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Investigating the role of meteorological drought and geodetic factors on land subsidence vulnerability using fuzzy overlay

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ABSTRACT

Land subsidence has caused severe environmental hazards in most plains of Iran due to unbalanced extraction between groundwater and rainfall and the geodetic factors. In this regard, three basins of Kohpaye Segzi, Isfahan Borkhar, and Najafabad in Isfahan province were selected to study the areas with land subsidence vulnerability. Changes in aquifer water volume influenced by geodetic factors and meteorological drought were studied. The maps of the Standardized Water Level Index (SWI) and isodeep were provided in ArcGIS 10.7 software using the statistical data of piezometric wells (2002-2018). The time series analysis of 6, 12, 18, and 24-month were performed by DIP software for September as the driest month of the year. the time series with the highest correlation was zoned to show the number of SPI changes. In the last step, the weight of all indices including groundwater loss, meteorological drought, slope, and altitude was equated to evaluate land subsidence vulnerability. Land subsidence vulnerability map was prepared by overlaying the fuzzy maps of indices with strategic points. The relationship between meteorological drought and groundwater level; and correlation analysis of these two parameters with the Pearson statistical method showed a positive correlation only in 18-months time series. The results also showed that 4202 km^2 of the region has located in high to very high drop class, and the groundwater table has decreased 9.05 m from 2002 to 2018. In general, with a negative trend of precipitation, a positive trend was observed in the standard water level index, which increases the effective stress and was the main reason for land subsidence. According to the vulnerability map, 49 and 12.5 percent of the study area were categorized into high and very high classes of landslide vulnerability, respectively. The results showed that the probability of land subsidence will increase in the next few years because of reduction in precipitation due to climate fluctuation, slope effects, altitude, over-harvesting of groundwater potential in all parts of the basin, especially in the northern areas, and increasing density and loading especially in recent years.

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Introduction

As defined by the US Geological Survey, land subsidence involves land subsidence of the earth's surface, which occurs for various reasons on a large and small scale (Nadiri *et al*., 2019). This term is commonly referred to the vertical downward movement of the earth's surface, accompanied by a slight horizontal vector (Taheri Tizro, 2009; Yamani *et al*., 2010). Land subsidence is one of the most common geological hazards worldwide, indicating some form of natural or anthropological degradation (Allaby, 2013). Some of these causes are dissolution of subsurface formations, the density of fine-grained sediments due to extraction of fluids and underground reserves, drainage or vibration, hydraulic compaction, mechanical subsurface erosion, lateral flow, instability of soils on sloping surfaces, shrinkage and swelling of clay soils, earthquakes or landslides, over-exploitation of groundwater, natural or human-made cavities, oxidation of lead-rich materials, and tectonic activity (Galloway and Burbey, 2011), which can affect on local or large scale. The rate of land subsidence has reached 50 cm per year in some parts of the country due to falling aquifer levels, which is very dangerous and unique in the world. It causes a lot of damage to various sensitive areas, including infrastructure, transmission lines, residential area and agricultural lands. (Mortazavi *et al*., 2011; Bahrami *et al*., 2018). Digging deep and semi-deep wells due to recent droughts (meteorological, hydrogeological and agricultural droughts) and digging new wells reduce water resources, reduce groundwater tables and drying many wells. It has caused land subsidence in fine-grained lands, changes in soil quality parameters and salinization of lands, and reduced vegetation density in many parts of Iran (Tardast *et al*., 2012).

On a global scale, the risk of land subsidence peaked due to declining groundwater levels as industrialization and urbanization grow in the 1950s and 1970s (Waltham, 1989). Landslides have been reported in more than 150 cities located in arid and low-rainfall regions of the world (Hu *et al*., 2004; Pacheco *et al*. 2006). Locating in arid and semi-arid climate, groundwater is used as one of the main water supply source in Iran. The process of land subsidence due to groundwater abstraction can be justified according to the Tarzaghi relationship (Eq. 1). When water is extracted from groundwater aquifers, the hydraulic pressure decreases and the effective stress between the soil grains increases. This leads to land subsidence, which the amount of land subsidence will be different depending on the strength and stiffness of the soil grains.

$$\sigma_e = \sigma_t - \rho \qquad (1)$$

In this relation σ_e and σ_t are the effective stress and the total stress, respectively and ρ is the hydraulic pressure.

This degradation occurs at a slow rate, so it does not appear until a significant effect is produced (UNESCO, 2015). However, Land subsidence can also occur as a sudden collapse in different parts of the earth. In regional land subsidence, it cannot be said that one part suffers and the other parts remain safe (Aalipour Erdi *et al*., 2017). Research shows that land subsidence is regional type in Isfahan that damages caused by it covers the whole the entire plain of Isfahan and all parts of the province.

The development of agriculture and the continuation of groundwater abstraction have intensified the occurrence of this phenomenon in Isfahan province. As this process continues, irreparable damage will happen. Isfahan province is created sinusoidally from several U-shaped surfaces. Land subsidence problem become more critical from around the Zayandehrood River to the northern and northeastern parts of the region.

The most critical part of Isfahan plain is Borkhar plain in which Isfahan airport is also located, in which makes the issue more serious. According to the statistics of Isfahan Regional Water Authority, out of 60,000 wells in Isfahan province, about 43,000 wells have exploitation license, and about 17,000 wells are illegal and do not have exploitation license. Irrigation of agricultural land and excessive abstraction of groundwater has intensified subsidence in the Isfahan plain. Therefore, considering the soil texture, the type of land use, vegetation density, drying of surface water resources, and decline of aquifers in Isfahan plain, the need to study the phenomenon of land subsidence is more serious. Because without considering the management and scientific process, it will creat severe problems for residential houses, agricultural lands, etc. in the future.

Rafsanjan plain (Tabatabaee and Mohseni Nasab, 2015), Mashhad (Behniafar *et al*., 2010), Kaboudar Ahang Hamedan (Merikhpour *et al*., 2012), Tehran (Ataee and Zamanipour, 2016) are region that have suffered land subsidence. Salehi *et al*. (2013) investigated the land subsidence of the southern Mahyar plain using radar interferometry. In this study, the relationship between groundwater table decline and land subsidence was investigated. The results of ENVISAT satellite radar images showed that the maximum land subsidence rate was 8.2 cm per year during 2003-2006. Based on the results of time series analysis, the earth surface is falling at a constant speed as a result of a drop in the water table. Shrestha *et al*. (2017), in assessing the risk of land subsidence in Kathmandu, Nepal, showed that the northern and northeastern parts of the region are susceptible to land subsidence. On average, 1.6 mm of land subsidence occurs annually due to uncontrolled groundwater abstraction.

