

## Experimental Investigating the Relationship Between Land Subsidence and Groundwater Level Decline in Karaj Plain: A Comparative Study of leveling and DInSAR

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### Abstract

Land subsidence is a phenomenon that occurs due to the interaction between groundwater flow and soil deformation. This study investigates the contradiction between land subsidence and groundwater depletion in the Karaj plain. By examining the hydrogeology and measuring land subsidence using leveling and DInSAR methods from 2015 to 2023, the results revealed that the subsidence rate in a crescent-shaped area formed from the northwest to Mohammadshahr is significantly higher than other points, with 158 mm/year. This paradox, considering the minimal groundwater depletion in this zone, raises questions about the direct and always-existing relationship between subsidence and groundwater depletion. An investigation of three hypotheses for land subsidence in the central plain was conducted. The hypotheses included the installation of piezometers in a shallow perched aquifer overlying a main aquifer, annual fluctuations in groundwater levels due to wastewater injection into the aquifer, and erosion of loose particles due to high inflow and outflow rates. Based on the evidence collected, it is most likely that the second hypothesis, the role of the main aquifer in land subsidence, is more probable than the other two hypotheses. The results of leveling are consistent with radar interferometry methods, demonstrating a significant correlation. The negative correlation of 66 to 88% indicates that maximum soil consolidation occurs after two years. In general, two locations in the central plain (Mehrshahr) continue to experience high subsidence rates, while the subsidence rates of the three other points in the northwest plain have significantly decreased.

**Keywords:** *Land subsidence, Groundwater Level Decline, Leveling, DInSAR, Karaj Plain.*

## Extended Abstract:

### 1. Introduction

Begheri and colleagues (Begheri et al., 2021), through a study of 290 areas affected by land subsidence in 41 countries worldwide, found that 76.92% of land subsidence cases globally are attributable to human activities, with groundwater extraction accounting for the highest share at 59.75% in this phenomenon. Several studies have been conducted in various plains in the country to analyze land subsidence using InSAR. Among these studies, mention can be made of the study by Rajabi et al. (2022) in the Aliabad plain of Qom with a subsidence rate of 150 millimeters per year, the study by Manafi et al. (2018) in the southwestern plain of Tehran with a subsidence rate of 220 millimeters per year, and the investigation of the distribution and mechanism of formation of subsidence fissures by Rokni et al. (2019) in the Nishabur plain.

### 2. Materials and methods

In this research, the first stage involved an initial hydrogeological assessment of the Karaj plain. The second stage of the Karaj plain subsidence assessment was conducted using leveling data collected by the National Cartographic Center of Iran between the years 1989 to 2013. The third stage involved subsidence evaluation of the plain between the years 2014 to 2022 using Sentinel-1 satellite data. The relevant images were collected from the Sentinel-1A satellite, an advanced Synthetic Aperture Radar (SAR) satellite operated by the European Space Agency. This SAR satellite operates in the C-band and utilizes a new imaging mode called Terrain Observation by Progressive Scans (TOPSAR) to achieve a 12-day revisit cycle and a wide swath coverage of 250 kilometers by 250 kilometers with medium resolution. The Sentinel-1A images exhibit high overlap in the study area. Furthermore, the SAR images were acquired in a descending orbit using the Interferometric Wide swath mode (IW) with VV polarization. The GMTSAR software was then used for data processing. Finally, in the fourth stage, the results of groundwater level reduction and leveling were compared with DInSAR results to investigate various hypotheses in subsided areas.

### 3. Results

The radar interferometry processing was conducted using the powerful GMTSAR software under the Linux operating system. Subsequently, utilizing coding in MATLAB software, the map of the average land subsidence rate from all these interferograms was generated (Fig 1). The map of the average land subsidence rate in the Karaj plain depicts a crescent shape extending from the northwest to the southwest, passing through Chahar Bagh, Khoramdasht, and Mehrshahr. This crescent signifies the expansion of the affected area from the northwest towards the Karaj plain. The highest land subsidence rates, reaching 158 millimeters per year, have been observed in the central and northwest sectors of the region.

For a more detailed examination of the land subsidence phenomenon in the Karaj plain, the land subsidence rate maps were divided into five zones with varying rates. The results presented in Table 3 indicate that 6.6% of the plain area is classified as highly hazardous, and 8.18% is classified as at high risk of subsidence. This highlights a serious subsidence crisis in this plain.

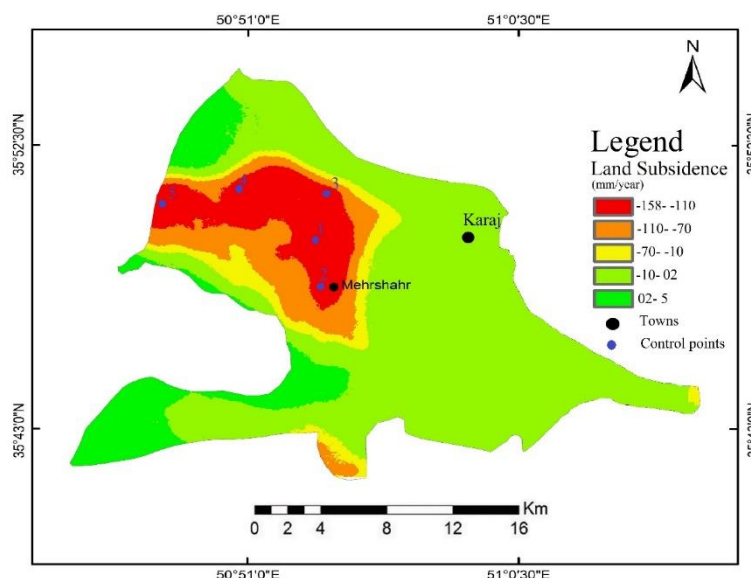


Fig. 1 The vertical annual displacement during the years 2014-2023.

#### 4. Conclusion

Studies suggest that the land subsidence rate in the crescent-shaped area from the northwest to the southwest of the Karaj plain is significantly higher than in other regions. Interestingly, this area is considered one of the areas with the least groundwater decline in the Karaj plain. This contradiction raises uncertainties regarding the direct and constant relationship between subsidence and groundwater decline. Investigating three hypotheses, including installing piezometers in the central part of the plain in a shallow unconfined aquifer, the positioning of the main aquifer in the second layer, and the annual fluctuations in groundwater levels due to sewage injection into the aquifer and the washing away of particles due to high input and output flow rates, showed that the likelihood of the second-layer aquifer playing a primary role in land subsidence is higher than the other hypotheses.

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