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Investigating the Role of Faults in the Establishment and Survival of Settlements using Remote Sensing and Geographic Information System (GIS). The Case of Sahneh County in Iran

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A B S T R A C T

Accessibility of water resources is often one of the prerequisites for a residency to be established and survive over time. As water transfer from remote areas was almost impossible until few centuries ago, water supply was more important in the past, when life would have been fully interrupted and settlements evacuated in case of drought. On the one hand, many studies indicate that faults play a major role in the location of springs outflow; on the other hand, the fault structure specifies the rivers' path in many cases. This study aimed to investigate the role of fault in the establishment and survival of human settlements in Sahneh County, Iran. Firstly, the correlation between the springs-rivers distribution and the location of faults in the area was calculated. Then, a correlation analysis was run between the springs with fault origin and rivers influenced by tectonic structures, on the one hand, and the distribution of settlements in the area on the other hand. The results show that 72.5% of the springs are located in the fault zone; Darband and Dinavar rivers also follow tectonic structures. The final results indicate that the faults have had primary contribution to the formation of 26.1% of the settlements.

1. INTRODUCTION

The most important and undeniable factor for the formation and survival of a settlement is the existence of water resources for drinking and cultivation. This issue becomes more important in arid and semi-arid areas. The pattern of hydrographic network, the fertility of available soil, and some other factors have obviously influenced the status of rural settlements [1]. Water is so important in Iran that the first villages have been formed according to the availability of water and land. As stated by Mahdavi (2008) the word "Aabadi", a place with water and plant, originates from the word "Water" in Persian [2, p. 8]. A spring is formed where water table hits the earth's surface or strikes the permeable layers leading the water to the earth's surface. Various geological and geomorphologic factors may be influential in springs' occurrence [2, pp. 164-165]. According to Farid (2009) Tabriz city could not manage to avoid its northern fault, due to its plain groundwater that supplies drinking water for its citizens [3, p. 71]. It is expected that more than 2.7 billion people in the world will face serious water shortage, by 2025 if countries continue to consume water resources at the current rate [4]. Iran is located in an arid and semi-arid region of the world. The average annual rainfall is of about 250 mm in Iran, of which 50% occurs in just 21% of the whole country [5]. Regarding the access to water resources, Iran can be separated in three climatic parts:

1). The arid central part, which is mainly dependent on aqueducts;

2). The humid area in the north of Iran with permanent rivers;

3). Semi-arid mountainous areas across the country.

Water supply has been increasingly focused on over the last decades. About 4% of the whole development budget of the country was spent on water maintenance until 1979, which increased to about 10-11% by 2005 [4].

Remote sensing data is applied to identify promising areas in terms of groundwater hydrologic resources, which could be used in case of crisis [6, p. 105]. Geographical Information Systems (GIS) have become such essential tools in groundwater studies that it is inevitable to work on hydrologic issues without using them [6, p. 115]. GIS technology allows users to access hydrologic data at different levels. Users, namely managers, who intend only to observe or combine data may use web based GIS [6, p. 119]. Geology is influential both in controlling geological hazards and groundwater currents.

The major faults and fractures influence the formation and alterations of groundwater in two ways: a) *Directly*: the fractures are appropriate spots for water penetration into the ground; they can also be suitable locations for water outflows as springs. b) *Indirectly*: the major faults and fractures cause displacements in geological formations and result in formation of new aquifers. They also lead the flowing waters by altering the height, formation of alluvial fans and deposition of alluvial sediments near the mountains [7]. Studies have been done on the relationship between the fractures' surfaces and the accessibility to water resources. Abbaszadeh et al. (2013) studied the relationship between fractures and the location of springs in Gorgan region. Results showed that the springs are mostly located near the major fracture zone in the study area [8]. Kalantari et al. (2012) investigated the influence of fractures on water discharge of Chamasyab spring in the East of Khoozestan. Results showed that the concentration of fractures increases the permeability of Aghajary formation by creation of secondary porosity and played an important role in the spring's discharge amount [9]. Ahmadipour (1998) conducted a study in Alashtar region in Lorestan, and found that all Karstic springs in the region are located at the intersection of existing fractures [10]. Kazemi et al. (2006) investigated the influence of structural factors on water regimes in karstic region of Lar using remote sensing data and GIS [11]. Results of their study indicated a close relationship between the springs' abundance and their distance from tectonic elements. Khorsandi Aghaei et al. (2008) studied the relationship between water resources and faults in Lar valley located in the north of Tehran [12]. Results illustrated that 60% of the rivers were influenced by the faults, 57.5% of the springs outflowed in the Fracture zone. Ahmed (1996) used the fracture lines to explore groundwater in hard formations of Morocco's arid and semiarid areas [13]. FAO organization (2003) examined fractures to find promising areas for groundwater resources using GIS and remote sensing as part of their studies in northern Iraq [14]. Mokhtari (2005) investigated a new tectonic map in the evolution of quaternary fluvial systems on the northern slopes of Chelcheli [15]. Amirahmadi and Jomedisavand (2012) showed that 98.46% of water streams in Shah Jahan northern slope follow fault structures [16].