Jamour *et al*. (2019) evaluated the crisis of land subsidence and saltwater intrusion in the Minab aquifer. The results of groundwater levels showed that the water table decline has intensified in this aquifer since 2001. On average, the water level has dropped by about 46 cm annually.

The results of Turani *et al*. (2019) study on land subsidence in the west of Golestan province using the radar interference method showed that a land subsidence area has occurred in the northern part of Gorgan. Despite seasonal fluctuations, water level and rainfall charts showed a downward trend despite the seasonal fluctuations in this area from 2006 to 2010. The consequence of this groundwater table decline could be land subsidence in the region.

Ahmadi *et al*. (2019) studied the land subsidence of Khorramdareh plain using the radar interferometry technique and its hazards. Their results showed that the maximum subsidence rate aligns with the satellite line of sight is 49 mm per year in the Khorramdareh plain. The results of fixed GPS station in the region indicates an increase in land subsidence rate from 16 mm per year in the 2006-2009 to 51 mm per year in 2013-2017.

Salehi Motahed *et al*. (2020) assessed land subsidence using radar interference measurements, and field measurements in Mashhad. They studied its causes and its effects. Their results showed that two land subsidence bowls are seen, one in the northwest and the other in the southeast of city. Most land subsidence rates have occurred in areas, where apart from a sharp decline in groundwater table, having fine-grained soil texture and alluvial thickness.

In many cases, land subsidence caused by groundwater abstraction is irreversible. However, in most studies, researchers generally seek to calculate the rate of land subsidence. It emphasizes the need to study the land subsidence potential in different parts of country to control and manage this phenomenon. In this regard, this study tried to prioritize the indicators affecting the land subsidence phenomenon, geodetic factors and meteorological drought were used. Overlaying these indicators, land subsidence vulnerability map was provided by the fuzzy method.

Material and methods

Area of study

Isfahan province located in central of Iran. The study area including three regions of Kohpaye-Segzi, Borkhar, and Najafabad with elevation of 1570 m above sea level is approximately 11923 km^2. The study area located in longitude of 51° 39′ 40" E and latitude of 32° 38′ 30" N (Fig. 1).

Average precipitation is about 75-100 mm in the Borkhar and 110-160 mm in the Najafabad and Kohpaye. The maximum temperature is 39 degrees Celsius in summer, hot and dry summers, and in winter, it reaches a minimum of -18 degrees Celsius. Also, the average annual temperature is 27 degrees Celsius, and the number of frost days in a year is 91 days. The study area is located on a relatively flat plane with a slope of about 2%. The northeast of the region has flatlands with alluvial sediments.

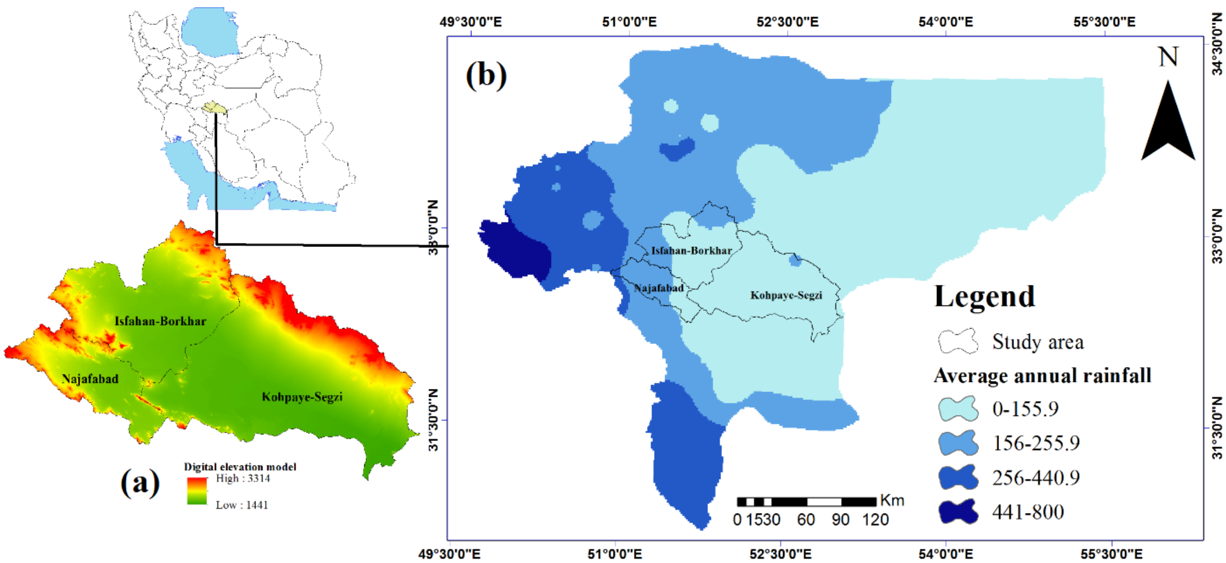

Figure 1. (a) Location of the study area and (b) average annual rainfall of the study area and Isfahan province

Methodology

To investigate the occurrence of land subsidence, the factors affecting this phenomenon, such as meteorological drought, slope, altitude, changes in groundwater table were studied (Fig. 2) (Sharifikia, 2013; Ahmadi *et al*., 2014; Shadfar *et al*., 2016). In this regard, the layers related to each factor were provided and constructed in the ArcGIS10.7 environment. Ordinary Kriging, Radial Basis Functions, Inverse Distance Weight, and Global polynomials methods were used to interpolation each parameter. R-Squared coefficient R^2 and Root Mean Square Error (RMSE) were used to determine the best interpolation method for water table changes and zoning of other parameters and validation. IDW method with low RMSE and high R^2 selected as the best estimating method in the region for zoning and mapping. Overlaying the raster layers of strategic points of meteorological and geodetic factors, the land subsidence vulnerability map of the area was provide by the fuzzy method.

