Prof. Dr. Salah Elsayed. University of Sadat City

h 09:00-10:30, April 23, 2026, Sala Riunioni, DICATAM

An overview of the study area in Kafr El Sheikh Governorate as a coastal region and the applications of machine learning to determine water quality for the Nile River, Egypt

Abstract: Managing water resources in coastal delta regions is becoming increasingly difficult due to climate change, sea-level rise, saltwater intrusion, population growth, and rising agricultural demand. Kafr El Sheikh Governorate, in the northern Nile Delta, is particularly vulnerable to water scarcity and salinization, with significant impacts on agriculture, groundwater sustainability, and coastal ecosystems. This seminar presents an AI-based framework for improving water-use efficiency, reducing salinity intrusion, and strengthening resilience under future uncertainty. The proposed approach combines machine learning and deep learning models to predict key hydrological and agro-environmental variables, including surface water availability, groundwater levels, soil moisture, and salinity distribution. By integrating remote sensing, agricultural statistics, meteorological observations, historical hydrological records, and climate scenarios, the framework supports more adaptive and sustainable water management in coastal delta areas.

Short Bio: Prof. Salah Elsayed is Professor of Agricultural Engineering at the University of Sadat City, Egypt. He previously served as Assistant Professor and Associate Professor at the same university and obtained his PhD from the Technical University of Munich, Germany. His research focuses on water resources management, irrigation, water quality assessment, remote sensing, and the use of machine learning for environmental and agricultural applications. He has published more than 100 papers in high-impact journals and has coordinated or contributed to several national and international research projects on water quality monitoring, groundwater assessment, precision phenotyping, and AI-based water management, including the PRIMA-funded AI4Water project.

Short Bio:

Personal Basic Information

Prof . Salah Elsayed

- 2000.9~2004.3 Mansoura University
  Agricultural Engineering — Master's Degree
- 2007.7~2011.9 Technical University of Munich, Germany
  Agricultural Engineering — Doctoral Degree
- 2011.12~2016.12 University of Sadat City — Assistant Professor
  Agricultural Engineering
- 2016.12~2021.12 University of Sadat City — Associate Professor
- 2021.12~Present University of Sadat City — Professor

PROJECTS

1- Improvement of water and salt tolerance of wheat genotypes under field conditions by high throughput precision phenotyping" from 17.04.2012 to 16.10.2015 granted by Science and Technology Development Fund (STDF) ; Grant number (No. 3150)- proj– Direct cost (100000 euro)

2. "Utilization of quality indices and high throughput techniques for water and sediments quality monitoring programs" 12.2020 until 12.2022 granted by University of Sadat city, Grant number (17),– Direct cost (5000 euro).

3."Integration of water quality indices and ground-based remote sensing data using machine learning to assess groundwater quality for drinking and irrigation in Makkah Al-Mukarramah Province, KSA" 05. 2020 until 5.02022 granted by Deputyship for Research & Innovation, Ministry of Education in Saudi Arabia, Grant number (IFPRC – 082 – 123 – 2020),– Direct cost (35000 euro)

4. Development of nondestructive high throughput sensing to estimate biochemical parameters of horticultural crops under different ripening stages" 08.2021 until 08.2023 granted by Sadat City University. Grant number (17), Direct cost (5000 euro euro).

5. Water and Food Security Efficient Project" 05.2019 until 05.2022 granted by NUFFIC Netherlands , Direct cost (40000 euro).

6. Optimizing Water Resources in Coastal Areas using Artificial Intelligence" 07.2025 until 07.2028 granted by STDF, – Direct cost (190000 euro).

Publication (100 papers published in high-impact journals)

1- EL Osta, M., Masoud, M., Niyazi, B. Elsayed. S., *et al.* Utilizing machine learning algorithms to improve predictions of groundwater quality indices for irrigation in an arid environment of Saudi Arabia. *Environ Earth Sci* 84, 389 (2025).

2- Gad M, Gaagai A, Agrama A A, El-Fiqy WFA, Eid MH, Szűcs P, Elsayed S, et al., Comprehensive evaluation and prediction of groundwater quality and risk indices using quantitative approaches, multivariate analysis, and machine learning models: An exploratory study. Heliyon, Volume 10, Issue 17, e36606 .

3- Elsayed, S.; El-Hendawy, S.; Khadr, M.; Elsherbiny, O.; Al-Suhaibani, N.; Alotaibi, M.; Tahir, M.U.; Darwish, W. Combining Thermal and RGB Imaging Indices with Multivariate and Data-Driven Modeling to Estimate the Growth, Water Status, and Yield of Potato under Different Drip Irrigation Regimes. Remote Sens. 2021, 13, 1679.

4- Elsayed, S., Hussein, H., Moghanm, F.S., Khedher, K.M., Eid, E.M., Gad, M. Application of Irrigation Water Quality Indices and Multivariate Statistical Techniques for Surface Water Quality Assessments in the Northern Nile Delta, Egypt. Water 2020, 12, 3300.

5-Elsayed, S.; Gad, M.;Farouk, M.; Saleh, A.H.; Hussein, H.;Elmetwalli, A.H.; Elsherbiny, O.;Moghanm, F.S.; Moustapha, M.E.;Taher, M.A.; et al. Using Optimized Two and Three-Band Spectral Indices and Multivariate Models to Assess Some Water Quality Indicators of Qaroun Lake in Egypt. Sustainability 2021,13, 1040.

1. Agricultural Water Management (Published by Elsevier).
2. International Journal of Climate Change Strategies and Management (Published by Emerald Group Publishing).
3. PLOS ONE Journal (Published by Public Library of Science).
4. Field Crops Research (Published by Elsevier).
5. Journal of Agronomy and Crop Science (Published by Wiley).
6. Bragantia (Published by Instituto Agronômico de Campinas).
7. Industrial Crops and Products (Published by Elsevier).
8. Journal of Experimental Agriculture International (Published by SCIENCEDOMAIN international).
9. African Journal of Agricultural Research (Published by Academic Journals).
10. In Vitro Cellular and Developmental Biology – Plant (Published by Nature Publishing Group).
11. Journal of Integrative Agriculture (Published by Chinese Academy of Agricultural Sciences and Elsevier).
12. Scientific Reports (Published by Nature Publishing Group).
13. Water, (Published by MDPI).
14. Sensors, (Published by MDPI).
15. Sustainability, (Published by MDPI).
16. Agriculture, (Published by MDPI).
18. Remote sensing, (Published by MDPI).
19. Energies (Published by MDPI).
20. Applied science (Published by MDPI).
21. Hydrology (Published by Elsevier).
22. Advances in Civil Engineering (Published by Hindawi)
23. Frontiers in Plant Science (Published by Frontiers Group).

Egyptian Team

Prof. Hossam Jahin
Professor of Analytical Chemistry, National Water Research Centre, NWRC

Prof.Dr.Mohaned kamel Fattah.Prof. of Hydrogeology and Hydrogeochemistry, USC

Prof.Dr.Aida Mohamed Allam, Prof.of Horticlture crop physiology and postharvest, USC

Pof. Mohamed Ahmed El-Howeity Prof. Soil Science and Soil Microbiology, USC

Prof.Sameh B. Elkafrawy, Head of marine science Dept. National Authority for Remote Sensing and Space Sciences, NARSS

Stakholders

no	Stakeholder Name	Type of Stakeholder	Engagement Level – consulted / actively involved / informed only.	Preferred Communication Channel
1	Minstrey of Water Resources and Irrigation (MWRI)	Government	consulted	physical meeting
2	Directorate of Irrigation for West Kafr El Sheikh	Government	actively involved	physical meeting
3	Directorate of Irrigation for East Kafr El Sheikh	Government	actively involved	physical meeting
4	Directorate of dirange for Kafr El Sheikh	Government	actively involved	physical meeting
5	Water Management Research Institute (WMRI)	Research	actively involved	physical meeting
6	Groundwater Research institute (GWRI)	Research	actively involved	Contact by tele.
7	National Water Research Center (NWRC)	Institutional	consulted	Online meetings
8	Farmers Users	NGO	end user	Online meetings
9	National Authority for Remote Sensing and Space Sciences (NARSS)	governmental research institutes	actively involved	Online meetings

Stakholders visiting on Sunday, April 12, 2026

Dr. Maha El Bialy director of Kafer el Sheikh research Area
Water Management Research Institute – National Water Research Centre.

Engineer, Mohamed El-Samody
General Directorate of Irrigation for East Kafr El-Sheikh

Stakholders visiting on Sunday, April 12, 2026

Engineer Mohamed Zakaria
General Directorate of Irrigation
in West Kafr El-Sheikh

Engineer Reda El-Shafei,
General Directorate of Kafr El-Sheikh Drainage

This visit focused on providing the following data from the relevant authorities

1- Water sources data (primary and secondary canals) within the kafer Elshikh governorate, including their levels and available discharge quantities.

2- Inventory and description of mixing stations (for blending treated agricultural wastewater) and mechanisms for its reuse in irrigation.

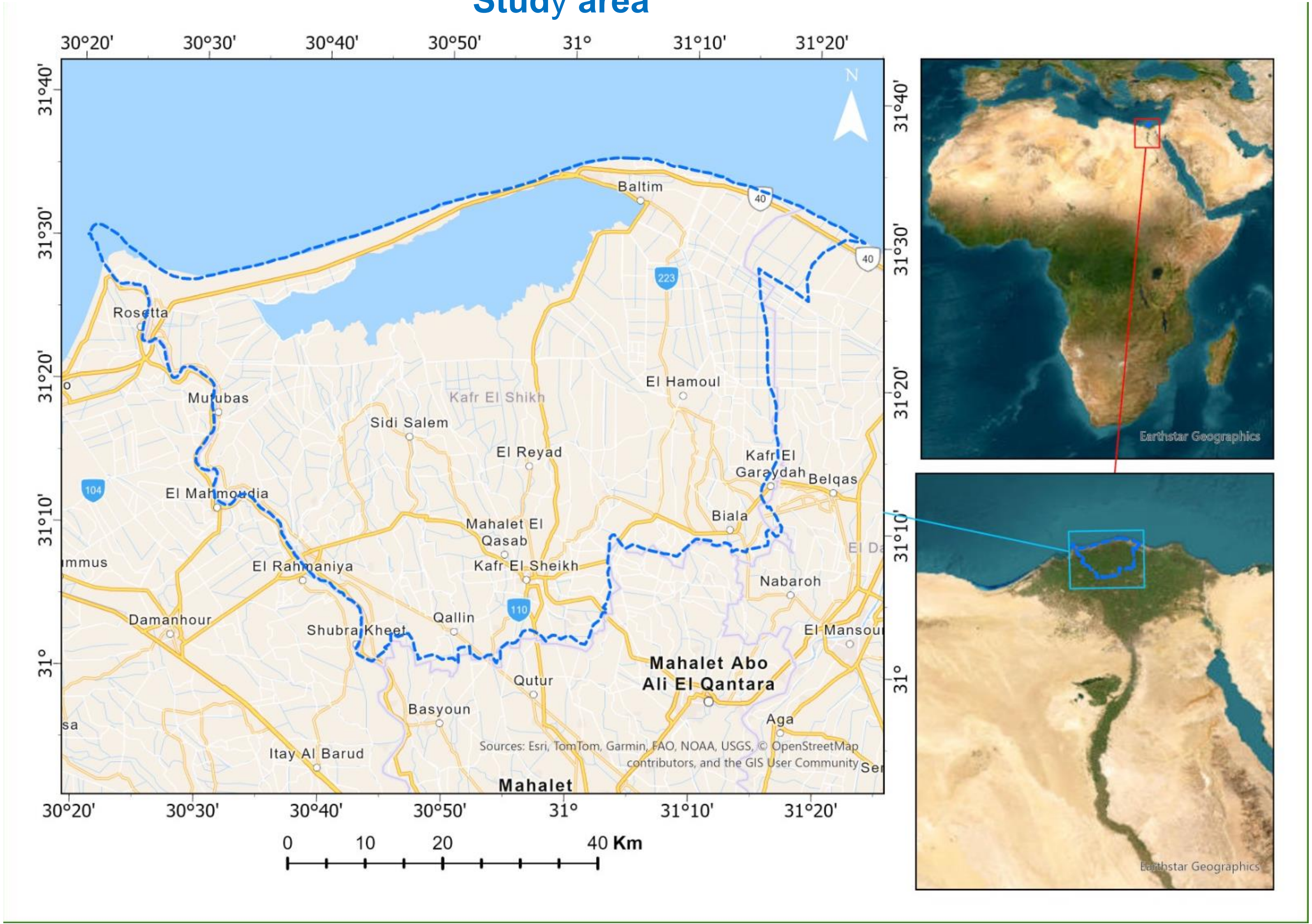
3- Available analysis results for evaluating water quality.

