Journal of Namibian Studies, 34 S1(2023): 1290-1311 ISSN: 2197-5523 (online)

Modeling The Indexes Of Chemical Weathering In Chwarta Region At Sulaymaniyah: An Empirical Study

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Abstract:

The aim of the current research is to investigate the chemical weathering indexes in Chwarta region at Sulaymaniyah. Chwarta area is (2091) km^2. The study also aims at illustrating the features of weathering processes by adopting particular models and indexes through employing modern technologies resulting from converting their data into database. The study was illustrated according to five indexes that vary in results up to the final classification of the severity of weathering based on these indexes. One of the most crucial applied geomorphological features of wetlands, the study area, is the study of weathering processes. The interrelationship among various processes resulting from the preparation of the weathering of the rock fragments and their displacement by erosion led to several geomorphological forms that are exposed to constant erosion by wind and water, which expose them to continuous erosion by removing the weak parts. This study is concerned with analyzing weathering and erosion processes and their environmental impacts in the study area.

Keywords: modeling, indexes, chemical weathering, Chwarta.

Introduction:

Applied geographic studies are essential, where some of them are related to modeling the geomorphological processes. They reach precise numerical results compared to descriptive studies in the light of information revolution and geographical techniques. Such studies must be paid more attention. The chemical weathering represents the second branch of weathering, which is increasingly prevail in wet areas, including Chwarta region, which represents the downtown of Sharbazhir district. The remote sensing data was adopted in order to demonstrate the chemical weathering processes and their impact on the formation of landforms. Therefore, we note that Chwarta region is one of the high-altitude areas that affect the geomorphological processes and the environment through soil creep, slip and rock fall, which leads to the destruction of agricultural areas, blocking roads and sabotaging tourist areas. Therefore, the area was studied through field investigation, analysis, and using Arc GIS techniques. This study has come up with detailed results of the effect of chemical weathering in Chwarta.

The problem:

The main problem is represented in the following questions (Do modern digital technologies have a role in detecting weathering? To what extent it is possible to predict the construction of various models based on indexes?)

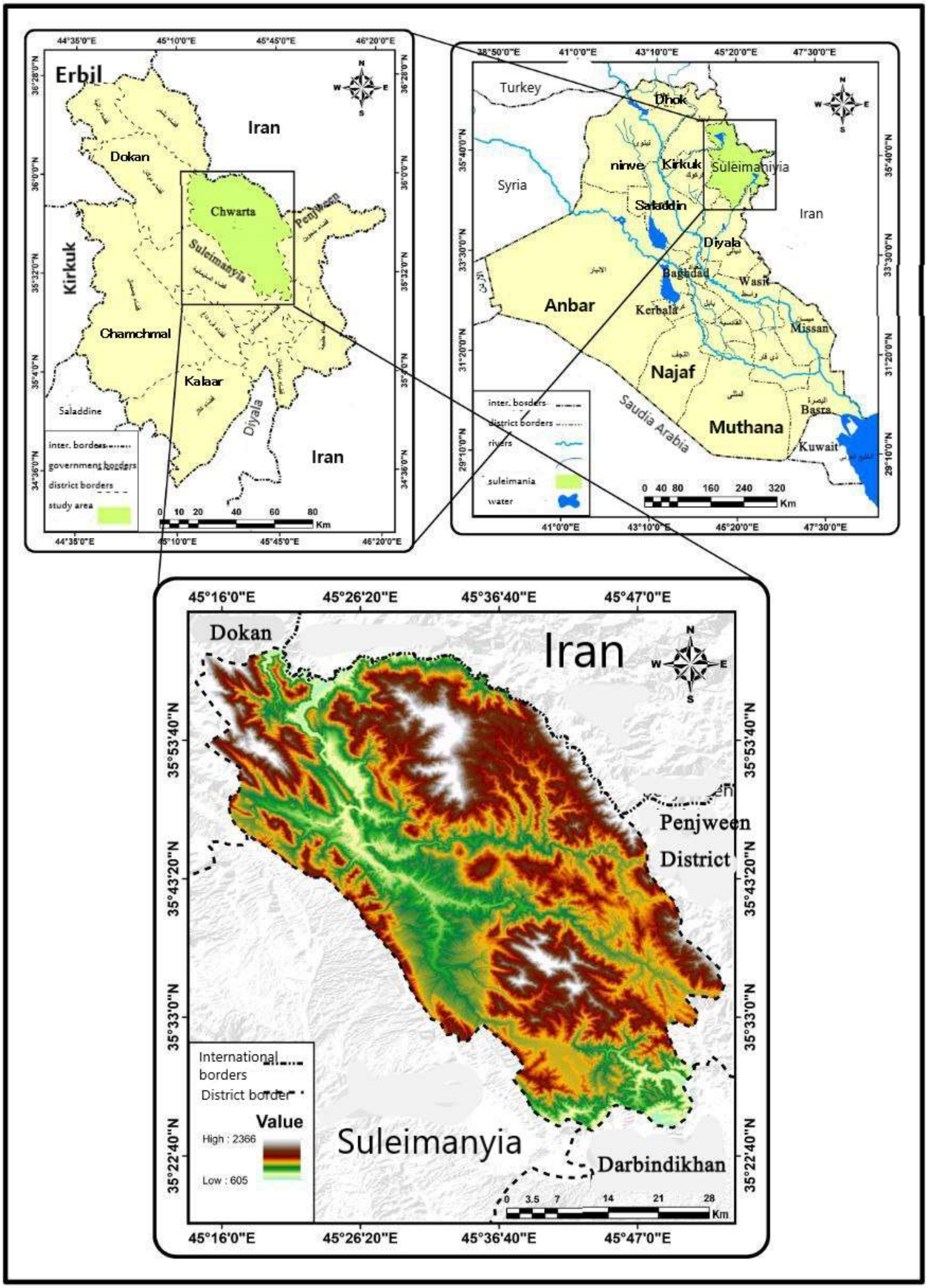
The hypothesis:

The hypothesis is (digital regions can be built for analysis and the variation of chemical weathering distribution by using modern digital technologies. There are geomorphological indexes for weathering represented by -WIP-V-CIA-CIW)

The location of study area:

The study area is located in the northeastern part of Iraq in Sulaymaniyah, among latitudes (35.24-36.03) north and longitudes (45.52-45.23) east. Iranian borders form its northeastern boundary; Bachdar district, its northwesterly border; Halabja district, its southeasterly border, and Sulaymaniyah City Center, its western border, with an area of 188,2122 km2 and a perimeter of 195.74 km. See map (1).

