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GIS and Water Quality Index Based to Assess Spring Water Quality, A Case Study of Bani Kinanah District, Irbid, Northwestern Jordan

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Abstract - Springs in northwestern Jordan are significant sources of freshwater for local communities. The reliance on springs to fulfill the growing demands for water has been intensified in the past decade, following the decline in rainwater due to climate change. Thirty water samples were collected from springs located in Bani Kinanah District, northwest Jordan, and tested for various water quality parameters, including pH, EC, TDS, Na^+, Ca^{+2}, Mg^{+2}, K^+, Cl^-, F^-, SO_{4-2}, NO_{3-}, TH, TA, Fe, Mn, Pb, and Zn. The results show that most water quality variables fall within the acceptable limits for drinking water set by the World Health Organization (WHO) and the Jordanian standards, except for a few indicators. The chemistry of spring water is mainly governed by rock weathering, with dominant Ca-Mg-HCO_3 type of water. The spatial distribution of TDS in spring water shows relatively high levels in springs located in northern and northeastern areas. Based on the water quality index (WQI), twenty-six springs are either of excellent or good water quality, and are suitable for drinking purposes. Whereas four springs (Kharja, Malka, EL Za'agah, and Sa'ed) have poor quality and designated for irrigation and industrial usage. This may be due to its proximity to residential areas, as noted in the field observation. Evaluation of the spring water suitability for irrigation shows that most springs are of excellent to good quality, and only a few springs fall under the category of good to permissible for irrigation.

Keywords: Water Quality Index (WQI), Geographic Information System (GIS), spring water, Bani Kinanah

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Introduction

Background

The scarcity of freshwater resources is globally a widespread and alarming issue that remains critically a major constraint to economic development. In addition to natural dimensions, humans have been a major contributor to the scarcity of water because of unsustainable water use practices and water quality deterioration (Al-Rawabdeh *et al*., 2013; Al-Taani, 2013; Al-Taani *et al*., 2018a; Muhaidat *et al*., 2019). Jordan, is an arid to semi-arid country, suffers acute shortages of water resources, and is considered as one of the poorest countries in the availability of natural water resources (Nortcliff *et al*., 2008; Al-Taani, 2014; Al-Taani *et al*., 2018b).

The scarcity of water resources in Jordan is primarily due to the lack of surface freshwater resources. According to Mohsen (2007), there are only three small rivers in Jordan; namely: the Yarmouk River, Jordan River, and Zarqa River, all of which are partially contaminated and are unsuitable for drinking usage (Al-Taani *et al*., 2012; Al Shwayatt *et al*., 2019; Muhaidat *et al*., 2019). Thus, Jordan relies heavily on groundwater basins and rainfall during the winter season to feed dams and ground aquifers (Al-Rawabdeh *et al*., 2014; Al-Harahsheh *et al*., 2020; Al-Taani *et al*., 2021). There are twelve groundwater basins in Jordan (Mohammad, 2017), which constitute the main source of water to meet the increasing demands of the Jordanian population, and may requires an assessment of the risks of vulnerability to groundwater extraction (Putranto, *et al*. 2020)

Many groundwater aquifers are over-abstracted, and depletion became widespread (Al-Taani *et al*., 2018a; Al-Harahsheh *et al*., 2020). In addition to excessive pumping, low recharge rates, and low rainfall totals, these aquifers are deteriorating in quality due to industrial and human activities, poor agricultural practices, and improper sewage disposal operations in many areas (Al-Rawabdeh *et al*., 2013). This, in turn, leads to an acceleration of groundwater pollution (El-Naqa and Al-Shayeb, 2009; Obeidat *et al*., 2013). Therefore, searching for new water resources at the present time is considered a necessity by using some modern geophysical and electrical methods in the exploration process (Nugraha, *et al*. 2021).

Many studies conducted on the status of water in Jordan, highlighted a profound water crisis where great efforts have been made to look for alternative water resources to meet the growing demands of all sectors at the local level (Al-Kharabsheh and Ta'any, 2005; Hadadin *et al*., 2010). Seawater desalination, water harvesting, and limiting irrigation to treated wastewater were proposed to handle shortages of potable water.

Many residents in Bani Kinanah District (northwestern Jordan), especially those in rural areas, rely primarily on water harvesting wells to collect rainwater during the winter time and secure enough water for meeting their needs in the dry summer season. However, this has shifted in recent years due to a decline in rainwater as a result of climate change and extended periods of drought (Abdulla and Al-Shareef, 2009).

People are increasingly becoming dependent on spring water that is scattered in valleys, for drinking purposes and daily uses, irrigating crops, or watering livestock. But, high population growth (due to Syrian refugees and birth rates), and increasing human activities, in the particular discharge of wastewater from olive oil mills, sewage, and uncontrolled septic tanks (drain field) have threatened these significant water resources.

This study is intended to monitor and assess water quality parameters for spring water within Bani Kinanah District, northwestern Jordan. These springs are the prime source of water for local communities. Thirty springs have been sampled and assessed for a variety of water quality indicators. This assessment is of significant importance as the water quality of these springs is life-threating for dwellers of this region.

Area of Study

Bani Kinanah is one of Irbid governorate districts located in the far northwestern part of Jordan. The district lies between 32.605° N to 32.756° N and 35.647° E to 35.909° E with an area of about 248.316 km^2 (Figure 1). The district includes twenty-seven villages and small towns, with an estimate population number of about 152,650 (DS, 2022). This large number of residents adds more pressure on the existing water resources in the area. In addition, a large number of people are living in close proximity to these springs which have become highly vulnerable to pollution, either by the release of pollutants from septic tanks (spread in the area due to the lack of sewerage systems), uncontrolled grazing, or unregulated water use.

