7th Intercontinental Geoinformation Days

igd.mersin.edu.tr

Estimation of land subsidence using DInSAR and SBAS techniques

Mojdeh Miraki*[1], Hormoz Sohrabi [2], Siavash Bakhtiarvand Bakhtiari [2]

[1]*Tarbiat Modares University, Faculty of Natural Resources, Department of Forest Science and Engineering, Tehran, Iran.*
[2]*Mobarakeh Steel Company, Esfahan*

Keywords
Land subsidence
Interferometry
SBAS technique
Sentinel-1
Mobarakeh Steel Company

Abstract

Land subsidence is one of the few environmental hazards that has received much less attention than other hazards due to low human casualties. However, subsidence over time causes irreparable damage to cities and adjacent areas and facilities, and infrastructure. In the present research, land subsidence in Isfahan province in Iran and specifically in the area of Mobarakeh Steel Company (MSC) using the traditional interferometric method by two images related to the years 2016 and 2021 and time series analysis using the SBAS method by 621 Interferometer and 178 epochs and 159 Sentinel satellite images were used in the ascending direction. The maximum subsidence rate was about -83 mm per year and -28 cm in 5 years for Isfahan City, after processing with time series and traditional interferometric method, respectively. The results of the two methods were close to each other, which can confirm the correctness of the estimated subsidence. Also, the obtained maps were matched with the subsidence maps of the National Cartographic Center of Iran, and it was found that the land subsidence areas are located in the two hotspots of Isfahan and Mahyar plains. Subsidence has expanded in a trend of Isfahan, Shahreza, and Mobarakeh, Iran.

1. Introduction

Subsidence of the earth's surface, as one of the destructive geological phenomena, is a sinking of the ground that occurs on a large scale (UNESCO). Land subsidence can be caused by natural geological and geotechnical phenomena such as ice, compaction of deposits, dissolution of soluble materials and rocks, slow movements of the crust, and the release of lava from the solid crust of the earth. Or it is due to human activities such as mining and tunneling, civil constructions, and compaction caused by loading, subsidence of waste landfills, and subsidence caused by underground fluids such as oil and gas and extraction of underground water.

In the meantime, excessive extraction of water from underground aquifers is one of the main causes of subsidence all over the world. Extracting underground water and not replacing it causes a decrease in pore water pressure and an increase in effective soil stress in the lower layers. The increase of the effective stress ultimately leads to the compression of the compressible layers that are located in the underground water. These layers are mainly made of clay and silt sediments, whose density will lead to subsidence on the earth's surface. Subsidence changes are investigated using ground and remote sensing methods. The high frequency of observations in remote sensing methods (radar interferometry), as well as time and cost saving compared to other methods, provides the user with a comprehensive view of changes in the shape of the earth (Declercq et al. 2017; Du, 2017; Zhu, 2015).

The change in the process and amount of subsidence can cause serious damage to the facilities and also the buildings located on them, which is considered a threatening risk, especially for industrial and residential areas. The subsidence is detected in most areas only when it affects the surface morphology, especially in the facilities and equipment, and causes a lot of damage and destruction. Considering the extensive facilities and infrastructure of Mobarakeh Steel Company in the center of Iran, the investigation of the process and position of subsidence in Mobarakeh Plain is more needful than before.

2. Method

To estimate subsidence in this study, two methods of DInSAR and SBAS techniques.

* **Corresponding Author**

*(mojde.miraki@gmail.com) ORCID ID xxxx – xxxx – xxxx – xxxx

Cite this study

Miraki, M., Sohrabi, H., & Bakhtiari, S. B. (2023). Estimation of land subsidence using DInSAR and SBAS techniques. Intercontinental Geoinformation Days (IGD), 7, 246-249, Peshawar, Pakistan

2.1. DInSAR method

Radar interferometry uses the phase difference of the radar image with high spatial resolution to produce a digital elevation model of the area and estimate the deformation and displacement of the earth's crust.

In this section, the subsidence was calculated using the phase difference of two images in the years 2016 and 2021 from the Sentinel-1 satellite images in the Snap software in the following steps.

- Split
- aplay orbit
- co-registration
- Interferogram
- Deburst tops
- topographic phase removal
- Goldstein phase filtering
- phase unwrapping
- snaphu import
- phase to displacement
- Geometric
- Export

In this method, the lack of temporal and spatial correlation between the images causes almost every interferometer to include large areas where the correlation is low, and the measurements made in these areas are not reliable or cannot be performed at all. These limitations cause the interferometric method alone to not be a complete tool for monitoring and measuring ground surface distortions and topographical changes.