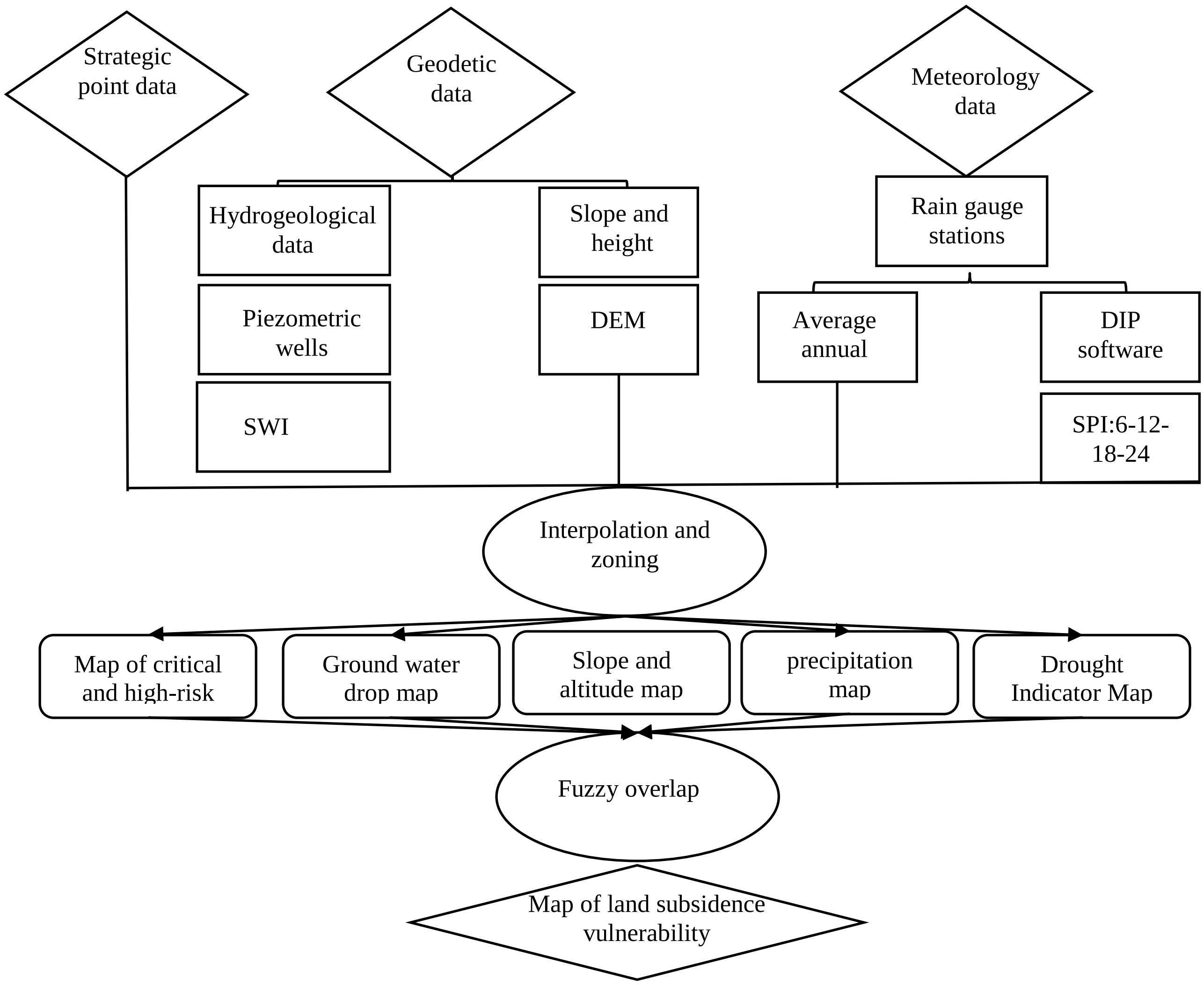

Figure 2. The conceptual design for mapping land subsidence vulnerability by fuzzy method

Rain gauge stations and standard precipitation index (SPI)

The geographical coordinates and rainfall of 72 meteorological stations taken from the Iran Meteorological Organization were used to analyze the temporal and spatial variations of rain; and the role of meteorological drought on groundwater quantity. Based on the three studied basins, the annual precipitation information of 18 relevant stations in terms of millimeters (Table 1) were selected as pilot points for the period 2002-2018. Creating its raster layer in the ArcGIS environment, the zoning map of precipitation amount of the region was prepared (Fig. 1). Fig. 3 shows the locations of meteorological stations and piezometric wells.

Table 1. Characteristics of study basins

Basin number	The name of the basin	UTMY	UTMX	Area (square kilometers)	Rainfall class	Average annual rainfall
1	Isfahan-Borkhar	3646862	536170	377.562	1-2	0-155, 155.1-255mm
2	Kohpaye _ Segzi	3603980	578960	642.475	1	0-155 mm
3	Najafabad	3613865	510495	175.490	1-2-3	0-155, 155.1-255, 255.1-440 mm

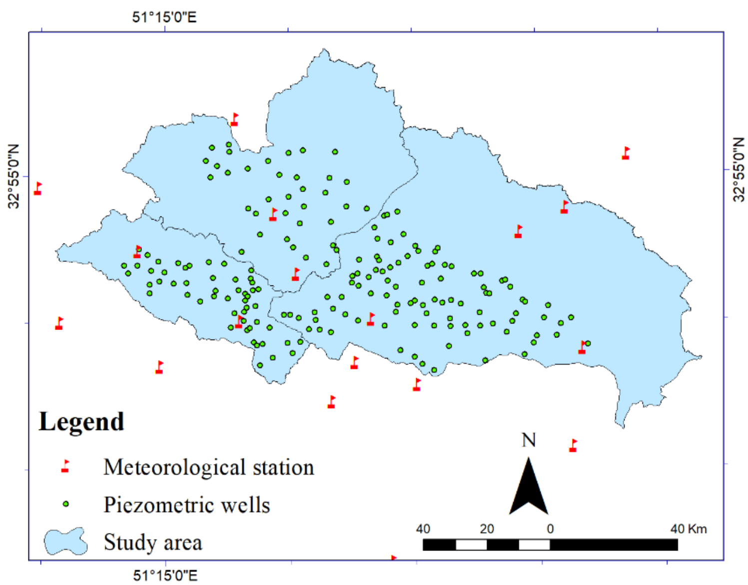

Figure 3. Location of piezometric wells and meteorological stations in the study area

Using DIP software (Naserzadeh and Ahmadi 2013), the standard precipitation index for 6, 12, 18, and 24 months was determined for all stations. Then, interpolating by the IDW method, the mean values of the standard precipitation index of all stations were provided during the research period of 2002 to 2018 . After calculating the SPI, meteorological drought was assessed. A Drought occurs when a negatively standard precipitation index persists. Severe drought occurs when the SPI is less than or equal to -1. If the SPI is positive, the drought will end (Table 2).

