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Original Research Article

Investigating the Vulnerability and Resilience of Isfahan City Against the Phenomenon of Land Subsidence

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Abstract | In recent years, the land subsidence phenomenon caused by potential and human activities has emerged in different parts of the world, Iran, and especially in Isfahan due to excessive extraction of groundwater, drought, and other factors. Such a phenomenon has brought about serious damage to the environment, infrastructure, economy, agricultural land, residential buildings, roads, and other structures. As a result, it has sustained environmental, economic, and social losses. For this reason, the analysis of urban vulnerability and resilience resulting from this land subsidence in Isfahan has been considered as a tool to prevent the occurrence of disasters. This research aims to answer the question of how vulnerable and resilient Isfahan city is to the phenomenon of land subsidence. The purpose of this research is to investigate the role of urban resilience on the vulnerability of Isfahan city to the phenomenon of land subsidence. In this study, first, using radar interferometry technique, the rate and amplitude of subsidence as a factor in generating risk was entered into the system analyzer in the GIS environment Then, with the help of qualitative analyses, urban resilience indicators were examined in the city of Isfahan.. The results indicate that areas north of the city and parts in a strip shape are also at increased vulnerability due to their proximity to hazardous factors such as faults, channels, old aqueducts, fuel storage sources, oil pipelines to these reservoirs, and the constant change in the course of the river. It also shows that most of the existing construction in the area is unprincipled and disproportionate to the hazardous conditions.

Keywords | *Vulnerability, Urban Resilience, Land Subsidence, Radar Interferometry, GIS, Isfahan.*

Introduction| In recent decades, over-exploitation of underground resources such as oil, gas, and water extraction has caused environmental accidents in different parts of the world. One of the environmental consequences is affected by the indiscriminate extraction of underground water resources which is accompanied by the increase in population and the development of agricultural and industrial activities. It is the subsidence of the earth (Abedini, 2013, 79). Land subsidence (the lowering of the ground surface) is a potentially destructive hazard that can be caused by many natural or human-induced factors, mainly due to the movement of solids or fluids underground. Compared to other geological hazards such as earthquakes, floods, and landslides, land subsidence causes fewer casualties. On the other hand, its adverse consequences are so severe that they directly affect human, industrial, agricultural, and civil development. The importance of addressing this issue is highlighted by knowing that most of the harmful effects resulting from this phenomenon are irreversible. Damage caused by subsidence and ground cracks is irreparable, costly, and destructive, and its occurrence can be a factor in creating and exacerbating the vulnerability of centers of human activity.

Vulnerability is the logical consequence of risk-taking caused by living in risky areas and shows the state of resilience due to the capacity to accept risk and the ability to repair it. Vulnerability is a multifaceted process that appears in the form of environmental, political, economic, and social vulnerability (Ezquerro et al., 2020, 12). In such conditions, sufficient knowledge of the degree and level of vulnerability, analysis, and explanation of the characteristics and conditions of human groups and

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risk-prone places can improve spatial-environmental planning addressing vulnerability and subsequent crises. The absence or lack of attention to this issue can turn a phenomenon like subsidence in its environment into a threat and disaster.

Historical and old studies about the city of Isfahan and its surrounding areas indicate that this city will not be safe from the possible dangers of any geomorphological hazard, especially the subsidence phenomenon, in the future as it was not safe in the past. According to the latest data from the Geological Organization, currently, the rate of subsidence in the Isfahan-Barkhwar plain is about 160 millimeters per year, and Shahid Beheshti Airport of Isfahan is settling between 8 and 12 centimeters per year. We understand the importance of this concern when we know that in the world when the rate of subsidence reaches 4 mm per year, a critical situation is declared, while during the years 1400 SH to 1401 SH in the northern regions of Isfahan, the rate of subsidence was declared to be 156 mm, which is approximately 40 It is equal to the global rate.

Research Background

In relation to land subsidence, this issue has been considered in many researches. Based on the findings of the background and based on the information of the subsidence working group in the UNESCO organization, the oldest known subsidence occurred in the United States of America in 1900. The studies of this working group have been detailed investigations on 42 subsidences in 15 countries of the world (Baffoe, 2020). In Iran, for the first time in the Rafsanjan plain (1346 SH), land subsidence due to the drop in the underground water level was reported.. The most important studies conducted in the framework of the research are as follows:

Jian et al. (2023) examined the effects of land subsidence on flood inundation from Hurricane Harvey in an article titled, "Does flooding get worse with subsiding land? ". They found that the overall change in flood depth due to land subsidence is relatively minor, with 6 cm of floodwater depth for every 1 m of subsidence in the worst affected area. The effect of land subsidence on flood depth shows strong nonlinearity in time, where the effects from hot spots of previous land subsidence can change as land subsidence continues.

Vanlalnunpuii & AshKanojia (2023) in their article titled "A review of resilience measures for land subsidence-prone areas" carried out, concluded that measures should be implemented using a comprehensive strategy and continuous research with effective tools on subsidence are necessary to identify possible hazards and prevent what may cause or trigger those hazards.

Ezcuero et al. (2020, 12) proposed a comprehensive method, from automatic detection to the probability of building damage, in a paper entitled " Vulnerability Assessment of Buildings due to Land Subsidence Using InSAR Data in the Ancient Historical City of Pistoia (Italy)". They highlighted risks in areas of land subsidence.

Akbar et al. (2019), in an article titled " Adaptive urban design principles for land subsidence and sea level rise in coastal area of Tambak Lorok, Semarang" concluded that adapting the urban space can reduce the impact of the disaster and create a resilient coastline to reduce the risk of natural disasters.

In Iran, Rajaee & Nosrati Heshi (2017), in an article titled " Investigation of the vulnerability of urban fabric with an emphasis on the phenomenon of land subsidence (case study: Tehran)", concluded that due to the population growth, migration, and pressure on the plain of Tehran, as well as the increase in consumption in the agricultural, industrial, and drinking sectors, along with the climate changes and the resulting drought, will lead to unfavorable consequences for Tehran from an economic, social and environmental point of view and will increase land subsidence and cause irreparable natural and human hazards in many parts of Tehran.

