

Investigating the role of duality in geomorphology using radar data in Bahadoran plain of Yazd

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Abstract

Many varied attitudes exist about how the changes occur in the land-surface from the time of William Davis's research to the latest researchers in the history of geomorphologic philosophy and many different terms are used by scientists in order to observe their ideas related to geomorphic phenomena. The phenomenon of duality has been seen less in the geomorphology field. There exist some contradictory phenomena in nature, but further investigation can show their correlation clearly. Durability can be considered as a better dynamic entropy. In this research, radar interferometry technique has been used in Yazd-Bahadoran area and the amount of subsidence and uplifting has been investigated Through field and library studies and the results have been compared with the other researchers' studies, which is a new concept in the literature of geomorphology under geo-duality. The study results indicate that the main reason for the subsidence was not to cut down the level of groundwater, and in this regard the tectonic movements play a significant role. Also, the study shows a significant relationship between subsidence in the Bahadoran plain and the collapse in adjacent heights in terms of duality or dichotomy.

Keywords: Subsidence, Uplifting, Duality, Geomorphology, Radar images

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1. Introduction

Land subsidence due to groundwater extraction has been known as a major problem with environmental impacts in many areas. The effects of subsidence due to inappropriate groundwater abstraction, geological factors and groundwater are also very effective. The porosity of the aggregates of the soil layers, density, type, kind and composition of the layers, the pumping method, the geological structure of the area, the hydraulic conductivity of the layers, rainfall and temperature, are the factors affecting the subsidence of the land (Akbari et al., 2009).

Excessive groundwater abstraction leads to a drop in groundwater level and a decrease in fluid pressure resulting in an increase in particle pressure, which leads to a density and a phenomenon of subsidence of the earth.

In Iran, almost a thirty-year history has been related to land subsidence, If this phenomenon occurred only in some of the provinces, such as Kerman and Yazd. Also the present field of Isfahan, Khorasan, Tehran, Tabriz, etc., are subsiding and this problem increasingly occurs in Governments which are more prominent (Ghani Ardekani and Maleki, 2016). Among all the downsides which occur in Iran, the extraction of underground water is the most important factor for land subsidence.

The Iranian plateau is located at the site of Saudi Arabia, India and Eurasia. The intersection of these folios has caused alteration to the shell of the Iran plateau which is surrounded by wrinkles and mountains, such as the Zagros in the west and southwest, the Alborz and Kopeh Dagh in the north and northwest, and the mountains of east and south east (Makran) which have a high seismicity. With the advent of techno-movement that has existed for many years in different parts of the terrestrial zone, the uplifting or rise can be seen (Adib et al., 2016) at the end of the altitudes more often, and sometimes elsewhere in Iran.

To identify the fault patterns in the Zagros; three geological sections are depicted to estimate the elevation during the fault of Zagros. Zagros faults indicate the general state of tectonic movements in the course of a natural fault (Monserrat et al., 2014). In this region, fault patterns and lithogenic curves indicate a reversal of tectonic movements during the old faults. Considering the geological sections and stratigraphic sections and the age of the Zagros fault, the minimum vertical fault velocity from the beginning of sedimentation of Bakhtiari formation in Zagros is 2.05. 01 mm per year (Hakimi, 2015).

When the lithosphere is compressed and moves to occupy less space, the stones are crushed, bent, eaten, or moved upwards. Conflict with horizontal structure has been due to the ground forces and by horizontal and vertical curvature and folding forces which can be and seen in different forms of anticline and syncline. Broken bubbles or hot spots: These low-density forms move upwards, sometimes up to 3,000 kilometers. The active processes in the cones influence their evolution and therefore can consider the movements of the faults and the displacement of the earth's surface. Investigating Maroon basin characteristics in the southwest of the country regarding tectonic and geologically new changes indicate that the uplift in this region is very active and tectonic has a great influence on settlements and land forms (Maqsoudi et al., 2018).

There exist both different and separate phenomena interacting upon each other in nature. In many cases the association of these phenomena is expressed as solidarity and one can also measure these relationships through mathematical methods. Among them, one can find a pair of phenomena

having some connections to each other (Pourkhosrowani, 2015) but these relationships cannot be suggested as a matter of solidarity, and their connection in terms of feature between them has been raised as duality. Duality describes a connection with symmetry, operating in an opposite direction and the expression of a certain proportion can be considered as one of its characteristics. Each scientific theory presented by the scholars of world is characterized in terms and metaphors that follow the structure and patterns of the technique. Therefore, the structure and technical patterns are based on concepts, basic patterns, literature, and theories. In different sciences, the processing and conversion of the basic words of this science is required. Here it is possible to refer specifically to the duality.