4- Other hydrological or technical data that support this the project.

5- Drainage network within the East Kafr El-Sheikh area, including its flows and water levels.

6- Available records and data regarding the quality of wastewater at these sites

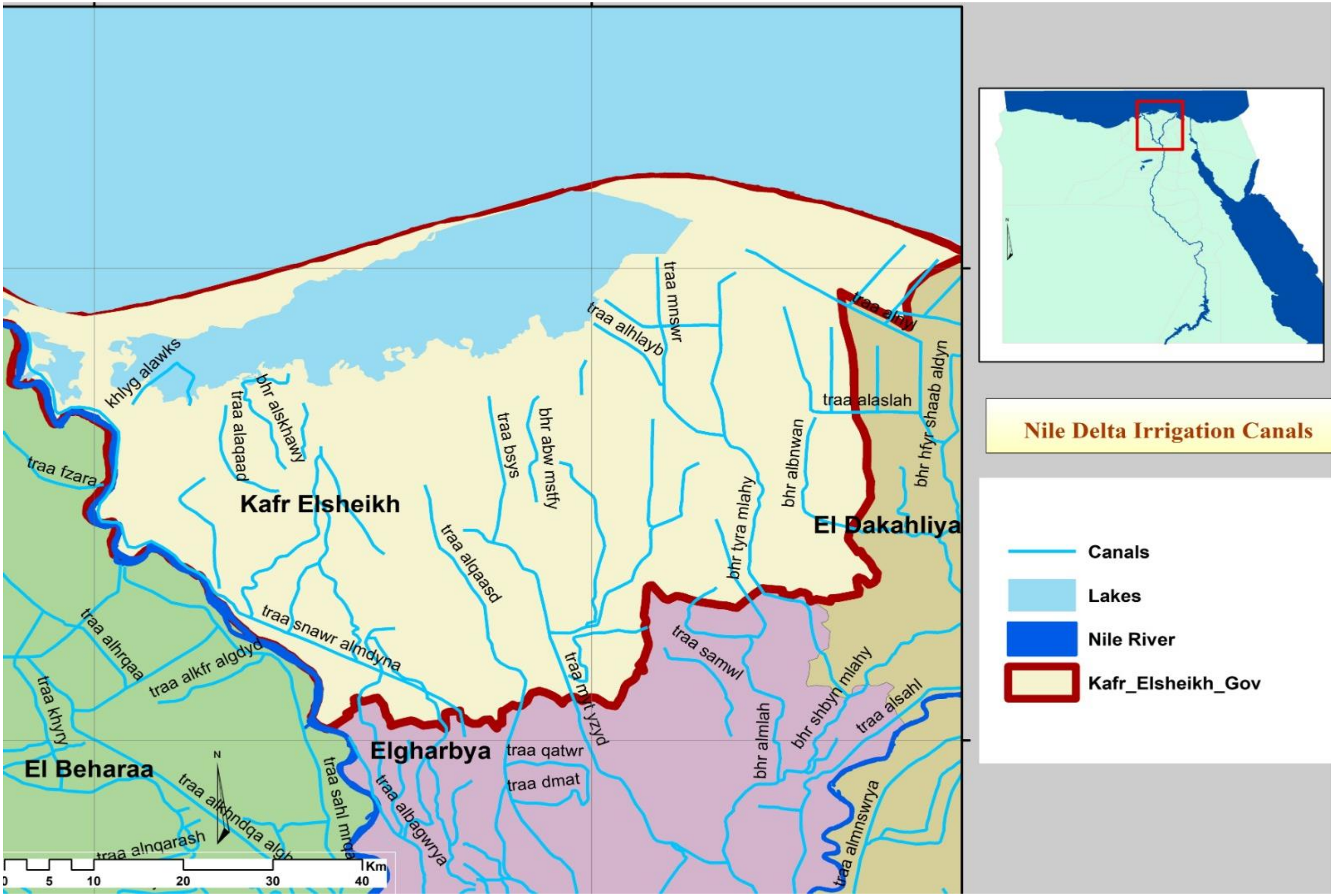
Study area



Sources: Esri, TomTom, Garmin, FAO, NOAA, USGS, © OpenStreetMap contributors, and the GIS User Community

Earthstar Geographics

Earthstar Geographics


Nile Delta Irrigation Canals
Canals
Lakes
Nile River
Kafr_Elsheikh_Gov
Kafr Elsheikh
El Dakahliya
Elgharbya
El Beharaa
khlyg alawks
traa fzara
traa alaqaad
bhr alskhawy
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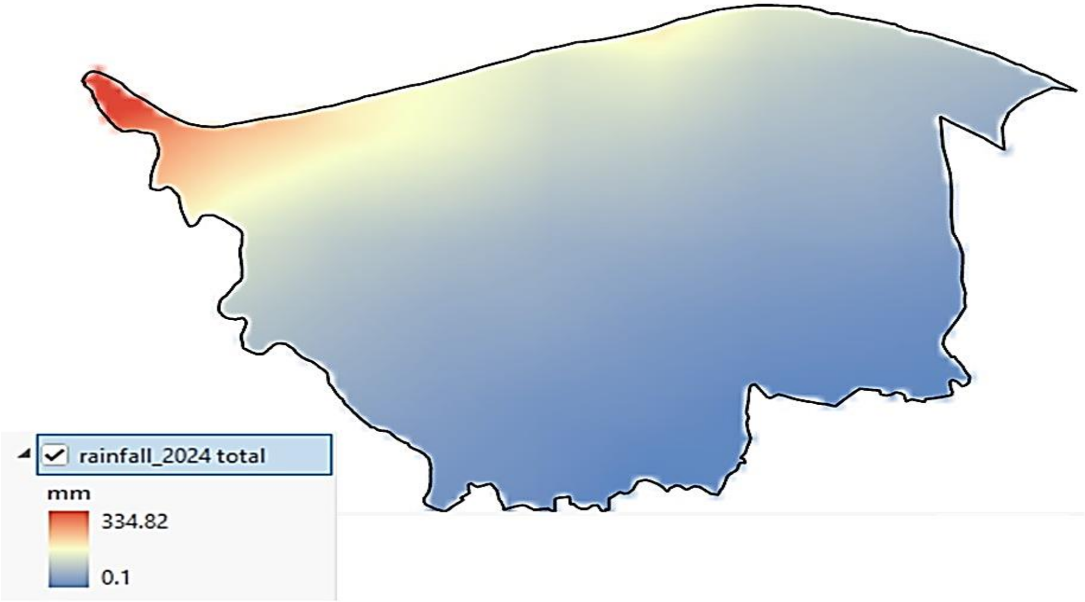
traa alaslah
bhr hfyr shaab aldyn
traa alhy
traa alhlayb
traa mnswr
N
0
5
10
20
30
40
Km

Climatic & Geographic Data

Climate (P, T, ETP):

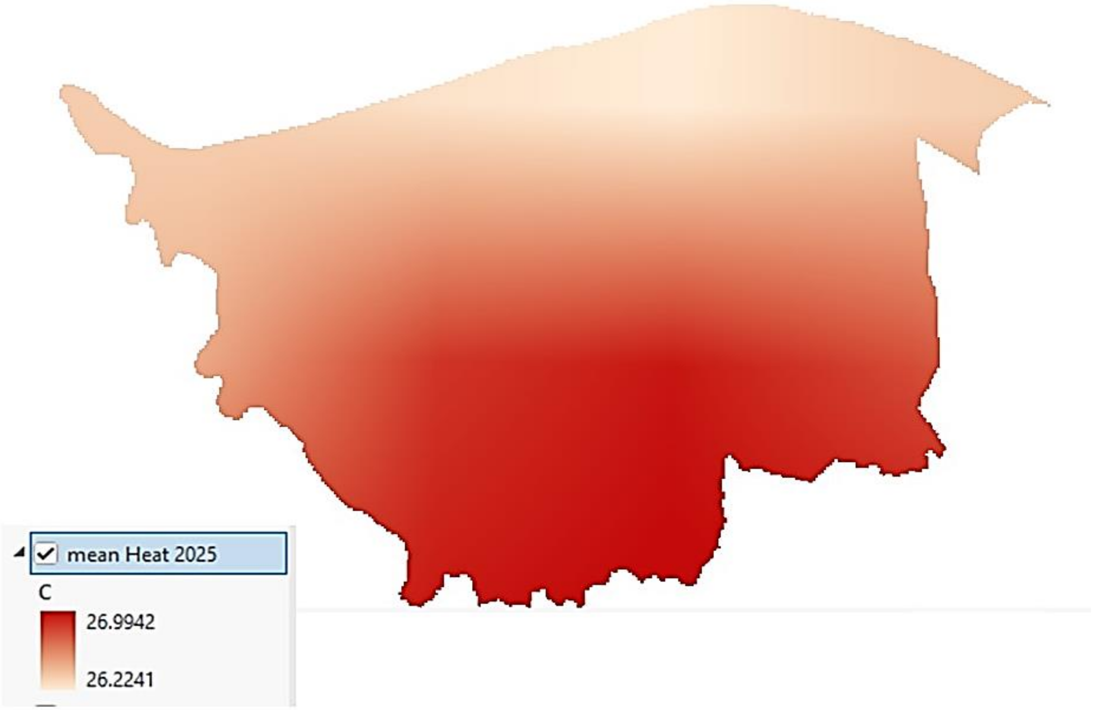
Precipitation (P): The governorate has semi-arid to arid climate. Rainfall occurs in winter, generally ranging from 0.1 to 335 mm per year, increasing toward the north near the Mediterranean Sea.