Begi (2023), in an article titled "Analysis and simulation of ground subsidence in the north of Isfahan city", concluded that there is a drastic change in the alluvial texture in Isfahan, especially in the north of Isfahan. They added that an unimaginable increase in the thickness of the clay layer. It has happened from about 2 meters in the vicinity of the Si-o-se Pol bridge in Isfahan (city center) towards the north of the city, and at the same time, the reduction of the water level in the last few decades has had significant effects on structural destruction.

Basiri et al. (2022), in an article entitled "Land subsidence and increase in seismic vulnerability in Isfahan metropolis", land subsidence and the increase in seismic vulnerability in the metropolis of Isfahan, concluded that the most important aggravating factors for the occurrence of danger include the exploitation of water, the sudden collapse of the land in Isfahan, may be due to the penetration of underground fissures and the extraction of minerals, which has been emphasized in most researches. Another point is the emergence of land subsidence technology in the city, as well as the asymmetric settlement of the land. The formation of a large number of these sinkholes during the earthquake caused the blocking of the relief routes, and the cutting of the scientific pipes during the past years and fires, it has gained wider dimensions in the research of land subsidence, which will be used more now.

In Shirani et al. (2021)'s article" Assessment of land subsidence in the Najafabad Plain using the differential synthetic aperture radar interferometry (DInSAR) technique " used the data gathered by radar satellites to prepare risk zoning map and forecast risk. They found

that the process of land subsidence from the point of view of location can be directly used as a management and planning basis for prioritizing control and preventive actions.

Karimi et al. (2013) , in an article entitled " Measurement of the level of risk of land subsidence in No.[18] urban residence area of Tehran" concluded that the subsidence phenomenon in the 18th district and its surrounding areas has a wide pattern. The map of the spatial distribution pattern of the residential areas shows the settlement of a significant part of the houses in this area in the area involved in the settlement phenomenon.

As stated in this section, many Iranian and international researchers have researched this issue, but no one has addressed the issue of resilience in the ground subsidence. This article aims to help improve urban resilience against land subsidence, and this is the difference between this article and other research.

Theoretical Foundations:

• Resilience

The International Strategy for Risk Reduction (UNISDR) in a comprehensive definition introduces resilience against natural hazards as follows: the ability of a comprehensive system or community at risk to withstand, absorb, adapt, and recover from the effects of a hazard in an efficient and timely manner including through the protection and restoration of its essential and essential structures and functions.

In the dictionary, there are several meanings for the word resilience, such as recovery power, rapid recovery, change, buoyancy, and elasticity. But in general, most researchers use the term resilience as the concept of returning to past conditions, which is derived from the Latin root Resilio, meaning "going back", and the use of the concept and application of resilience has a very long history, at least for a century BC (Rajaee & Nosrati Heshi, 2017, 2). The term resilience was defined for the first time by Holling in the science of ecology as the ability of a system to absorb shocks, changes, and disturbances to maintain the functioning of the system (Holling, 1973).

Studies show that the term resilience was used for the first time in physics and mathematics to describe the ability to return to the original form of some special materials that change shape when moved. It has lost itself and is not related to a specific science, and also today, resilience is a term and it should be expressed in the correct form in correspondence and conversations We should know that changes are introduced to the whole of a set and change the shape of its members (Wang et al., 2015). Currently, resilience, especially urban resilience to achieve sustainability, has become one of the most important topics of research and research, and Table 1 shows some of the most important definitions of the concept of urban resilience mentioned by people in the research.

Today, the concept of resilience has entered the field of planning with different social, economic, physical, managerial, and environmental orientations. However, most of its attention is focused on environmental issues, and a large part of its research is dedicated to managing the reduction of environmental hazards such as earthquakes, floods, storms, and global warming (Bell et al., 1987).

Considering the issues discussed above, it can be stated that the term resilience has been repeatedly redefined and developed through exploratory, metaphorical, and normative dimensions. This term has been used by different scholars in different disciplines for example, Adgar in social systems, Carpenter et al., in human and social systems, Labibel et al. in socio-ecological systems, Berneau and colleagues in short-term disaster management and Pickett et al. (2004) in social and economic systems (Dehghan Soraki, 2013).

After his initial definition of urban resilience, Holling (1973) considered factors to measure the level of resilience, and by measuring each of these factors, it can be seen that the target area has resilience against risks, based on his theory and other scientists. The following components can be extracted for measurement (Table 2 & Fig. 1).

Of course, some theoreticians in this field, like Adgar, have added or subtracted components to these cases, and some other scientists have completely rejected these factors, but in this research, the focus is on measuring the resilience of Isfahan to this component.

• Urban vulnerability

For many centuries, natural disasters and accidents have always threatened human societies and put human lives at risk in various social, economic, residential, environmental, and other fields. Until the end of the 19th century, the dominant approach and attitude in the issue of reducing vulnerability in dealing with accidents was based on the theoretical concepts of crisis management.

Vulnerability is a process that reduces the stability of the community to face and deal with the risk event. Vulnerability is a type of preparedness and aptitude of the community affected by risky events. Thomas (2005) mentions vulnerability as the ability of the economic-social and Qizic systems of societies, as well as readiness and flexibility against the pressures of natural hazards (Nasire Zare & Karam, 2023). In developed societies, hazards can cause a lot of economic damage, but in developing areas, due to the loss of life, the damage mainly means the loss of human beings. Vulnerability is defined by UNESCO as the degree of loss of an element or set of elements at risk due to the occurrence of a natural phenomenon, which is on a scale from zero (no damage) to 1 (loss). In 2000, the Australian Crisis Management

Table 1. definition of resilience from the point of view of scientists. Source: Authors based on Tran & Wang, 2020; Bahrami & Hemmati, 2019, 42.

