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Investigation of Land Subsidence in Orzuiyeh Plain of Kerman Using Radar Differential Interference Method (DINSAR)

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Abstract

The phenomenon of subsidence of the earth occurrence causes wide–raging problems and dangers. The occurrence of this phenomenon causes problems for farmers, the destruction of communication lines and infrastructures and some other issues. In this research from differential interference (DINSAR) and using ASAR sensor data from 2009 to 2010 and sensors sentinel 1 in 2014 – 2015 in relation to the Kerman's Orzuiyeh plain, it is tried to depict the phenomenon of desertification in the picture of the Kerman valley. Temporal and spatial changes have been made in this plain. Seascape software is used to process the image. The results of the series analysis shows that the region is continuously subsiding; the amount of subsidence per year 2008 to 2009 is 15 centimeters, the most abandoned has been in the northwest and central plain; and in 2009 by 9, and 100 cm in 2010, which is still the highest amount of subsidence in the northwest and central plain. For the year 2014 and 2015 it is 8.2 cm which is in the southeast part of the Orzuiyeh plain. Observing the subsidence images of these years it can be concluded that Orzuiyeh's desertification is dynamic and a trend from the north to west of the plain.

Keywords*:* Radar interferometer, Orzuiyeh, Subsidence, ASAR, Sentinel 1.

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1. Introduction

Earth's subsidence is a gradual or sudden collapse of the earth's surface due to the changes in shape and displacement of particles (Rahnama et al., 2006). Different causes, irrespective of the source and manner of the occurrence, causes subsidence, which can include underground fired, mineral mining and extraction of mineral resources, oil and gas extraction, extraction of underground water, liquidation chemical and tectonic movements of the earth's crust which are among the factors that cause the phenomenon to subsist (Shemshaki, 2006).

This phenomenon is only detected in most areas that are in surface morphology especially in facilities and equipment it will cause destruction and damage. Urban areas due to population density, vital buildings and structures, especially injuries are more affordable.

This phenomenon could damage the streets, bridges and hills, disrupting water supply lines, gas and sewage, as well as buildings causing cracks. Therefore, in order to assess the risk and better manage resources controlling the precise timing and location of land surface changes are required. The GPS technique uses precise continuous observation and alignment of surface change but in a series of limited points that are the same stations (Reccardo et al., 2004). Therefore, it is able to capture the range of the region affected by the phenomenon and will not be modeled. Radar interferometry technique is a powerful way to show the level changes in very high spatial resolution (Berardio et al., 2000).

Underground land exploded by the overuse of underground resources, is one of the events that have been observed in Iran. This phenomenon can cause irreparable damage to areas if not properly managed. Today, land abandonment is considered as a dilemma due to the excessive withdrawal of water from underground resources has severely threatened the human societies and the inhabitants of the suburbs.

By studying the subsidence of the region and gaining its growth rate caused by this phenomenon in the region and provide it to the municipality, the ministry of roads and other agencies and institutions to avoid the dangers and threats from the subsidence phenomenon (effecting the construction of buildings, subway, railway, etc.).

The severity of soil subsidence in Iran's plains is at least 90 times higher than the most critical conditions in the developed countries. The annual subsidence rate crisis is considered to be four millimeters in advanced countries. However, in 2006 the subsidence rate in our country was 17 centimeters per year that increased to 36 centimeters in 2011 (The eastern daily, 2012).

Reports from all over the world related to land subsidence to dry and low rainfall areas such as Arizona and California Arica, the cities of Osaka and Tokyo in Japan, Venice in Italy, Bangkok in Thailand, Jakarta in Indonesia, Calcutta in India and Mexico City in Mexico(Rahnama, and FarahamKazemi). Radar interferometer (INSAR) is an invaluable technique for measuring the shape of the earth. Because of the high spatial resolution and the ability to obtain distant interferometry information, it uses the phase difference in between the two images of a region in order to estimate the region's change. On the bases of behavioral control there is a need to transform the time of phenomenon occurrence in the study area. Therefore, several images at different time intervals of the region is needed to perform the inference mapping between the time intervals to calculate the rate of change.