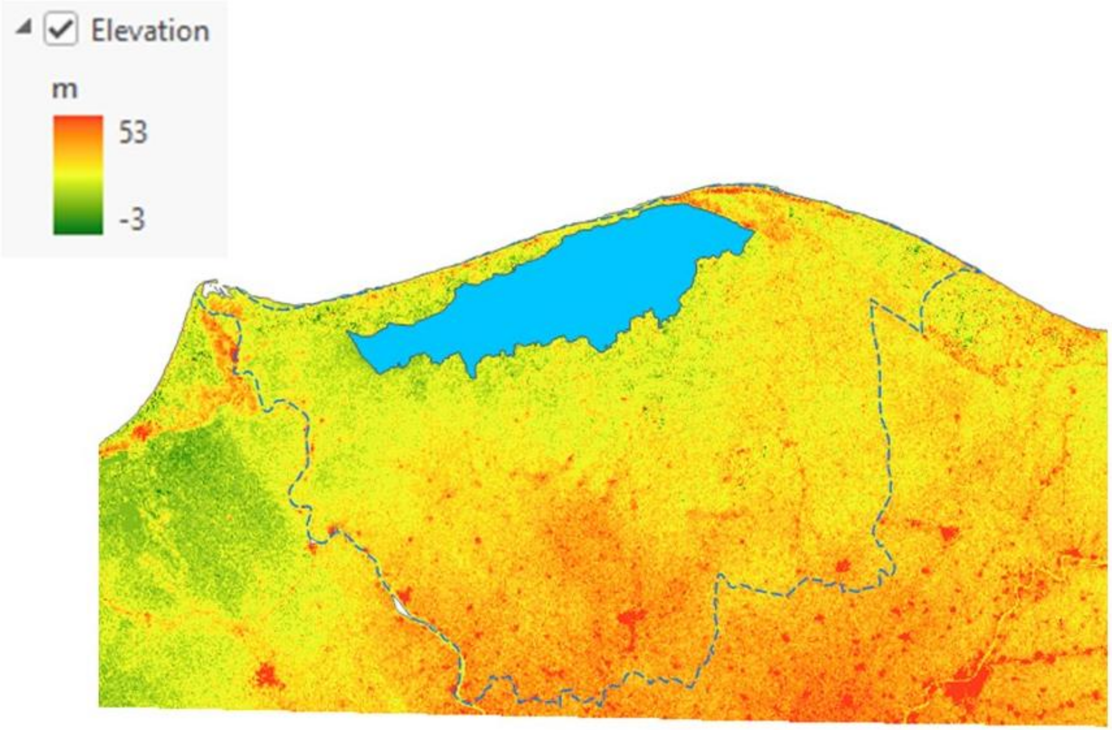
Temperature (T): Summers are hot (average highs 30–34 °C), while winters are cool to mild (average lows 9–12 °C).

Evapotranspiration (ETP): Evaporation rates are very high due to temperature and wind, increasing soil and surface water salinity.

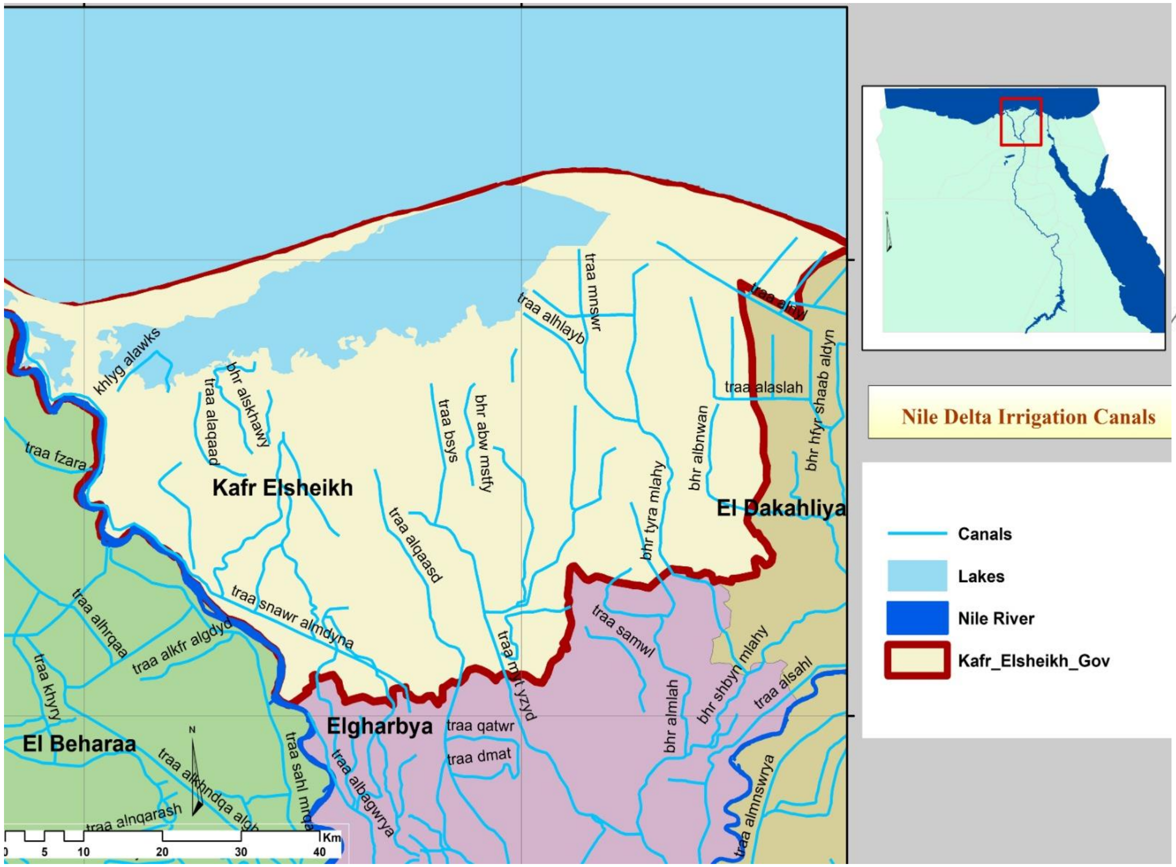
Land Cover & Use: Most of the land in the delta is agricultural, with extensive aquaculture areas in the north (near Lake Burullus), in addition to residential areas.

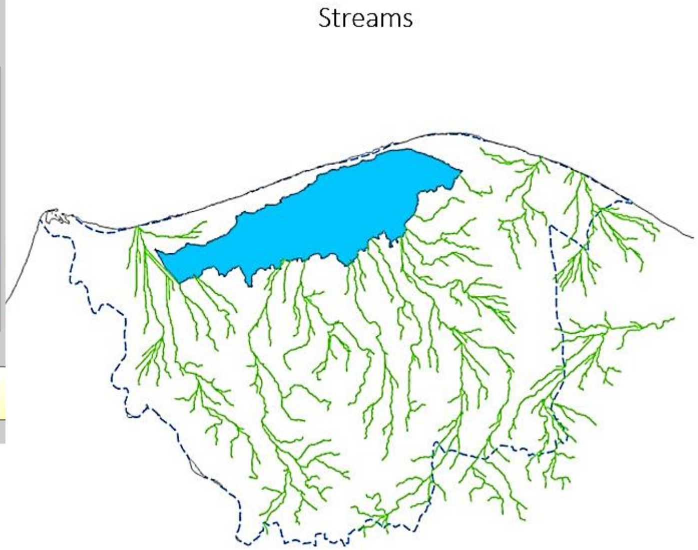


B- Topography and DTM (30m)



Hydrographic Network: The Rosetta Branch (Rashid) of Nile River passes along the west, intersected by a dense network of irrigation canals and drains

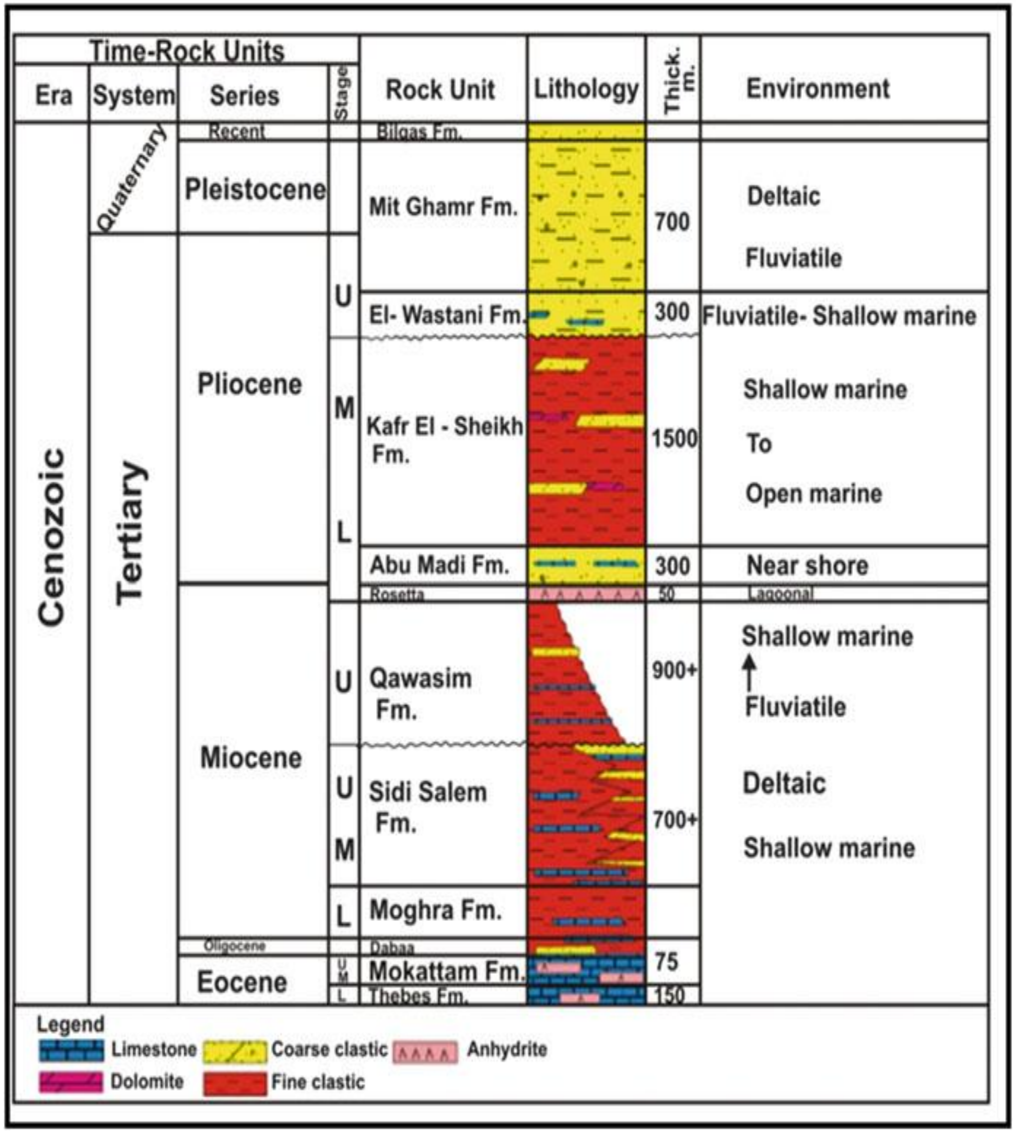




2- Geological Data

a- Stratigraphic Log:
Nile Delta Aquifer Located within the Nile Delta Basin, and composed of recent sedimentary layers (Quaternary/Recent age).

b- Rock characterisation
Surface: Clay & Silty clay soil resulting from Nile deposits.
Subsurface: Layers of sand and gravel (aquifer material) interbedded with impermeable clay layers.



Time-Rock Units				Rock Unit	Lithology	Thick. m.	Environment
Era	System	Series	Stage				
Cenozoic	Quaternary	Recent		Bilgas Fm.			
		Pleistocene		Mit Ghamr Fm.		700	Deltaic Fluviatile
	Tertiary	Pliocene	U	El- Wastani Fm.		300	Fluviatile- Shallow marine
			M L	Kafr El - Sheikh Fm.		1500	Shallow marine To Open marine
				Abu Madi Fm.		300	Near shore
		Miocene		Rosetta		50	Lagoonal
			U	Qawasim Fm.		900+	Shallow marine ↑ Fluviatile
			U M	Sidi Salem Fm.		700+	Deltaic Shallow marine
			L	Moghra Fm.			
		Oligocene		Dabaa			
		Eocene	U M	Mokattam Fm.		75	
			L	Thebes Fm.		150	

Legend
Limestone
Coarse clastic
Anhydrite
Dolomite
Fine clastic

Geological Data

Layer	From (m)	To (m)	Lithology
1	0	10	Clay & Silty clay
2	10	60	Fine to medium sand
3	60	200	Medium to coarse sand with gravel

c- Geological Profile:
Characterized by the presence of a thick upper clay layer, underlain by a water-bearing sandy layer (Quaternary Aquifer).

d**- Study site geometry (Dimensions)**
The site is generally flat, with very slight natural slopes toward the north and northeast (toward Lake Burullus and the Mediterranean Sea).