Researcher	Definition
Alberti et al. (2003)	Resilience is a concept that combines the ability to learn, adapt, self-reorganize, and achieve balance as well as absorb disruptions.
Walker et a. (2006)	Resilience is the ability of a system to absorb disturbance and reorganize while changing and maintaining the originality of the same function, structure, identity, and feedback.
Boodin (2004)	The speed at which a system returns to tidal after displacement, regardless of how much oscillation is required.
Pickett et al. (2004)	Urban resilience refers to the capacity of a system, in this case, a city, to adapt in the face of chaos.
Allenby & Fink (2005)	Resilience means the capacity of a system to maintain its function and structure against internal and external changes.
Adger (2005)	The capacity of related social and environmental systems to absorb repeated disturbances so that essential structure, functions, and feedback are maintained
Perrings (2006)	The ability of a system to withstand market or environmental shocks without losing its capacity to allocate resources effectively
Coaffee & O'Hare (2008)	Urban resilience refers to changes in design (structural, architecture, spatial planning) and management and governance measures aimed at preventing or reducing the physical and social vulnerability of urban areas and protecting the lives, properties, and economic activities of the city.
Hamilton (2009)	Resilience is the ability to return and provide one's main functions of life in the face of adversity and other risks.
Warde kker et al. (2010)	A resilient system is a system that can tolerate disturbances by using characteristics or criteria that limit its effects, reduce or neutralize damages and disturbances, and allow the system to respond, recover, and quickly adapt to such disturbances.
Leichenko (2011)	Resistance to shock and extensive stress is called resilience.
Liao (2012)	Urban resilience against flooding is the city's ability to withstand flooding and reorganize in the event of physical damage and economic disruption to prevent death and injury and maintain the current socio-economic identity.
Desouza & Flanery (2013)	Resilience is the ability to absorb and respond to changes in urban systems.
Lu & Stead (2013)	The capacity of a city to absorb disturbances and maintain its function and structure is called resilience.
McPhe arson et al.(2015)	Resilience refers to a set of urban ecosystems that bring the benefits of livelihood and urban prosperity.
Folke (2016)	The concept of resilience means the ability and stability of a system in the face of disturbances and the system's ability to develop despite changes and disturbances.
Meerow (2016)	The ability of an urban system and all its ecological-social and technical-social networks on temporal and spatial scales is defined as maintaining optimal functions or quickly returning to them in the face of disturbances.
Spaans, & Waterh out (2017)	Resilience is the ability of individuals, communities, institutions, companies, and systems in a city to survive, adapt, and grow regardless of the type of chronic stress and acute shocks they are exposed to.

Table 2. Research components based on scientists' theory. Source: Authors.

Component	The scientist
Geomorphology	Walker et al. (2006
Geology	Alberti et al. (2003)
Watercourse	Meerow et al. (2016), Pickett et al. (2004)
Physiography	Holling (1973)
Water resources	Perrings (2006)
Aqueducts	Pickett et al. (2004)
Neighborhood	Holling (1973)
Road network	Holling (1973), Lu & Stead (2013)
Building density and population	Holling (1973)
The condition of the buildings	Holling (1973)
User status	Holling (1973)

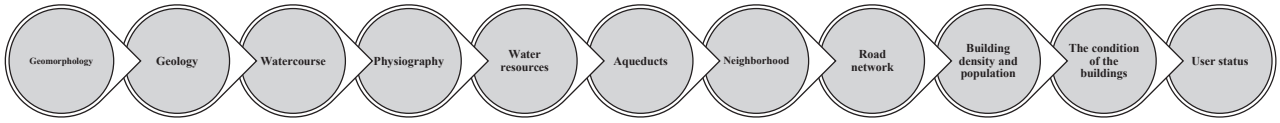

Fig. 1. Important factors of measuring resilience. Source: Authors.

Center defined hazard vulnerability as a degree of sensitivity and resilience of society and the environment (Ghasemi et al., 2019)

Urban vulnerability is the amount of damage caused to the components and elements of a city in the event of an accident, depending on their quality. The vulnerability of the city is a widespread phenomenon that includes all the factors in a city, and due to the dependence of the elements on each other, the vulnerability of the city also expands rapidly (Ferretti et al., 2007). Urban vulnerability is a measure of the differences in the capacity of urban communities to deal with the effects of natural hazards based on their location in the material world (the spatial structure of the city) and the social characteristics of those communities (the social structure of the city) (Goli et al., 2019, 9). In other words, vulnerability is a mathematical function and it is called the amount of damage predicted for each element exposed to catastrophic risks, with a certain intensity Vulnerability is the process of estimating the vulnerability of certain elements that are exposed to possible risk due to the occurrence of calamities (Abedini, 2013, 81) Urban vulnerability analysis, analysis, evaluation and prediction of the possibility of life, material and spiritual damage to the city and its residents. According to the theory of vulnerability and its conceptual characteristics, there is a certain amount of vulnerability in every urban space, but the levels and scope of vulnerability and safety are not uniformly distributed in the city Spaces labeled as polluted, defenseless, and vulnerable are places where all kinds of violence, crimes and even environmental hazards occur, while in other places there is no pattern of urban insecurity and consequently vulnerability or less vulnerability occurs (Rahnema & Mirassi, 2016, 49).

In general, vulnerability is a logical consequence of being exposed to danger and the state of resilience is caused by its acceptance capacity and its ability to repair. In general, the concept of vulnerability provides a very suitable framework for understanding the nature of the crisis, crisis events, the effects and consequences of the crisis, as well as the response to the crisis at different levels.

• Land subsidence

According to UNESCO, subsidence is the collapse or subsidence of the earth's surface that occurs for different reasons on a large scale. Population growth along with the excessive expansion of water resources for use in agriculture and industry has many adverse consequences in the quantitative and qualitative aspects of water resources (Sharifikia et al., 2011). Usually, this term stands for the vertical downward movement of the earth's surface (Poland, 1994).

According to the definition of the Geological Institute of the United States of America, it includes the collapse or subsidence of the earth's surface, which can also have a small horizontal displacement vector.

Land subsidence causes significant changes in the hydrological characteristics of the land, such as the direction and speed of groundwater flow. Other consequences of subsidence include damage to engineered structures such as buildings, roads, pipelines, and well casings. Low-rainfall areas suffering from drought are mainly prone to land subsidence. However, groundwater extraction is the primary cause of land subsidence. (Sharifikia et al., 2013) In terms of the formation process of subsidence, slow movement and slow subsidence of the earth or its sudden collapse are included.

Subsidence is the depression of the earth's surface topography that is directly or indirectly caused by human activity. The environmental effects of land subsidence in urban areas are numerous and can be separated and classified as social, economic, environmental, and infrastructure effects as shown in Table 3.