2.2. Time series analysis using SBAS interferometric method

The SBAS method for interferometric time series analysis was proposed by Berardino et al. (2002). In the SBAS time series analysis, only image pairs are used whose vertical component of the baseline is less than the critical value of the baseline, and their time baseline is also minimal at the same time. In this way, only interferograms that have a suitable quality are formed. After that, a grid of images is created, then the displacement value of each pixel is estimated using the least squares method.

The stages of time series processing and analysis were performed in the LiCSBAS package as follows:

- Identify frame ID
- Download GeoTIFF from COMET-LiCS Web
- Convert (and Downsample)
- GACOS Correction
- Mask Unwrapped Data
- Clip Unwrapped Data
- Quality Check
- Loop Closure
- Small Baseline Inversion
- Calculate STD of Velocity by Bootstrap
- Mask Time Series
- Filter (& Deramp) Time Series
- Display results
- Export results

3. Results

Fig 1 shows the map of land surface changes using the traditional interferometry (DInSAR) method between 2016 and 2021 in Isfahan province. In this map, the amount of subsidence in two images with a time difference of 6 years is 28 cm, which is observed in Isfahan City and even near the studied area of Foolad Mobarakeh.

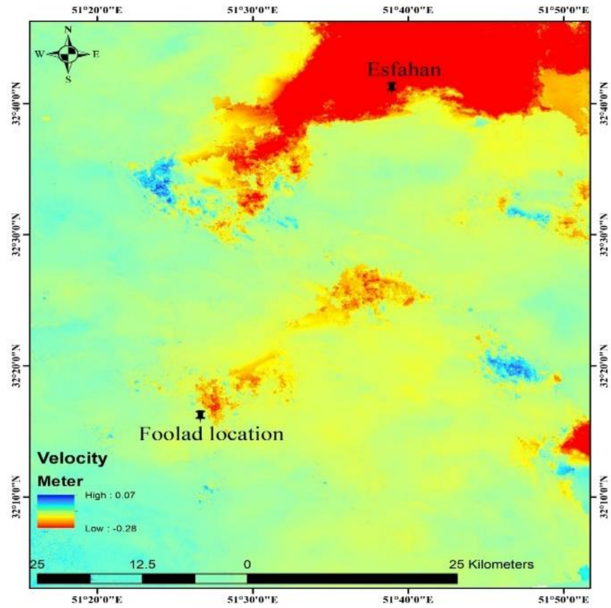

Figure 1. Land surface changes Map in 2016-2021 using the DInSAR method.

Spatial and temporal inconsistency causes noise and limitations in the phase of interferometry, and this noise created in the phase can be called inconsistency in the phase between two radar images taken from the same area at two different times under the title of coherence between two images. The coherence value ranges from 0 (all information is related to noise) to 1 (information is free from noise). As seen in the coherence map in Fig 2, many regions have low coherence. For this reason, the SBAS method was used in the time series analysis, which has more acceptable results than the PS method in areas with low coherence.

The result of annual land surface changes using 621 images between 01/01/2016 to 01/12/2022 using SBAS time series analysis is shown in Fig 3. The highest annual rate of subsidence with the value of 83 mm per year is related to the Isfahan City.

After the coherence value determination in each pixel, the values with low coherence were removed. Also, the low-pass filter in place and the high-pass filter in time were included in the final results.

Finally, after the completion of the time series analysis, the changes of the land surface can be extracted from each pixel of the output map with a spatial resolution of 90 meters. In the current study, 3 points in the study area were considered as pilots and the graph of land surface changes was prepared for the mentioned points, which is shown in Fig 4.