The radar interferometry (INSAR) has many advantages in measuring and displaying the earth's crust displacement, such as light sensitivity to dynamic variations, high spatial resolution, and wide coverage. The use of SAR images of dynamic variation of our region can be obtained by mapping the change accurately to about a millimeter. Subsidence has been observed in some plains of Iran such as: Arak Nahavand, Khomein, Natanz, Kashmar (Lashkari pour et al., 2006), Mashhad (Lashkari pour et al., 2005; Akbari et al., 1999), Neyshabur (Moteq et al., 2007), Hashtgerd (Haghighat Mehr et al., 2010), Noqah and Baharman (Sharifi Kia, 2012), Rafsanjan (Rahnama and Kazemifar, 2006), Sistan (Rahnama and Firouzan, 2002), Yazd and Ardakan (Alamin, 2002, Komak panah, 2007, Amigh, 2009). Hashami et al. (2015), in an article, examined the subsidence modeling of Neishabour plain using time series and DINSAR technique for the period of 2003 to 2005. In this study, images of C band, an ASAR sensor, was used, the results showed that the subsidence rate in this area was between 10 and 15 centimeters.

Azardeh Pashaei et al. (2016) examined the subsidence of Saveh plain using radar interference method, the results showed that the spatial distribution of the subsidence areas indicates the maximum occurrence of subsidence in the eastern, northern and northwestern areas of Marand plain. The harmonization of the resulting subsidence maps with the land use and geological layers of the region indicates the role of uncontrolled extraction of groundwater in the occurrence of subsidence in Saveh plain. Also, the correlation of piezometric surface changes with the rate of subsidence correlation coefficients of 0.8, indicates a direct relationship between the drop-in groundwater level and the amount of subsidence that occurs on the earth's surface. Keshavarz et al. (2018) in a study calculated the rate of subsidence in Faryab industrial zone in Kerman province and the results showed that, the rate of land subsidence was -3cm in the region.

The rate of subsidence of Hashtgerd plain has been investigated using the radar interferometer technique with four radar image ASAR ENVISAT, for the period from 11/7/2008 to 24/10/2008. The results showed an average subsidence of 47 mm per month. The purpose of this paper is to demonstrate the inter radar interoperability capability, with a combined stomp (INSAR) for displaying ground changes. Identifying the subsidence regions and estimating their rates will have a significant role in controlling this phenomenon. The study in this field is necessary because the importance of this phenomenon as one of the natural hazards in the formulation of management strategies for the identification, prevention, reduction and compensation of damages effective structure. Therefore, obtaining the rate of subsidence in Iran is an important and innovative work temporally and must be calculated continuously. In this study, an attept is made to determine the level of subsidence in the earth for the province of Kerman's Orzuiyeh and monitor its changes over the period from 2008 to 2010 and 2014 to 2015.

2. Materials and Methods

2.1. Study area

The plain of Orzuiyeh ranges from 48°55′ to 59°58′, eastern longitude, and 28° to 59° and 28°, northern geographic with a distance of about 270 km from the center of Kerman province and is located in the southeast of Iran. Orzuiyeh, with an area of approximately 4980 square kilometers, covers about 71.2% of Kerman province and it is located to the north by Baft and east of Jiroft and Faryab (Figure 1). Orzuiyeh has a hot and dry climate with hot summers and cold winters. Due to the weather conditions the air and soil of the region are considered as important poles for the production of crops such as wheat, corn and cherry that unfortunately, with an increasing exploitation of ground water in the region and subsequent droughts, the groundwater level in the area has dropped dramatically. Since, Orzuiyeh region economy is based on agriculture which depends on water; reducing the quality, quantity and access to underground resources thus effecting the people of the region.