Based on the results obtained in the last few decades, the phenomenon of subsidence is divided into two groups in terms of origin: 1. Land subsidence due to natural processes/ 2. Subsidence due to human activities.

Subsidence caused by natural processes is divided into subsidence due to technological activities, fire eruptions, dissolution of rocks, condensation of deep sediments, melting of ice, and other natural processes. In contrast to these processes, human activities can induce rapid and more serious subsidence and typically include subsidence due to excessive fluid extraction and mining, which are caused by the interaction of humans and the existing environment (Karimi et al., 2012, 48) (Fig. 2).

In general, it can be said that the extent of damage to a place depends on several factors, the most important of which is urban resilience. If a city is resilient, it can control the damage caused by hazards and face the crisis with less shock. In the city of Isfahan, one of the risks that occurs repeatedly is the phenomenon of land subsidence. In this study, with the help of various tests, the risk of subsidence was first measured and then the resilience of this city against these subsidences was measured (Fig. 3).

Research Method

This study is applied in terms of purpose and analytical survey type. Quantitative and qualitative methods have been used simultaneously for data analysis. In this study, two steps have been used to investigate. In the first step, the vulnerability of Isfahan city is investigated with the help of GIS, which is a quantitative analysis. It has been paid against the subsidence phenomenon. In the next step, analytical methods are used to process radar images based on the differential interferometry technique through the phase extracted from the interferometer to

Table 3. Characteristics of the effects of land subsidence in cities. Source: Authors.

Classification	Impact sample	Impact Level
Infrastructure	Permanent breakage of buildings and roads	Directly
	Bending or overturning of houses and buildings	Directly
	Demolition of houses or buildings	Directly
	Breakage of pipelines and urban facilities	Directly
	Technical defect in sewer network and drainage system	Indirect
	Deterioration in the performance of infrastructure and buildings	Indirect
Environmental	Changes in the river channel and drainage systems	Indirect
	Continuous coastal flooding	Indirect
	Wider development of floodplains	Indirect
	Flooding of areas and infrastructure	Indirect
	Increasing the internal advance of seawater	Indirect
	Deterioration in the quality of environmental conditions	Indirect
Economic	Increase in infrastructure maintenance cost	Indirect
	Decrease in value of land and assets	Indirect
	Abandoned buildings and facilities	Indirect
	Disruption of economic activities	Indirect
Social	Burnout in quality of life and dynamic environment	Indirect
	Disruption in people's daily activities	Indirect

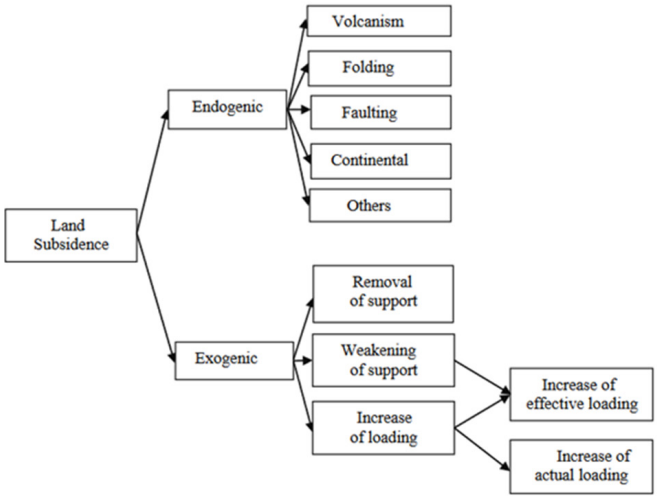

Fig. 2. Classification of the types of land subsidence in terms of origin. Source: Authors.

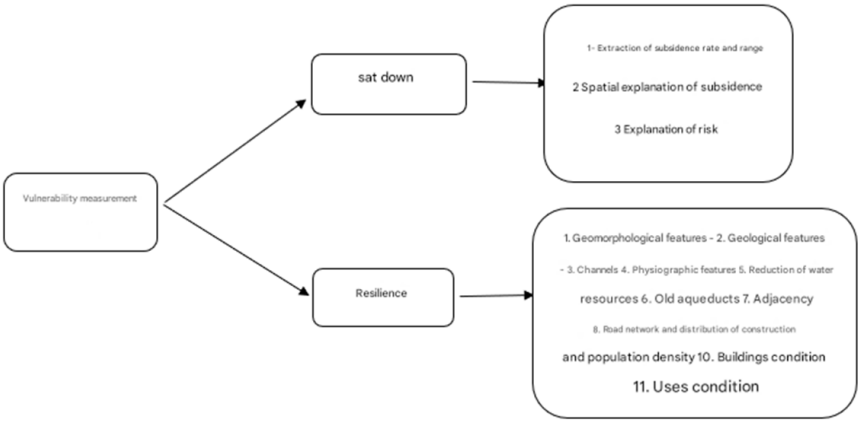

Fig. 3. Research flowchart. Source: Authors.

identify and determine the latest state of the areas subject to subsidence and determine the measurement and rate of its range. A differential radar interferometry technique with wide, frequent, and continuous ground coverage, as well as high time and spatial resolution, as one of the most accurate (in millimeter scale) and least expensive remote sensing techniques for identifying and displaying existing displacements It has come to the ground is By determining the areas subject to subsidence and classifying them based on the extracted rate, as well as analyzing documentary and registration data to explain the causes of subsidence, a survey was conducted using the D-GPS tool to search and identify the areas introduced in the images.

Research Findings

• Extraction of subsidence rate and range

For this purpose, the technique of differential radar interferometry has been used. This technique is based on the measurement of the phase difference values resulting from the repeated reception of two signals with a time difference from a flight phenomenon to the fixed platform. Also, to improve the accuracy and reduce the phase inconsistency, the period was reduced to at least 2 months. Based on this method, two interferograms were obtained over 4 months. The values resulting from this interference are also after performing other operations, converting the phase to displacement map and removing the pixels with values of zero (no change in height) and above zero (uplift), confirming subsidence at a maximum rate of 10 cm per period. The period of 4 months is in the study area, whose spatial distribution pattern is shown in Fig. 4.