Bani Kinanah District is known for its fertile soil that is suitable for growing grains, trees (especially olive trees), and fruits. In addition, it is one of the most attractive tourist regions for its unique greenery landscape, mountains along with several tourist destinations, and archaeological sites.

Land Use, Climate, and Hydrology

Olive trees and the production of olive oil are the main agricultural products in the studied area. Residents are also interested in cultivating winter crops such as wheat, barley, and lentils, in

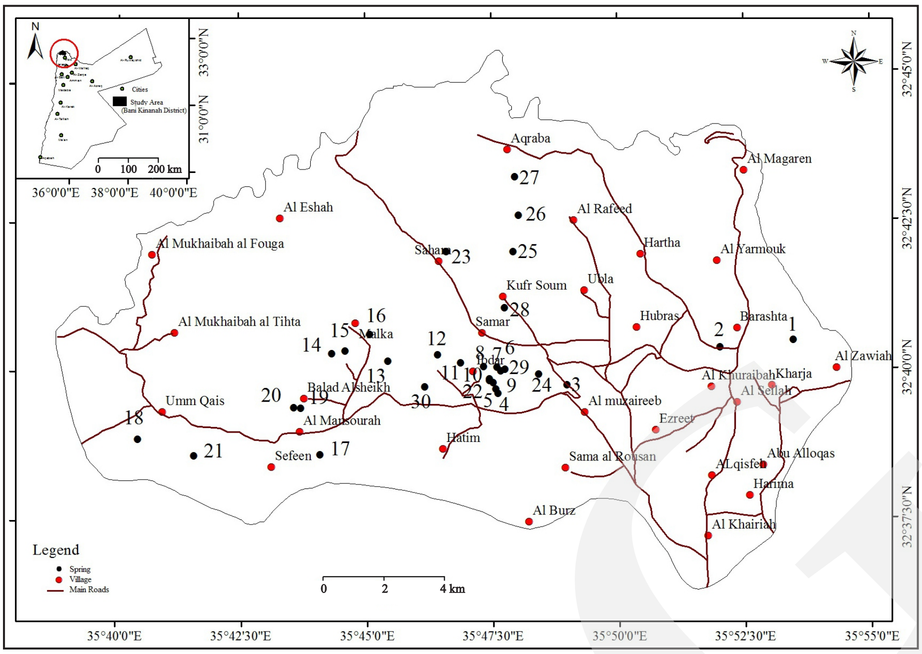


Figure 1. Location map of the studied area showing the distribution of sampling springs.

addition to some summer crops. The studied area contains natural forest lands mainly represented by oak and pine trees, in addition to grasslands and pastures (Agriculture Directorate, 2021).

The climate of the studied area is moderately hot in summer and cold rainy in winter time. The average annual temperature and rainfall is 21°C and about 450 mm/year respectively (Agriculture Directorate, 2021). Bani Kinanah District is part of the Jordanian Yarmouk Basin and has two main aquifers, the Upper Cretaceous Aquifer (B2/A7) which is recharged from Irbid and Ajlun Mountains (south) and from Jabal Al Sheikh and Jabal Al Arab-Druz in Syria (north). The second is the shallow aquifer (B4/B5), recharged directly from precipitation during the winter season where most of the karst springs found in the area belong to this aquifer (Salameh, 1996, 2004).

Materials and Methods

Sample Collection

Thirty spring locations were sampled on August 2022. Samples were collected in clean polyethylene bottles from well-known springs in Bani Kinanah District. Each collected sample was labeled and tested in the field for pH, EC, and TDS using calibrated portable electrode meters (Portable EcoScan pH meter and Portable HACH SensION5 EC/TDS meter), and the coordinates for each sample were measured using etrex GARMIN GPS. Samples were kept in a refrigerator at 4°C for further analysis in the laboratory. Major cations (Ca^{2+}, Na^{+}, K^{+}, and Mg^{2+}) and anions (NO_{3-}, SO_{4-2}, Cl_{-}, and F) were measured by Ion Chromatography IC (DIONEX ICS 1600, THERMOSCENTIFIC). Selected heavy metals (Fe, Mn, Zn, and Pb) were measured using Flame Atomic Absorption Spectroscopy FAAS (GF-FAAS NOVAA 800D ANALYTICA JENA AJ). Total hardness (TH) was computed by the Equation 1: (Eaton *et al.*, 1998):

$$\text{Total Hardness}\left(\frac{mg}{l}\right) = 2.497[Ca^{2+}] + 4.118[Mg^{2+}] \;.... (1)$$

Total alkalinity (TA) was measured using the titration method, in which 25 ml of the clean filtered samples were titrated with 0.02N H_2SO_4 using phenolphthalein and methyl orange indicators. The total alkalinity was measured using the Equation 2 (APHA, 1998):

$$\text{Total alkalinity} = \frac{\text{Volume of acid used*normality of acid*500}}{\text{Volume of sample}} \;.. (2)$$

Water Quality Index (WQI) was used to assess the quality of water. It is a mathematical tool that aims to reduce the complex water quality parameters and obtain a unitless single classifying value that can easily describe the degree of water pollution (Štambuk-Giljanović, 1999). There are various methods for calculating WQI, such as the National Sanitation Foundation Water Quality Index (NSFWQI), the Canadian Council of Ministers of the Environment Water Quality Index (CCMEWQI), The Oregon Water Quality Index (OWQI), and the Weight Arithmetic Water Quality Index (WAWQI) (Tyagi, 2013). In this study, the WQI for spring water samples was calculated using the weight arithmetic quality index method with respect to Jordanian drinking water standards (Table 1), except for EC and fluoride which were calculated with respect to WHO standards for drinking water. Drinking water quality parameters used to measure WQI are pH, EC, TDS, Na^+, Ca^{2+}, Mg^{2+}, K^+, Cl^-, F^-, SO_{4-2}, NO_{3-}, TH, TA, Fe, and Mn (Table 1).