3- Hydrogeological Data

a- Groundwater chemistry

Groundwater in the shallow layers is highly saline ranges from 5500 to 12700 mg/ L (brackish to saline) due to the natural soil salinity and seawater intrusion from the north.

Date		Well depth (m)	Location	T (^{o}C)	PH	EC ms/cm	Water Depth (m)
2018	January	200	El Hamoul	25.1	9.1	8.8	2.49
2019	January			24.8	9.02	9.8	2.59
2020	January			21.2	8.57	8.6	2.3
2020	November			21.2	9.62	9	2.3
2021	September			23.6	8.02	11.2	1.94
2022	February			23.9	7.67	11.2	1.53
2022	August			24.8	8.47	18	1.82
2018	January	220	Baltim	24.9	8.6	16.9	F
2019	January			25.2	8.71	17.5	F
2020	January			22.9	7.96	18.6	0.5
2020	November			24.2	8.84	16.8	1.05
2021	September			23.1	7.88	19.9	1.25
2022	February			23.3	8.55	18.7	0.55

b- Hydrodynamic data

- **Porosity:** High in the sandy layers.
- **Permeability:** Moderate to high, decreasing in the clayey zones.

Layer	Porosity	Hydraulic conductivity K (m/day)	Transmissivity (m2/day)	Storage coefficient
2	0.3	40	8000	0.001
3	0.25	70	15000	0.0008

C- Aquifer Recharge

Aquifer Recharge: The aquifers are mainly recharged by irrigation water leakage from canals and drains, as well as from the Rosetta Branch.

Source	Recharge Rate	Unit
Irrigation return flow	400	mm/year
Rainfall	50	mm/year

d- Piezometric table values

Piezometric Table: The groundwater level is high and very close to the ground surface, causing **waterlogging problems**. Depth to water table is 1-2.5 m.

e- Boreholes, Wells, and Discharge:

Wells are present; however, the use of groundwater for irrigation is limited due to its high salinity. Irrigation mainly depends on Nile water.

Applications of machine learning to determine water quality for the Nile River, Egypt

Outlines

1. Introduction
2. Objectives
3. Water Quality Evaluation Using Irrigation Water Quality Indices
4. Water Quality Prediction Using Artificial Neural Networks, and Partial Least Square Regression Models

Introduction

* The **Nile River** is Egypt's **main source of freshwater**.
* It supports **residential**, **agricultural**, and **industrial** activities

- The Nile River is divided into two main streams, Rosetta and Damietta.

- **Rosetta Branch** is around 225 km long, 180 m wide, with a depth of 2 to 4 m. which starts in EL-Kanater El-Khayria and terminates at Rosetta Estuary in Rashid City, 30 km upstream of the sea, where excessive water is released to the Mediterranean Sea through the Rosetta Estuary.

- **Damietta Branch** is around 242 km in length, with an average width of 200 m and this branch is characterized by variable depths with an average of about 8 m

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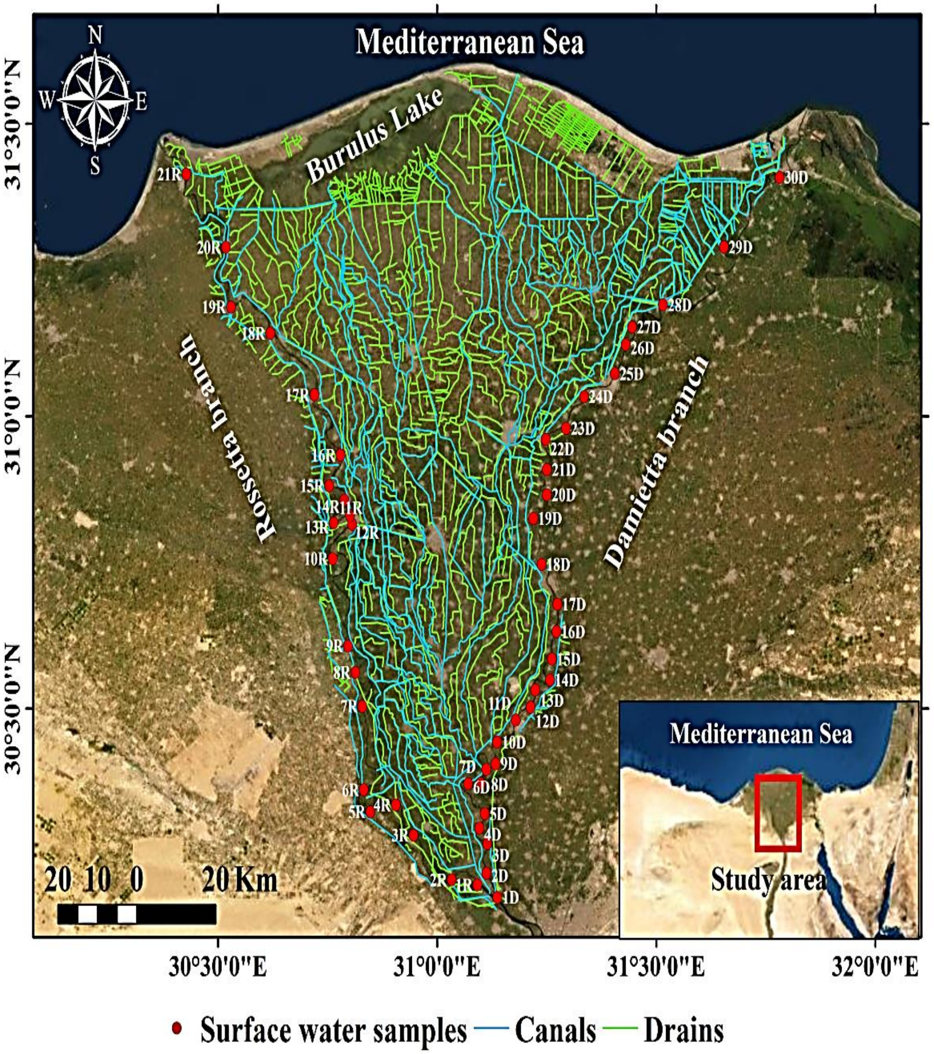


Distribution map of surface water samples obtained along Nile River branches.

Introduction

* **Major Pollution Sources:**

1- Untreated residential sewage
2- Agricultural runoff (pesticides, fertilizers)
3- Industrial waste (chemical effluents)

Impacts:

1- Declining water quality
2- Threats to public health
3- Damage to aquatic ecosystems
4- Risks to food and water security

Introduction

Water quality Indices (WQI)

Water quality is strongly impacted by the physicochemical properties of water bodies as well as their interactions with each other

1- The irrigation water quality index (IWQI)

2- Sodium absorption ratio (SAR)

3- Sodium percentage (Na %)

4- Soluble sodium percentage (SSP)

5- Permeability index (PI)

6- Magnesium hazard (MH)

2

Specific Objectives

The present research focuses on the following **three primary objectives:**

Evaluating surface water availability for irrigation using several irrigation water quality indices (IWQIs).

Determine the accuracy of utilizing the Artificial Neural Networks (ANN) and Partial Least Square Regression (PLSR) models to quantify IWQIs of surface water.

Discuss the feasibility of employing the ANN and PLSR models as advantageous methods for making informed judgments on IWQIs.

Materials AND Methods

Samples Collection and Analysis

* Surface water samples (n = 51) were obtained from different sites along the Nile River.

* In this study, some physicochemical parameters including temperature (T ° C), hydrogen ion concentration (pH), total dissolved solids (TDS), potassium (K^+), sodium (Na^+), magnesium (Mg^{2+}), calcium (Ca^{2+}), chloride (Cl^-), sulfate (SO_4^{2-}), bicarbonate (HCO_3^-) carbonate (CO_3^{2-}), nitrate (NO_3^{2-}) were measured

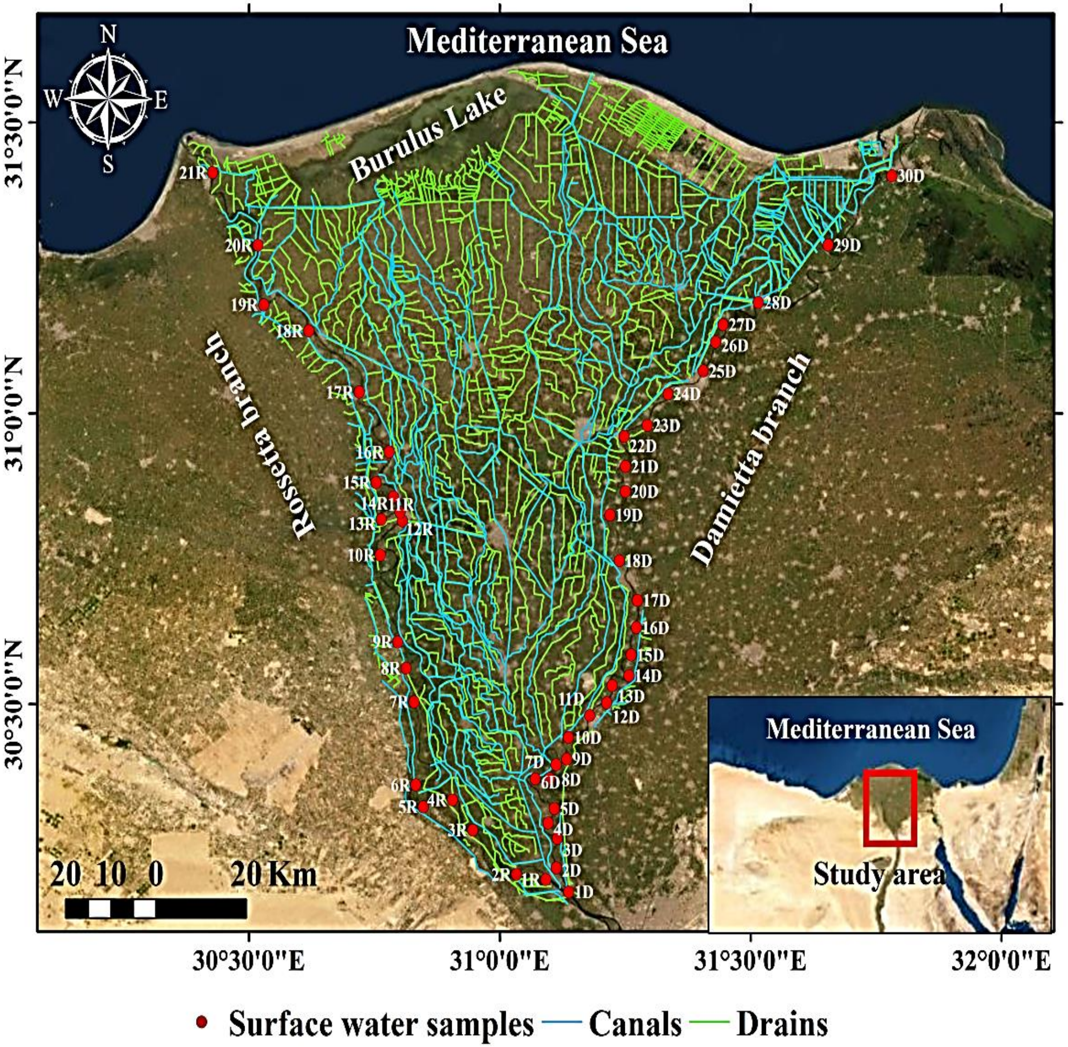


Fig.4 Distribution map of surface water samples obtained along Nile River branches

Table 1. The Irrigation Water Quality Indices, and the equations.