According to the above map, the lands subject to subsidence in the central areas of Isfahan are more at risk of subsidence than the surrounding areas. The maximum rate of subsidence in this range in the form of points with a maximum radius of 800 meters is 2.5 cm per month and its maximum is about 1.5 cm. The amount of subsidence from the main core in the central part of Isfahan has been decreasing in all geographical directions.

• Spatial explanation of subsidence risk

To produce a map of the spatial pattern of high-risk areas, the two-factor subsidence rate and amplitude extracted by the interferometer were entered into the system analyst in the GIS environment. The output map represents cells with different values from the risk generation factor. Based on this, the classification of the value of the cells introduced in the output map below was divided into 4 different ranks under the title of very high-risk areas, high-risk areas, relatively high-risk areas, and relatively low-risk areas.

According to Figs. 5 & 6 and Table 4, it can be seen that nearly half of the study area is in high-risk and very high-risk areas.

• Explanation of vulnerability

In this study, the spatial explanation of risk in two patterns of residential facility risk and population risk was investigated. To explain the risk of residential units and facilities, first, the map of the construction dispersion pattern was extracted with the help of a field survey.

According to Fig. 7 and Table 5 the findings indicate that all urban facilities and settlements in this area are at risk of accidents. 60% of the properties have low to relatively low risk and only the remaining 40% have high risk.

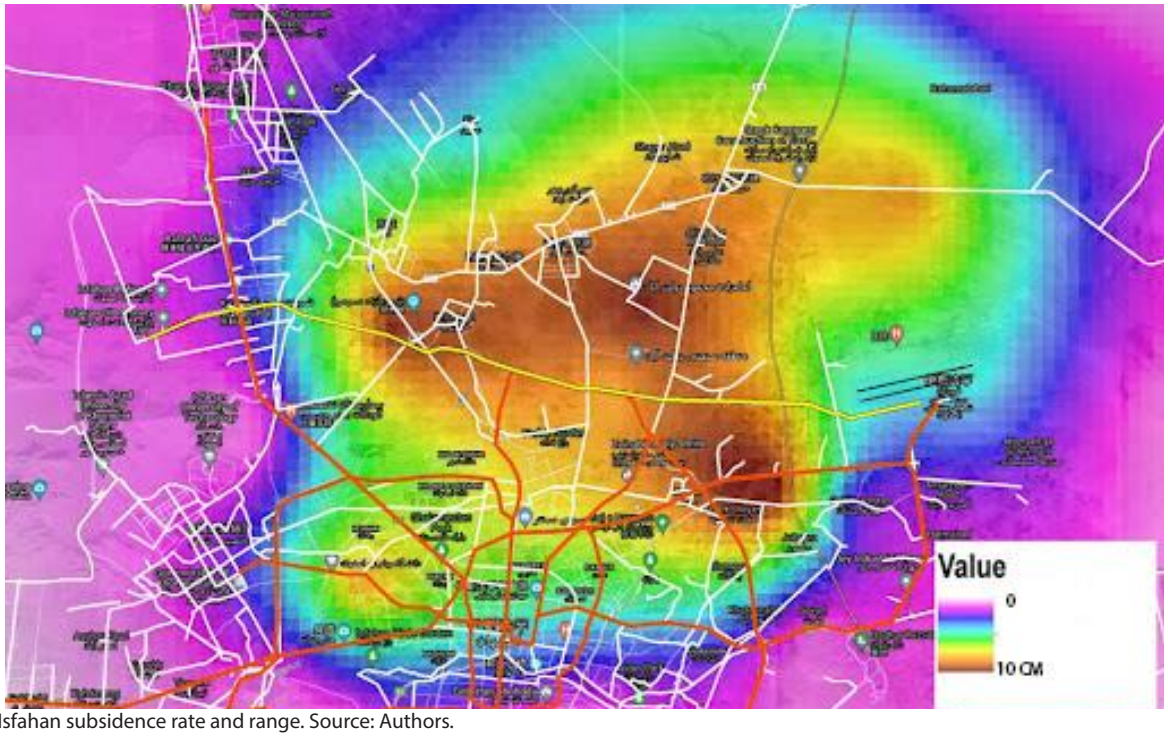

Fig. 4. Isfahan subsidence rate and range. Source: Authors.