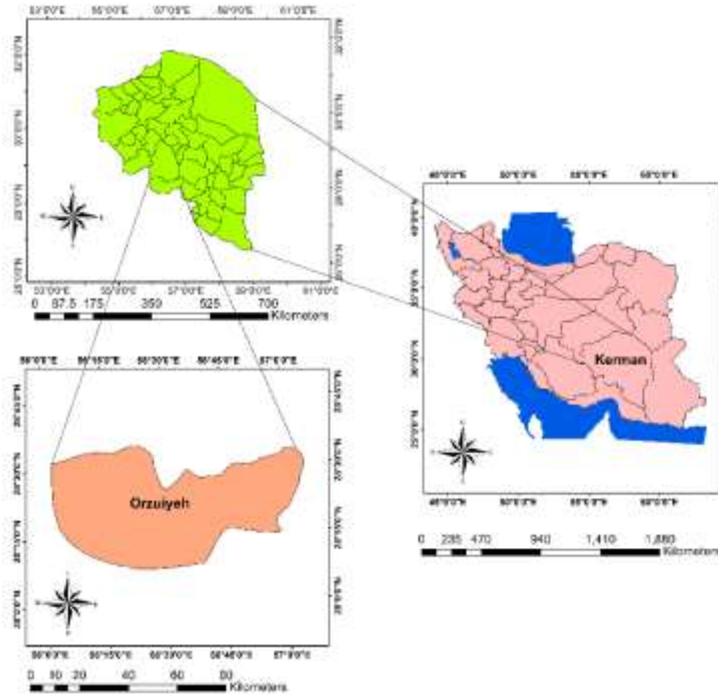

Figure 1. Study area.

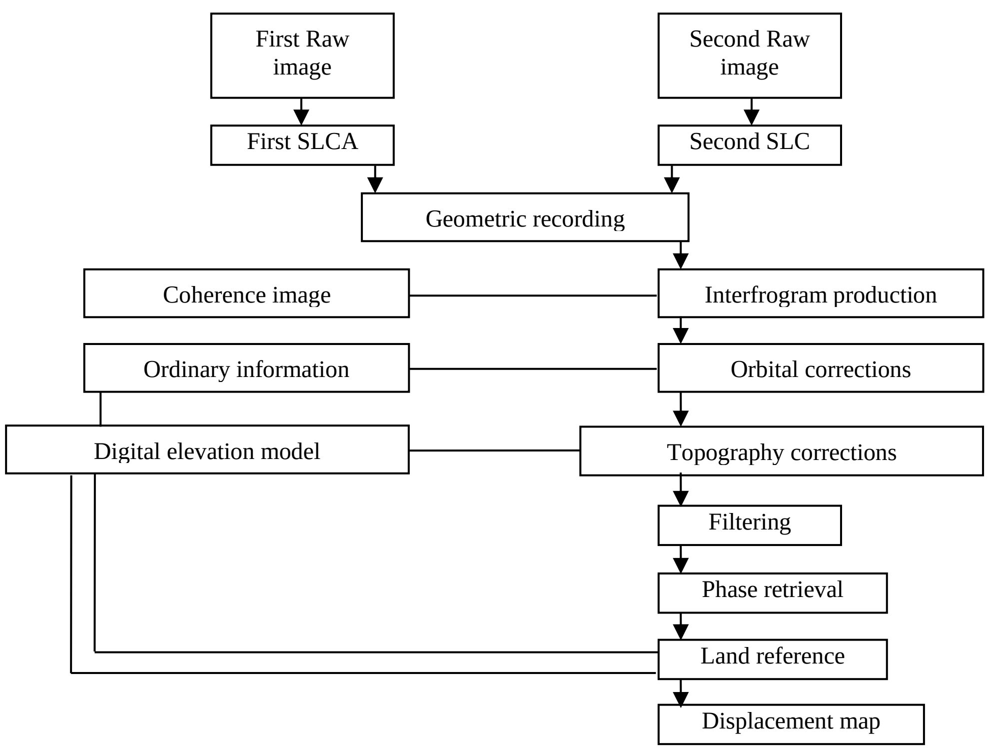

Figure 2. the interferometer Processing stages

2.2. Satellite data used

The study has used three images of the ENVISAT- Asar satellite, two images of Sentinel 1 satellite, all images have C-band. The information in the images can be seen in Table 1.