Map (1) the location of the study area in Iraq and Sulaymaniyah


Erbil
Iran
Dokan
Chwarta
Penjween
Suleimanyia
Kirkuk
Chamchmal
Kalaar
Diyala
Saladdine
Iran
inter. borders
government borders
district borders
study area
Turkey
Dhok
Syria
nirwe
Kirkuk
Suleimaniyia
Saladdin
Iran
Diyala
Bagdad
Wasit
Anbar
Kerbala
Missan
Najaf
Saudia Arabia
Muthana
Basra
Kuwait
inter. borders
district borders
rivers
suleimania
water
Dokan
Iran
Penjween
District
International borders
District border
Value
High : 2366
Low : 605
Suleimanyia
Darbindikhan

Weathering:

Weathering means that whereby rocks are fragmented and decomposed on or nearby the earth's surface due to weather factors prevailing in the atmosphere and water that affect the study area. However, the activity of weathering processes compared to the entire earth is a very limited field, because the effect of external weathering processes reaches up to the extent of the exposed surfaces of the rock.

Chemical weathering:

It is the chemical reactions that lead to the chemical decomposition and subsequent change in the mineral composition of the rock as a result of the influence of some active natural factors. These factors are always associated with water, where oxygen, carbon dioxide and water vapor are biologically among the most important components of the atmosphere. Water vapor is considered one of the most main factors because it directly affects the process of hydrolysis and hydration, and because it indirectly affects the completion of chemical reactions in the oxidation process and carbonization. See image (1)

Image taken on 3/23/2023

It is possible to distinguish between the following processes by which chemical weathering of rocks occurs:

A- Oxidation:

It is the addition of more oxygen to the composition of ferrous minerals that are found in levels above the ground water level. For instance, what happens to clay sedimentary rocks that are characterized by their blue or gray color because they contain ferrous components as long as they are isolated from air. When exposed to the atmosphere, its iron components oxidize and turn red or brown (1). This phenomenon is clear in the study area on the western side in the district of Siwayli because it occurs in clay rocks. These are found in zonal structure, the levels of which are brown while the lower layers are bluish-grey.

2- Solution:

Halite (the table salt) is the most soluble mineral in water, which is a compound of sodium ions and chlorine ions. The reason for the high solubility of halite in water is that it retains a neutral electric charge. The water molecules surrounding each ion also contain poles, which means that the side of an oxygen atom has a small negative charge and the side that contains a hydrogen atom has a small positive charge. The formation of two halos causes them to disperse and the pulling force of water attracts sodium ions from the crystalline fabric of the metallic halo. Similarly, chlorine ions are also transported and diffused from the positive terminals of the two water molecules (2). This process takes place in the study area and is considered one of the usual operations, especially after the rainy season or during the rainy season.

3- Hydration:

It means that water or its vapor combines with some of the elements that make up rock minerals so that they grow. With this expansion, there is pressure acting on the rock, weakening it and breaking it. Anhydrite (calcium sulfate), one of the minerals that accepts hydration, transforms into gypsum (Gypsum) when mixed with water, (3) which increases the size and expansion of the outer shells of the rocky surfaces, while the size of the inner masses remains constant. The outer membranes is separating in the form of crusts, which is observed in the fields of the study area in the clay rocks due to the minerals that make up the rocks expanded with water. They increase in size during the rainy season when the area becomes wet. It promotes chemical weathering processes in very shaded areas, due to its high moisture content. Therefore, the role of chemical weathering plays a role in.

4- Carbonation:

This means that water vapor and carbon dioxide affect the elements of potassium and calcium, which form the minerals of igneous rocks, and leads to the formation of large carbon crystals of carbons that differ in their shape from the original rock mineral. The formation of these crystals necessarily weakens the crystalline or mineral structure of the rocks making them vulnerable to weathering and removal. The effects of this process are not limited to igneous rocks, but can affect all rocks (Al-Shanawi, 1992).

5- Organic weathering or organic activity:

Some organisms have a significant impact on the decomposition of rock particles, the openings in rocks, and even their geological number. The effect of these organisms is either physical or chemical. This weathering is represented by aspects, including:

Weathering related indexes:

The intensity of weathering is reflected in the degree to which the mobile components of soil and river sediments are beneficial compared to the immobile components. Weathering indexes, especially chemical ones, are used to find fossils and marine sediments and to monitor changes in river composition and properties to assess soil fertility and development. It reflects the climatic influences on the weathering of the parent rocks, and describes the shifts associated with modern tectonics in the context of environmental monitoring. The researchers explained a set of indexes related to weathering, which can be described as follows:

1- Parker index (WIP)

WIP index Mode is an acronym for Weathering Index Parker.

WIP index was proposed by Parker in 1970, it includes degradation of elements (sodium, potassium, magnesium and calcium) during the weathering process, according to experts. It is considered the most appropriate index for assessing the water weathering of rocks, as the index is extracted according to the equation developed by Parker

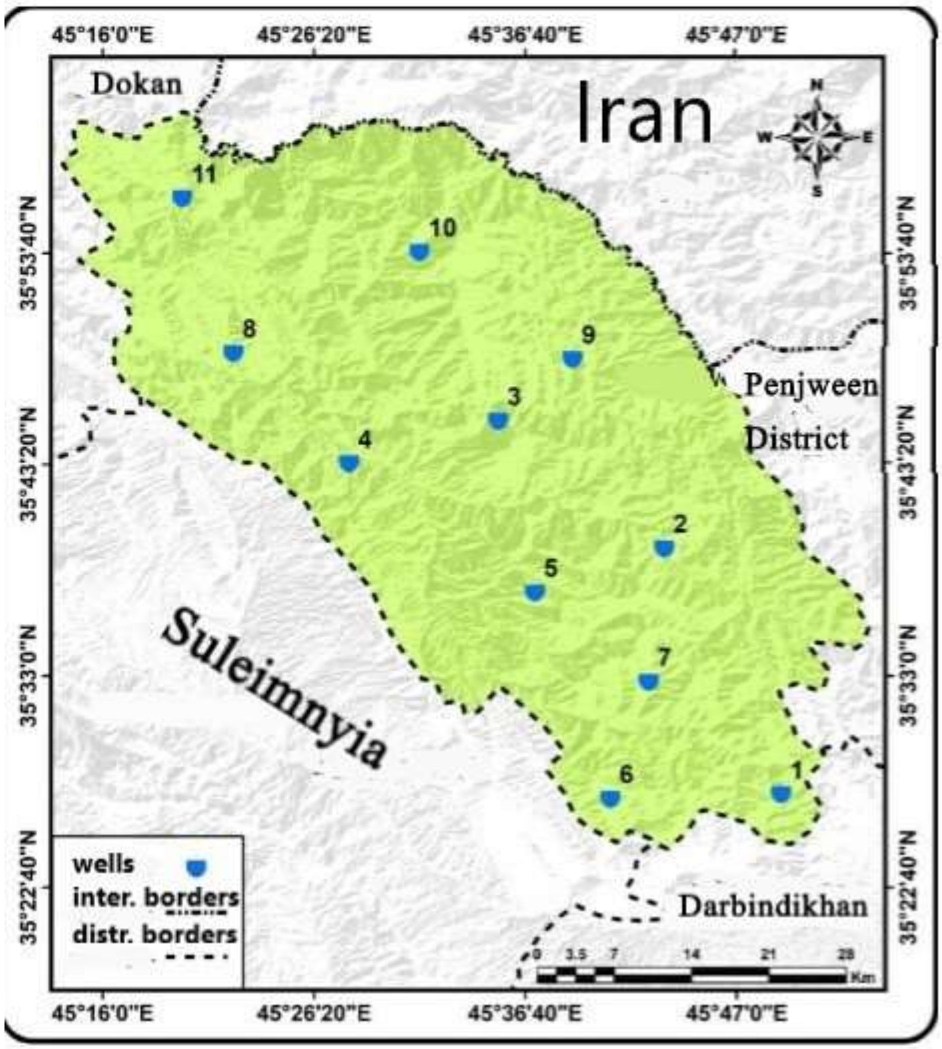
$$\mathrm{WIP} = \left(\frac{2\mathrm{Na2O}}{0.35} + \frac{\mathrm{MgO}}{0.9} + \frac{2\ \mathrm{K2O}}{0.25} + \frac{\mathrm{Cao}}{0.7} \right) \times 100$$