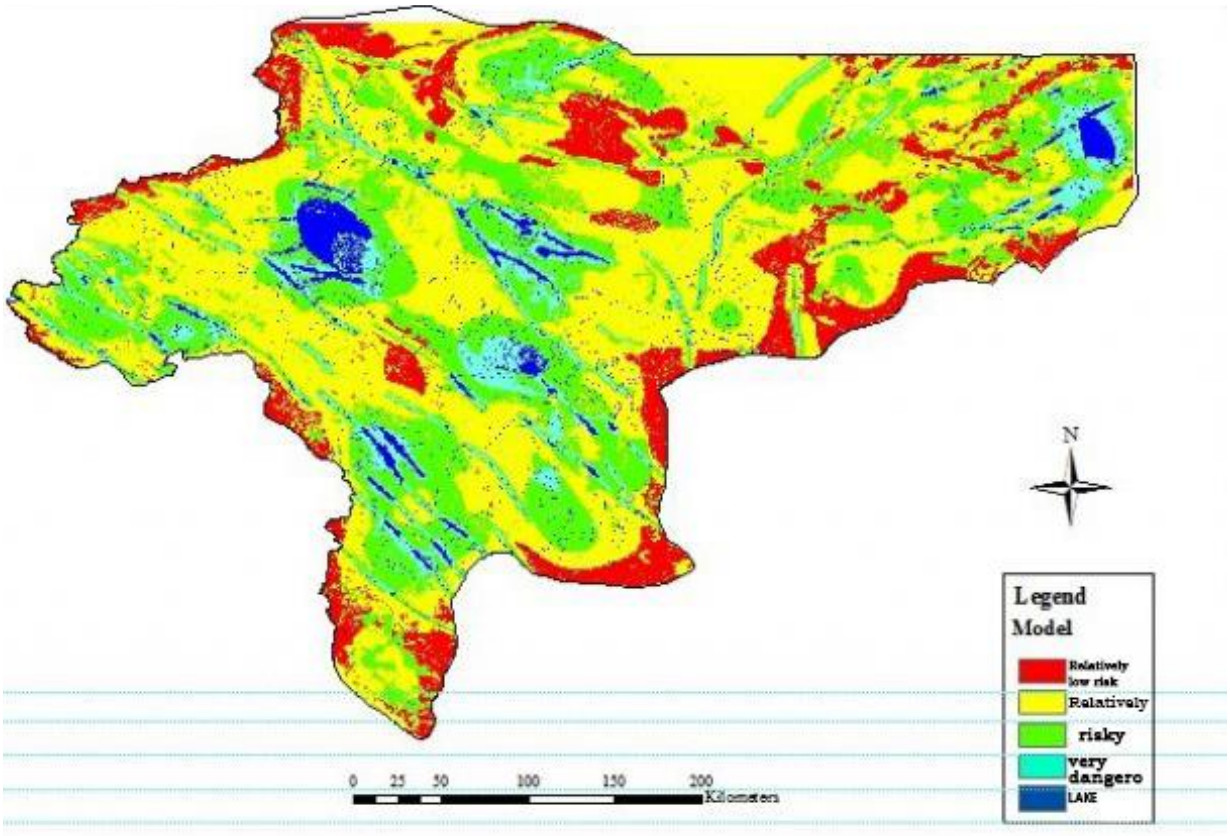

Fig. 5. Spatial explanation of land subsidence risk in Isfahan. Source: Authors.

Table 4. Area and percentage of land subsidence risk based on zoning. Source: Authors.

Danger zone	Area (square meters)	Percentage
Relatively low risk	9558500	33
Relatively risky	44191615	40
Risky	9091600	17
Very dangerous	8540900	10

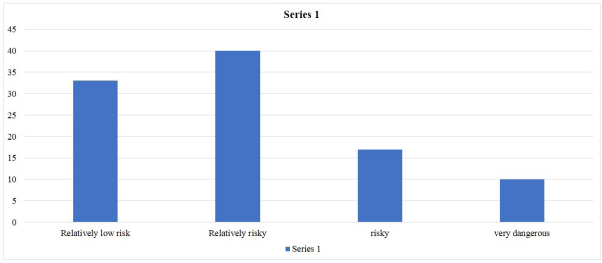

Fig. 6. Diagram of the level of risk of land subsidence in Isfahan . Source: Authors.

The vulnerability of the population and human groups has been analyzed based on the presence or absence of the population in the risk area due to the limited access to suitable location data. For this purpose, for a more appropriate understanding of the human groups located in the risk area and to explain the spatial distribution pattern and the degree and degree of vulnerability based on the volume of the exposed population, we have used the population density index per unit level.

According to Table 6 To extract the population at risk, by using population statistics located in the blocks and the spatial model map of the risk of the houses, the risk values were extracted for the population living in the studied area. According to the findings, more than half of the population living in the area has a high to very high vulnerability due to their settlement in risky areas.

• Evaluation of urban resilience indicators in Isfahan

According to Holling (1973)'s opinion, in evaluating the resilience of the city, natural features, geology, types of uses, road network, etc. . are among the indicators that should be examined. which was examined in this study as follows:

- Geomorphological feature

The investigation of the geomorphology of Isfahan city shows that the city is located in the outlet part of the catchment basin of the northern highlands on geomorphic

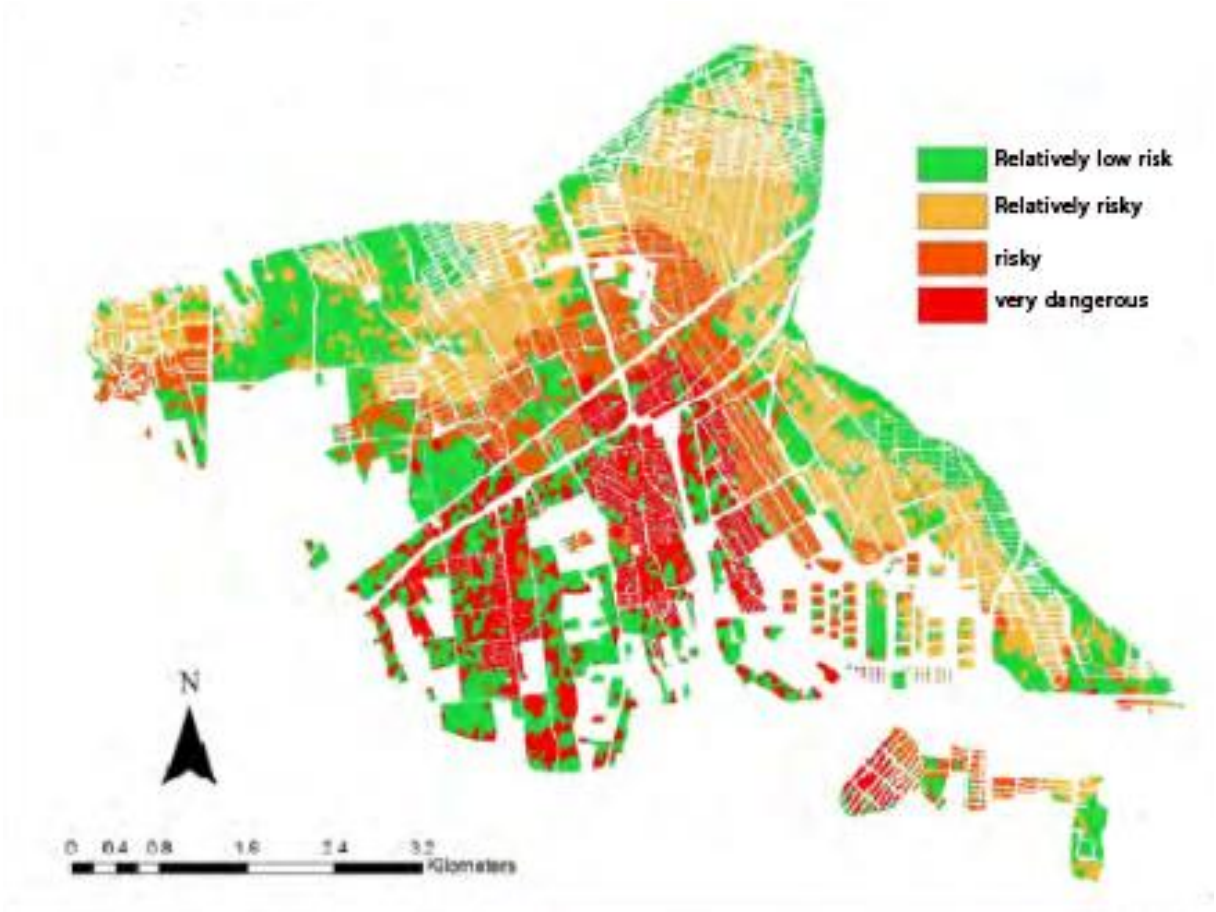

Fig. 7. Risk tolerance of residential and utility units in Isfahan. Source: Authors.

