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INSAR TECHNIQUE TO ALLOCATE LAND SUBSIDENCE IN KARAJ AND TEHRAN (SHEHRIAR, WARAMINAND DJADJROUD) AREAS

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ABSTRACT

Aquifer and hydro system compaction is a worldwide phenomenon, where there is a sudden sinking or gradual downward settling of the earth's surface with little or no horizontal motion. This phenomenon is noticed to take place in many countries, among which is Iran. Water well casing and installations in areas such as Hamedan , Kerman, Meshhed, Tehran and others seem to rise into the air, or some times to produce fissures in the sediments and/or showing sinkhole in carbonated rocks. Soil compaction and / or land subsidence could cause damages to surface and subsurface urban installations.

UNISCO was interesting in this worldwide phenomenon and tried to study it in different countries by work group using GPS, SAR and InSAR techniques that uses radar satellite image. Iran in cooperation with other countries was interesting to see the extension and reasons for Tehran's subaburbs land subsidence by using the new InSAR techniques. The later studies indicated the existence of subsidence areas in north west, south - south west and south east of Tehran with an average soil sink of about 15 cm This subsidence is mostly in a flat area with no special activities except for agriculture and a heavily water well production. Therefore, it is concluded that this sediment compaction is due to depletion of aquifer (i.e. water level drop), which causes aquifer compaction.

INTRODUCTION

Soil subsidence is a worldwide phenomenon, where there is a sudden sinking or a gradual down ward settling of the earth's surface with little or no horizontal motion. The soil subsidence may be due to many factors among which is aquifer over production and declining in water table of ground water, compaction of unconsolidated or new sediments, tectonic movement (i.e. earthquake, plate movement and others).

UNISCO has reported soil subsidence in the USA for about twenty years. Moreover, UNISCO started to study this phenomenon worldwide through a group of work in different parts of the world by using GPS, SAR and InSAR.
This phenomenon is noticed to take place in Iran in Aber Kuh,Kharaj, Faminin, Kerman, , Meshhed, Rafsinjan, Hamadan (Kabodder Ahan Valley), and Tehran(Kharaj,,Maain Abad, Shehriar and Waramin Valleys). Likewise,similar cases were also reported in Arak, Khumain, Kolbaigan, Nahawand, Natanz, and Yazd. In some of the above areas, water well installations seem to rise into the air or showing to be sticking out of the land surface, or sometimes produces fissures in the sediments and/ or showing as sinkholes in carbonated rocks that damage canals, water networks, gas pipelines, oil pipelines and dams (Figure 1).

Figure 1: Water well installations seems to rise in the air due to sediment's compaction

Topography of the area is sometimes changed which will affect flood regime and water recharging into aquifers. This phenomenon becomes distinct physically and sometimes dramatically visible.

People in Iran were concerning about this phenomenon. Therefore, they seeked help (from Oxford and Cambridge Universities) to study and explore the reasons and extend of soil subsidence around Tehran City and suburbs by using InSAR and GIS tools.

AREA MOVEMENT

Tehran and suburbs are located on the south side of Elburz Mountains that are N of Iran extended from Korasan in the east till Atherbaijan in the west, which is a part of ALP-HAMALAIA active and young mountains.

Elburz Mountains were formed from processes of faulting and mountains movements (towards N of Iran) due to Arabic Plate movement and collapsing with Eurasian Plate (Figure 2).

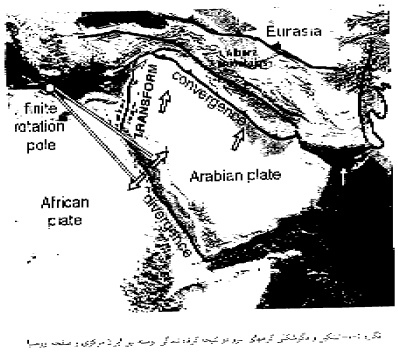


Figure 2: Arabic Plate movement towards Eurasian Plate

Therefore, the layers in the area and their structures were not uniform (except in Eocene Era), where Hezar Derahe formations were formed in Tehran-Kharaj area.

Hezar Derahe formations are divided into Hezar Derahe alluvial (sediment A), inhomogeneous alluvial sediment of north Tehran (Bn), where it is silt in Kehrizig sediment (Bs) and (sediment C) is in Tehran alluvial.

LAND SUBSIDENCE IN IRAN AND OTHER COUNTRIES

Moreover, land subsidence was reported in *some areas in Iran* as shown in table 1 *with their causes*.

Table 1: Land Subsidence in some areas in Iran and causes

No	Period year	Place	Depth of subsidence, mm	water Using purposes
1	1 971- 1 981	Zarand	8 000	Agriculture
2	1 971- 1 981	Rafsanjan	7 500	Agriculture
3	1 971- 1 981	Kashoyiah	7 000	Agriculture
4	1 971- 1 981	Kerman arean	6 500	Agriculture
5	1 971- 1 981	Sierjan	6 000	Agriculture

From above table, it is obvious that the people of Iran were acquainted with the soil subsidence phenomena for a while.