Table 1. Specifications of the used radar images

Image number	satellite	Sensor	Date of imaging	Image mode
1	ENVISAT	ASAR	09/10/2008	ASA_IMS
2	ENVISAT	ASAR	29/10/2009	ASA_IMS
3	ENVISAT	ASAR	09/09/2010	ASA_IMS
4	SENTINEL1	C-SAR	29/10/2014	S1A_IW_SLC__1SSV
5	SENTINEL1	C-SAR	24/10/2015	S1A_IW_SLC__1SSV

2.3. Methods

One of the useful tools for monitoring subsidence in a region is radar interferometer. This method, by comparing the phases of two radar images taken from a region at two time intervals,and to determine the level changes in the earth, complication phase on the surface of the earth, proportional to its distance to the sensor radar. In the technique, mixed radar images containing the phase values and the amplitude of the return wave from the side – to – side sensor are combined with each other and an image produced called an interferogram. The Interferogram is an image of the two difference phase of the image taken at two different times which are geometrically accurate (Manisons et al., 2003).

Matched and a SAR system employs an electromagnetic wave at wavelengths ranging from several millimeters to centimeters and under any water conditions it flies overnight and day; the reflection signal, both in terms of intensity and reflected phase of each element, in a land-based separation cell, arrays of imaginary values are recorded. These fantastic leveled of surface reflection show the earth. Whenever there are two radar images from an area at a different time.

Provided that the model and elevation of the area is available, the image of the relevant interferogram can identify any displacement occurring in the area. If the radar distance to the ground point in both imaging is equal, the return phases are the same and their difference is zero. The radar distance changes to the ground point, hence the second image phase will be shifted and this shift signifies the changes in the surface of the earth. The amount of these changes is proportional to half the wavelength that produces a fringe in the interference.

Interferogram phase contains topographic information, orbital errors, object displacement and atmospheric effects. The topographic and atmospheric errors should be removed to obtain the movement of the earth's surface over a period. This effect can be neutralized by using duplicate images (time series-based methods such as SABS) or global atmosphere model (such as MODIS or MERIS) or corrected observations of GPS stations. Component circuitry is also possible by using accurate satellite orbital information. The topography component can be eliminated through digital land models. Therefore, only the phase difference remains resulting from the transformation (Fateh Allahi et al., 2018).

After receiving the data, first the baselines were extracted. The baseline spatial is the distance between the positions of the two sensors in the orbit. The basic baseline should be checked because it has a direct effect on the topography phase. A spatial basis allows calculating the target height and topographic map. The spatial baseline is one of the impotent factors in selecting the image pair. The baseline time should be considered, because if the time interval between two images is high then there is the occurrence of time uncertainty. The next step is the geometric correction of image, were the geometric errors related to the difference in antenna positions during the imaging of an area are eliminated. At this stage, the base image is sampled vertically based on the effective factors, which causes the image to stretch due to the topography. The interferogram is obtained from the phase difference of the two radar images that indicate the changes, which is done after the geometric correction. Table 2 shows the processed interferograms in the Orzuiyeh plain.

Table 2. Specifications of interferograms of the Orzuiyeh plain

satellite	master	slave	Temporal Baseline(day)	Spatial Baseline(meter)
ENVISAT	29/10/2009	09/10/2008	385	44.027
ENVISAT	09/09/2010	29/10/2009	315	51.243
SENTINEL1	24/10/2015	29/10/2014	360	40.921

Within the interference, there is a color line called Fringe. Each fringe has a phase, a difference phase of 2π shows the radians that is usually half the wavelength and, in the Intergraph, a full-color cycle of blue (from zero radium) to red (2π radians) and includes red, green, yellow and blue colors. The geometric recording image can be used to calculate the composite correlation coefficient of two – dimensional. Indeed, it represents coherence of the phase correlation between the two images and the value changes from 0 to 1, and the images whose coherence is between 7,0 and 1, have the best interferogram production (Rozban, 2016). It should be noted that the interferometer obtained at this stage is the only geometric error which should be removed at the later stages of the topological error by applying appropriate filter.

