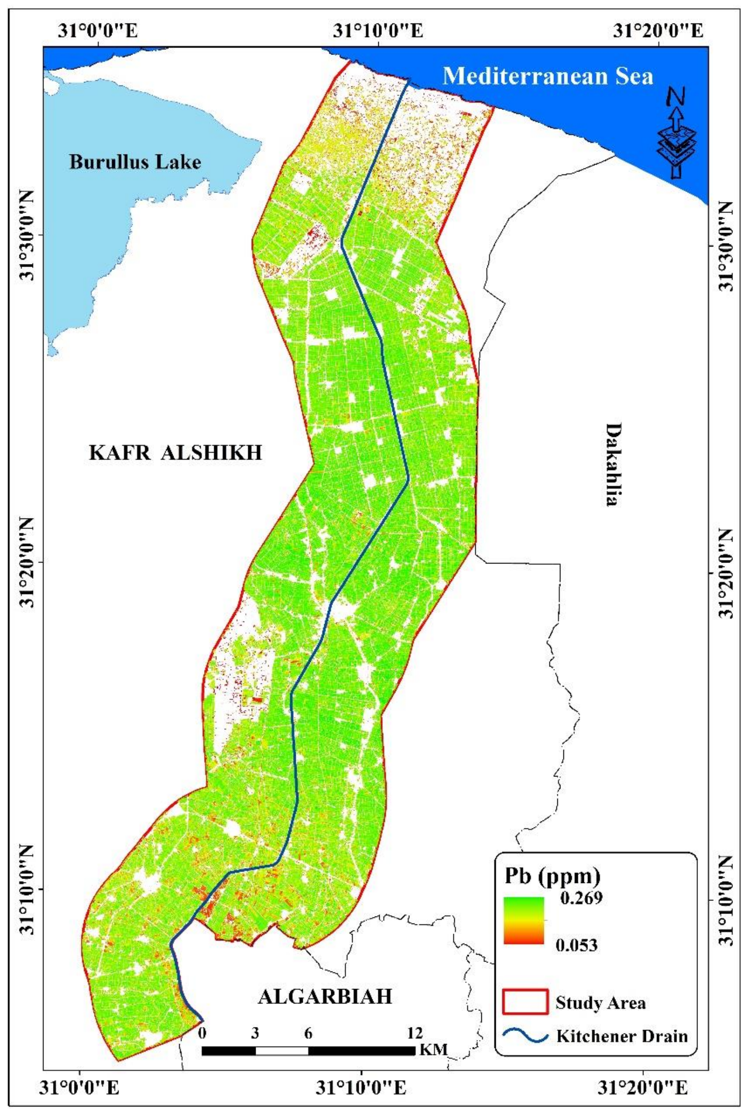
Soil Validation of MLR Model for the study area