Table 1. Jordanian Standards and WHO Guidelines for Drinking Water Quality (WHO, 2004; JS, 286/2015)

Parameter	Units	Jordanian Standards	WHO Standards
pH		6.5 - 9.0	6.5 - 8.5
EC	µs/cm	-	400
TDS	mg/l	500-1500	500 - 1000
Na^+	mg/l	200-400	200
Ca^{2+}	mg/l	75 - 200	100
Mg^{2+}	mg/l	50 - 150	50
K^+	mg/l	10 - 50	20
Cl^-	mg/l	200-500	250
F^-	mg/l	-	1.5 - 2
SO_4^{2-}	mg/l	200-500	250
NO_3^-	mg/l	< 70	50
TH ($CaCO_3$)	mg/l	< 500	500
Alkalinity ($CaCO_3$)	mg/l	100-500	125 - 350
Fe	mg/l	0.3 - 1	0.3
Mn	mg/l	0.1-0.5	0.1 - 0.2

The weighted arithmetic mean method for calculating water quality index is widely used to assess water quality worldwide. According to Brown *et al*. (1970) and Abbasi and Abbasi (2012) the WQI Equation 3 is:

$$WQI = \frac{\Sigma QnWn}{\Sigma Wn} \quad \text{...} \quad (3)$$

where Qn is the quality rating score, calculated based on the equation (4):

$$Qn = \left[\frac{(Vn - Vi)}{Vs - Vi}\right] * 100 \quad \text{..................................} \quad (4)$$

and Wn is the unit weight, calculated by the Equation 5:

$$Wn = \frac{K}{Sn} \quad \text{...} \quad (5)$$

where:
Vn is the actual amount of n^th parameter present,
Vi is the ideal value of the parameter (Vi = 0 for all parameters, Vi for pH= 7),
Vs is the permissible limit for the n^th water quality parameters according to Jordanian drinking water standard,
Sn is the recommended standard for the i^th parameters, and
K is the constant of proportionality, calculated based on the following Equation 6:

$$K = \frac{1}{\Sigma \frac{1}{Sn}} \quad \text{...} \quad (6)$$

The computed WQI values were then classified into five categories (Brown *et al*., 1972) in order to determine the water quality status (WQS) (Table 2).

Table 2. WQI Values, Water Type, and Possible Use of the Spring Water Sample (Abbasi and Abbasi, 2012)

WO1	**Water Type**	**Possible Use**
0 - 25	Excellent	Drinking, Irrigation, and Industry
26 - 50	Good	Drinking, Irrigation, and Industry
51 - 75	Poor	Irrigation and Industry
76 - 100	Very Poor	Irrigation
> 100	Unsuitable for Drinking	Proper treatment required before use

GIS Analysis

ArcGIS 10.8 was used to map the spring water sample locations based on the coordination measured in the field. A geological setting map was obtained by digitizing, which showed that the majority of spring water were located in Umm Rijam Formation (chert-limestone) (Figure 2). The digital elevation model (DEM) was downloaded from the United State Geological Survey (USGS) website (https://earthexplorer.usgs.gov). The DEM was used to delineate the drainage basin within the studied area. Spatial distribution for TDS and WQI values was represented using inverse distance weight (IDW) in order to interpret the trend of water quality.

Results and Discussion

The results of chemical analysis of spring water samples are shown in Table 3. The pH of spring water ranged from 7.01 to 8.44 with an average of 7.73. The highest values of pH were recorded in springs 6 and 26, while spring 20 showed the lowest value. These values are within the Jordanian permissible limit for drinking water (JS, 286/2015) (Table 1). The EC levels varied from 356 µs/cm to 2008 µs/cm, twenty-seven samples exhibited EC values greater than the WHO recommended limit (Table 1). TDS concentrations ranged from 172 to 1134 mg/l with an average of 366.4 mg/l (Table 3). All spring samples have TDS values that are within Jordan acceptable limit for drinking purposes (Table 1). The total alkalinity (TA) shows values ranging from 128 mg/l to 352 mg/l with a mean amount of 240 mg/l (Table 3), of which all are below the maximum allowable limit of Jordanian drinking water standard (Table 1).

The total hardness (TH) of spring water varies between 154.4 mg/l (sample 1) and 731.5 mg/l (sample 16) (Table 3). In general, the high TH values are primarily attributed to the introduction of Ca^{2+} and, to a lesser extent, Mg^{2+} into the water, where Ca^{2+} is released from Ca^{2+} bearing minerals (carbonates) (Batayneh *et al.*, 2014). Mg^{2+} possibly originated from the dissolution of dolomitic limestone (Batayneh and Al-Taani, 2015). These