where:

- = Parker WIP index
- = sodium oxide Na2O
- = magnesium oxide, MgO
- = potassium oxide K2O
- Cao = calcium oxide

Data for these elements were obtained by analyzing well water from the study area. Furthermore, the measurements of (11) wells were obtained only for the records that contain measurements of these elements, but they are distributed in all geological formations in the region. Map (1)

Map (1) the geographical distribution of the wells that contain the required elements in the study area



Source: The map was made by the researcher, depending on the Ministry of Water Resources, the National Center for Water Resources Management. Well distribution maps, scale 1:1,000,000, Baghdad 2023, by using the program (Arc GIS 10.4).

Table (1) shows values for the elements mentioned in the wells numbered from the north to the south of the region. The variation can be seen in the values of calcium oxide, as it reached (12.1-64).

Table (1) Elements studied in well water

Wells	Calcium oxide	Magnesium oxide	Weathering oxide chlorides	Sulfate oxide	Sodium oxide	Potassium oxide	Aluminum oxide	Final classification of weathering
1	76	24	12.2	123	2.3	1.1	0.8	34.2
2	16.5	19	12.6	55	76	2.1	27.5	29.8
3	24	28.5	15.4	47	19.9	0.8	9.0	20.7
4	26	28	11.3	35.2	5.4	1.3	9.6	16.7
5	64	19.4	14.1	15.2	12.3	0.7	15.7	20.2
6	48	29	39	104	53	2.3	12.5	41.1
7	14.7	41.8	40.2	15	154	5.2	13.5	40.6
8	40	29	60.2	20.1	16.8	1.4	12.1	25.7
9	13.2	15	9.4	13.2	4.5	0.7	0.1	8.0
10	12.1	13	8.5	12.1	9.1	1.3	0.4	8.1
11	14.1	14	7.5	10.5	5.1	0.4	2.1	7.7

Source: The table was made by the researcher, depending on the Ministry of Water Resources, National Center for Water Resources Management, Department of Groundwater, (unpublished data) Baghdad, 2023

Through applying the equations for weathering indexes, and based on Table (1), the results of applying the equations in Table (2) are clear, with a clear discrepancy between one index and another.

Table (2) Approved indexes application values

Well No.	WIP	V	CIA	CIW	PIA
1	**15718.1**	**0.02**	**1.00**	**1.01**	**1.00**

2	**49576.8**	**0.27**	**22.52**	**22.92**	**22.52**
3	**18606.7**	**0.14**	**16.76**	**17.01**	**16.76**
4	**10951.1**	**0.18**	**22.70**	**23.41**	**22.70**
5	**18887.0**	**0.17**	**16.94**	**17.07**	**16.94**
6	**42205.1**	**0.11**	**10.79**	**11.01**	**10.79**
7	**349455.2**	**0.01**	**0.82**	**0.82**	**0.82**
8	**19656.5**	**0.16**	**17.21**	**17.56**	**17.21**
9	**6683.8**	**0.02**	**0.54**	**0.56**	**0.54**
10	**9413.0**	**0.05**	**1.75**	**1.85**	**1.75**
11	**6804.1**	**0.08**	**9.68**	**9.86**	**9.68**

Source: The table was made by the researcher, depending on the table No (1).

It becomes clear through map (2) that the distribution of WIP index is within the study area and the least values were within the southern parts of the study area by (6683,8-18635,7). As for the highest values, they were in the northern and northeastern parts with values (205848,8-349455,2). Thus, the study area was divided into three categories:

1- Low weathering category:

The levels of the weathering index appear to be the lowest in the southern parts within the study area, as they lie between (6683.8-44886.2) as the lowest and highest limits, with an area of (1415 km2) and a rate of (67.10%).