Table 2. Assessment of drought status based on SPI values (McKay *et al*. 1993)

Drought classes	SPI values
Completely wet	2<
Very wet	1.5-2
Relatively wet	1 _ 1.5
Gently moist	0 _ 1
Mild drought	-1 _ 0
Moderate drought	-1.5 _ -1
Severe drought	-2 _ -1.5
Very severe drought	-2<

Groundwater table decline and Standard Water Level Index (SWI)

In studies related to the causes of land subsidence, the analysis of groundwater table fluctuations has a significant role. Therefore, the obtaine data from Iran Water Resources Management Company were evaluated, and incomplete data were reconstructed. Finally, 185 piezometers wells representing the study area with appropriate distribution were selected. The annual data of standardized water level index were prepared for three basins of Najafabad, Isfahan, Borkhar, and Kohpaye_ Segzi during the research period of 2002- 2018.

To prepare the raster layers of water table decline, the water table average of each well were estimated, and plotting the time series diagram of water table changes in piezometric wells by Excel 2013, the amount of decline and the coordinates of the piezometers were imported in the software.

The Data were interpolated for the entire area, and then the raster layer was created to integrate with other data. After ranking the layers, the classified maps of groundwater table decline were provided for five periods (2002, 2006, 2010, 2014, and 2018). Overlaying the maps of five research period s, the groundwater decline map was prepared in four classes of low, medium, high, and very high for the whole study period.

The SWI as a scale to determine the extent of nutritional decline of groundwater was calculated using Eq. 2.

$$\text{SWI} = (W_{ij} - W_{im})/\sigma \quad (2)$$

In the above relation W_{ij} is the water level of piezometric wells of i to j, W_{im} is their monthly average, and σ is the standard deviation. The calculated SWI values were classified and used to determine hydrological drought. Positive SWI values indicate drought, and negative values (Less than zero) indicate normal conditions (Table 3) (Bhuiyan *et al*., 2006; Pour Mohammadi *et al*., 2017).

Table 3. Classification of SWI standard water level index

Drought classes	SWI values
Very severe drought	> 2
Severe drought	1.5-2
Moderate drought	1-1.5
Mild drought	0-1
Wet year	0 >

After calculating the average of meteorological stations, correlation between SPI and SWI were studied by SPSS software and Pearson correlation test to compare the effects of precipitation changes on groundwater quantity (Kundzewicz and Robson, 2004; Barker *et al*., 2017; Huang *et al*., 2016). The time series having the highest correlation with SWI was used to zoning and mapping the standard precipitation index.

The Pearson correlation coefficient estimate the degree of linear correlation between two random variables (Theodore and Pearson, 2004). The value of this coefficient varies between -1 to 1. A value of (1) meaning a complete positive correlation, (0) indicating no correlation, and (-1) representing absolute negative correlation.

Slope

To investigate the effect of slope on land subsidence, a slope map was prepared using DEM and its raster layer was used to overlay with the groundwater table map (Fig 4).

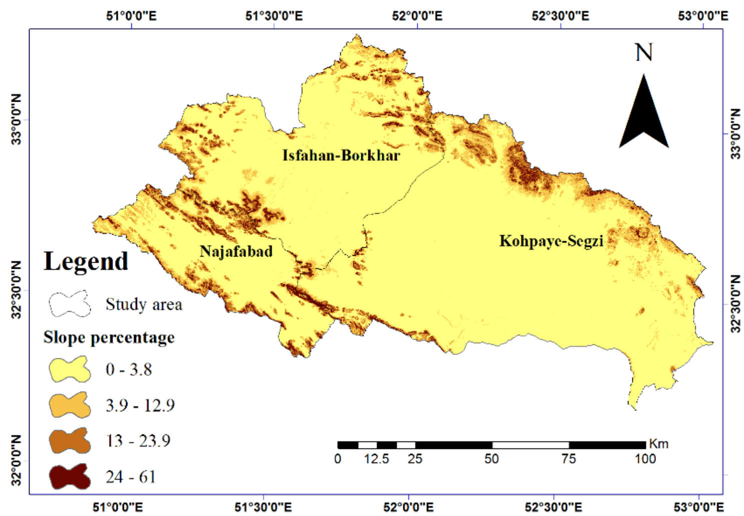

Figure 4. Slope map of the study area

Vulnerable and strategic areas

There are generally different ways to measure vulnerability. One of the most common methods used in this study is indicator-Based Vulnerability Assessments[1] methods. Index-based methods to quantify vulnerability are based on selecting some potential indicators and combining them with relevant levels of vulnerability. Many researchers have used this method locally and globally (Leichenko *et al*., 200; Nasabpour *et al*., 2018).

There are two options for calculating vulnerabilities using IBVA. The first option is to consider equal importance, as the result, equal weight for all factors (Me-Bar and Valdes, 2005). The second option evaluate the different extent and assign different weights to vulnerability factors. In the present study, the first method has been used (Nasabpour *et al*., 2018).

Some area suffers from irreparable damage due to land subsidence, so the geographical location of these areas was received from the municipality of Isfahan province. The high-risk areas were divided into strategic points of grade 1 (residential areas, antiquities, hospitals, water and electricity transmission lines), grade 2 (military barracks, railway stations, power plants), and grade 3 (factories, mines, poultry farms, etc.). Then, these points were in put the software, and by preparing a map of strategic and vulnerable points, the geographical location of each point in the study area was determined.

Finally, the map of land subsidence vulnerability was calculated and plotted using the fuzzy overlay operation in ArcGIS software. For this purpose, after providing zoning maps related to each indicators, the layers in equal weights were obtained using Fuzzy Operation Gamma. The

[1] IBVA

layers were classified using Natural Breaks method in ArcGIS software, and then merged and overlapped. The Fuzzy Operation Gamma is defined as Eq. 3.

$$\mu(x) = ((\text{Fuzzy Algebric Sum})^{\gamma} * (\text{Fuzzy Algebric Product})^{1-\gamma} \quad (3)$$

In relation 3, γ is a number between zero and one. The correct and conscious choice of γ creates values in the output that indicates a flexible correlation between the decreasing tendencies of fuzzy multiplication and the increasing trends of fuzzy sum (Bonham-Carter, 1991; Cloetingh *et al*., 2000). In this study, $\gamma = 0.9$ was considered. Also, in Natural Breaks classification, the classes and categories in this method are determined based on the inherent natural groupings in each group.

Results

Aquifers respond to spatial changes in precipitation and meteorological drought

In this study, rainfall fluctuations showed a large part of changes in groundwater table. Standardized water level index has a weak correlation (0< 0.7) with time scales of 6, 12, and 24 months SPI, which indicates no change in groundwater decline due to SPI.

The maximum correlations are related to the 18-month SPI in the three basins, and the groundwater table in this period is strongly affected by fluctuations caused by rainfall (Table 4). Figure 5 shows the response of the studied basins to rainfall changes based on 18-month SPI. According to the results, the study area has been in drought for 18-month time series and has not had any wet years.