The high or broken Zagros area contains a large number of fractures and faults compared to the neighboring areas. Sahneh county is also located in this fractured system. The ophiolitic mass related to the closure of Neotethys Ocean due to Laramid tectonic motion approves this claim [17, p. 137].

The Sahneh fault is the middle part of the young Zagros fault. No relationship can be clearly established between the seismicity of Sahneh region and any specific fault in the area [18]. Sahneh fault has been exceptionally stretched and its direction differs up to 20 degrees from the direction of other faults in the region. It is also formed in the shape of a palm tree in the area between the faults of Nahavand and Morvarid. A devastating earthquake with a magnitude of 7 on the Richter scale has occurred on this fault on 24.04.1008 [19]. Moreover, systematic earthquakes with magnitudes of 5 to 6.5 on the Richter scale have occurred in Sahneh in the last century [20]. Last significant activities of this fault date back to the earthquakes on 24.04.2002 and 24.12.2002 with values of 5.4 and 5.2 on the Richter scale that indicate a hazardous region [19].

The current research aims to find out if there is any meaningful relationship between the faults and fractures in the region and water resources; and if the answer is positive, whether there is any adaptation between the springs created by faults and the villages, as a common pattern in Iran and other arid and semi-arid countries. If there was such relationship, it could be concluded that the faults were influential in the creation and survival of human settlements in the region.

2. THE STUDY AREA

Sahneh County is located in the East of Kermanshah Province location in longitudes ranging from 47°6'E to 47°51'E, while latitudes range from 34°19'N to 34°48'N. Its extent is of about 6.2% of the total area of Kermanshah Province. The county borders on Kermanshah city to the North, on Songhor County to the East and Northeast, on Kangavar to the Southeast, on Harsin to the West, and on Lorestan Province to the South. Sahneh city has about 85,000 inhabitants and it is geologically located in the broken Zagros zone that is highly faulted.

There are three major faults in the area called Sahneh, Dinavar and Sartakht. Historical studies on seismic activities in the region indicate that it is a hazardous region, namely proven by: the earthquake of 27th April 1008 at 7 Richter magnitude, which completely destroyed Dinavar city and more than 16,000 people were killed [21]; Farsinaj's earthquake at 6 Richter magnitude on 13th December 1957 that killed 1130 people [22]; and an earthquake at 5.4 Richter magnitude killing one person on 24th April 2002 all suggesting a hazardous area to live in. In contrast, water supply has been the most motivating factor for the ancient people to live in this area. The oldest settlement in the region dates back to 9800 BC and is formed on a hill known as Sheikh Abad near an adjacent river.

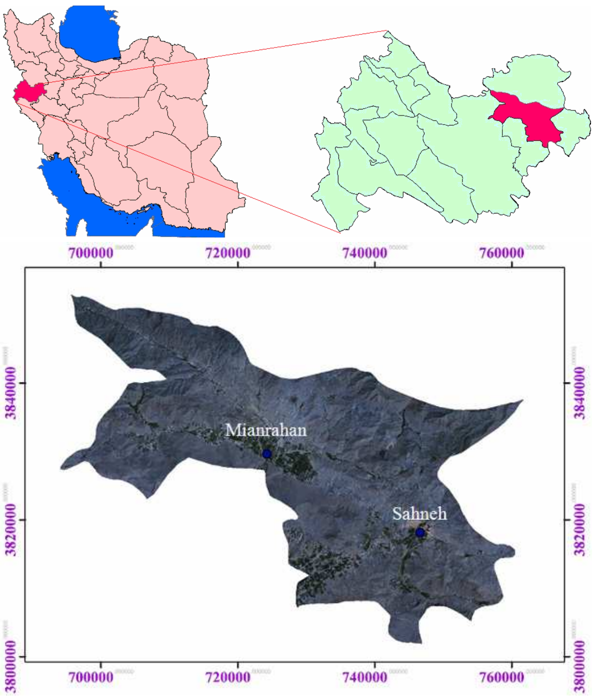

Fig. 1. The study area.

3. METHODOLOGY

Maps of the faults, rivers and villages in the study area were required to implement the study.