Table 5. The number and area of residential units - risky facilities by risk groups. Source: Auhtors.

Risk rating	Number of residential-facility units	Percentage
Relatively low risk	11605	19
Relatively risky	54123	41
Risky	32079	38
Very dangerous	21061	2

Table 6. Risk susceptibility of the population living in Isfahan. Source: Authors.

Title	Relatively low risk	Relatively risky	Risky	Very dangerous
Population	9138	99490	61838	60797
Family	5841	57323	30896	42919
Percentage	4	39	25	32

forms such as old and new alluvial cones, high permeability and the continuous change of the river's course on it, which these features from the point of view of urbanization are due to The strength of the earth's structure, the feeding of underground water resources and the reduction of the volume of runoff during rains are suitable and opportunities, but with urban construction on it, these features become threats such as the increase of the volume of runoff due to the covering of the ground surface through the asphalt of streets and roofs of buildings and the reduction of the feeding of water sources, the pollution of water sources due to the infiltration of various wastes into them, and the increase of seismicity. The core of the city is located on the lead plain with fine-grained sediments with less permeability, which causes the destruction of agricultural lands, which results in the reduction of food production and pollution of soil resources.

- Geological features

The investigation of the geological indicators of the region indicates many tectonic movements of the second era,

and the presence of 63 active faults in Isfahan, colored mixtures (ophiolites), is the result of compressional and compressive movements of the Upper Cretaceous, unfortunately, some of the vital uses of this city are in the vicinity of this fault. has been located.

- Pipes

Isfahan was a city with a primary biological core and a stream in the sense of geo-atmospheres in the main core of the city. The role of the Zayandeh River and the material networks branching from it, in the past, has been of special importance in agriculture and water supply, surface water collection, and city settlement. The existing means and materials and the non-compliance with the rules of river protection in this city have caused a lot of human and financial losses in the crisis conditions of these means and materials.

- Physiographic feature

The high slope in the northern parts of the city adds to the flooding of the region, and the decrease in the slope in the south and the central core causes problems such as the lack of drainage of surface water and various sewage, resulting in the flooding of roads and houses.

- Reduction of water resources

The uncontrolled development of the city to the surrounding natural resources and their change of use (covering the ground with asphalt, streets, and constructions) has resulted in the lack of supply of underground water sources and sometimes due to the infiltration of sewage into the sources, it has resulted in their pollution on the one hand and Excessive consumption of water with the growth of the population, on the other hand, has reduced the water resources in the city of Isfahan, which is looking outside the region to supply the shortage.

- Old aqueducts

Investigating the subsidence and lowering of the underground water level to less than 3 meters in some areas of the city indicates the existence of more than 20 old aqueducts under the city, some of which are drainage channels by the relevant departments in the early years of various excavations in the city and the implementation of Ego have been closed and some have been closed due to the owners not dredging. Over the years, due to the impenetrability of the bedrock of the city, water collected in the channel of these aqueducts and found its way to the upper layers, causing the roofs of the aqueducts to collapse. The water level has risen in the city.

- Neighborhood

The proximity of some uses in the city with residential, transportation, and sports uses in these areas, the proximity of gas facilities with green space, and the proximity of extensive medical, judicial, and service use with faults and so on. . . There is an inconsistency in this city. It means incompatible uses in some areas of this city are incompatible with each other.

- Road network

The road network of this city is divided into two categories, the old and new roads, which in the old road and the border are narrow and winding and have an organic structure based on the need of time to form the road without a regular geometric shape, but in the new road, structure shows a higher traffic load tolerance, which generally does not respond to the traffic load in times of danger due to the low width, adjacent structures, the shape of the connection, the mismatch of the width of the road and the height of the building in many areas of the city.

- Distribution of construction and population density

According to the documents of the statistics center in Isfahan, an imbalance can be seen in the examination of the different regions and areas of the city, such that the building density in the north and northeast is higher than in the south, west and central core of the city, but the population density is higher in the west and south of the city instead of open space. Green is also not responsive to the population in these areas.

- Condition of buildings

Examining the distribution of types of uses in this city shows that according to the basic principles of urban planning, there is no balance and in many areas of the city there is no proportion between density and open spaces, which will lead to a lack of resilience. High-rise buildings and structural land features by dividing the city areas revealed that the location of a large number of high-rise buildings built in the city was chosen without study, and the amount of public green and open space is very low. In the analysis of the vulnerability caused by access, the index of the width of the passage was used, and the result was that the width of the passage was directly related to the level of resilience, that is, the passages should be better according to the hierarchy of urban functions. Vulnerability is also reduced due to better accessibility. The existence of dead-end alleys and a narrow communication network makes it difficult to access the old fabric of the city, which generally includes the central areas. But in new constructions, the ratio between the height density and the width of the passage is not observed, it has also caused the communication network to face problems. It has not been observed.

- User status

According to the conducted studies, major anomalies in the safety structure are evident in terms of the condition of the city's housing structures. Land use has a very effective role in resilience. Such as therapeutic, residential, educational uses, etc., as the ratio of mass to

space (occupancy level) increases, resilience decreases. However, the incompatibility of some uses can be seen in this city. Uses that require storage near residential areas cause land subsidence in these areas.

• Factors threatening the urban resilience of Isfahan

The physical expansion of the city of Isfahan, which is more or less limited in all aspects, shows that natural factors (such as the low slope of the central and southern core of the city, which causes the problem of collecting surface water and sewage, the high level of underground water Locked in the old aqueducts under the city, encroachment on the canals...) and human factors have played a key role in the progress of the spatial development of the city.