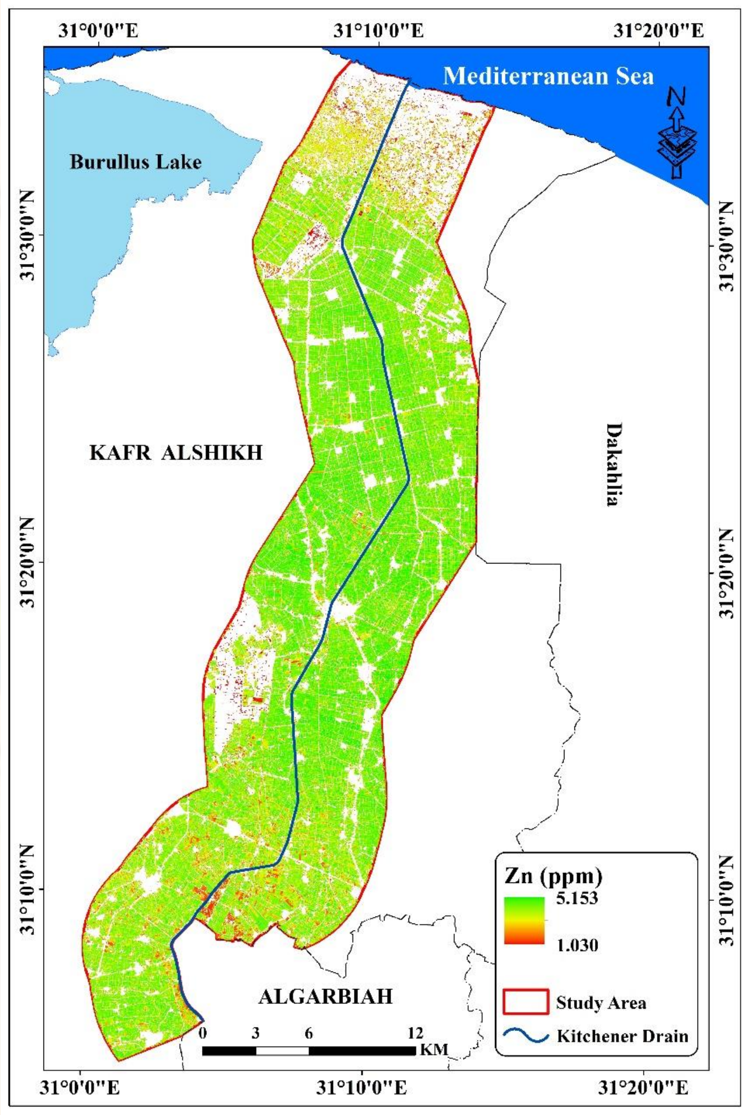
5. Statistical Analysis

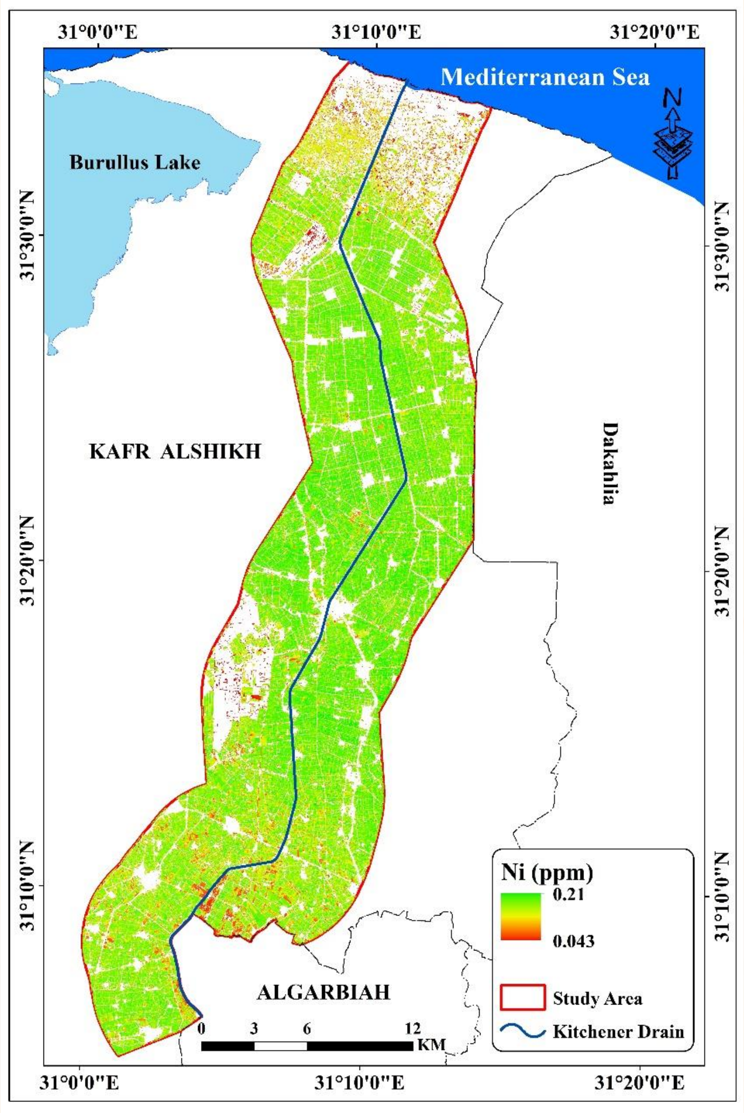
5

Results

Relationship between NDVI and heavy metals concentrations







Spatial distribution of Pb , Zn and Ni

5 Conclusions

- Heavy metals are pollutants of great importance for human health and ecosystems. The use of geoformation technologies to determine the presence of these pollutants in soils, plant and water is a good tool.
- The generation of a spatial datasets on the distribution of polluted (soils, plant and water) and potential sources of pollution is of utmost importance in informed decision-making.
    - The results give an indication that the use of drainage waters in irrigation not only effect on the soil quality as identified by metal indices but also represent as hazard to health of population. The soil of agricultural lands use wastewater from Kitchener drain enriched with metals exceeding the natural limits.
        - Awareness for those populations should be introduced and search for another possible source of irrigation water or treats water is a must to keep soil, plants and finally the health of population to prevent accumulation of different contaminants to human.
            - Spectroscopic techniques have become attractive to assess Soil and plant Contamination

Thank you

Threshold and Guideline Values for heavy metals in Soil

H.M	Threshold Value	Lower Guideline Value	Higher Guideline Value
Ni	50	100	150
Cu	100	150	200
Co	20	100	250
Pb	60	200	750
Zn	200	250	400
As	5	50	100

4. Risk Assessment