In order to remove the interferogram noise, a matching filter is used and finally, the interferograms smoothing step is performed to eliminate the phase component due to the topographic effects a digital elevation model with a resolution of 90 meters and an inaccuracy of 10 meters is provided by the SRTM.

3. Result and Discussion

Geotechnical and surveying system is usually set up in regions where the likelihood of a change in shape is very high. The main advantage of these systems is the use of high precision measurement to control the change, but the major disadvantages include: the complexity of the measurement tool, low number of observations, low spatial resolution, mapping costs, etc. But the radar interferometry method can observe a wide area which is cheaper than other method.

The images obtained from interval processing of the Orzuiyeh plain, which is the displacement rate of the earth's surface in the right direction, indicating the land subsidence for 2008 – 2009 is as large as 15 centimeters and its height is 6 centimeters and the subsidence in the images obtained from interference for 2009 to 2010 is 4, 11 cm and arise of 8 cm, and in the images of 2014 – 2015, the level of subsidence in plain is 8, 12 centimeter arise to 6 centimeters.

After processing images from ASAR and Sentinel 1 of Orzuiyeh plain and obtaining the level of displacement in night , to get the chart of this shift in each time period 2008 – 2009 and 2009 – 2010, and 2014 to 2015 a profile will be drawn on these images; which is used to plot this profile based on the stretching of the Orzuiyeh plain northwest to southwest.

The starting point of this profile is from the northwest plain and ends southeast of the plain (Figure 3), which shows the surface displacement diagram in the vertical direction based on the withdrawal of the profile drawn on processed images is abandoned in the Orzuiyeh plain.

The amount of leveling in the vertical direction can be well done in the maps prepared from the processing of radar images and degree of surface displacement in the direction of drawn profile on those images are shown in Figure 3. In Figure 3, the right side show the profile in the vertical direction and the left side show the map resulting from the Arc Map software.