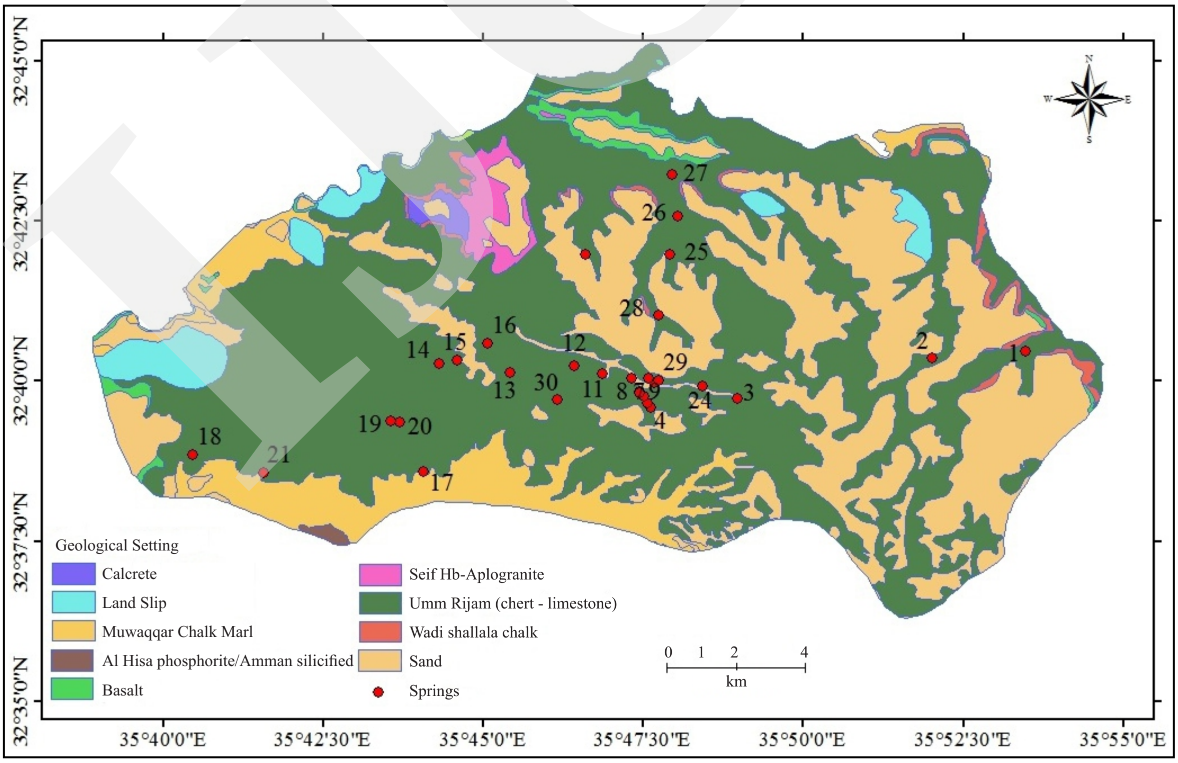


Figure 2. Geological map for the studied area.

Table 3. Results of Chemical Water Analysis

Spring ID	Spring Name	Lat (N)	Long (E)	pH	EC µs/cm	TDS	Ca^{2+}	Mg^{2+}	Na^{+}	K^{+}	Cl^{-}	F^{-}	NO_3^{-}	SO_4^{2-}	ALK $CaCO_3$	TH	Fe	Mn
						mg/l												
1	Kharja	32.675	35.891	7.54	1067	535	119.61	15.84	49.90	68.12	66.24	0.89	0.26	0.02	244	363.89	0.23	0.36
2	Quailbah	32.673	35.867	7.48	918	494	86.45	7.22	16.24	1.82	15.55	0.84	0.18	0.00	208	245.59	0.20	0.30
3	Ettrab	32.662	35.816	8.35	446	227	83.99	6.14	15.60	0.48	15.91	0.89	0.03	0.00	196	234.99	0.06	0
4	El Ghanam	32.660	35.794	8.03	404	191	65.25	5.84	18.12	0.17	15.92	1.05	0.04	0.00	160	186.95	0.05	0
5	El Baida	32.661	35.793	7.73	367	180	64.73	4.39	12.87	0.13	12.62	0.93	0.04	0.00	160	179.69	0.02	0
6	Samar	32.666	35.794	8.44	356	172	54.57	4.41	11.14	0.13	11.69	0.79	0.04	0.00	128	154.43	0.02	0
7	El Mnaggah	32.667	35.793	8.36	442	186	60.33	4.42	11.62	0.25	12.61	1.00	0.04	0.00	164	168.84	0.03	0
8	El Dundanah	32.667	35.789	7.82	895	477	104.43	13.91	41.09	52.25	70.84	0.92	0.26	0.00	208	318.04	0.20	0.28
9	Esh Sheikh	32.663	35.792	7.95	631	328	127.74	10.27	25.14	0.48	19.75	1.46	0.30	0.00	332	361.25	0.15	0.13
10	El Harrathin	32.664	35.791	7.53	954	508	156.98	11.37	41.00	66.08	72.22	1.07	0.26	0.00	248	438.79	0.21	0.32
11	Taba'a	32.669	35.781	7.24	496	260	129.13	5.67	11.95	0.62	16.84	1.57	0.26	0.99	244	345.79	0.08	0
12	Abu Habis	32.671	35.774	7.54	493	256	91.20	9.56	14.72	0.11	15.30	0.96	0.02	0.00	256	267.08	0.06	0
13	Um Jurain	32.669	35.757	8.18	684	309	86.35	14.30	20.03	0.45	23.86	1.61	0.14	0.01	304	274.53	0.12	0
14	Atiyya	32.671	35.739	7.44	560	278	96.99	6.96	14.00	0.33	20.20	0.98	0.11	0.00	276	270.85	0.09	0
15	El Sukkar	32.672	35.743	7.28	550	281	102.19	7.74	15.57	0.33	15.52	0.85	0.06	0.00	264	287.03	0.10	0
16	Malka (albalad)	32.677	35.751	7.07	2008	1134	256.62	22.04	101.00	128.39	246.06	1.48	0.99	0.00	268	731.54	0.24	0.39
17	Ra'an	32.643	35.734	7.36	651	314	101.86	12.92	21.57	1.07	34.08	0.92	0.14	0.00	284	307.55	0.13	0
18	Um Qais	32.648	35.674	7.77	858	434	83.76	27.36	41.63	3.04	72.92	2.36	0.11	0.08	252	321.81	0.19	0.25
19	El Tasah	32.656	35.728	7.17	609	313	104.83	9.30	18.01	0.51	21.28	1.13	0.14	0.00	312	300.06	0.13	0
20	El Kelab	32.656	35.726	7.01	688	355	130.00	9.05	19.69	0.62	29.84	1.07	0.19	0.00	352	361.86	0.15	0.14
21	El Assal	32.643	35.693	8.26	576	289	60.86	15.87	17.21	0.57	23.25	1.55	1.25	17.30	244	217.33	0.10	0
22	Hammania	32.664	35.791	7.93	705	380	97.28	8.88	28.37	49.34	43.41	1.09	0.30	0.00	248	279.49	0.16	0.19
23	Saham (albalad)	32.700	35.777	7.89	716	375	100.91	10.12	35.73	17.09	60.76	0.76	0.36	0.00	208	293.65	0.16	0.17
24	El Magharah	32.665	35.807	7.28	493	264	92.72	6.54	16.98	3.41	20.30	0.98	0.14	0.00	240	258.46	0.08	0
25	El Za'agah	32.700	35.799	8.43	1113	657	108.42	16.86	75.97	92.70	196.34	1.21	0.91	0.00	172	340.16	0.23	0.39
26	Sa'ed	32.710	35.801	7.43	969	524	131.46	19.64	51.12	19.82	111.69	2.18	0.66	0.00	296	409.14	0.22	0.35
27	Aqraba	32.721	35.799	7.86	789	398	80.22	18.82	41.86	21.52	74.50	2.01	0.35	0.00	236	277.81	0.17	0.21
28	El Bardeh	32.684	35.796	7.23	770	404	112.17	10.02	33.71	29.57	57.96	1.18	0.36	0.00	248	321.34	0.19	0.24
29	El Foutaha	32.667	35.796	8.44	368	180	69.93	4.38	10.66	0.15	13.17	1.02	0.16	0.00	176	192.65	0.03	0
30	Um Khiraq	32.662	35.769	7.98	547	289	104.47	9.15	18.07	1.00	27.61	1.07	0.08	0.00	280	298.52	0.11	0