According to the map, almost all areas are in the mild drought, and a small part in southwest of the Najafabad basin has the humid climate. It indicates almost the same climate with slight fluctuations in the study area.

Table 4. Water level index and standard precipitation index and time series (6, 12, 18 and 24)

BASINS PARAMETERS	ISFAHAN-BORKHAR				NAJAFABAD				KOHPAYE-SEGZI			
SPI	6	12	18	24	6	12	18	24	6	12	18	24
SIG. (2-TAILED)	0.262	0.565	0.819	0.295	0.903	0.501	0.833	0.207	0.209	0.371	0.285	0.805
PEARSON CORRELATION	0.370	-0.119	0.778	0.621	0.042	0.774	0.772	0.619	0.411	0.761	0.954	0.474

Hydrogeological studies

The time series diagram of water level fluctuations of piezometric wells showed a drop in water table has occurred during the study period in the entire study area, especially the Isfahan-Borkhar basin. There was a 10 meters decline in the aquifer of this basin from 2002 to 2018. The largest fluctuation of groundwater depth relative to the ground level is related to Najafabad basin, where the water depth has decreased from 28.34 m in 2002 to 40.34 m in 2018. Also, the R-Squared coefficient of Kohpaye_Segzi, Najafabad and Isfahan-Borkhar are 0.9161, 0.8555 and 0.9621, respectively.

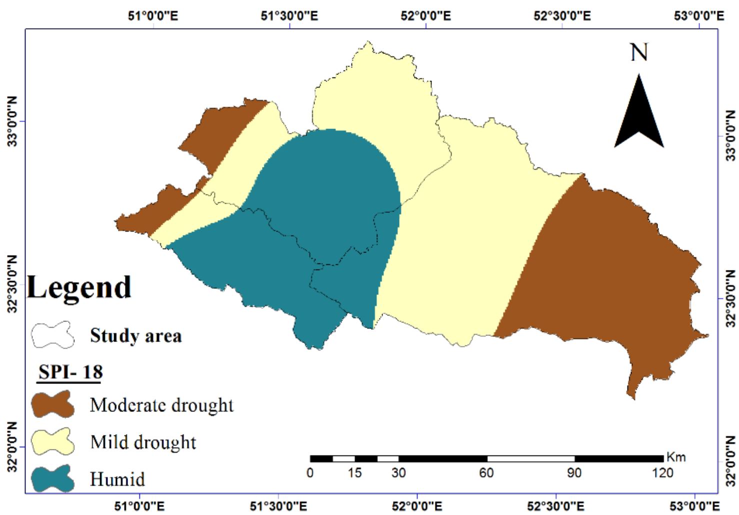

Figure 5. Changes in precipitation in the 18 months SPI time series in September (2002-2018)

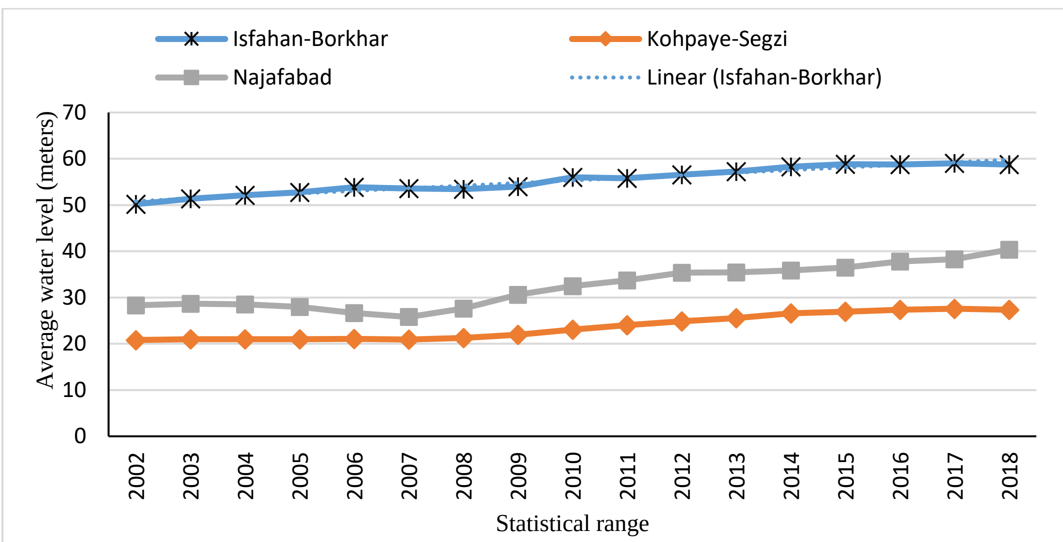

Figure 6. Fluctuations of water level of piezometric wells in Isfahan plain

Results of groundwater depth studies

Figure (7) shows the iso-maps of groundwater-surface depth. The depth of groundwater table is different in the study area due to the topographic slope, altitude, and extraction from wells.