IWQIs	Unit	Formula
Irrigation Water Quality Index (IWQI)	mg/L	$\sum_{i=1}^{n} Q_i W_i$
Sodium absorption ratio (SAR)	meq/L	$[Na^+/\surd(Ca^{2+} + Mg^{2+})/2]\times 100$
Sodium percentage (Na %)	meq/L	$(Na^+ + K^+)/(Ca^{2+} + Mg^{2+} + Na^+ + K^+)]\times 100$
Soluble sodium percentage (SSP)	meq/L	$[Na^+/(Ca^{2+} + Mg^{2+} + Na^+)]\times 100$
Permeability index (PI)	meq/L	$[(Na^+ + \surd\, HCO_3^-)/ (Ca^{2+} + Mg^{2+} + Na^+)]\times 100$
Magnesium hazard (MH)	meq/L	$[Mg^{2+}/(Ca^{2+} + Mg^{2+})]\times 100$

1- The Irrigation Water Quality Index (IWQI) is a useful tool for determining the quality of irrigation water for agriculture. It reduces complex analytical data to a single number score, making it simple for decision-makers to understand and react on water quality data.

$$\sum_{\mathrm{i}=1}^{n} Q_i W_i$$

The IWQI calculation integrates important variables including bicarbonate (HCO3), sodium absorption ratio (SAR), electrical conductivity (EC), sodium (Na), and chloride (Cl) into single value grade agricultural water.

IWQI Range	Water Quality Category	Interpretation / Recommendation
>85	Excellent	No restriction for irrigation; safe for all crops.
70 – 85	Good	Suitable for most crops; monitor sensitive crops.
55 – 70	Moderate / Permissible	Some risk; use caution especially with salt-sensitive crops.
40 – 55	Poor	Unsuitable for long-term use; may harm sensitive crops and soils.
<40	Unsuitable	Not recommended for irrigation; may cause severe soil/crop damage.

2- The Sodium absorption ratio (SAR) measures the percentage of main and earth alkaline cations available to crops in water. It was used to evaluate the possibility that Na+ would build up in the soil, primarily to the harm of Ca2+ and Mg2+, as a result of constant use of sodic water. The SAR is a useful indicator to determine the suitability of agricultural water based on sodium risk, which is strongly related to the soil's exchangeable salt levels.

$$[Na^{+}/\sqrt{(Ca^{2+} + Mg^{2+})/2}]\times100$$

SAR Range	Water Class	Sodium Hazard	Suitability for Irrigation
< 10	Low (S1)	Low hazard	Suitable for all soils and crops.
10 – 18	Medium (S2)	Medium hazard	Suitable for coarse-textured or organic soils; some restrictions on crops.
18 – 26	High (S3)	High hazard	May require soil amendments (gypsum); suitable only for salt-tolerant crops.
> 26	Very High		Generally unsuitable; needs

3- Sodium Percentage (Na %) indicates the ratio of sodium ions (Na^+) relative to other major cations in water. High Na% can lead to sodium accumulation in soils, reducing soil structure and fertility. **Na %** determined the salinity level, with respect the quantity of Na^+ and K^+ in comparison to Ca^{2+} and Mg^{2+}.

$$(Na^+ + K^+)/(Ca^{2+} + Mg^{2+} + Na^+ + K^+)]\times 100$$

Na% Range	Water Class	Sodium Hazard	Suitability for Irrigation
< 20%	Excellent	Very Low	Suitable for all crops and soils.
20 – 40%	Good	Low	Generally safe; minor effect on permeability.
40 – 60%	Permissible	Moderate	Use with caution on sodium-sensitive crops.
60 – 80%	Doubtful	High	Limited use; suitable only for well-drained soils and salt-tolerant crops.
> 80%	Unsuitable	Very High	Not recommended; harmful to most soils and crops.

4- Soluble sodium percentage (SSP) was used to estimate salinity by comparing Na^+ concentrations to Ca^{2+} and Mg^{2+} concentrations, whereas irrigated water containing a high concentration of Na^+ ions scatters Mg^{2+} and Ca^{2+} ions. The high content of Na^+ in irrigated water exchange mechanism for Ca^{2+} and Mg^{2+} in soil, which lead to decrease the permeability of soil and poor internal drainage. A high content of Na^+ in water produces toxicity, resulting in scorched leaves and destroyed tissues.

$$Na^+/(Ca^{2+} + Mg^{2+} + Na^+)]\times 100$$

Range	Water Quality Category	Interpretation / Recommendation
< 60	Safe	Water is considered safe and suitable for irrigation
> 60	Unsafe	Water is not safe and not suitable for irrigation

5- The Permeability Index (PI) The **Permeability Index (PI)** is a key indicator used in irrigation water quality assessment, reflecting how water affects soil permeability over time. It considers the relative concentrations of sodium, calcium, magnesium, and bicarbonate ions in the water, which influence soil structure and permeability.

$$[(Na^{+}+\sqrt{\ } HCO_3^{-})/ (Ca^{2+} + Mg^{2+}+ Na^{+})]\times100$$

Typical classification of PI values:

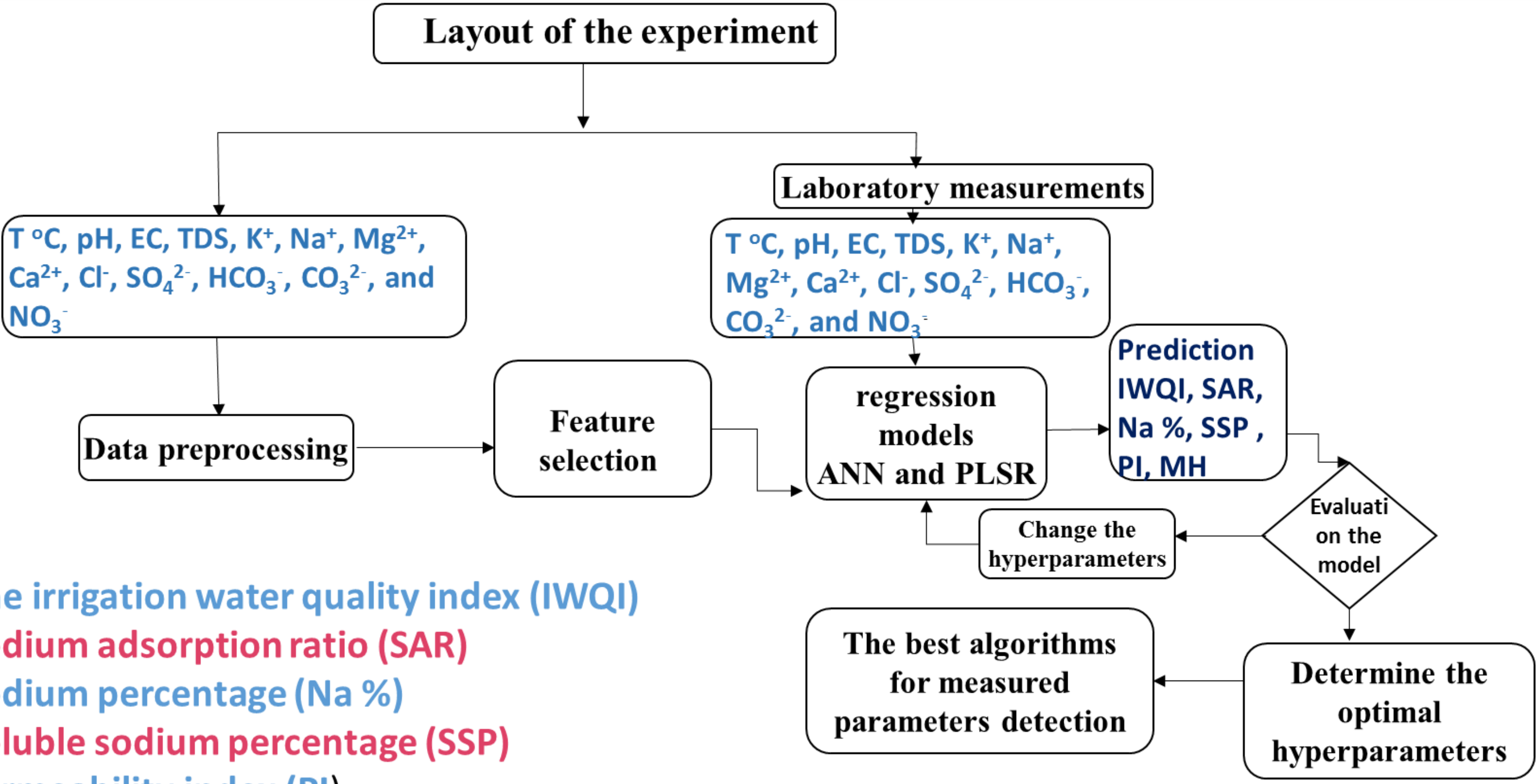
PI Value (%)	Classification	Impact on Soil Permeability
PI > 75	Class I (Excellent)	No significant effect on permeability
25 < PI ≤ 75	Class II (Good)	Slight effect, generally safe
PI ≤ 25	Class III (Unsuitable)	Likely to cause permeability problems

6- The Magnesium hazard(MH) plays an important role in determining the suitability of water for irrigation, where the high concentrations of Mg^{2+}, as well as Ca^{2+} in water, can increase the soil pH, decrease the availability of phosphorous and the soil quality, and finally, cause a significant decline in crop production. An HM value of <50 is recommended for irrigation purposes, whereas one >50 is considered unsuitable for irrigation.

$$[Mg^{2+}/(Ca^{2+}+ Mg^{2+})]\times 100$$

MH Value	Suitability for Irrigation	Interpretation / Recommendation
< 50	Suitable for irrigation	Water is considered safe and suitable for irrigation
> 50	Unsuitable for irrigation (high Mg)	Water may negatively affect soil and crop production; not recommended for irrigation

Layout of the experiment



Layout of the experiment

T °C, pH, EC, TDS, K^+, Na^+, Mg^{2+}, Ca^{2+}, Cl^-, SO_4^{2-}, HCO_3^-, CO_3^{2-}, and NO_3^-

Data preprocessing

Feature selection

Laboratory measurements

T °C, pH, EC, TDS, K^+, Na^+, Mg^{2+}, Ca^{2+}, Cl^-, SO_4^{2-}, HCO_3^-, CO_3^{2-}, and NO_3^-

regression models ANN and PLSR

Prediction IWQI, SAR, Na %, SSP , PI, MH

Evaluation the model

Change the hyperparameters

Determine the optimal hyperparameters

The best algorithms for measured parameters detection

1- The irrigation water quality index (IWQI)
2- Sodium adsorption ratio (SAR)
3- Sodium percentage (Na %)
4- Soluble sodium percentage (SSP)
5- Permeability index (PI)
6- Magnesium hazard (MH)