3.1. Fault layer

First, images of Landsat ETM+ (2001) were taken to prepare a layer of faults as the reference. The band composition of (1-4-7) was used for visual interpretation. Morphological and Direction/ Convolution filters were applied in the directions of (135°, 90°, 45° and 180°) to enhance the fracture lines. A faults layer was finally produced in GIS considering field data and comparing the ground-based observations with image lineaments.

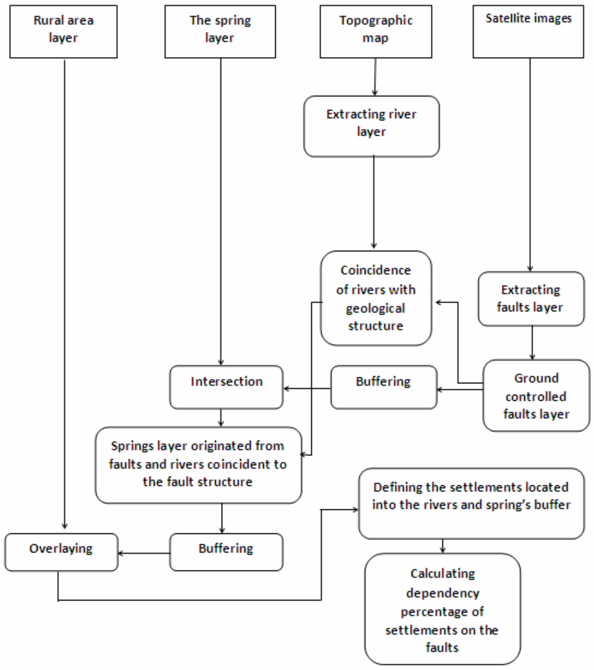

Fig. 2. The research flowchart.

3.2. Rivers and villages layer

The rivers and villages layer were extracted from 1:50,000 national topographic maps with UTM coordinate system.

The rivers layer was overlaid by the springs points to represent the relationship between springs and rivers in the region. The rivers layer was also compared to the faults layer to examine the relation of rivers and the faults distribution. Then, the layer of rivers located in the fracture zone and the layer of rivers located on the fault zone were merged into a single layer. Two buffers of 500 and 1000 m were defined for the zones. Furthermore, they were overlaid by the settlements layer in order to specify whether the settlements were dependent on water resources related to the faults. Finally, the share of settlements located within the buffer of fault-related water resources was calculated. In addition, the relationship between the faults and water resources was determined.

4. RESULTS AND DISCUSSION

The results of the present study can be investigated in three sections: the relationship between the springs and the faults, the relationship between the rivers and the faults, and the relationship between fault related water resources and the settlements. The results for each of them have been explained in detail in the following sections.

4.1. The relationship between the springs and the faults

As illustrated in Figure 3, there is a high dependency between the springs and faults. More than 32% of springs were located within the 400 meter of faults buffer and 72.5% of the springs were located within a distance of 1000 meters from the faults.

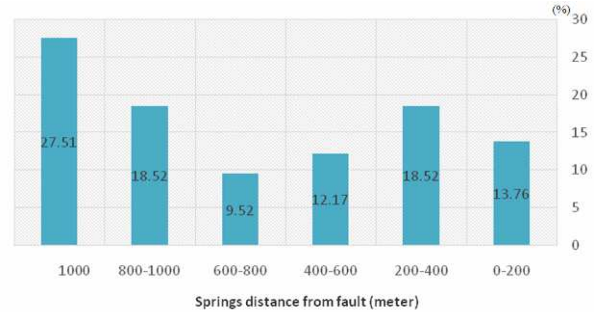

Fig. 3. The percentage of the springs located at different distances from the faults.

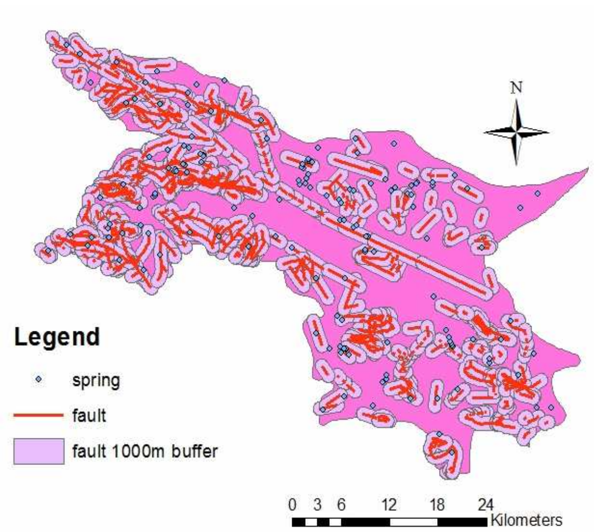

Fig. 4. The map of springs located within the buffer of 1000 meters from the faults.

Fig. 5. Darband waterfall in Sahneh caused by a fault (Maleki, 2010).