2- Medium weathering category:-

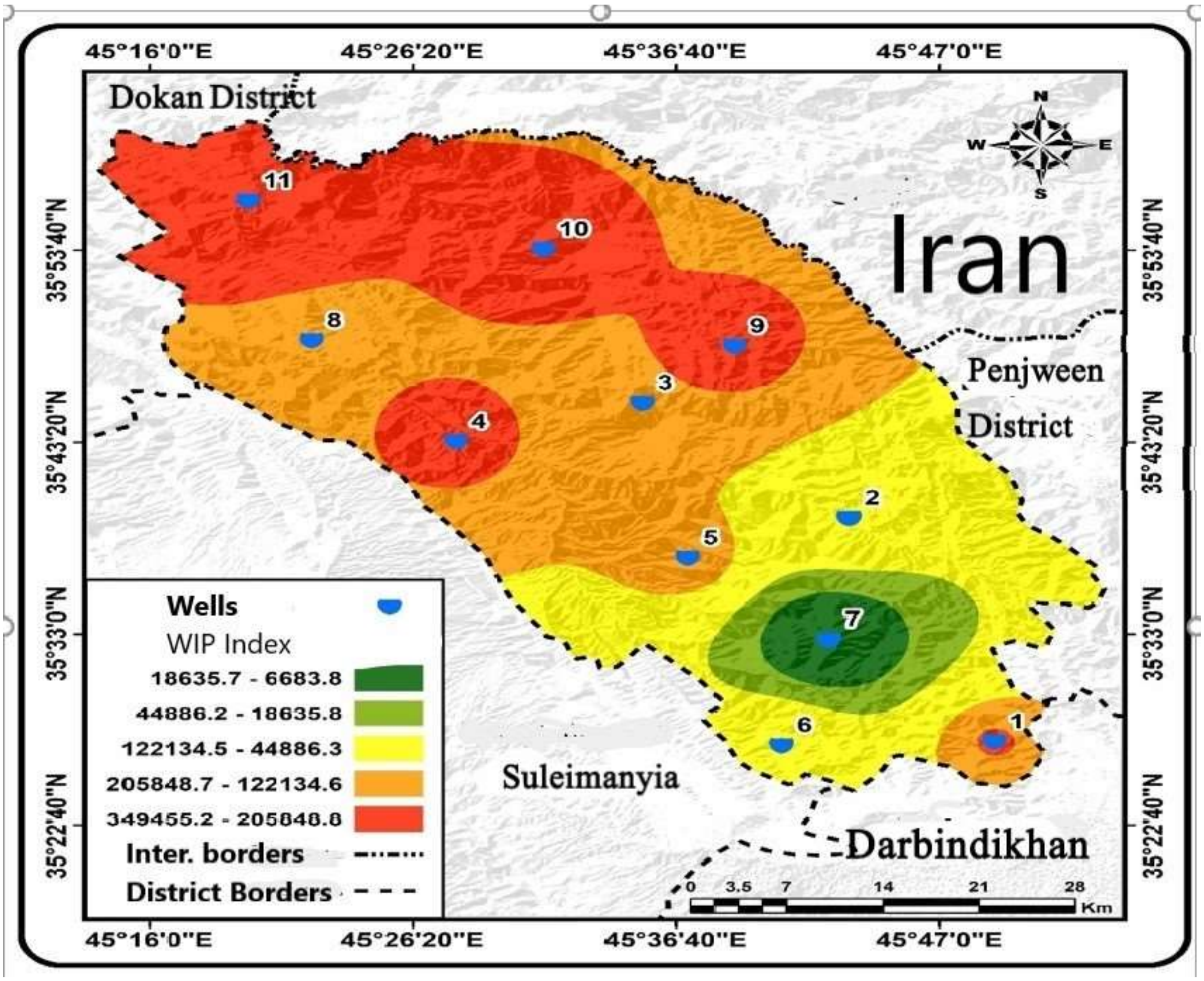
It shows the weathering index levels with average values for the weathering levels, and it extends clearly in the study area from the northern parts to the southern ones, with an amount of (18635.8-

122134.5) as the lowest and highest limits, and with an area of (629 km2) and a rate of (29.80%).

3- High weathering category:

Here, there is a clear effect of weathering levels and their distribution in the northern and northeastern parts, and a small part in the western parts and in the south, with an amount of (205848.8-349455.2) with an area of (65 km2) and a rate of (3.10%).

Map (2) Distribution of (WIP) index Levels



Source: The map was made by the researcher, depending on Table (2) and by using the program (Arc GIS 10.4)

Table (3): (WIP) Index Categories Classification, area by km² and the percentages %

WIP index	Main categories	Area Km2	Percentage%
High weathering	18635.7-6683.8 44886.2-18635.8	1415	67.10
Medium weathering	122134.5-44886.3 205848.7-122134.6	629	29.80
Weak weathering	349455.2-205848.8	65	3.10
Total		2109	100

Source: Map (2)

2- (V) Vogt's Index:

One of the most important indexes used to diagnose weathering over time (V). is an index. (Vogt's Residual 1972) is the results of many studies that have been completed, but the aforementioned WIP is added in the index. The index is based on the proportion of elements and is an attempt to determine the weathering maturity of the clay by the residual ($Al2O3$) oxide sediment. Higher values indicate increased weathering intensity. To apply this index the following equation is used

$$\mathbf{V} = \frac{\mathbf{Al2O+K2O}}{\mathbf{MgO+Cao+Na2O}}$$

where:

V = Vugest index

Al2O3 = aluminum oxide

According to the results obtained by applying this index, there are differences between wells, which range from (0.27 to 0.01) and these are the highest values recorded from other wells of the region, which ranged from (0.27) to (0.01). It can be seen from the map (3) that the distribution of the lowest values index values were in the southern sections within the study area as (0.01-0.03) while the highest values are distributed in the northern and northeastern sections and part of the southern sections with values as (0.18 0.27). Thus, the study area was divided into three categories:

1- Low weathering category:

The levels of the weathering index appear to be the lowest in the northern and central parts of the study area, as they lie between (0.01-

0.06) as the highest and lowest levels, at a distance of (192 km2) and at a rate of (9.10%).