results indicate that twenty-nine springs lies within the Jordanian drinking water standard of 500mg/l (Table 1), and one spring has a TH value that exceeded the permissible limit (Table 1).

Low nitrate concentrations were observed ranging from 0.02 mg/l to 1.25 mg/l with an average value of 0.27 mg/l (Table 3). These values suggest that springs are unaffected by agricultural activities (*e.g.* fertilizers) where agriculture is the common land use in this region. These levels of nitrate are far below the Jordanian permissible limit of 70 mg/l (Table 1). Spring water showed no sulfate content, except for a few samples. The maximum value of 17.3mg/l for sulfate was measured in spring 21 (Al Assal) (Table 3), and is likely released from localized gypsum-bearing rocks.

Chloride concentrations of spring water samples range from 11.7 mg/l to 246.1 mg/l (with a mean of 47.9 mg/l) (Table 3). These values are well within the Jordanian permissible limit (Table 1). The concentration of fluoride varies between 0.76 mg/l and 2.56 mg/l (Table 3), where twenty-seven springs have fluoride values within WHO recommended range of 1.5-2 mg/l for drinking water standard. Three springs (18, 26, and 27) have fluoride levels slightly exceeding the permissible limit of WHO (Table 1).

The calcium content of spring water shows values ranging from 54.57 mg/l to 256.62 mg/l (Table 3), with an average amount of 102.2 mg/l. Except for spring 16, all spring water samples have Ca^{2+} values below the Jordanian standard limit for drinking water (Table 1). Magnesium and sodium concentrations range from 4.38-27.36 mg/l, and 10.66-101 mg/l, respectively (Table 3). These values are well below the Jordanian allowable limits (Table 1).

Potassium ranged in concentration from 0.11 mg/l to 128.39 mg/l with an average value of 18.7 mg/l (Table 3). Five spring water samples (1, 8, 10, 16, and 25) have values in excess of the Jordanian standard limits of 50 mg/l (Table 3 and Table 1).

Spring water samples were analyzed for selected heavy metals (Fe, Mn, Pb, and Zn) (Table 3). Results show no Pb and Zn or their concentrations are below the detection limits. Low concentrations of Fe and Mn were observed for spring water ranging from 0.02-0.24 mg/l, and 0-0.39 mg/l, respectively (Table 3) which are below the maximum permissible limits of Jordanian drinking water standards (Table 1).

The spatial distribution of TDS in spring water shows relatively high levels in springs located in north and northeastern areas (Figure 2). Lower concentrations of TDS are observed in the lower central of the studied area, except for spring 18, which consistently exhibits higher values for other water quality parameters, exceeding the drinkable water standards (Table 3). The studied area has similar geologic settings with dominant carbonate rocks. This suggests the variations in TDS values are attributed to the over abstraction of groundwater and/or fluctuation of water table which is likely to accelerate the dissolution of rocks and increase TDS levels (Figure 3).

Agricultural discharges following excessive irrigation are probably another contributing cause of TDS. Additionally, land cover and water flow directions (Figure 4) are the other contributor influencing spring water salinity, where springs with higher levels of TDS are located down-gradient, compared to upper-gradient ones.

Plot of TDS (ppm) against Na/Na+Ca demonstrates rock weathering as a dominant process releasing ions in spring water (Gibbs, 1970) (Figure 5). Evaporation-crystallization is a minor contributor to water chemistry.

The piper trilinear diagram (Figure 6) indicates the dominance of the Ca-Mg-HCO_3 water type. Only two spring water samples showed a mixed type of water. Also, this suggests recharging water (Ca-Mg-HCO_3 type), where the infiltrating water carries the dissolved carbonate to end up in water (Chadha, 1999).

Based on the WQI classification (Table 4), twenty-six springs (86.67%) in the studied area are suitable (excellent to good) for drinking usage. Only four spring water samples (13.33%) are classified as poor springs and therefore are undrinkable, but can be designated for irrigation and industrial purposes.