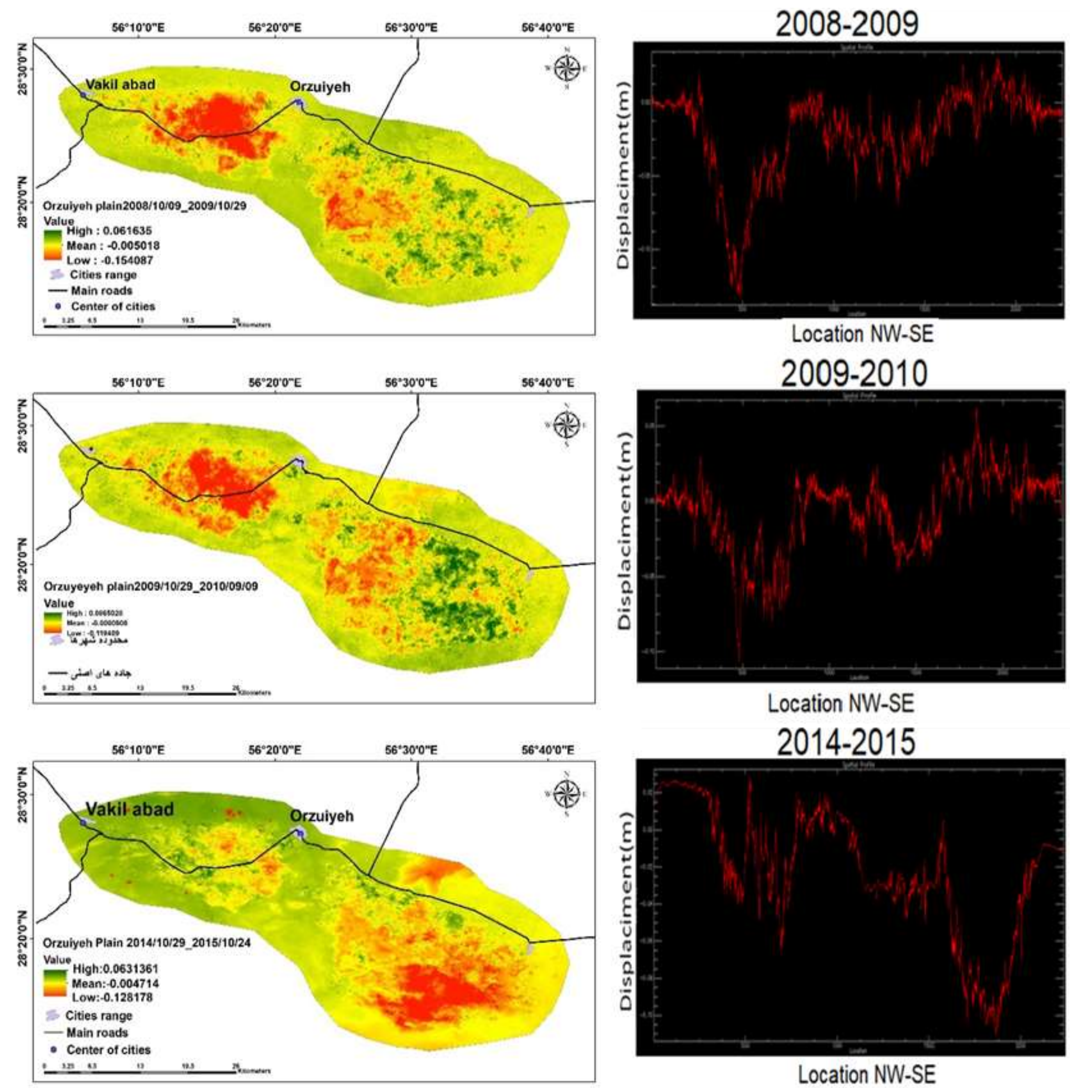

Figure 3. shows the Map of the Displacement in the Orzuiyeh plain between 2008 and 2009 and 2009 to 2010 and 2014 to 2015.

By examining the images obtained from interferometry processing and according to the state of subsidence and its expansion in the plain and the information derived from the chart of the profile drawn on the images with the northwest direction to the southeast of the Orzuiyeh province it can be concluded that from 2008 to 2009, the highest rate of subsidence is in the northwest and then in the central part and the lowest rate was in the southwest. These results, with similar results obtained by Keshavarz et al. in different studies, showed that the plains of Iran as well as different regions in Kerman province are subsiding with increasing rate of subsidence, and using Sentinel 1 and Asar satellite data is an appropriate and acceptable tool.

4. Conclusions

Subsidence is one of the most important geological hazards due to low human casualties compared to other sudden natural phenomena such as earthquakes, landslides, and floods has been less considered. This phenomenon is usually associated with many risks. In this study, the amount of subsidence in the area of

Orzuiyeh plain in Kerman province was determined with the help of the radar interference technique. Sentinel 1 and Asar measuring images were used at different time intervals to obtain the subsidence. In 2009 – 2010, the lightest rate of subsidence still occurred in the northwestern part of the country the least amount is in the southwest, but the level of subsidence in the central parts is higher than in 2008 – 2009.

In 2014 – 2015, the highest level of subsidence was in the western part of the plain and the lowest in the northwest area according to these results it can be stated that the subsidence of Orzuiyeh plain has been dynamic since 2008 to 2015 from northwest to southeast. It is suggested that the balance be tacked from underground water journey and dispersion of wells in the area and receive a water level modeling and examining their correlation with the values obtained from the interference of the radar date and manage the methods and individuals who take the ground date, and as a result to provide a comprehensive and standardized guided for land date collection across the country.

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