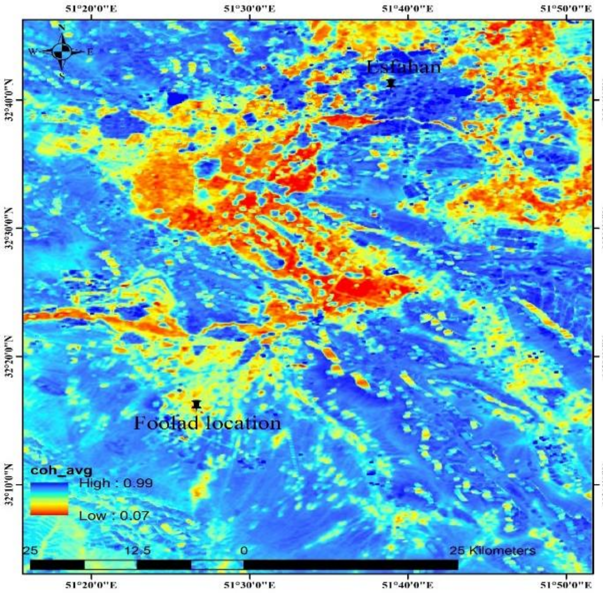

Figure 2. Coherence map in the study area

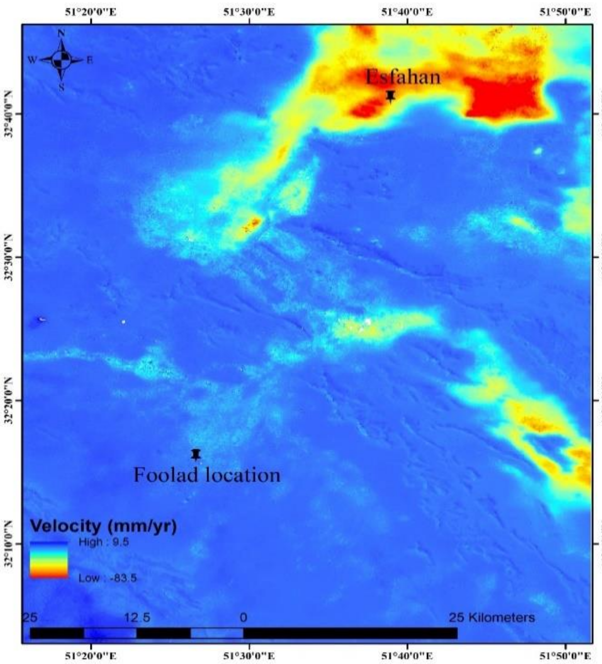

Figure 3. Velocity Map of displacement in 2016-2022 using time series analysis.

4. Discussion

As expected, after processing the radar images using the SBAS interferometric time series technique, a large area of Isfahan province had subsidence in the period between 2016 and 2022.

In Fig 4, sinusoidal fluctuations can be seen, which may be related to the lowering of the aquifer level and its re-feeding in the rainy season and the type of soil texture. The graph generally shows a decreasing trend with a low slope, which requires careful monitoring of the area and preventing the occurrence and consequences of subsidence in the future.

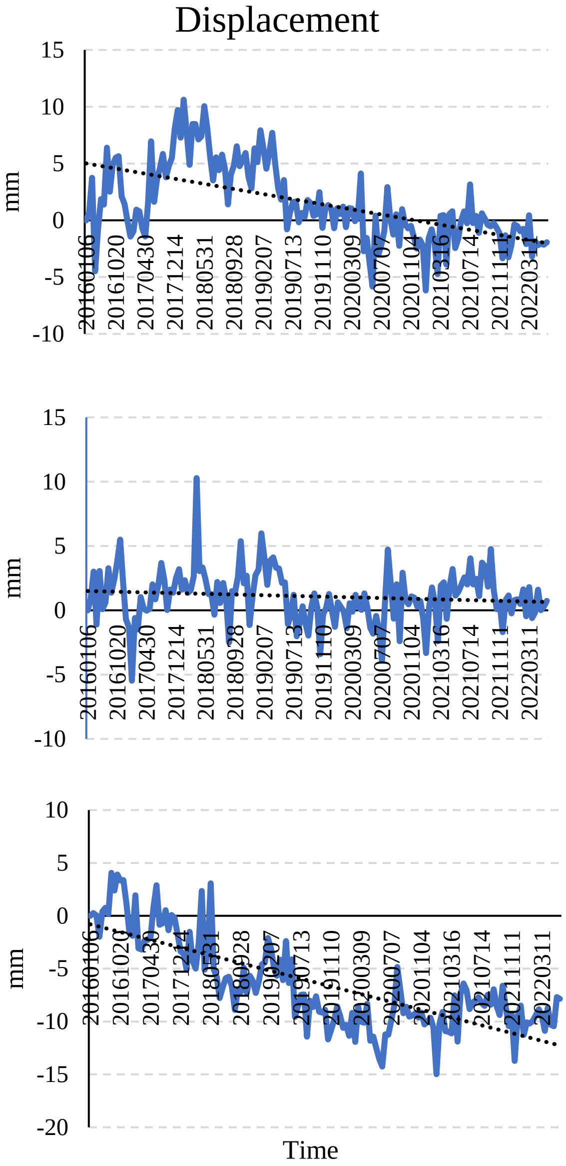

Figure 4. Displacement changes at the three pilot points

The maximum subsidence rate obtained after processing with time series and traditional interferometric method was approximately -83 mm per year and -28 cm in 5 years for Isfahan City, respectively. The results of the two techniques were in close agreement with each other, which can confirm the correctness of the subsidence obtained. Also, according to Fig 5 and the relatively good overlap of the resulting maps with the subsidence maps of Iran National Cartographic Center, it is clear that the determined areas of subsidence are located in the two hotspots of Isfahan and Mahyar plains. Subsidence in Mahyar Plain has passed through Isfahan City, Shahreza, and Mobarakeh in a certain process.