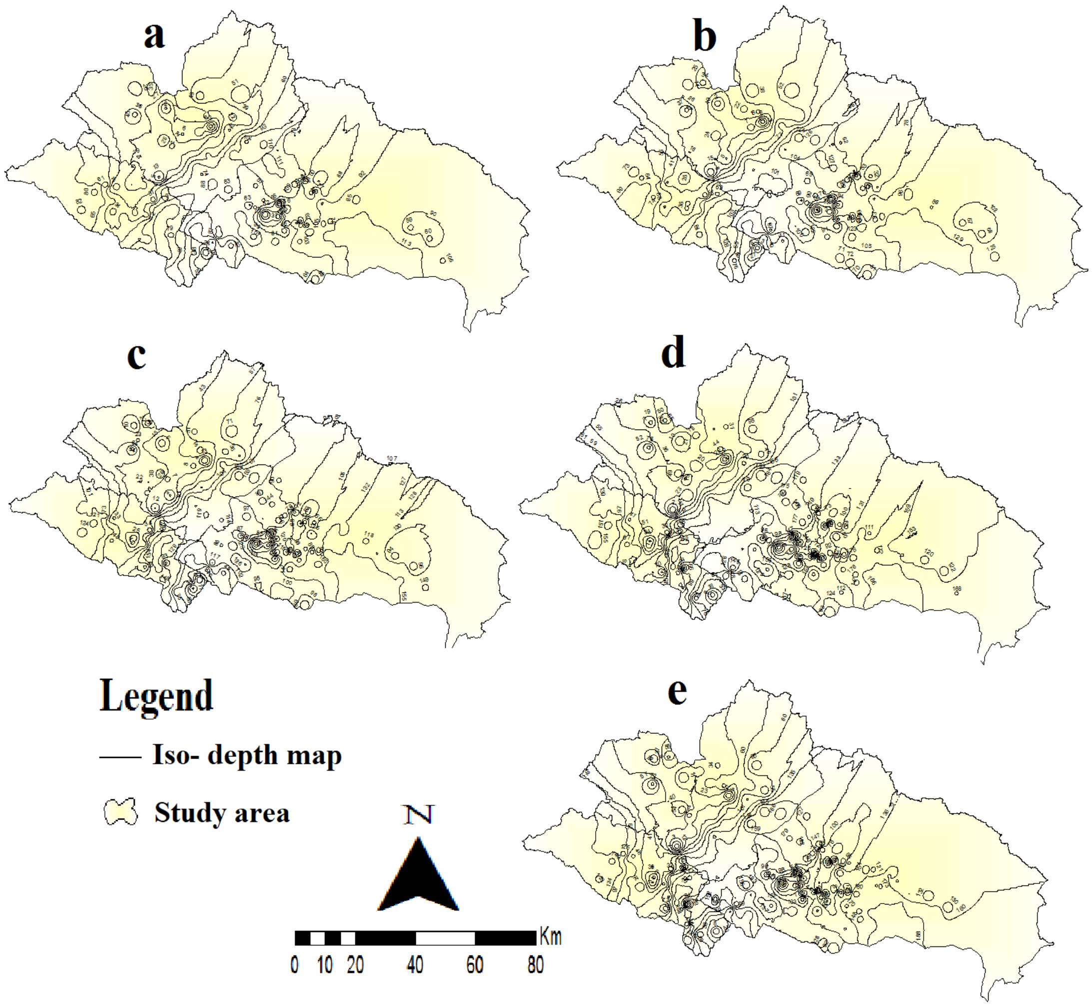

Figure 7. Map of co-depth lines of wells in the study area of 5 research period s
(Iso-depth map a_ 2002, b_ 2006, c_ 2010, d_ 2014, e_ 2018)

Figure 8 shows the areas faced groundwater table decline due to excessive groundwater abstraction. The average groundwater depth of the whole basin has decreased from 33.10 m in 2002 to 42.14 m in 2018. The highest decline was related to the Isfahan-Borkhar basin and then Najafabad basin.

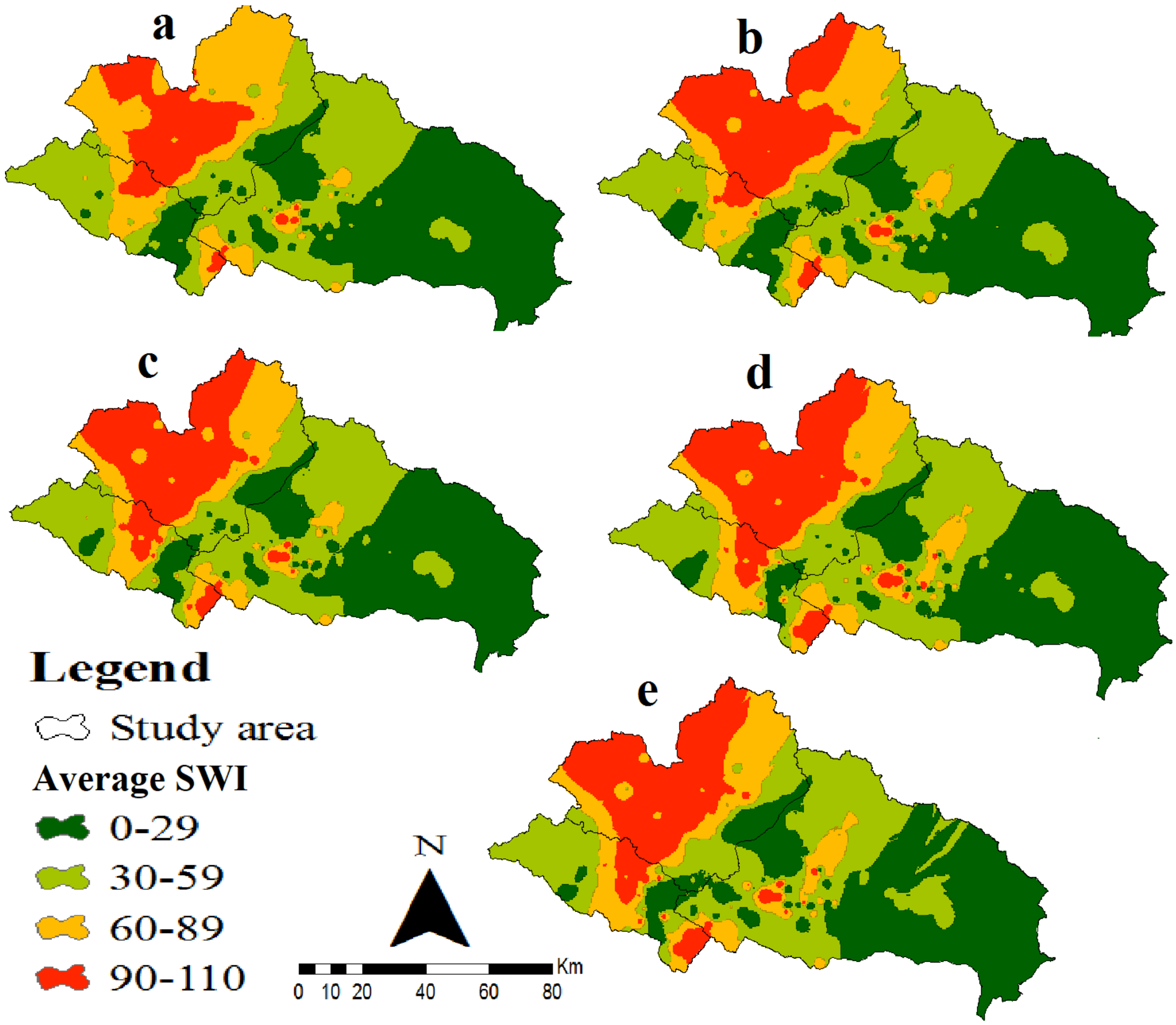

Figure 8. Standardized water level index of Isfahan plains in 5 research period s (SWI Maps, a_ 2002, b_ 2006, c_ 2010, d_ 2014, e_ 2018)

Analyzing of groundwater table indicates that the quantity of groundwater has a downward trend. Fig. 9 shows the interpolation maps of the standard water level index, classified in four classes: low, medium, high, and very high, for five-studied periods. The map shows that out of the total area, 2363 km^2 has a substantial groundwater reduction.1839, 4124 and 3629 km^2 located in high, medium and low classes, respectively. About 4202 km^2 faced a sharp groundwater decline located very high and high classed. According to the mentioned results, it can be said that three study basins, especially Isfahan Borkhar and Najafabad are in critical conditions.