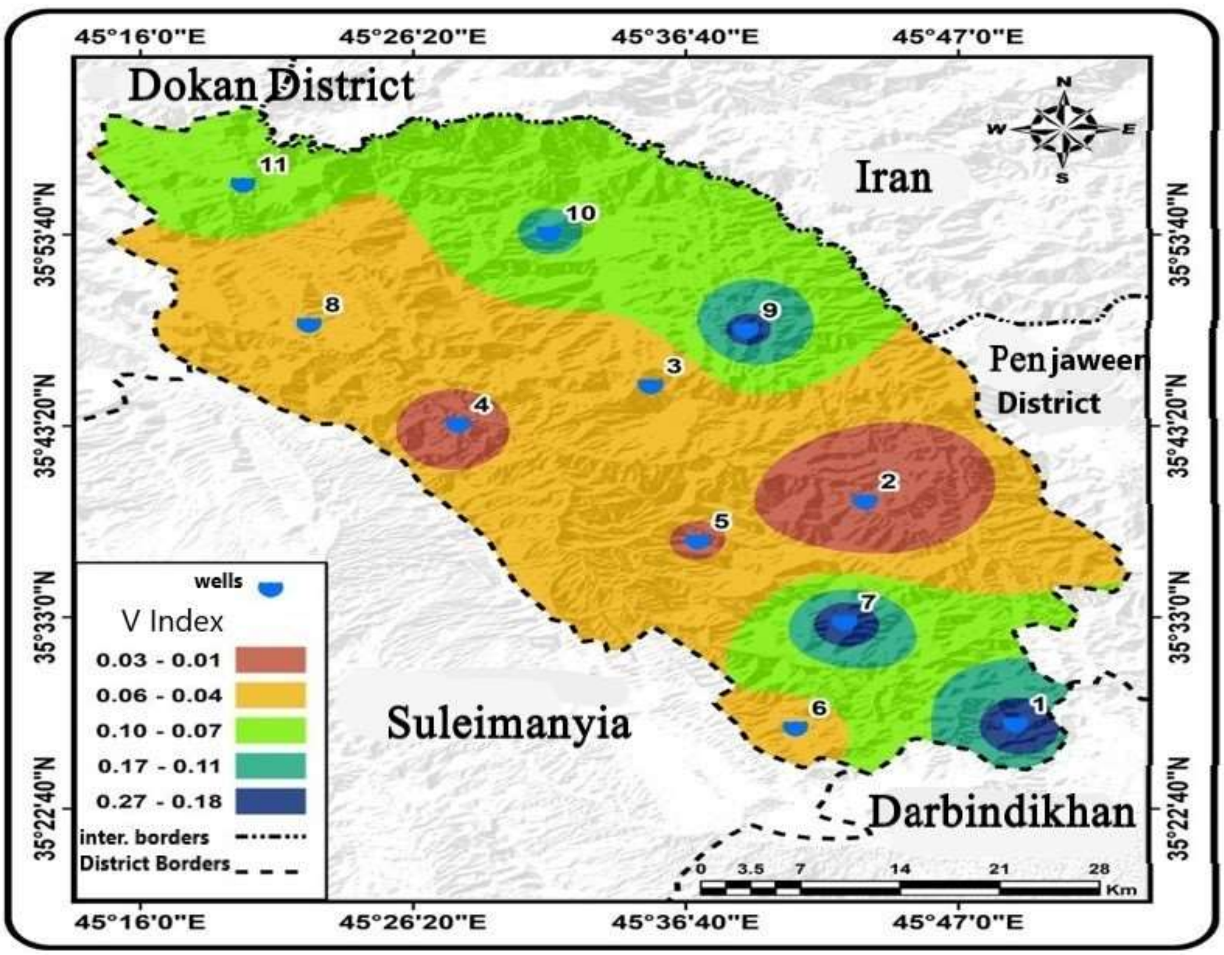
2- Medium weathering category:

It shows the weathering index levels with average values of the weathering levels, and it extends clearly from the study area from the northern sections and the southern parts, with an amount of (0.07 - 0.17) as the lowest and highest limits, and a distance of (1749 km2) with a rate of (82.90%).

3- High weathering category:

The effect is clear for weathering levels and their distribution in the northern, northern, and northeastern sections, and some parts of the western and southern regions, by (0.18-0.27), at a distance of (168 km2), and by (7.9%).

Map (3) Distribution of weathering levels according to (V) index



Source: The map was made by the researcher, depending on Table (2) and by using (Arc GIS 10.4)

Table (4) Classification of index categories (V), area km2, and percentages.

V index values	Main categories	Area Km2	Percentage%
High weathering	0.03-0.01 0.06-0.04	168	**7.9**
Medium weathering	0.10-0.07 0.17-0.11	1749	**82.90**
Weak weathering	0.27-0.18	192	**9.10**
Total		2109	**100**

Source: The table was made by the researcher, depending on map (3)

3- (CIA Index):

(CIA) is the acronym of Chemical Index of Alteration. (Nesbit and Young 1982). It is the result of investigations developed by this index and it is the most used means for finding river sediments. It reflects the silica weathering intensity values from the lowest to the highest watercourse, analyzing the total nominal value of chemical weathering and previous physical weathering conditions. It often shows fixed proportions of aluminum oxide to the moving proportions of it. The distribution of the CIA values varies within the study area. It is clear from map (4) that the lowest values were in the central parts of the study area, reaching (0.54-6.06). As for the highest values, they are distributed in the northern and northeastern regions, and part of the southern regions, with values (20.06-22.70). Thus, the study area was divided into three categories:

1- Low weathering category:

The levels of the weathering index appear to be the lowest in the eastern and western central sections within the study area, as they lie between (0.54-11.62) as the lowest and highest limits, in an area of (66 km2), with a rate of (3.10%).

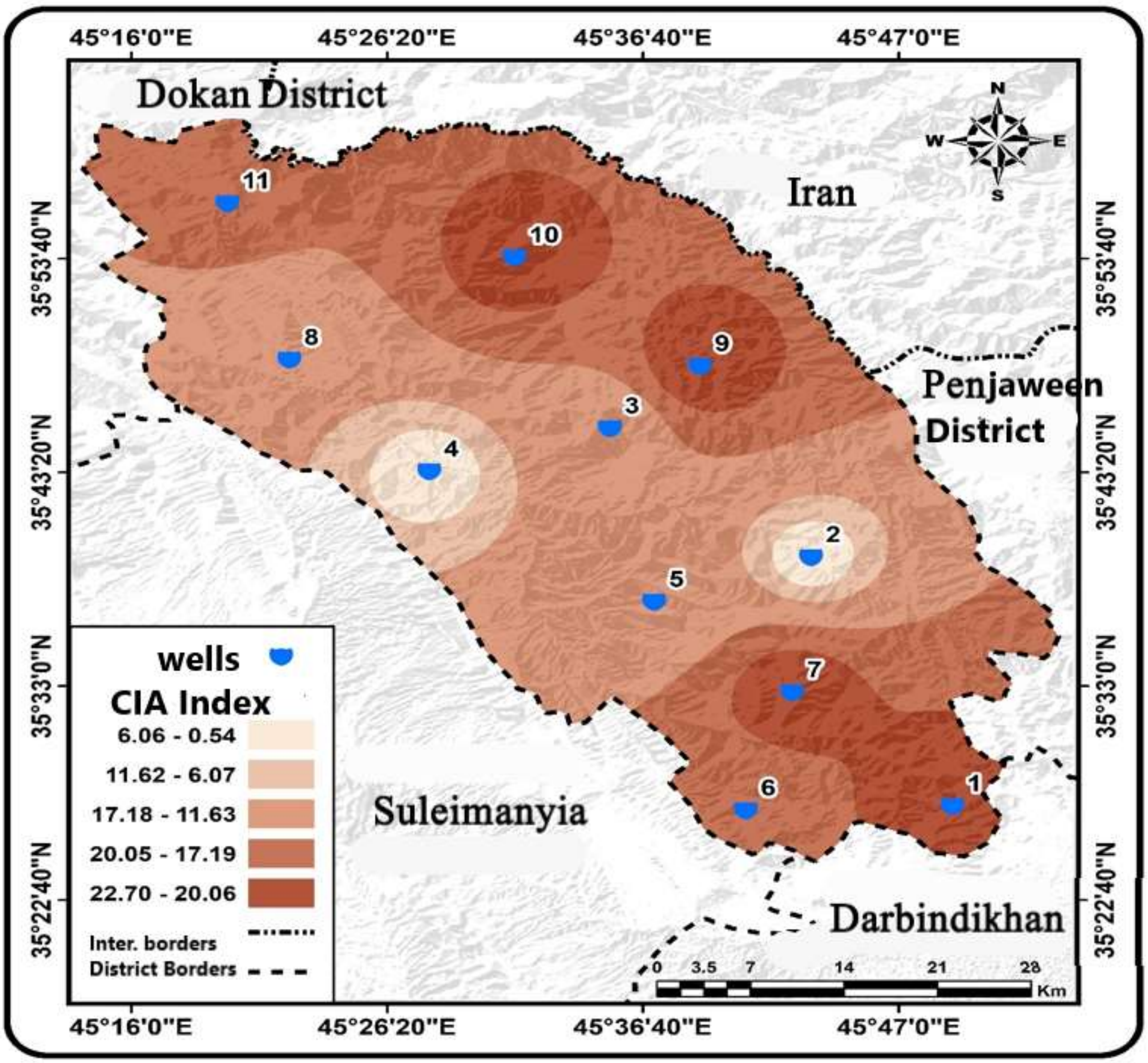
2- Medium weathering category:

It shows the levels of the weathering index with average values of weathering levels, and it extends clearly in the northern parts to the southern parts, with an amount of (11.63 - 20.05) as the lowest and highest limits, and in an area of (948 km 2), with a rate of (44.90%).

3- High weathering category:

Here, the clear effect of weathering levels and their distribution in the northern and northeastern sections and part of the southern parts appears by (20.06 - 22.70) and with an area of (1095 km2) at a rate of (51.90%).

Map (4) Distribution of weathering levels according to the CIA index



Source: The map was made by the researcher, depending on Table (2) and by using (Arc GIS 10.4)

Table (5): Classification of the CIA index categories, area km2, and percentages.

CIA index values	Main categories	Area Km2	Percentage%
High weathering	6.06-0.54 11.62-6.07	1095	**51.90%**
Medium weathering	17.18-11.63 20.05-17.19	948	**44.90%**
Weak weathering	22.70-20.06	66	**3.10%**
Total		2109	**100**

Source: The table was made by the researcher, depending on Map (4)

4- Index (CIW):

(CIW) is an abbreviation for (Chemical Index of Weathering). The high values indicate the rocks rich with alminuim oxide, calcium oxide, and potassium oxide). This index was developed by Harnois in 1988. It adopts (CIA) index values and excludes the (KO) index which is similar to the following equation (2): (CIW)

$$\text{CIW}=\frac{\text{AL 2O3}}{\text{AL2O3+Cao+Na2O}}\times 100$$

where:

= Chemical Index of Weathering (CIW).

= aluminum oxide Al2O

= calcium oxide, Cao

= sodium oxide Na2o

The results of applying the (CIW) index showed that there were variations in weathering levels. The highest values were within the water well No.4 by (23,41), whereas the lowest values were wells No. (9) as well as (2) by (22.92) and (0.56). Map (5) shows the distributions of solubility levels, which were divided into five levels ranging from (0.54-22.70) as the lowest and highest limits.

It is clear from map (5) that the distribution of the (CIW) index varies within the study area. It is noted that the lowest values were in the middle sections within the study area, reaching (0.56-1.60). As for the highest values, they are distributed in the northern, northeastern, and some southern parts, with values (17.14-23.41). Thus, the study area was divided into three categories:

1- Low weathering category:

It is noted that the levels of the weathering index are lowest in the central and southern parts of the study area, as they lie between (0.56-3.74) as the lowest and highest limits, with an area of (241) and a rate of (11.40%).

2- medium weathering category:

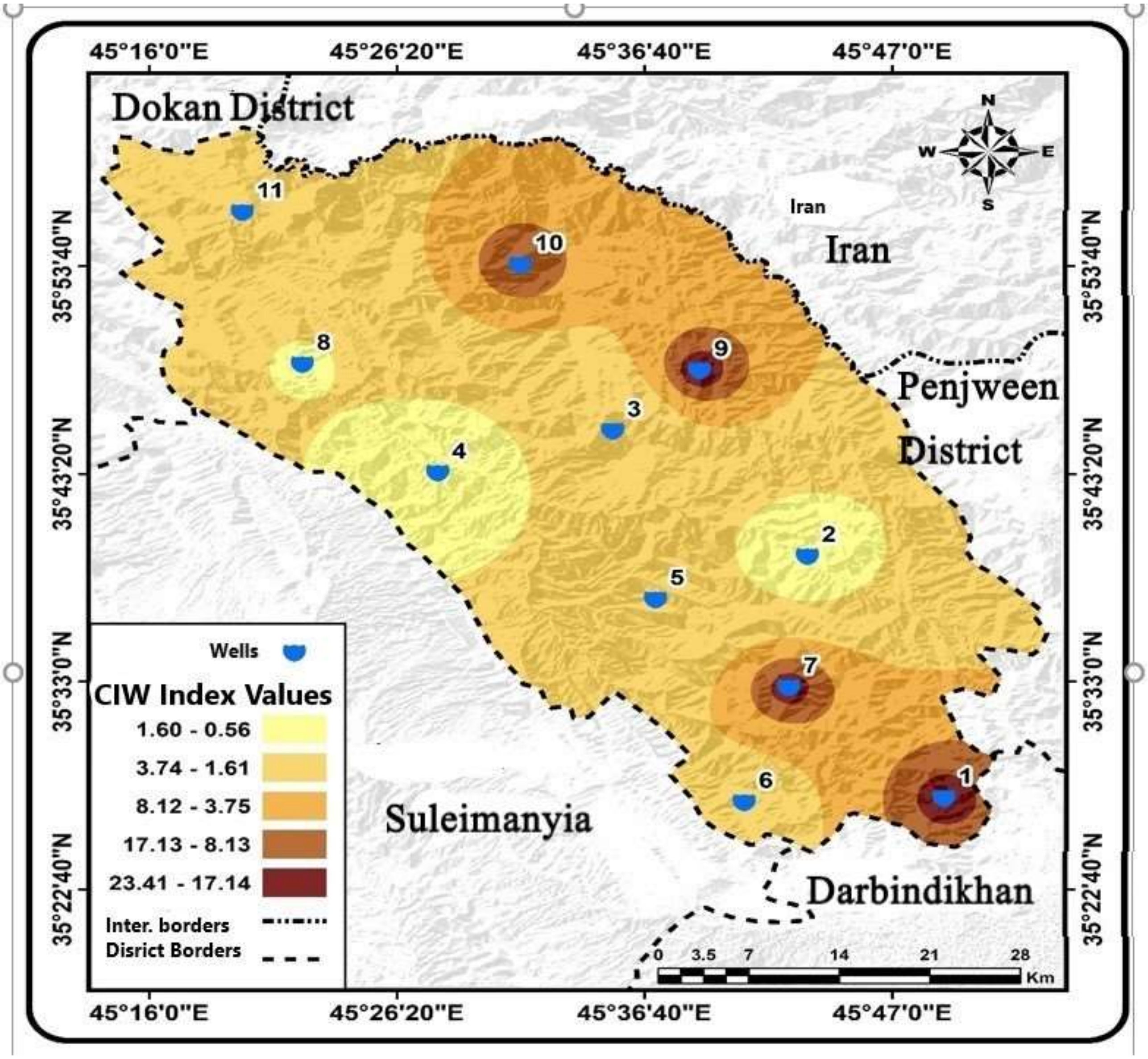
It shows the levels of the weathering index with average values for the levels of weathering, and it appears clearly in the northeastern and southern parts with an amount of (3.75-17.13).