According to the two production maps and the map obtained from the Iran National Cartographic Center, subsidence is expanding with a certain trend, which according to the necessary investigations and the correspondence of the map with the ground reality in the areas of subsidence, agriculture, and water pumping. Underground are more abundant than the adjacent areas

(Fig 6). This process started in Isfahan City and extended to Shahreza and Mobarakeh cities, which requires the investigation of piezometric wells and groundwater level changes in the study area.

According to the mentioned cases, it is necessary to check the underground water and the changes in the water level of the piezometric wells and establish the subsidence monitoring system in the study area.

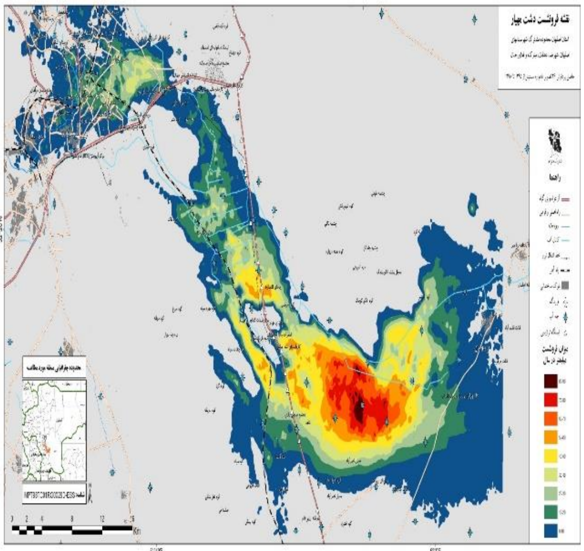

Figure 5. Subsidence map of Mahyar Plain (downloaded from the website of Iran National Cartographic Center)

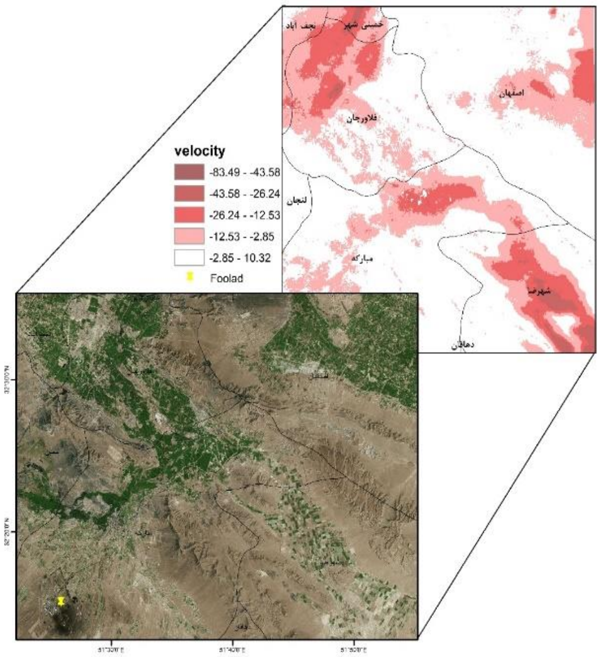

Figure 6. Correspondence of annual subsidence rate (mm) with ground reality image

References

Berardino, P., Fornaro, G., Lanari R., & Sansosti, E. (2002). A new algorithm for surface deformation monitoring based on small baseline differential SAR interferograms, in IEEE Transactions on Geoscience and Remote Sensing, 40(11), 2375-2383, Nov. 2002, https://doi.org/10.1109/TGRS.2002.803792.

Declercq, P. Y., Walstra, J., Gérard, P., Pirard, E., Perissin, D., Meyvis, B., & Devleeschouwer, X. (2017). A study of ground movements in brussels (Belgium) monitored by persistent scatterer interferometry over a 25-year period. Geosciences, 7(4), 115. https://doi.org/10.3390/geosciences7040115

Du, Y., Feng, G., Peng, X., & Li, Z. (2017). Subsidence evolution of the Leizhou Peninsula, China, Based on InSAR observation from 1992 to 2010. Applied Sciences, 7(5), 466. https://doi.org/10.3390/app7050466

Zhu, L., Gong, H., Li, X., Wang, R., Chen, B., Dai, Z., & Teatini, P. (2015). Land subsidence due to groundwater withdrawal in the northern Beijing plain, China. Engineering Geology, 193, 243-255. https://doi.org/10.1016/j.enggeo.2015.04.020