The accumulation and unprincipled growth of industries and as a result the migration of people from the villages of the region to the city has caused the expansion of new residential areas in it. In parallel with that, communication networks have also been developed according to the needs of the residents and according to the opinion of real estate sellers (higher square footage sales). Since these actions were carried out without specific plans and principles, a large part of the agricultural lands and other lands with natural talent in the region have also been destroyed, and the share of industry and construction has destroyed more than 25% of the agricultural and high-quality lands in the region. The growth of industry and population has resulted in excessive exploitation of water resources and has caused a lot of damage to the underground water reserves, and the combination of these factors has changed the natural characteristics of the earth. Among the other factors investigated is the spatial layout of rescue centers in the city. The physical expansion of this city has happened without studying the crisis of the city against natural disasters. Parts of the city that include worn-out texture, and marginal areas are among the most vulnerable parts of the city due to low housing quality indicators and lack of proper infrastructure. The communication network of the city has increased the vulnerability of the city due to the lack of radial streets next to the traffic rings, the existence of a complex communication network in the narrow width of the border and the old fabric, the juxtaposition of the old and new communication network has increased the vulnerability of the city. It shows that the segmentation of fine-grained land has created the arrangement of open spaces within the parts and irregular network passages. A large concentration of commercial, production, and service activities due to the location of the market in the central core of the city, while increasing the temporary population density, in combination With the increase in the deterioration of the area, the safety standards have been reduced. The road network and the level of access can play a decisive role in the resilience of the spatial and physical structure of the city because, in times of crisis, any service depends on the existence of a smooth and active road network. Most of the central, southern, and marginal regions have low resilience in terms of access to the appropriate road network. Another factor that plays a major role in resilience. The role of open spaces as a texture changer in reducing damage to the body is very weak. Blocks with high population density, narrow communication networks, long distances from rescue and rescue centers, and a high degree of isolation are less resilient, and the resilient zone with a low and very low spectrum is evident in the west, center, and parts of the north. The factor is caused by the features of the land, high population density, construction, and low width of the communication network.

Discussion

As mentioned earlier in the studies, one of the most important challenges facing the metropolis of Isfahan is the phenomenon of land subsidence. This process is the result of excessive extraction of underground resources, especially water, and the imposition of loads resulting from human activities on the surface. The findings of the research indicate the effectiveness and necessity of vulnerability assessment studies in connection with the phenomenon of land subsidence to organize and rearrange these points to prevent the accident from turning into a disaster. Unfortunately regarding the risk of subsidence due to its very slow occurrence, population groups are at risk, and even in some cases managers and officials are not easily informed of its existence it is obvious that in this situation vulnerability is due to the lack of adjustment beliefs in the risk Flexibility will occur with maximum laterality.

Also, in the field of urban resilience against this phenomenon, it is confirmed that it was investigated due to the importance of the city's communication network during natural disasters. Among the problems of the road network of the city are the low service levels of the roads and the construction of streets that are inconsistent with the fabric of the city, which will multiply the vulnerability of the city in case of a crisis. According to the conducted studies, major abnormalities in the safety structure are evident in terms of the condition of the city's housing structures. Another essential variable in resilience is the relative density of the population. Excessive population density will cause a reduction in services per capita, an increase in traffic and air pollution, social anomalies, and many other problems, each of which will multiply the vulnerability of the city in case of natural crises. Among the problems that the construction of high-rise buildings in different urban areas has, is the increase

in the undetermined amount of traffic of the resident population, which also harms the per capita uses. That is, in the comprehensive plan, for each user, a specific service ceiling is considered for its population, and there is a possibility that the considered level is not sufficient for the new population, and excessive reduction of the population also causes problems in the process of service delivery. If the amount of construction as well as population density is distributed in a balanced way, at the level of the city, a variety of solutions can be offered regarding the texture of the city, for example, its land use, paying attention to the possible risks of various accidents to create a safe city against natural disasters, zoning the city based on the risk of natural disasters, respect for privacy and the proximity of dangerous uses, the transference of dangerous uses outside the residential context of the city.

Conclusion

The subject of the research is a practical issue in the area of city resilience and land subsidence. The research attempts to investigate the vulnerability and resilience of Isfahan against the phenomenon of land subsidence. This study employed a theoretical-applied approach and comparative and analytical methods.. This study shows that the problem of land subsidence in Iran is generally caused by the excessive exploitation of underground water. The findings of this research, documented in Tables 4, 5 & 6, show that all houses, populations, and facilities are at risk, although the degree of their risk is somewhat different. Also, these findings emphasize the subjectivity of the spatial distribution pattern of risk in specific social conditions and Economic and environmental scope has had pervasive vulnerability in all fields. In general, the factors affecting urban resilience against natural phenomena such as land subsidence can be summarized as Table 7.

Table 7. Summary of factors affecting the urban resilience of Isfahan. Source: Authors.

Factor	Criterion	Impact
Geomorphological	Fault	The greater the distance from the fault, the greater the resilience and the less vulnerable.
	Watercourse	The distance from the watercourse, Valley, and Madi causes more resilience and less vulnerability.
	Green space	Greater distance from green spaces reduces resilience and increases vulnerability.
Physiography	Slope	The higher the slope, the greater the vulnerability and the lower the resilience.
	Height	The higher the height, the higher the vulnerability and the lower the resilience.
	Direction	Sun-shaded slopes increase resilience and reduce vulnerability.
The condition of the buildings	Antiquity	The older the building, the more vulnerable it is and the less resilient it is
	Higher	The higher the density of the building, the greater the vulnerability, and the lower the resilience of the building, the greater the vulnerability and the lower the resilience.
	Segmentation	The bigger the segmentation, the more resilience and the less vulnerability
	Texture	Regular tissue is more resilient and less vulnerable.
	The width of the passages	The greater the width of the passages, the lower the vulnerability and the greater the resilience
Uses	High-risk uses	The lower the number of high-risk uses, the lower the vulnerability and the greater the resilience
	Incompatible uses	The more incompatible users are, the greater the vulnerability and the less resilience.

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