Radar interferometry (InSAR) has also been widely considered in recent years as one of the non-geodetic methods with regard to the advantages of other methods (Cigna et al., 2012). This method among ground and space methods is considered as the most efficient method for measuring ground changes with high precision and spatial resolution. Its advantages are of high precision (Monserrat et al., 2014) wide coverage, high spatial resolution, and the lack of need for field work, cost-effectiveness, and the ability to access information in any weather conditions. In Iran, in the past few years, this method has been used to monitor earth's deformations. But to date, the ability of the radar interferometry technique in studying earth's deformations in comparison with the observations of the global positioning system has not thoroughly and extensively been evaluated. One of the reasons is the limited number of permanent GPS stations in the geodynamic network of Iran. The study of the ability and precision of this method seems necessary in measuring the displacement of the surface of the earth.

The purpose of this study is to investigate the duality using the radar interferometry method in Bahadaran plain of Yazd. The research hypothesis is that the correlation between subsidence and uplifting is significant in the study area - duality.

Case Study: Central Plain of Iran-Bahadoran Yazd

This area is in a geographical position of 54 degrees and 30 minutes to 55 degrees' east longitude and 31 degrees to 31 degrees 30 minutes the north latitude which surround the southern quarter of Yazd (Figure 1). Yazd and Mehriz cities are in the northwest. The pomegranate sheriffdom is part of the southeast. The climate of this area whose name is derived from Bahadoran village, is like a desert climate with high temperatures, low humidity and high vaporization. Its maximum temperature reaches to +48°C and reaches a minimum temperature of -15°C and its precipitation reaches to about 60-70 mm per year. This area does not have a river and agricultural activities are carried out through the aqueducts. The morphology of roughness is divided into three groups: slopes, plains and heights. The stone units of this area are mostly northwest-southeast which its northern side is towards Bahadoran and the southern and central parts of Pariya basin. These basins are located in hollow, therefore it is the location of waters flow in which a lot of salt remains due to high evaporation a lot of salt remains (Figure 1).

The second unit produces quaternary acquillite of alluvial tributaries that at the time of precipitation makes the existing streams. The high and rugged mountain ranges are the third unit formed by the carbonate formation of Taft.

The highest point of Kermanshah Mountain is at 2890 meters and the lowest elevation is Bahadran plain with a height of 1427 meters. Geologically, Paleozoic rocks are seen in a few hills scattered in the Bahadran plate and Jamal formation. The most extensive expansion of these rocks is from the northwest to the southeast, called Taft formation.

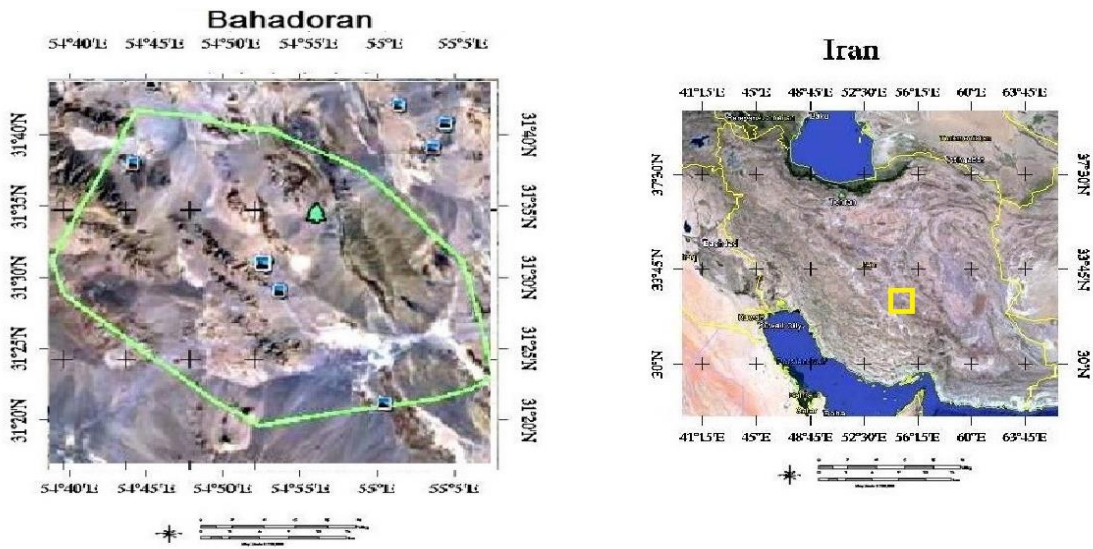


Figure 1. The studied area (Bahadoran plain of Yazd)

2. Materials and methods

Radar interferometer technique is one of the most powerful tools for monitoring the subsidence phenomenon (Buck, 2011). By comparing the phases of two radar images taken from a region at two different times, this method is able to determine the changes in the surface of the earth at that time interval. The phase is taken from an earth fault, proportional to its distance to the radar sensor. therefore, creating a change in this distance affects the measured phase by using image of a Radar interferometer technique by the name of a constructed interferogram. An interferogram is an image that contains a phase difference of two radar images which are recorded geometrically to each other (Yarahmadi et al., 2015). The interferogram phase contains topographic effects, orbital errors and atmospheric effects. In order to obtain the displacement of the earth's surface over a period of time, the orbital errors, the effects of the topography and atmospheric noise should be eliminated from the interferogram. To eliminate topographic effects, the SRTM digital elevation model is used with a spatial resolution of 90 meters. The atmospheric error can be modified with the help of atmospheric information and atmospheric model (Hakimi, 2015).