2. Human Health Risk Assessment

Reference dose (RfD) and cancer slope factor (CSF) for different metals.

Element	Rdf dermal	CSF (kg/day/mg)
Pb	0.42	8.5
Cd	0.005	6.1

Symbol	*Meanings*	*Default value*	*Reference*
C	Concentration of trace element in road dust (exposure point concentration)		US EPA[28]
IngR	Ingestion rate ($IngR_{child}$)	200 mg day $^{-1}$	US EPA[28]
EF	Exposure frequency (site specific)	180 day yr $^{-1}$	US EPA[28]
ED	Exposure duration (site specific) (ED_{child})	6 yr	US EPA[28]
BW	Average body weight	15 kg	US EPA[27]
AT	Averaging time for non-carcinogens for carcinogens	ED × 365 days 70 × 365 = 25550 days	Ferreira-Baptista and De Miguel[5]
InhR	Inhalation rate ($InhR_{child}$)	7.6m^3 day $^{-1}$	Van den Berg[49]
PEF	Particle emission factor	1.36 × 10^9 m^3 kg^{-1}	US EPA[28]
SA	Skin area exposed (SA_{child})	2800 cm^2	US EPA[28]
SL	Skin adherence factor (SL_{child})	0.2 mg cm^{-2} day^{-1}	US EPA[28]
ABS	Dermal absorption factor	0.01 for all except As 0.03 for As	Ferreira-Baptista and De Miguel[5]
CR	Contact (absorption) rate Ingestion CR = IngR Inhalation CR = InhR Dermal CR = SA x SL x ABS		
$IngR_{adult}$	Ingestion rate for adult	100 mg day^{-1}	US EPA[26,28]
$InhR_{adult}$	Inhalation rate for adult	20 m^3 day^{-1}	US EPA[26,28]
SA_{adult}	Skin area exposed for adult	5700 cm^2	US EPA[26,28]
SL_{adult}	Skin adherence factor for adult	0.07 mg cm^{-2} day^{-1}	US EPA[26,28]
BW_{adult}	Body weight of adult	70 kg	US EPA[26,28]
BW_{child}	Body weight of child	15 kg	US EPA[26,28]
ED_{adult}	Exposure duration of adult	24 yr	US EPA[26,28]