Layout of the experiment

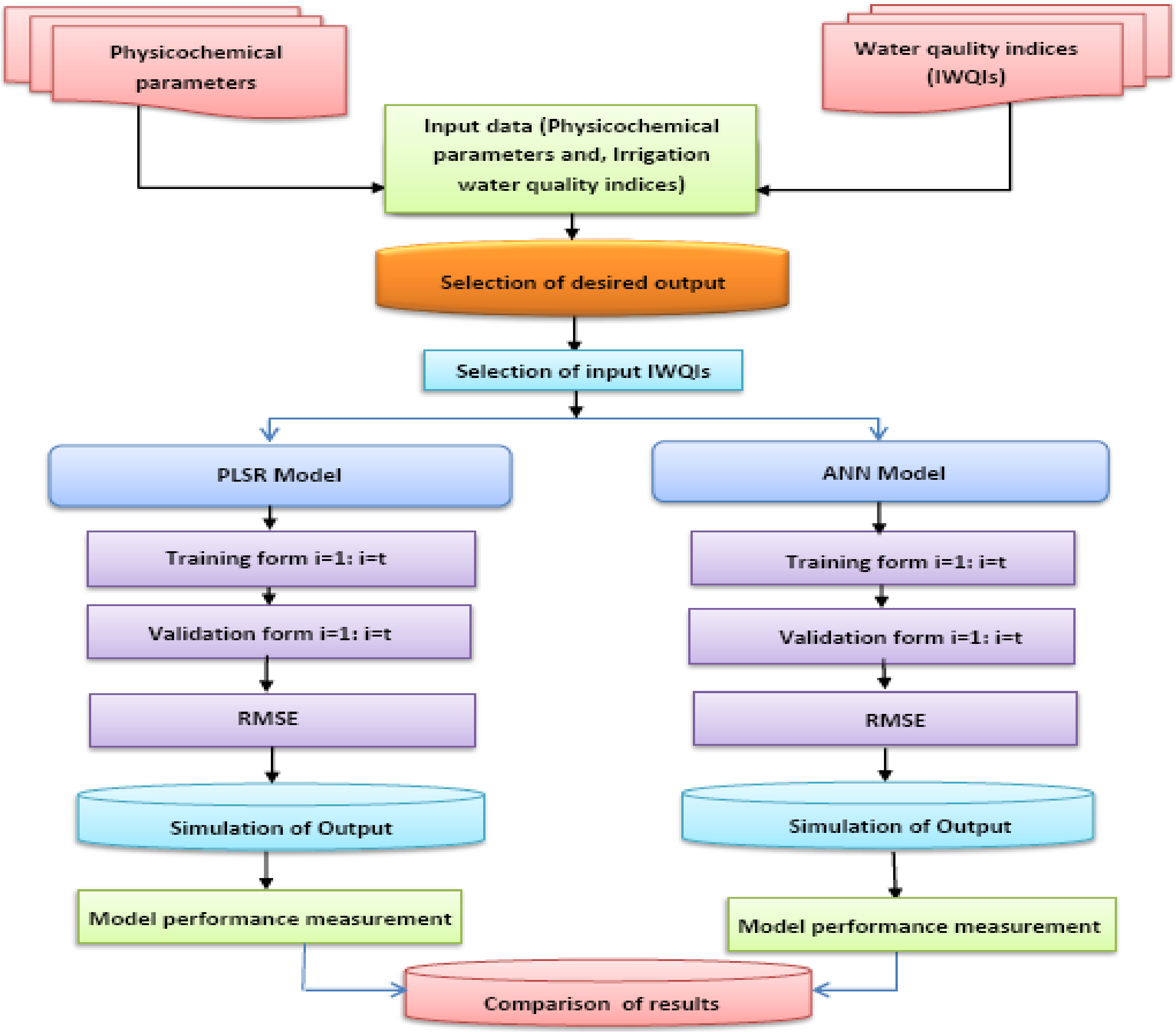


Figure. Flowchart of the ANN and PLSR models processes to evaluate different IWQIs of surface water samples.

Results

The different measured physicochemical properties are given as minimum (Min), maximum (Max), mean, and standard deviation (SD). All selected variables are provided in mg/L, except for temperature (T °C), EC (μs/cm), and pH.

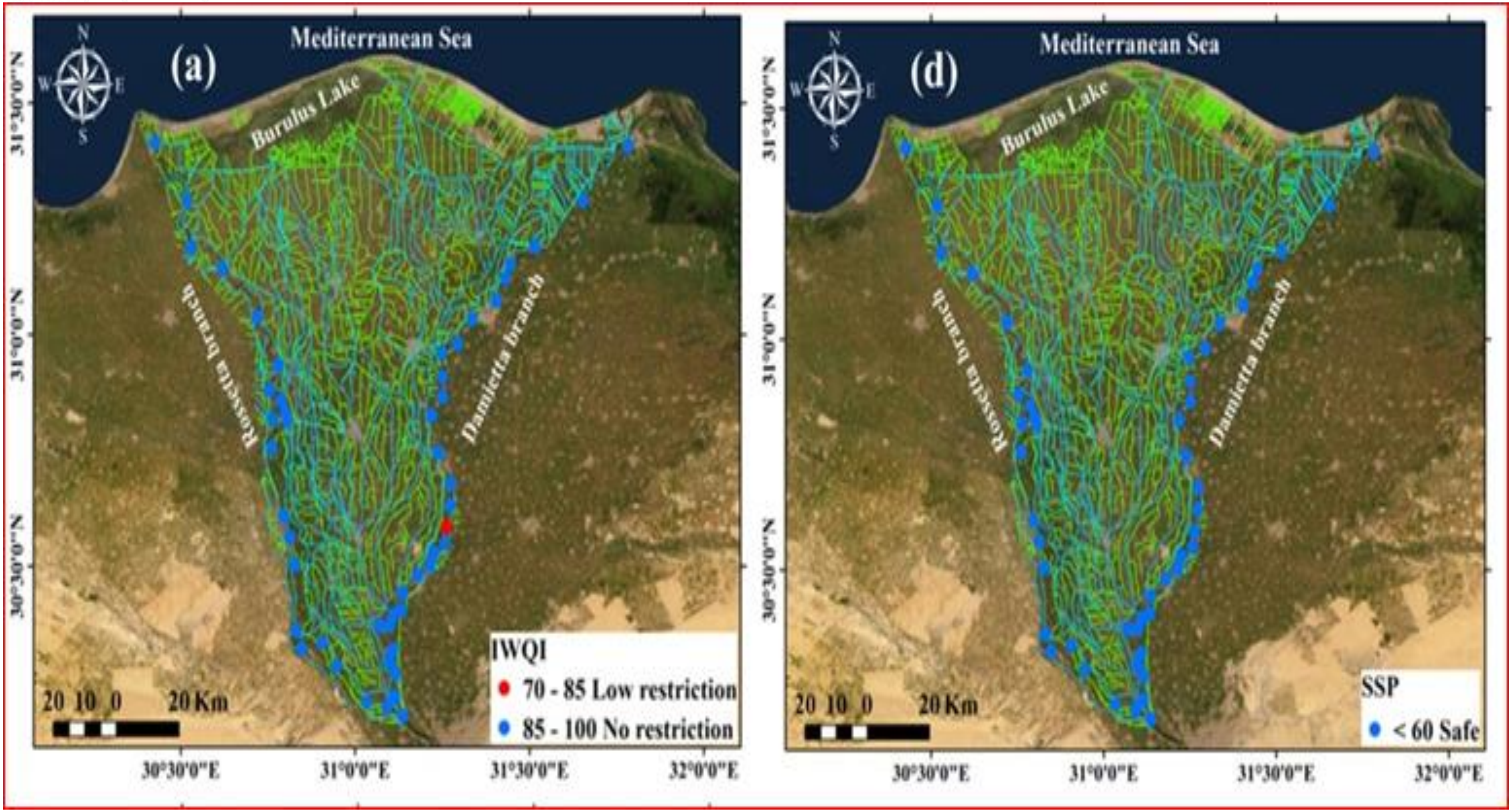
	T °C	pH	EC	TDS	K^+	Na^+	Mg^{2+}	Ca^{2+}	Cl^-	SO_4^{2-}	HCO_3^-	CO_3^{2-}	NO_3^-
	Rosetta branch, Nile River (n = 21)												
Min	27.0	7.40	341.00	218.00	3.11	20.70	8.20	16.00	35.50	11.00	88.40	N.D.	3.68
Max	33.7	8.10	544.00	348.00	16.81	38.91	19.00	36.00	88.70	22.00	134.00	N.D.	12.53
Mean	30.0	7.80	404.00	258.52	9.01	28.91	13.17	23.24	54.13	14.90	108.88	N.D.	6.11
SD	2.4	0.18	50.78	32.48	3.67	4.65	2.74	5.08	13.83	2.98	10.22	N.D.	2.41
	Damietta branch, Nile River (n = 30)												
Min	27.1	7.40	328.00	210.00	5.21	16.29	3.40	22.72	23.00	12.00	60.80	5.00	2.25
Max	28.1	8.40	703.00	450.00	14.41	46.05	22.80	44.00	61.00	33.00	208.60	19.00	8.51
Mean	27.4	7.89	385.40	246.63	8.15	22.36	12.15	28.06	40.10	16.80	104.17	8.87	5.48
SD	0.28	0.19	69.14	44.22	2.27	5.29	3.83	4.17	11.29	4.11	26.43	3.84	1.44

Statistical analysis of the different WQIs for the Nile River

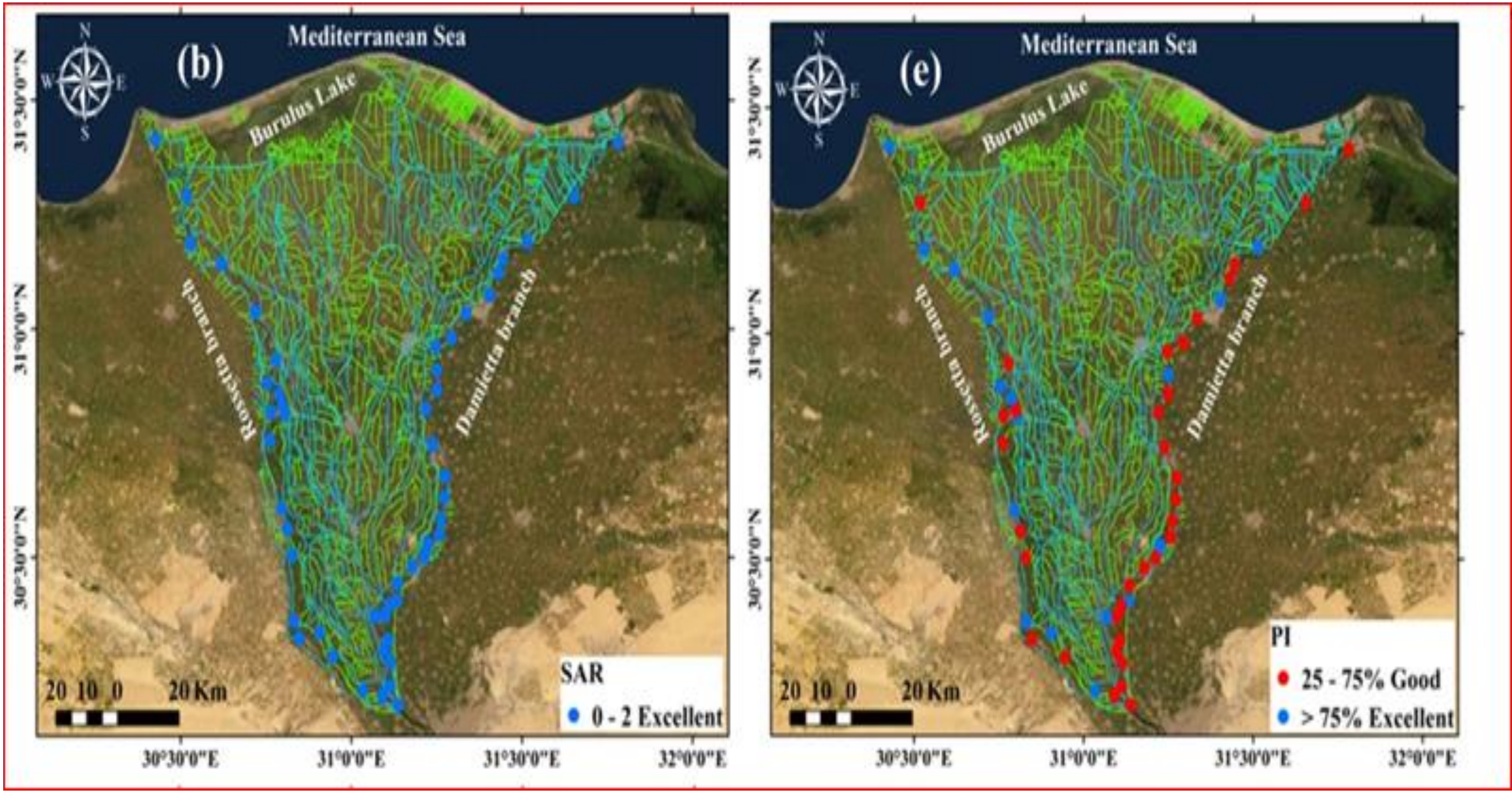
	IWQI	SAR	Na%	SSP	PI	MH
	Rosetta branch, Nile River (n = 21)					
Min	86.48	0.84	33.94	28.04	64.32	35.98
Max	95.79	1.47	45.92	42.98	85.97	59.00
Mean	90.46	1.20	40.07	36.08	76.25	48.30
SD	2.37	0.21	4.04	5.16	6.49	5.73
	Damietta branch, Nile River (n = 30)					
Min	81.56	0.66	26.98	23.55	57.24	14.12
Max	98.57	1.40	39.95	33.57	81.88	53.52
Mean	93.59	0.88	32.90	28.73	69.54	40.91
SD	3.13	0.14	3.10	3.01	6.05	8.62
	Data across two branches (n = 51)					
Min	81.56	0.66	26.98	23.55	57.24	14.12
Max	98.57	1.47	45.92	42.98	85.97	59.00
Mean	92.30	1.01	35.85	31.75	72.30	43.95
SD	3.22	0.23	4.98	5.41	7.02	8.35