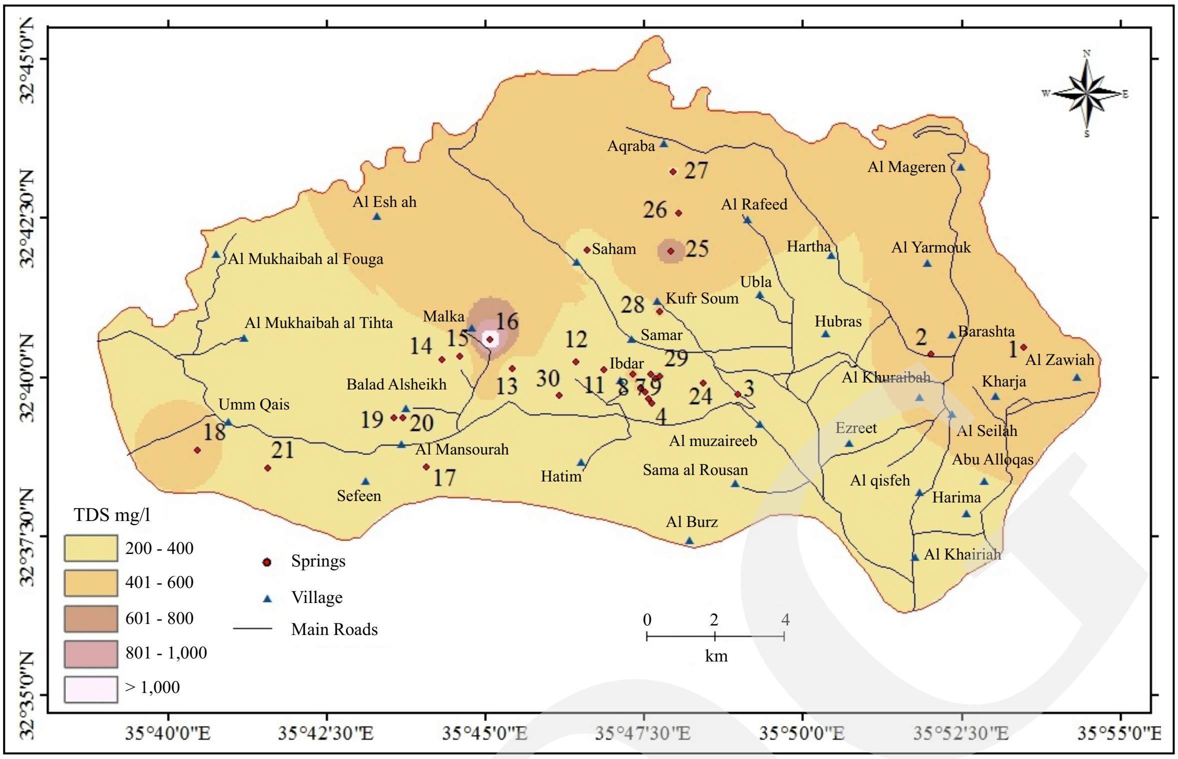
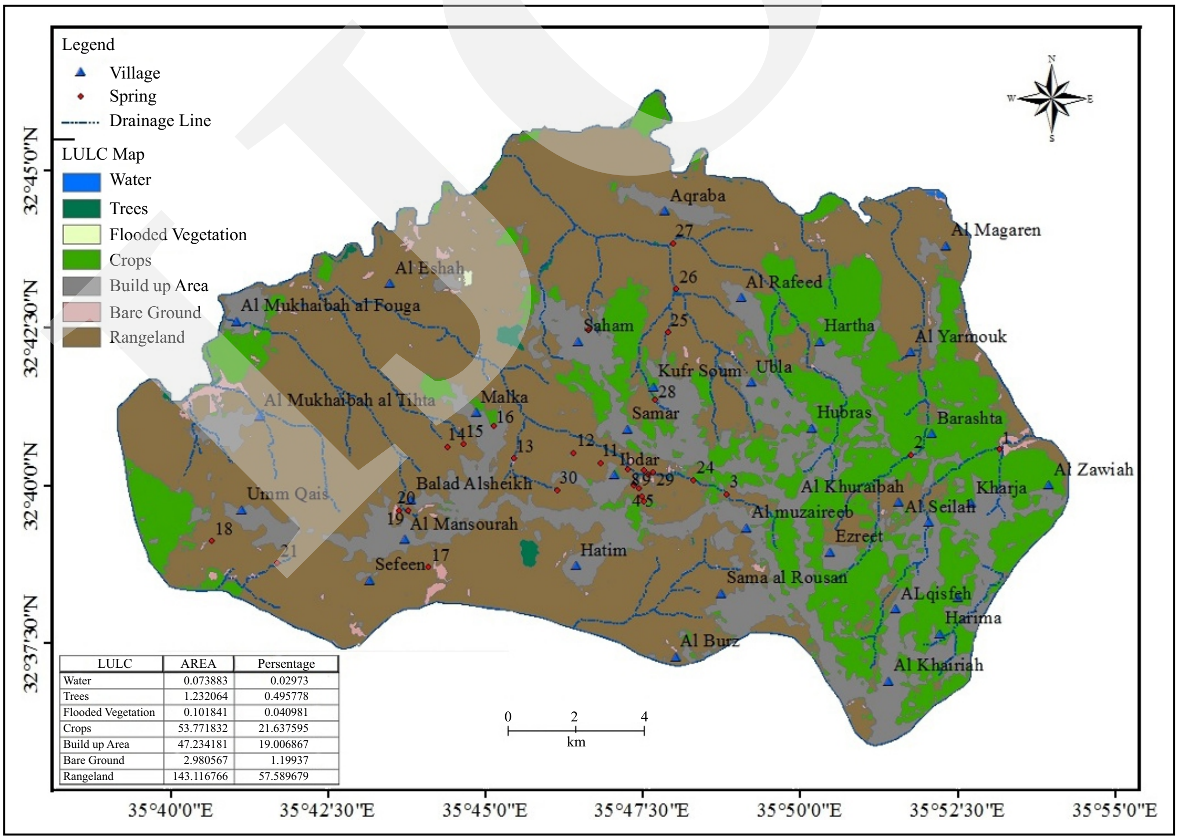


Figure 3. Spatial distribution of TDS for spring water collected from Bani Kinanah, N.W. Jordan.