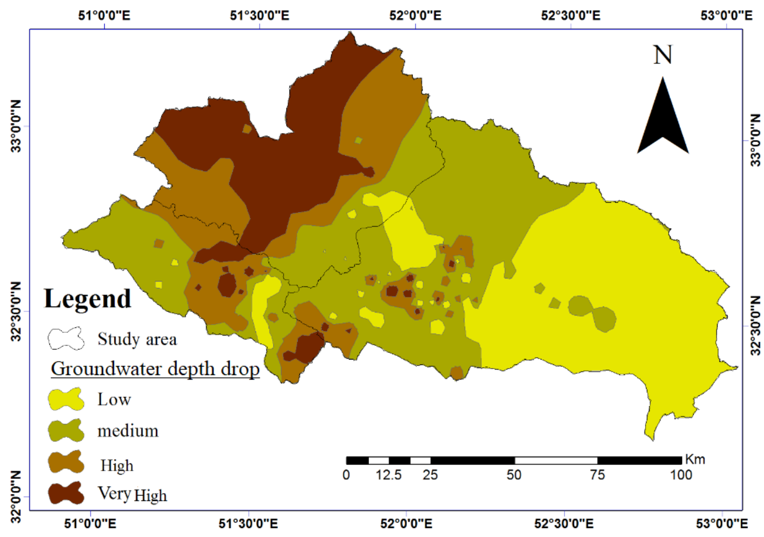

Figure 9. Groundwater drop zoning of the whole study period

Standard water level index has an upward trend from east to west of the region. The eastern and southern parts are in the medium and low decline classes, while the northern and western parts are in high and very high decline classes. Considering the study area mainly located in two rainfall classes 1 and 2, and only a tiny area of the Najafabad basin is in the three rainfall classes, indicating the dry weather conditions and unfavorable situation of the groundwater reserves.
Given above, the possibility of a landslide is not far off in the near future. Vulnerability map of obtained overlaying the groundwater decline layer with slope and elevation layers (Fig. 10) indicates that the amount of water decline has direct correlation with increasing slope and height. The process of groundwater decline has an increasing trend from east to north and west of the region.

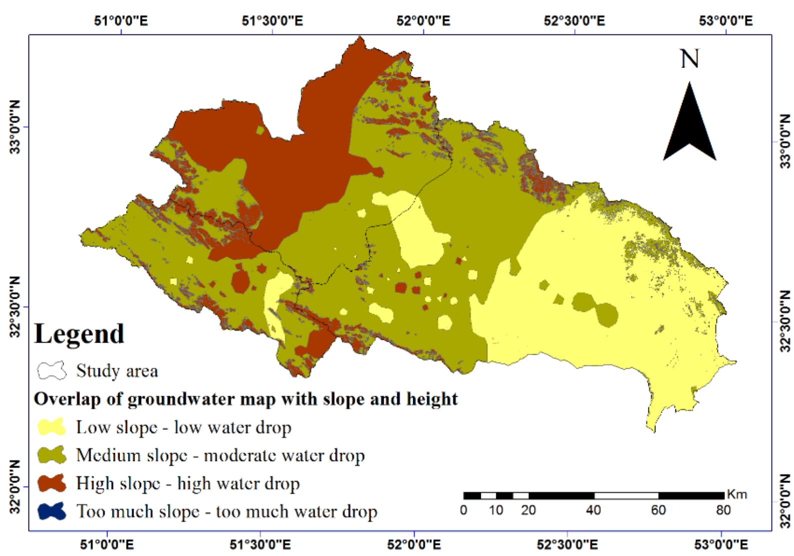

Figure 10. Overlay of groundwater-surface zoning layer with slope and elevation map

Strategic points affected by areas with land subsidence potential

The map of strategic points shows that the sensitive points distribute in the whole area, and in cases of landslides, severe damage are inflicted in any part of the basin. According to Fig. 11, high-risk areas (grade 1) have a very high distribution compared to grade 2 and grade 3.

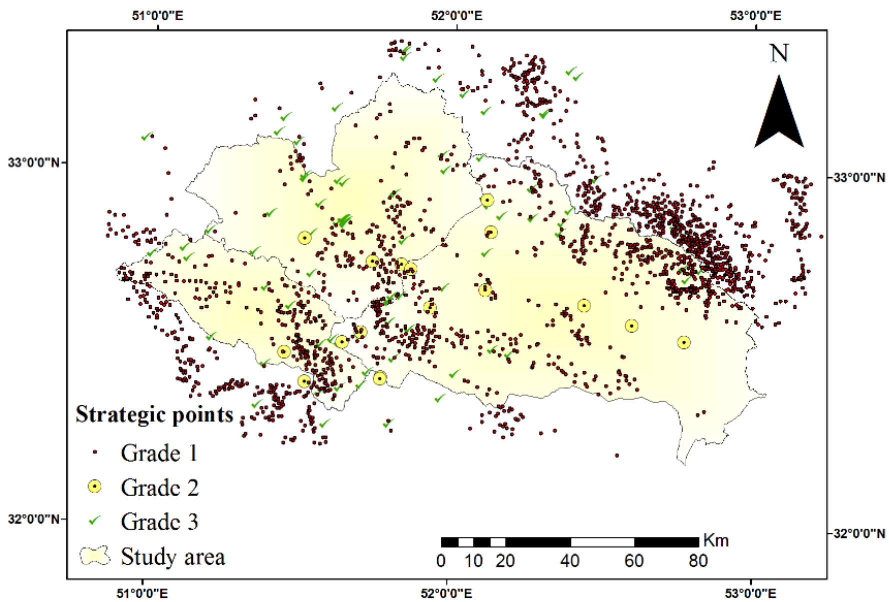

Figure 11. Map of strategic points of the study area

The vulnerability map to land subsidence was classified in 4 classes of the low, medium, high, and very high by the Natural Breaks method in ArcGIS software (Figure 12).

The land subsidence vulnerability map shows that the study area is mainly located in two classes of medium and high vulnerability. It should be noted that only the western parts of Najafabad and Borkhar located in very high vulnerable class.