Table 5. Categorization of the different WQIs across the Nile River.

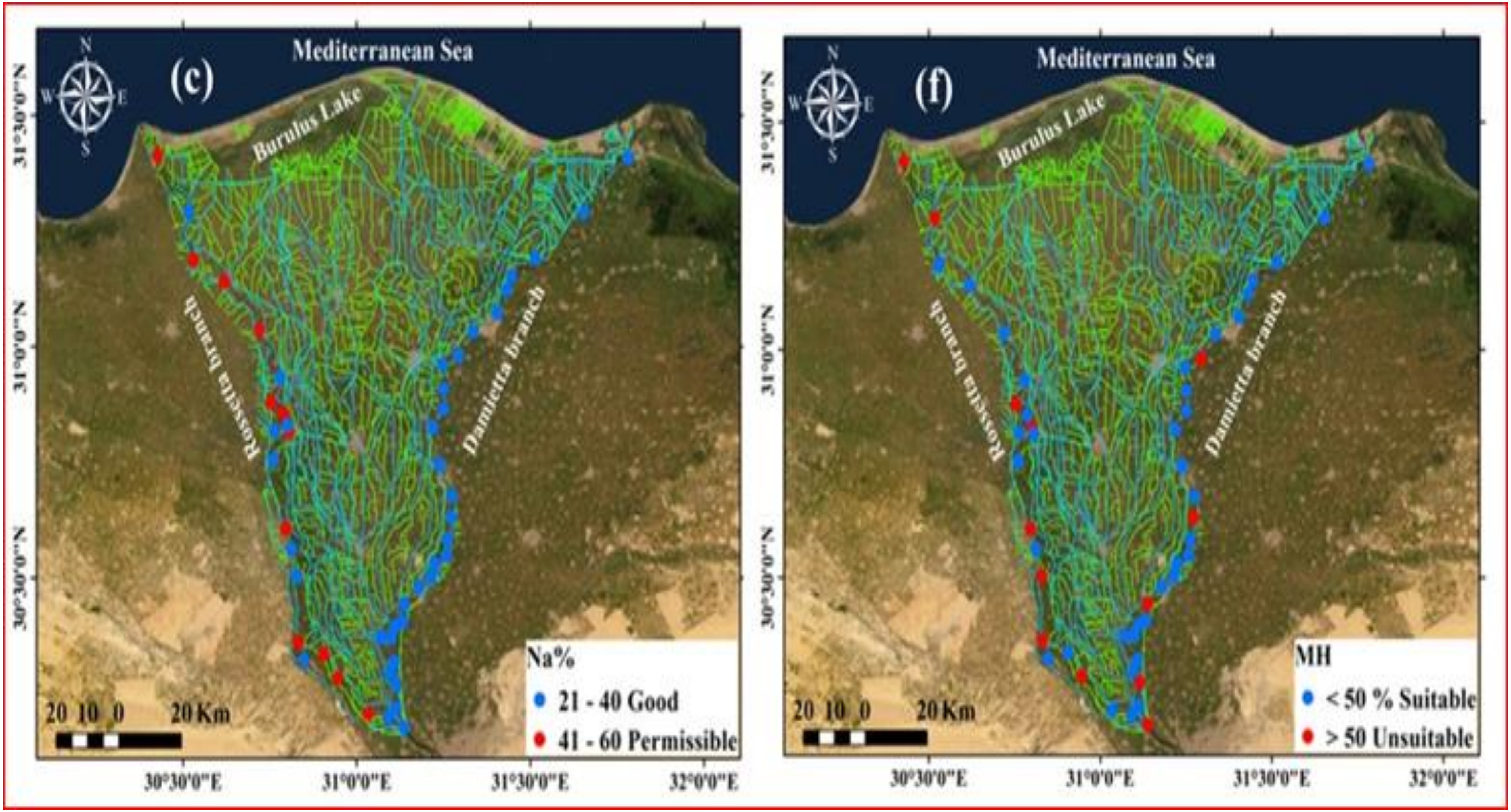
WQIs	Range	Water category	Number of Samples (%)		
			Rosetta branch	Damietta branch	Across two branches
IWQI	85 - 100	No restriction	21 (100%)	29 (97%)	50 (98%)
	70 - 85	Low restriction	0 (0.0%)	1 (3%)	1 (2%)
	55 - 70	Moderate restriction	0 (0.0%)	0 (0.0%)	0 (0.0%)
	40 - 55	High restriction	0 (0.0%)	0 (0.0%)	0 (0.0%)
	0 - 40	Serve restriction	0 (0.0%)	0 (0.0%)	0 (0.0%)
SAR	2 - 10	Excellent	21 (100%)	30 (100%)	51 (100%)
	10 - 18	Good	0 (0.0%)	0 (0.0%)	0 (0.0%)
	18 - 26	Doubtful or Fairly poor	0 (0.0%)	0 (0.0%)	0 (0.0%)
	> 26	Unsuitable	0 (0.0%)	0 (0.0%)	0 (0.0%)
Na %	0 – 20	Excellent	0 (0.0%)	0 (0.0%)	0 (0.0%)
	21 – 40	Good	9 (43%)	30 (100%)	39 (76%)
	41 – 60	Permissible	12 (57%)	0 (0.0%)	12 (24%)
	60 – 80	Doubtful	0 (0.0%)	0 (0.0%)	0 (0.0%)
	>80	Unsuitable	0 (0.0%)	0 (0.0%)	0 (0.0%)
SSP	< 60	Safe	21 (100%)	30 (100%)	51 (100%)
	> 60	Unsafe	0 (0.0%)	0 (0.0%)	0 (0.0%)
PI	> 75%	Excellent	11 (52 %)	6 (20%)	17 (33%)
	25 to 75%	Good	10 (48%)	24 (80%)	34 (67%)
	< 75%	Unsatisfactory	0 (0.0%)	0 (0.0%)	0 (0.0%)
MH	> 50%	Unsuitable	8 (38%)	5 (17%)	13 (25%)
	< 50%	Suitable	13 (62%)	25 (83%)	38 (75%)



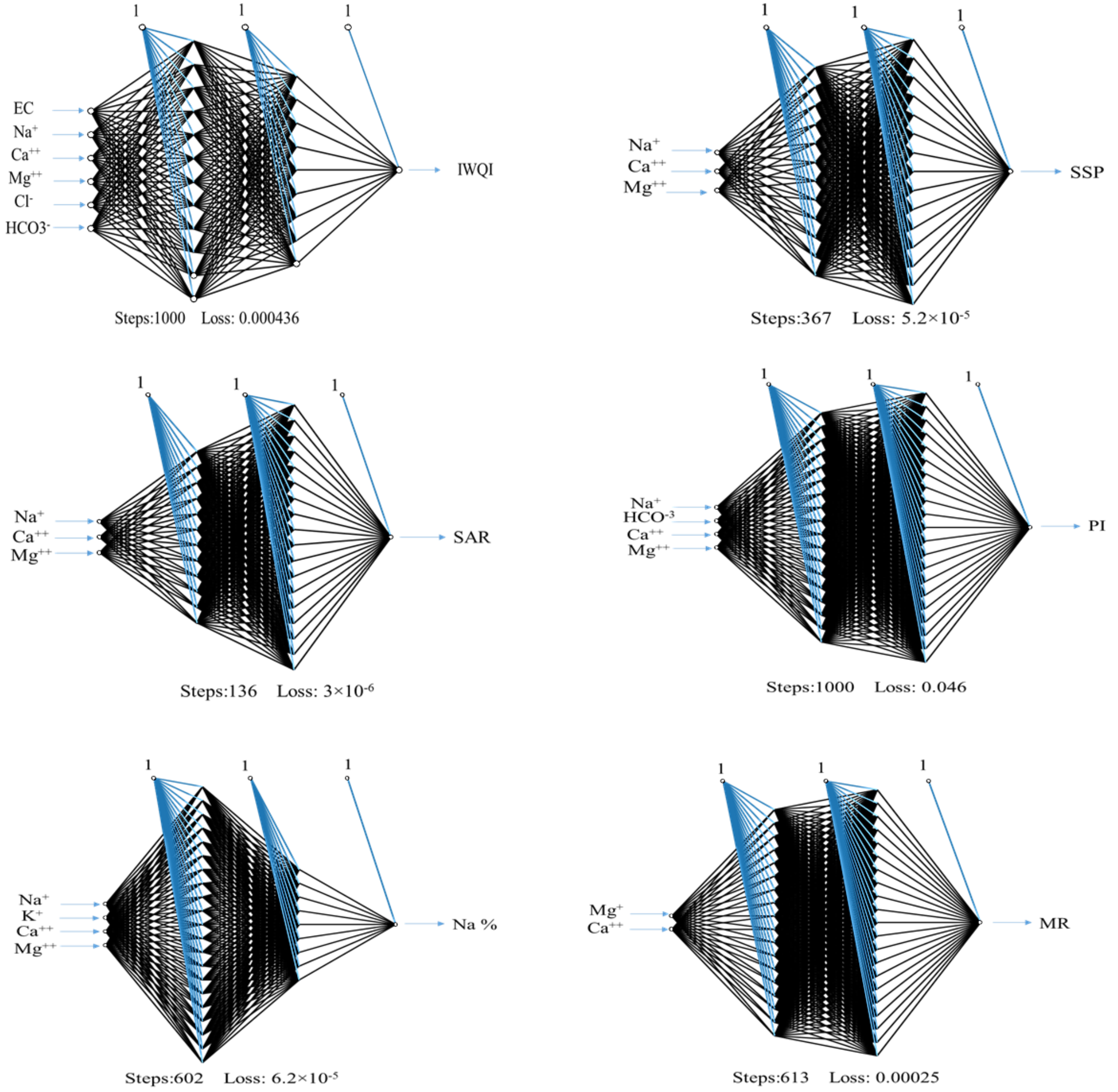
The IWQIs distribution maps: (a) IWQI, and (d) SSP



The IWQIs distribution maps: (b) SAR, and (e) PI.