LAND SUBSIDENCE IN OTHER COUNTRIES

Land subsidence was also reported in *some countries* (table 2).

Table 2: Land Subsidence in some other countries and causes

No	Period year	Place	Depth of subsidence, mm	
1	1 930-1 973	Venz-Italy	150	Drinking+Industry
2	1 865-1 931	London,England	180	Drinking+Industry
4	-	Tiaba	1 000	Drinking+Industry
5	1 928-1 943	Tokoyo-Ozako	3 000- 4 000	Drinking+Industry
6	-	Huston-Bay Town	2 700	Drinking+Industry
7	1 938-1 969	Mexico City	8 000	Drinking+Industry
8	1 947-1 948	Arizon-USA	2 300	Irrigation
9	-	California-Santa-Clara	4 000	Irrigation
10	-	California-Sanjwan	8 500	Irrigation
11	-	New Zealand-Wayrocki	4 000	Hot Spring
12	-	Willington	+ 9 000	Hot Spring

Table 2 shows how serious this phenomenon could be where there was down to 9 meter land sinking in some area of the world. The possible damages to installations over the surface as well as the subsurface can include buildings, dams, pipelines, canals, roads, railroads and others.

AREAS UNDER INVESTIGATION

It encloses Kharaj, and Tehran (Shehriar, Waramin and Djadjroud areas.

Valleys

Valleys such as Shehriar, Tehran and Waramin that are located between 35° 28'06"- 35°49'42" north Latitude and 51° 06' 37"– 51° 33' 13" east Longitude were under consideration, with a total area of about 8250 square kilometer, 350 square kilometer mountains (with a maximum height of 3 138 mDSL at Tojal peak) and 1900 square kilometer are valleys. The average height of the valleys is 1 100 mDSL. These valleys started from Elburz Mountains in the north and ended in Azad-Fisha Boyiah in the south. From east is Se Pajah, Bibi Shehrbano and from west is Kharaj's aquifer.

Valleys' Conditions

The valleys have the following conditions:
-Average rainfalls are about 250 mm/y (less at south and more at north).
-Average relative humidity at Mehraabad airport is about 40 percent.
-Average annual temperature variations are from 10 °C in the mountains up to 17°C at Mehraabad airport.
-The average evaporation from the valleys is about 2 500 mm per year (more at south and less at north).
-The wind flows normally from west with an average of 20 kilometer per hour in winter and from SE in summer.

Water resources

The water resources in the area consist of surface as well as ground that are described briefly below.

Surface water

There are 7 seasonal rivers and only 2 permanent rivers, namely Khan and Kharaj, from which the required water is maintained for the valleys. In the past years, part of Tehran's water is maintained from ground water from 522 canals, with a total water production of 393 MCM. Drilling a big number of wells in the two valleys caused most of the canals to go dry once ground water level went down.

Ground water

Ground water is coming from aquifers.

Aquifers

There are actually 3 alluvial aquifers in the area.

Aquifers description

The aquifers in the area are divided into 3 aquifers namely:
-Northern aquifer: It is extended from Elburz Mountains down to Abassabad-Yusifabad of Sediment A with a little permeability, the water of which flows into the main aquifer.

-Main aquifer: It is extended from Louizan Hills down to Bibi Sherbano, west (Shehrekahe Karb) and Kharaj's Aquifer and eastward to Shehrekahe Hezar's Fault. The sediments of the aquifer are C and B (with an average thickness of 130 meter and decreasing towards S and E) with medium to high permeability. The aquifer layers inclined at 50 per 1 000 at N and NW while it is about one per 1000 at middle of the aquifer. Water flows mostly from N to S (and NW to SE in the west part of the aquifer). Water recharge into aquifer consists of floods, permanent rivers, seasonal rivers, waste water and agricultural water. Transmissibility factor of the aquifer is variable between 50 m^2/d in NE, 2 000 m^2/d in W (Sherhriar valley) and 2 000 m^2/d at the middle of the aquifer. Moreover, the average storage factor varies from 1 to 3 percent (less at S and more at NE (15%).

-Perched aquifers: They consist of separated small aquifers in separated thin sediments of A and B.

Geology of the aquifers

Elburz Mountains are old Paleocene-Eocene rocks with a medium permeability that recharge the aquifers and surrender it from N. The aquifers sediments are made of above mentioned sediments (i. e. mainly quartz toward S with a high permeability) which came from weathering process of the mountains.

Geophysics of the aquifers

The geophysics of the area were done through CGG of France by using about 300 electrical sondages (mostly with AB= 2 000 meter). Electrical resistivity of new sediments is 300 Ω -m and decreasing towards S, while the old sediments have a resistivity of 25 Ω -m. This study indicates that the aquifer thickness is mostly in N(400 meter) and NW(300 meter)(as a syncline basin) that changes to 25 meter in E , SE and SW due to uplift in basement rock.

Aquifer's water level changes

The average annual water level drop in the main aquifer is less than one meter as computed from the aquifer's unit hydrograph.