The whole study area located in medium drought class, and only a very small area of Najafabad basin located in 3 rainfall class is in mild drought class. The highest annual rainfall (90.5 mm) occurred in the Najafabad basin in 2006, while the lowest annual rainfall (0.95 mm) in the Kohpaye-Segzi basin in 2018.

Due to distribution pattern of strategic points in the region, warnings such as change in agricultural patterns, preventing road construction in some places, paying attention to segzi railway lines, evacuation of low-populated residential areas having high risk and ..., is necessary.

The vulnerability map shows 5850 km^2 of the area (49%) located in high-risk zone, and 1473 km^2 (12.5%) is in very high-risk of land subsidence. Except for a limited area located in east of the Kohpaye-Segzi basin, the risk of land subsidence is high in the entire area.

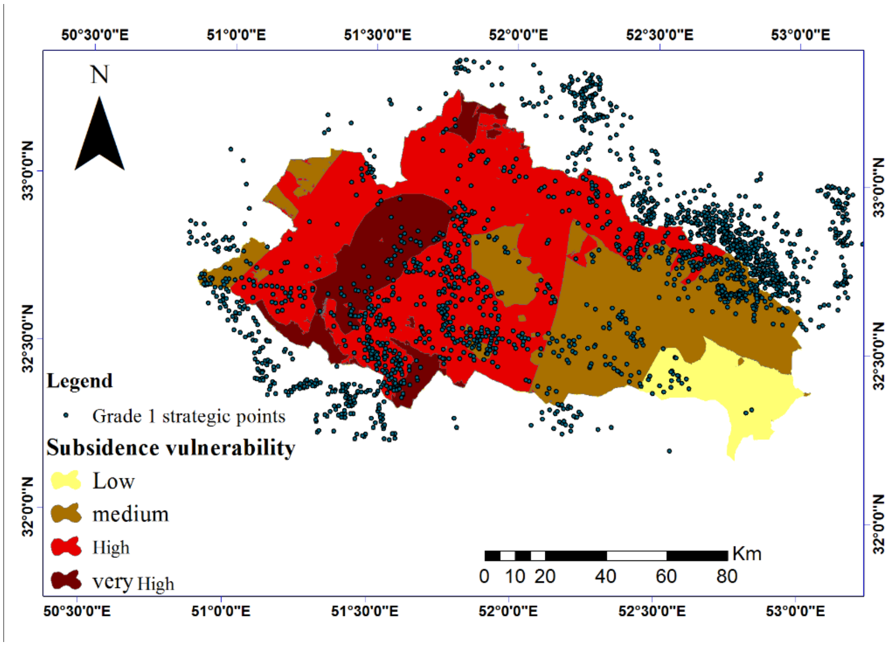

Figure 12. Land subsidence vulnerability map of the study area

Discussion

In this study, an attempt was made to calculate the vulnerability to land subsidence using the fuzzy overlay method and ArcGIS software. This study performed the vulnerability of lands affected by meteorological drought and geodetic factors in three basins of Kohpaye-Segzi, Najafabad, and Isfahan Borkhar located in Isfahan province during the 16-years period. The maps of slope, 18-month standard precipitation index (SPI), and standard water level index (SWI) were provided for three basins. Najafabad basin affected by the Zagros Mountains and rainy winds from the west is located in three rainfall classes with mild humidity. In the other words, the rainfall conditions of this basin in a very limited area are more favorable than the other two basins in the north and east, which is consistent with the results of Kamali and Asghari (2020).

Also, the analysis of time series trend and changes in the water storage volume showed that the depth of groundwater level has decreased from 33.10m to 42.14m between 2002-2018. Based on the groundwater decline zoning map, 2363, 1839 4124, and 3629 km^2 of the study area located in very high, high, medium and low classes.

Groundwater is one of the most important water resources in the country, and it is essential to know the amount of quantitative changes in these resources to manage it properly. In the present study, the changes in groundwater level affected by drought is evident, and has the highest correlation, especially in the steep and mountainous parts of the region, which is consistent with the studies of Tabatabaee *et al*. (2014). A comparison of zoning maps of five research period s of groundwater decline shows that the highest rate of decline is related to Isfahan-Borkhar and Najafabad basins. Kohpaye-Segzi has an upward trend to the west and northwest of the region. Therefore, the map of the region's vulnerability to land subsidence also shows the most significant potential for land subsidence in the two basins of Isfahan-Borkhar and Najafabad, which is in line with the zoning map of groundwater decline. Water table decline was determined as the main factor affecting the land subsidence. The results of Turani *et al*. (2019) study showed that the decline in the water table is the most critical factor affecting land subsidence.

According to the final map of land subsidence vulnerability, most of the study area is in two medium and high vulnerability classes. Also, parts of Najafabad and Borkhar basins are in a very high vulnerability class. In this area, due to the existence of the same climate, groundwater status and land use have a decisive role in vulnerability to subsidence land. There are areas with high and very high vulnerabilities in Najafabad basin that should be considered in land subsidence risk management.

The results showed that the probability of land subsidence will increase in the next few years because of reduction in precipitation due to climate fluctuation, slope effects, altitude, over-harvesting of groundwater potential in all parts of the basin, especially in the northern areas, and increasing density and loading especially in recent years. So that in the vicinity of Isfahan airport and even near the Naghshe-Jahan stadium, cracks caused by land subsidence are visible on the ground, and land subsidence is a very serious threat for this city. These results are corresponded with the studies of Salehi Motahed *et al*. (2020) in assessing land subsidence using a combination of radar interferometry and field measurements in Mashhad plain, Osmanoglu *et al*. (2011), and Radutu and Gogu (2019) in the study of chronological reflection on monitoring urban areas land subsidence due to groundwater extraction.

Conclusion

Isfahan province and the study area are faced natural drought due to its vicinity to Kavir desert. Isfahan province has faced a sharp decline in the water table due to over-potential agricultural activities, digging unauthorized wells in prohibited plains, various land-use changes, high population concentration and water consumption in various sectors of agriculture and especially industry. These conditions indicate a critical situation in terms of groundwater depletion that could lead to land subsidence.

It should be noted that areas with low vulnerability have lower management priorities, but this does not mean that they are not affected by land subsidence, so they should also be considered in land subsidence risk management.

To continue the research, it is suggested to use radar images to determine the exact location of land subsidence points. Also, using time series modeling of radar images, the land subsidence rate is monitored to enable the preparation of the average subsidence map. GPS data, geological features, and geophysical maps of sedimentary layers of the plain should also be used for additional studies. To control the existing conditions in the region, managers and planners must pay attention to zoning maps of water table decline and areas with land subsidence potential for any residential, agricultural, industrial and road construction planning in the future.

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