The IWQIs distribution maps: (c) Na%, and (f) MH.



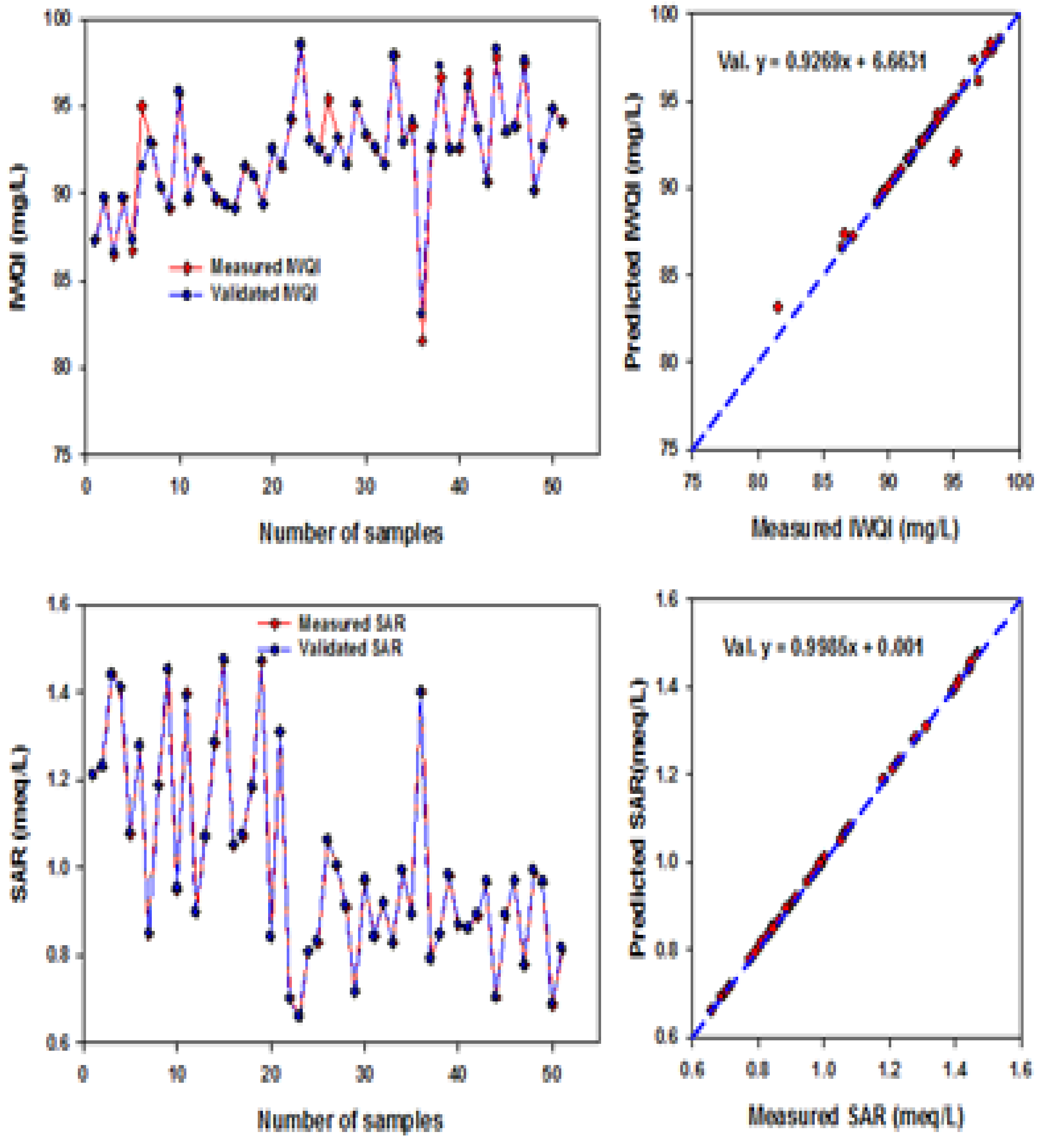
A neural network diagrams established for detecting IWQI, SAR, Na%, SSP, PI, and MR**.**

Findings of ANN to predict six IWQIs.

Variable	Ranking	Parameters (h_1, h_2, fn)	Calibration		Validation	
			R^2	RMSE	R^2	RMSE
IWQI	EC, Cl^-, Na^+, Ca^{2+}, HCO_3^-, Mg^{2+}	(12, 9, tanh)	0.999***	0.028	0.945***	0.255
SAR	Ca^{2+}, Mg^{2+}, Na^+	(12, 18, tanh)	0.999***	0.001	0.999***	0.001
Na%	K^+, Ca^{2+}, Mg^{2+}, Na^+	(21, 9, logistic)	0.999***	0.004	0.999***	0.009
SSP	Ca^{2+}, Mg^{2+}, Na^+	(12, 15, tanh)	0.999***	0.005	0.999***	0.008
PI	Na^+, HCO_3^-, Mg^{2+}, Ca^{2+}	(18, 21, tanh)	0.998***	0.302	0.994***	0.417
MR	Ca^{2+}, Mg^{2+}	(18, 21, logistic)	0.999***	0.005	0.999***	0.029

*** $P \leq 0.001$ indicating statistical significance. Where h1 and h2 are the number of neurons in the two hidden layers, and fn is the activation function.

Relationships between employing the ANN models to measure and validate output datasets of IWQI, and SAR

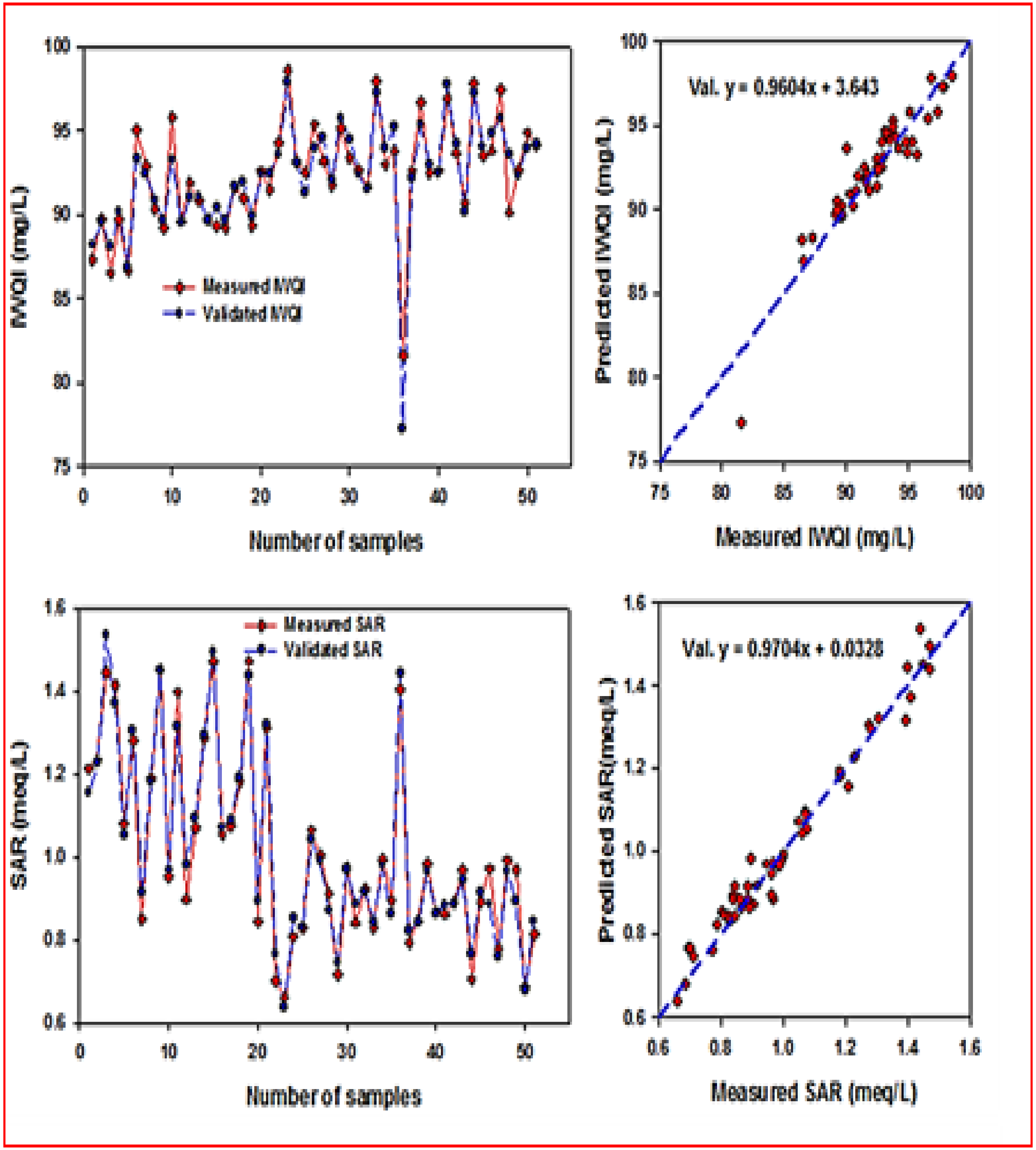


Findings of PLSR to predict six IWQIs.

Variable	Parameters	LVs	Calibration		Validation	
			R^2	RMSE	R^2	RMSE
IWQI	EC, Cl^-, Na^+, Ca^{2+}, HCO_3^-, Mg^{2+}	3	0.914***	0.932	0.872***	1.164
SAR	Ca^{2+}, Mg^{2+}, Na^+	2	0.970***	0.039	0.971***	0.038
Na%	K^+, Ca^{2+}, Mg^{2+}, Na^+	3	0.986***	0.577	0.982***	0.678
SSP	Ca^{2+}, Mg^{2+}, Na^+	3	0.992***	0.484	0.988***	0.571
PI	Na^+, HCO_3^-, Mg^{2+}, Ca^{2+}	2	0.982***	0.919	0.972***	1.126
MR	Ca^{2+}, Mg^{2+}	4	0.985***	1.026	0.982***	1.175

*** $P \leq 0.001$ indicating statistical significance. LVs is the optimal number of latent variables.

Relationships between employing the PLSR models to measure and validate output datasets of IWQI, and SAR.



CONCLUSION

* The IWQI values for the Nile River branches showed that approximately 98% of samples fell into the category of no restriction range, which prevents the growth of crops that can withstand salinity, and that approximately 2% of samples fell into the category of low restriction for irrigation usages.

* Combining elements with ANN and PLSR can result in efficient methods for precisely estimating six IWQIs in Cal. and Val. datasets surface water. For instance, The PLSR model produced robust estimates for six IWQIs in Cal. datasets, with R^2 values recorded between 0.91 to 0.99. Furthermore, in Val. datasets, the model recorded well estimates for six IWQIs, with R^2 values located between 0.87 and 0.99. In conclusion, the combination of physicochemical characteristics, IWQIs, PLSR, ANN models, and GIS techniques is successful and provides us a clear image for determining the conditions that regulate surface water's appropriateness for irrigation.


Thank you