In SAR SATELLITE AND THEIR DATA

Data were obtained from satellite, where InSAR method, was used to study the area. InSAR (Interferometer Synthetic Aperture Radar) is a powerful new tool that uses radar signals to measure deformations of the Earth's Crust at an unprecedented level of spatial detail and high degree of measurement resolutions. . It is a remote sensing technique that uses radar satellite image to sense small changes in land surface elevation. Radar satellite shoots constantly beams of radar waves towards the earth and records them after they bounced back off the Earth's Surface in database and / or maps

FORMULAS AND INTERPRETATION

Following formulas are used for soil compaction calculation and interpretation of the data:

$Su = Z1\ ((e1-e2) / (e1+1)) = Z1\ Cu \log (Pi2/Pi1)$

$Su = \log \int Pi$

Where:
Su= subsidence depth
Z1 = total thickness (total volume per square unit)
Cu=soil compaction factor
e= soil porosity
Pi1- Pi2=ΔP =infinitesimal P changes

Subsidence and location

By analyzing the satellite radar pictures from InSAR as a database, it was able to allocate land subsidence in north west of Tehrah namely KHARAJ AREA and south of Tehran namely **Shehriar** and **Waramin Valleys**. Moreover, there is another subsidence in south east TEHRAN, NAMELY DJADJROUD. Software (ROI-Pac) with digital height model helped in allocating these subsidences. However, the accuracy of the analyzed data base was determined within 2 cm at different time periods of 2, 3, 4, 6, 12, and 18 months (Figure 3).

Figure 3: Accuracy of analyzed data at diff time periods

From satellite color data and the analysis of land subsidence maps, land subsidence rates were determined at 70, 175, and 315 days, where there was no difference between the results (Figure 4).

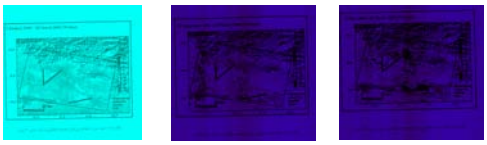
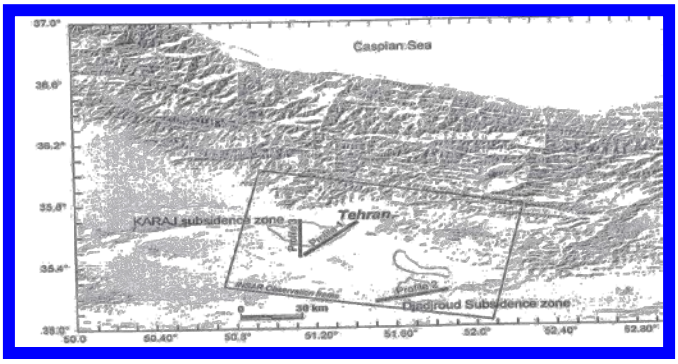


Figure 4: Analysis of land subsidence at diff day's periods

InSAR satellite radar pictures show that there are three subsidence areas (two in V shape in **KHARAJ** and **TEHRAN**) and another in south east Tehran at **DJADJROUD** with a total average subsidence of all three is 15 cm. The cross-section of these land subsidence are shown in the figure 5.



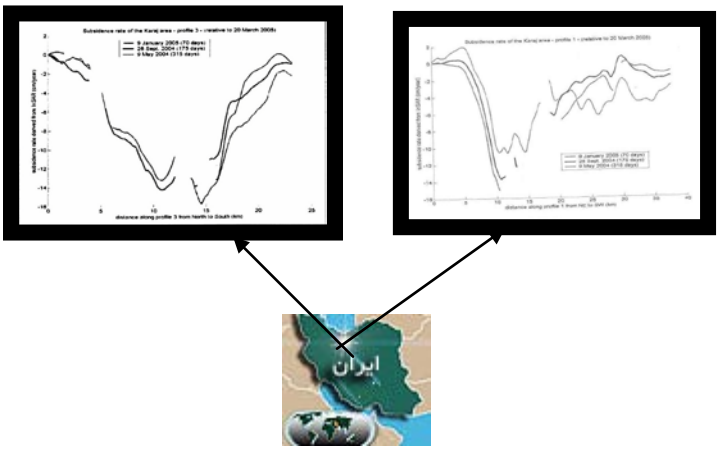


Figure5: land subsidence and their cross- section in KHARAJ TEHRAN AREAS

CONCLUSIONS

Following conclusions were drawn:
-InSAR data show that there is a land subsidence in north west, southwest and south of Tehran in V shape.
-This study shows that there is a land subsidence region in Shehriar valley (profile number two).
-The indicated area in Kharaj -Tehran is V shape with an average continuous yearly subsidence of 15 cm.
-Land subsidence is mostly in a flat area with no activities other than agricultural , therefore, it is concluded that the land subsidence is mainly due to the over production of ground water (depletion of aquifer) and decreasing in aquifer water level that causes compaction of aquifer's soil.

SUGGESTIONS

Moreover, following suggestions are recommended:
-Controlling ground water production to minimize aquifer water level decreasing in order to minimize damages resulted from them.
-To prevent further land subsidence need to apply artificial water recharge into the aquifer as soon as possible.
-Applying water resources management technique to save guard the ground water aquifers and minimize damage to surface and subsurface installations.

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