4.2. The rivers and the faults

Geological structures, lithology, and the resistivity to erosion determine the role of geology in justifying the water streams [23]. The events related to tectonics that can cause uplifting, subsidence, and horizontal or vertical displacement along the faults in an area, also, affect the fluvial system [15].

Dinavar river has been extended up to 30 kilometers along the Morvarid and Sahneh faults and drains the Dinavar plain. It has played a major role in the establishment of some villages in the region. The northern part of Sahneh Fault created the Sahneh waterfall. In addition, it leads Darband river from Darband valley to the city. Darband river is the main freshwater supply of the Sahneh city.

4.3. The relationship between the fault-related water resources and the formation and survival of settlements

Relationships were investigated between water resources, the fault system and the creation and survival of the settlements. Results showed that 18% of the villages were located within a distance of 500m from the fault-related water resources. 13% of springs and 5% of rivers were fault-related and affected by geological structures. These freshwater resources could be used directly as drink water. Sahneh city is the capital of the county and the river located on the fault passes through the city. About 36% of settlements were located in a distance of 1000m from the springs (27%) and rivers (9%). They could use these resources for cultivation activities.

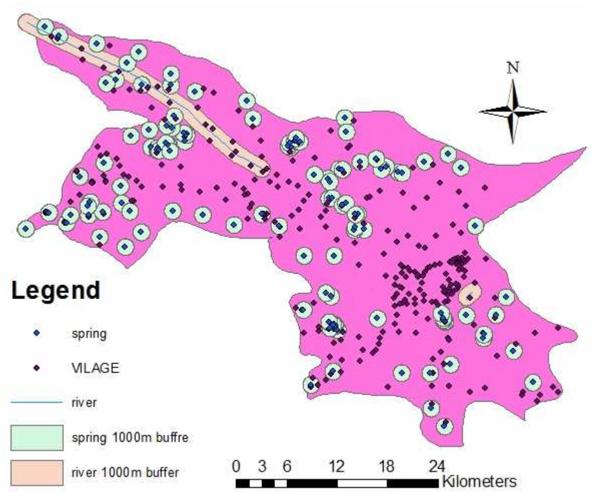

Fig. 6. Villages located within a distance of up to 1000m from fault-related springs and rivers.

Since the limitations of settlements increase with the elevation, a correlation analysis was run between the springs with fault mechanism and height classes.

Assuming the elevations up to 2000 m from the sea level as the appropriate height for human biological activities, the Figure 7 shows that about 30% of the springs are located in high lands over 2000 meter elevation, where the establishment of settlements is limited.

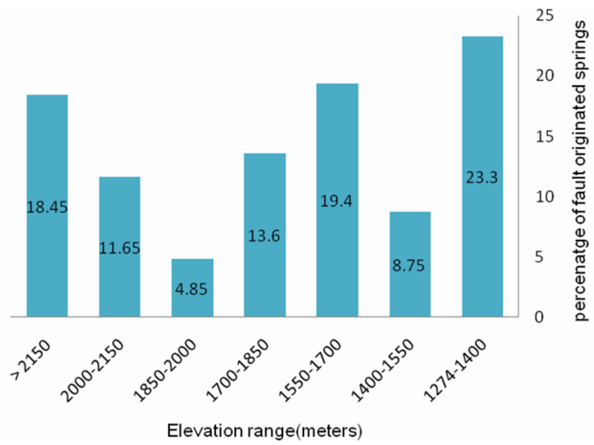

Fig. 7. The percentage of fault-related springs in different height classes.

Although, 30% of the springs are located above the 2000m elevation, only 5% of settlements are located at such height. Regarding the fact that 72.5% of springs are fault-related, and with respect to correlation analysis between the faults and the villages, it can be concluded that the faults are influential in the creation and survival of about 26.1% of villages in the region.

5. CONCLUSION

In this study, the relationship between the tectonic fault structures and distribution of freshwater resources that influence the creation and survival of human settlements was investigated. The relations between fractures, springs and hydrographic network were analyzed. The fault-related water resources were determined and a relationship was established between fault-related water resources and the existing settlements.

As shown by the results, 36% of the settlements are located within a distance of 1000m from the fault-related springs and rivers at elevations up to 2000m. Fault-related water resources have been highly significant in the creation and survival of 26.1% of rural settlements.

Nowadays, water transfer from far resources is possible which decreases the importance of local water resources in the distribution of settlements. Therefore, a historical study is recommended to be done in order to eliminate the impact of modern water supply systems on the relation of settlements' distribution and fault-related local water resources. Since many of old settlements have been abandoned and some springs that provided freshwater resources in the past are disappeared. Extensive archeological research is recommended to investigate such cases.

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