as the lowest and highest limits, with an area of (1733), with a rate of (82.20%).

3- High weathering category:

Here, a clear effect of weathering levels and their distribution appears in the northeastern and central parts and a small part of the south with an amount of (17.14 -23.41) and an area of (135) with a rate of (6.40%).

Map (5) Distribution of weathering levels according to the (CIW) index



Source: The map was made by the researcher, depending on Table (2) by using (Arc GIS 10.4)

Table (6): Classification of index categories (CIW), area (km 2), and percentages (%).

CIW index values	Main categories	Area Km2	Percentage%
High weathering	6.06-0.54 11.62-6.07	135	**6.40%**
Medium weathering	17.18-11.63 20.05-17.19	1733	**82.20%**
Weak weathering	22.70-20.06	241	**11.40%**
Total		2109	**100**

Source: The table was made by the researcher, depending on Map (5)

5- (PIA) index

The Plagioclase Index of Alteration was proposed by (Fedo et al) in (1995) as an alternative to the index (CIW). The values of this index reach about (50) for rocks that are not exposed to chemical weathering factors to a large extent nearly (100) for clay minerals such as (kaolinite and illite). It can be extracted according to the following equation:

$$PIA = \frac{AL2O3 - K2O}{AL2O3 + Cao + Na2O + K2O} \times 100$$

where:
(Fedo) Index = PIA
= aluminum oxide, AL2O3
= potassium oxide K2O
= calcium oxide, Cao
= sodium oxide Na2O

When applying this index, it was noticed that there were different values, as this index was divided into five levels. It is clear from (Map 6) that the distribution of the (PIA) index values was within the study area, where it was noted that the lowest values were in the southern sections within the study area, reaching (0.54 -6.06). As for the highest values, they are distributed in the northern, northeastern, and part of the northwestern sections, with values (20.06-22.70). Thus, the study area was divided into three categories:

1- Low weathering category:

The levels of the weathering index appear to be the lowest in the central, western, eastern, and southern parts of the study area, as they lie between (0.54-11.62) as the highest and lowest, with an area of (66) and at a rate of (3.10%).

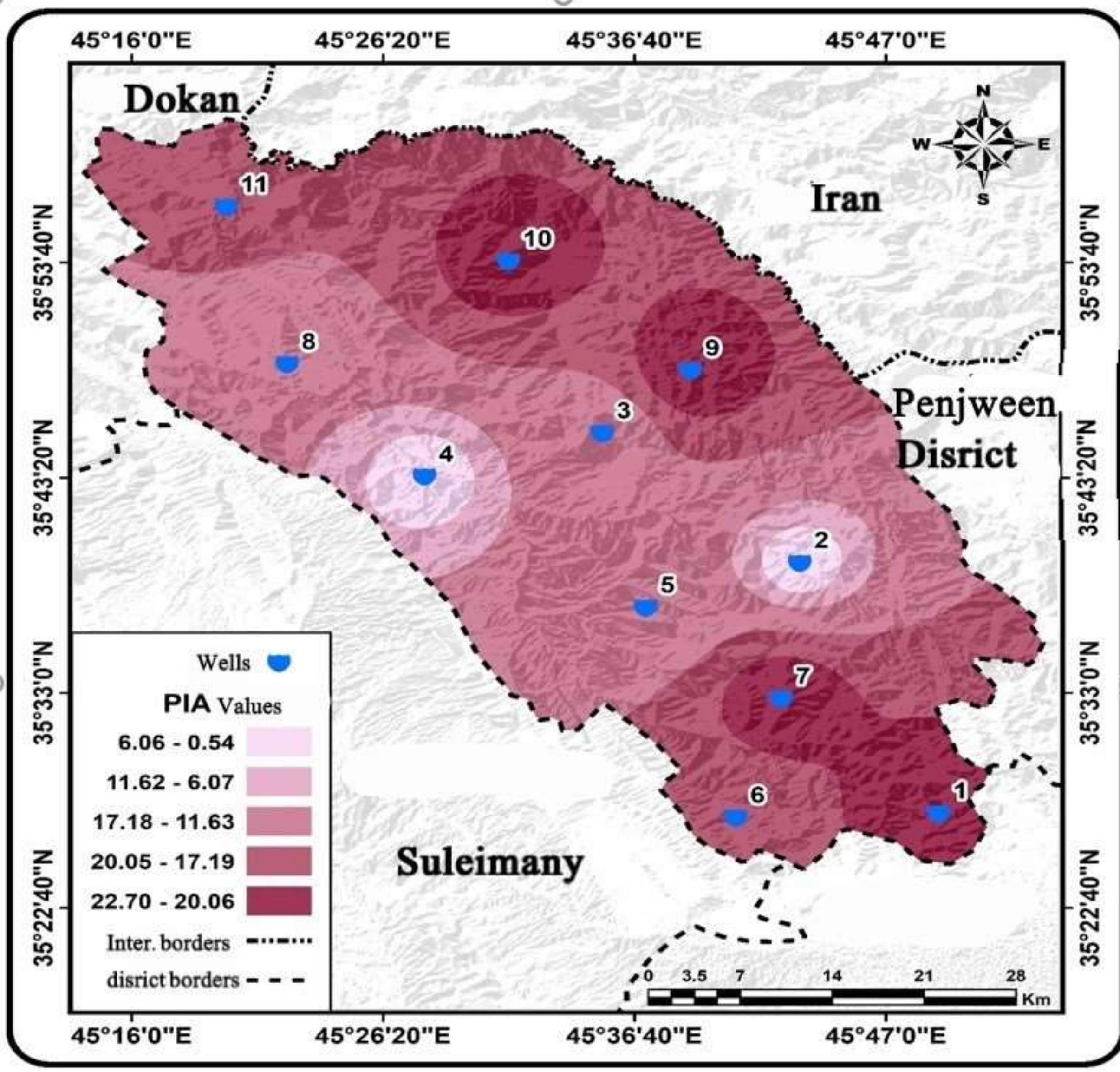
2- Medium weathering category:

The levels of the weathering index appear with average values of weathering levels, and they extend clearly within the study area from the northern sections to the southern sections, with an amount of (11.63 - 20.05) as the lowest and highest limits, and with an area occupying (948) and with a rate of (44.90%).