LULC	AREA	Persentage
Water	0.073883	0.02973
Trees	1.232064	0.495778
Flooded Vegetation	0.101841	0.040981
Crops	53.771832	21.637595
Build up Area	47.234181	19.006867
Bare Ground	2.980567	1.19937
Rangeland	143.116766	57.589679

Figure 4. General land use/land cover map within the studied area.

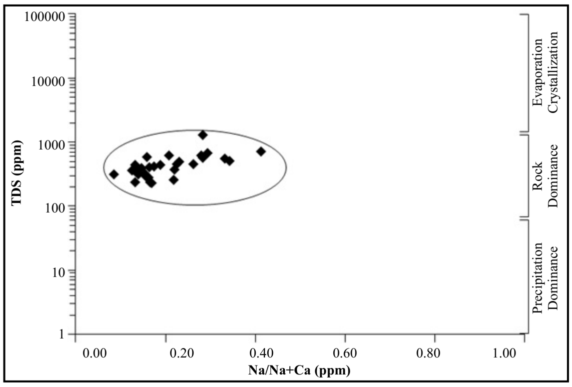


Figure 5. TDS vs. Na/Na + Ca of spring water samples collected from Bani Kinanah, N.W. Jordan.

Spatial distribution of WQI values of spring water samples shows excellent water is located in the lower middle and northwestern area (Figure 7), whereas the good quality springs dominates the northern, eastern, and western parts of the studied area. The poor water is scattered in central and eastern regions.

Springs were further assessed by Wilcox classification for their suitability for irrigation use (Figure 8). The plot illustrates that the majority of spring water (twenty-two samples) are of excellent to good quality, seven springs fall under

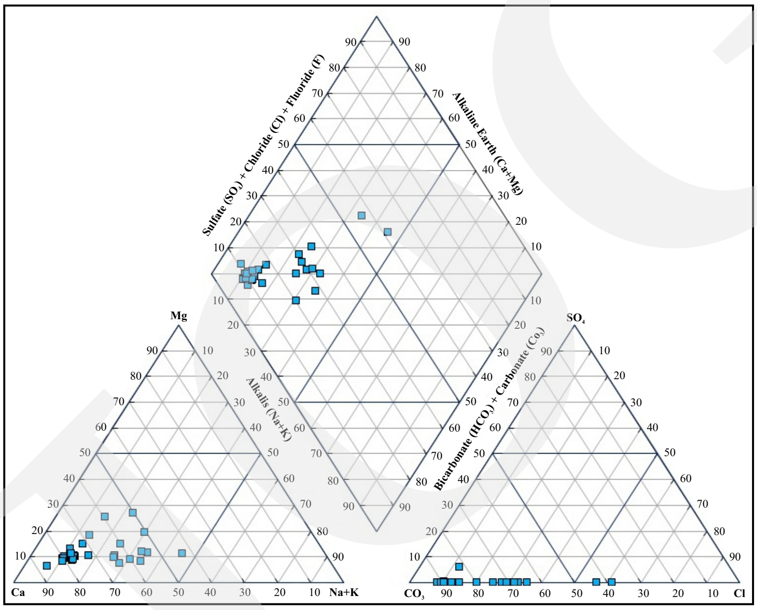


Figure 6. Piper plot showing the dominant anions and cations and classification of spring water samples.

Table 4. WQI Values for Spring Water, Classification Type, and Its Possible Usage

Spring ID	Spring Name	WQI Values	Water Type	Possible Usage
1	Kharja	53.70	Poor	Irrigation and Industry
2	Quailbah	44.82	Good	Drinking, Irrigation, and Industry
3	Ettrab	8.31	Excellent	Drinking, Irrigation, and Industry
4	El Ghanam	10.18	Excellent	Drinking, Irrigation, and Industry
5	El Baida	7.60	Excellent	Drinking, Irrigation, and Industry
6	Samar	8.25	Excellent	Drinking, Irrigation, and Industry
7	El Mnaggah	9.99	Excellent	Drinking, Irrigation, and Industry
8	El Dundanah	43.70	Good	Drinking, Irrigation, and Industry
9	Esh Sheikh	29.36	Good	Drinking, Irrigation, and Industry
10	El Harrathin	49.43	Good	Drinking, Irrigation, and Industry
11	Taba'a	13.37	Excellent	Drinking, Irrigation, and Industry
12	Abu Habis	9.26	Excellent	Drinking, Irrigation, and Industry
13	Um Jurain	16.30	Excellent	Drinking, Irrigation, and Industry
14	Atiyya	10.06	Excellent	Drinking, Irrigation, and Industry
15	El Sukkar	9.19	Excellent	Drinking, Irrigation, and Industry
16	Malka(albalad)	60.59	Poor	Irrigation and Industry
17	Ra'an	10.73	Excellent	Drinking, Irrigation, and Industry
18	Um Qais	50.46	Good	Drinking, Irrigation, and Industry
19	El Tasah	11.79	Excellent	Drinking, Irrigation, and Industry
20	El Kelab	27.43	Good	Drinking, Irrigation, and Industry
21	El Assal	15.54	Excellent	Drinking, Irrigation, and Industry
22	Hammania	35.13	Good	Drinking, Irrigation, and Industry
23	Saham (albalad)	30.33	Good	Drinking, Irrigation, and Industry
24	El Magharah	9.43	Excellent	Drinking, Irrigation, and Industry
25	El Za'agah	60.68	Poor	Irrigation and Industry
26	Sa'ed	59.89	Poor	Irrigation and Industry
27	Aqraba	43.24	Good	Drinking, Irrigation, and Industry
28	El Bardeh	40.13	Good	Drinking, Irrigation, and Industry
29	El Foutaha	10.07	Excellent	Drinking, Irrigation, and Industry
30	Um Khiraq	11.91	Excellent	Drinking, Irrigation, and Industry