3- High weathering category:

Here, the influence is clear in the northeastern sections and part of the southern sections, with an amount of (20.06-22.70) and an area of (1095), with a rate of (51.90%).

Map (6) Distribution of weathering levels according to the (PIA) index



Source: The map was made by the researcher, depending on Table (2) and by using the program (Arc GIS 10.4)

Table (7) Classification of index categories (PIA), area km2, and percentages.

PIA index values	Main categories	Area Km2	Percentage%
High weathering	6.06-0.54	1095	**51.90%**
Medium weathering	11.62-6.07	948	**44.90%**

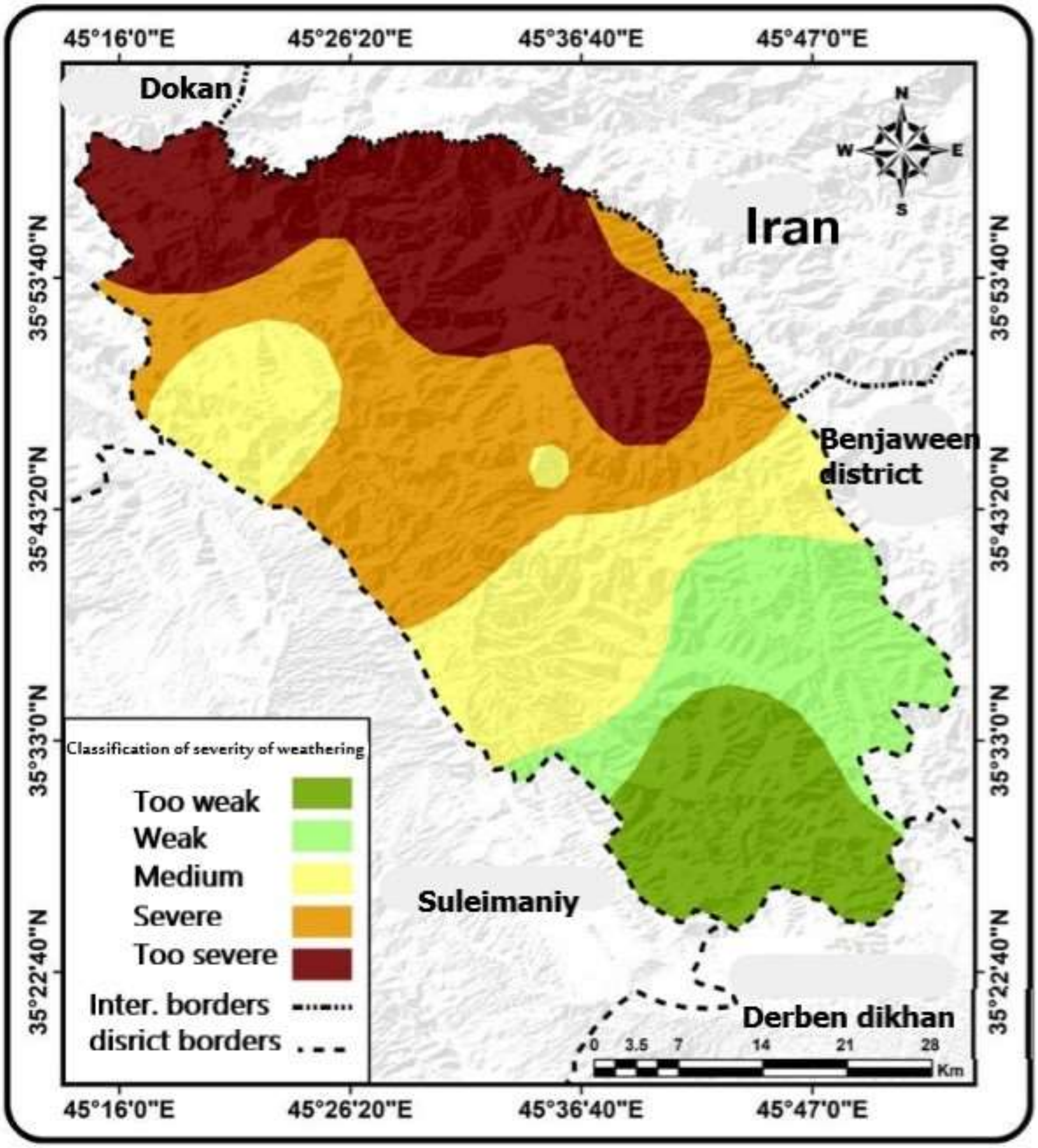
Weak weathering	17.18-11.63	66	**3.10%**
Total		2109	**100**

Source: The table was made by the researcher, depending on map (6)

6- The final classification of weathering indexes

This classification is the final result of all indexes, as the region was divided into five relied upon categories, which begin with very severe weathering, which is concentrated in the northern and northeastern regions. It occupies an area of (273 km2) with a rate of (12.9%). Severe weathering occupies an area of (286 km2), with a rate of (13.6%). Medium weathering with an area of (474 km2) at a rate of (22.5%), which was represented in the central parts. Weak weathering was within an area of (547 km2) with a rate of (25.9%) concentrated in the southeastern regions and part of the southwest. Finally, very weak weathering, which occupied an area of (529 km2), amounted to (25.1%), and was represented in the southwestern part of the region.

Map (7) Classification map of severity of weathering degrees



Source: The map was made by the researcher depending on Table (2) and using Arc GIS 10.4)

Table (8) final classification of weathering indexes

Grade	kM^2	%
Too weak weathering	529	%25.1
Weak weathering	547	%25.9
Medium weathering	474	%22.5

High weathering	**286**	**%13.6**
Too High weathering	**273**	**%12.9**
Total	**2109**	**%100.0**

Source: The table was made by the researcher depending on the map

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