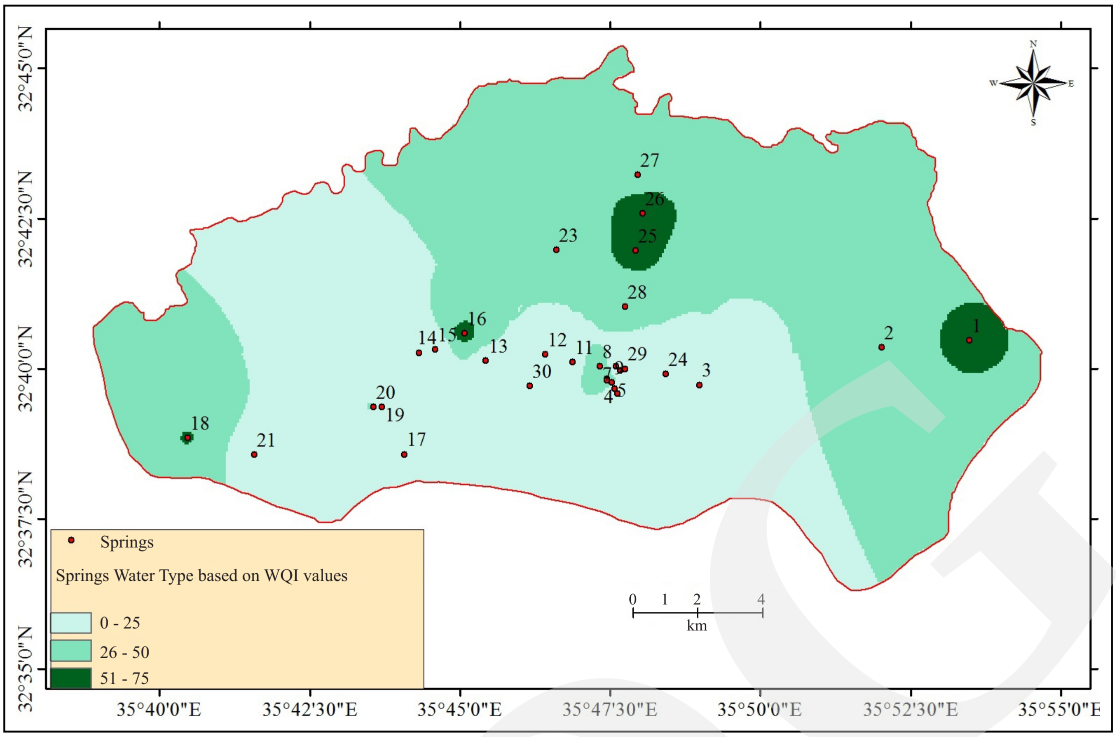


Figure 7. Spatial distribution of spring water type based on WQI values.

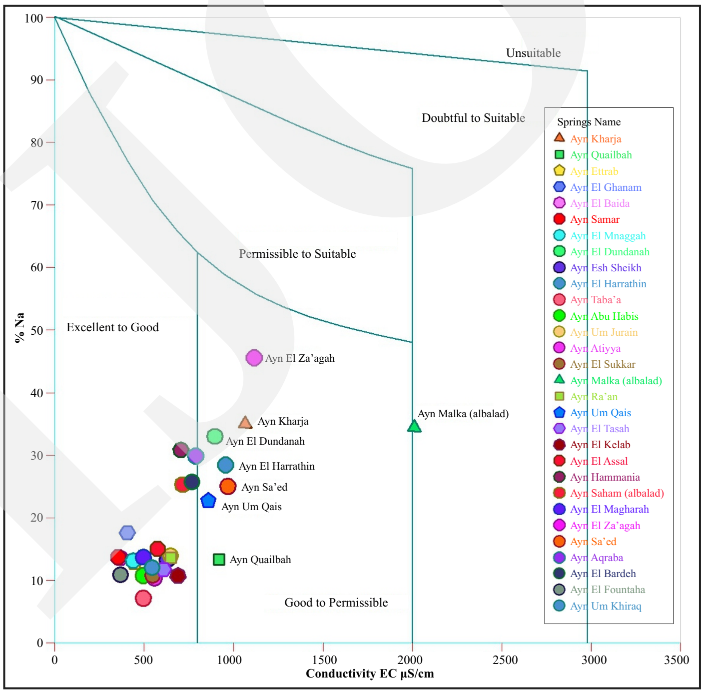


Figure 8. Wilcox classification of spring water quality for irrigation use.

the category of good to permissible, whereas one spring (Ayn Malka albalad) falls at the boundary between good to permissible and doubtful to suitable for irrigation.

Conclusions and Recommendations

Spring water in Bani Kinanah District, N.W. Jordan, is a significant source of water for local communities, either for drinking or irrigation purpose. A total of thirty spring water have been assessed for various water quality indicators. The vast majority of springs exhibit excellent to good water quality, and fall within the ranges listed for drinking water based on Jordan standards, with the exception of a few springs. The primary factor governing the water chemistry appears to be weathering of rocks, and low levels of heavy metals have been observed. Based on Water Quality Index (WQI) values, it was found that twenty-six springs are suitable for drinking, while only four springs (Kharja, Malka, EL Za'agah, and Sa'ed springs) are designated for irrigation and industrial usage.

Protecting spring water from pollutants is the responsibility of local community, because the local population is ultimately affected by spring water pollution. Therefore, raising awareness among local community members is the first step in preserving spring water resources. Taking some actions such as building cement basins around the springs is another important step to prevent human, agricultural, and animal pollutant arrival to the springs.

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