The use of synthetic aperture radar images (SAR) began to detect ground-level displacements at below centimeter grades late in 1980s, which ended in introducing radar interferometry method (element). This method has become a powerful tool for analyzing the tectonic movements of the earth's crust because it is able to accurately measure the earth's surface in a wide range, high spatial resolution, and also it is less time consuming and saves expenses in this regard. Interferometry of multiplication a mixed image SAR IN second-conjugate image is produced and creates an interferometric image and the phase of this image is the phase difference between the images.

In the atmosphere that leads to a change and creates an extra phase in the whole illustrated, these limitations make it difficult to use conventional radar interferometry (Eslamizadeh and Samanirad, 2010).

In 2000 & 2001, it was discovered that there are problems on the ground that, over time, their dispersal features are constant and are not influenced by factors such as long base and spatial time. Also, in areas with high roughness, the correlation between radar images is affected by the viewing angle and direction; the phenomena that have a dominant and stable replay over time are less affected by the lack of correlation. The researchers showed that if these effects were detected on the surface of the earth, it would not only be possible to monitor the displacement of the earth's surface at these points, regardless of the lack of correlation of radar images (Shirani et al., 2014) but also the effect of other harmful components on interferometric results including atmospheric effects and error associate to the digital earth model can be estimated and eliminated. There are some methods by which the stable dispersers are detected and the amount of surface displacement on those points is monitored. The technical specification of the (SAR) radar with artificial pore coherent imaging (phase data recording alongside the backward amplitude wave) and high-resolution images of the SAR marker create a high spatial area. On the other hand, the randomized phase image is basically random; the weighted average of the phase delay between sending and receiving all dispersions on the ground is in pixel But the difference in the phase between the two images can be as a change in the distance from the satellite to the earth, provided that the spatial distribution properties of the earth remain almost constant. In the interferometer of the rotational phase of the images taken from different shooting situations or shooting times, pixel to pixel are compared. By differentiating between these values, a new image is obtained which is the name of the interferometer. The final phase created in the interferometer which contains additional terms, is as Equation1:

$$\phi_{int}=W\{\phi_{def}+\phi_{atm}+\phi_{orb}+\phi_{\theta}+\phi_{N}\} \quad (1)$$

where, ϕ_{def} is the phase due to the pixel motion in the direction of the satellite's view (line of sight), ϕ_{atm} is the difference in the atmospheric phase delay between the two images, ϕ_{orb} is the remaining phase due to the orbital error, ϕ_{θ} is the remaining phase due to the viewing angle error (which is usually DEM error) and ϕ_{N} is the noise phase due to the diversity in the diffusers and thermal noise. The operator W indicates that the received phase has a value between these two figures (π and $-\pi$). Since the satellite does not record the correct numbers of proper wave cycles, one of the most important, and at the same time, the most difficult stages in radar interference is

estimating the number of correct cycles, which is called phase retrieval. (Ghani Ardakani and Maleki, ,2016)

lioIn radar interferometry which is a phase obtained from two images taken from a given region for producing interferometric. In fact, the interfering product is a mixed result of two radar images. These two images may be taken by an airplane or space containing two antennas with a specified distance (line-of-sight) (single-track interferometry) or two images at different intervals and from a similar platform (method intermittent crossing with frequent passage) (Ghani Ardakani and Maleki, 2016). The phase difference in the two images is shown in the form of an edge or border in the interfacing, where each boundary or edge is related to the fuzzy difference. The provided interferometer by InSAR method has the ability to display elevation changes and ripples (Chaussard et al., 2014).

The radar interferometry (InSAR) provides the possibility of generating digital models of roughness earth whose optimum heights for the 6.5-c wave band data is about 5 meters. This term is used to measure some of the parameters, such as topography, variation and displacement of the earth's surface which are caused by phase interference of two or more radar images taken from the same area (SAR) with a virtual hole (Iran Space Agency website). This method is capable of detecting surface changes occurring on the ground at different intervals with millimeter precision using at least three (two radar image + DEM)or more radar images (Figure 1). However, this accuracy will be the Equation1 of the data wavelength used and half its equivalent ($\lambda /2$). The radar interferometry method for measuring the surface changes of the earth's crust is admirable (Shirani et al., 2014).

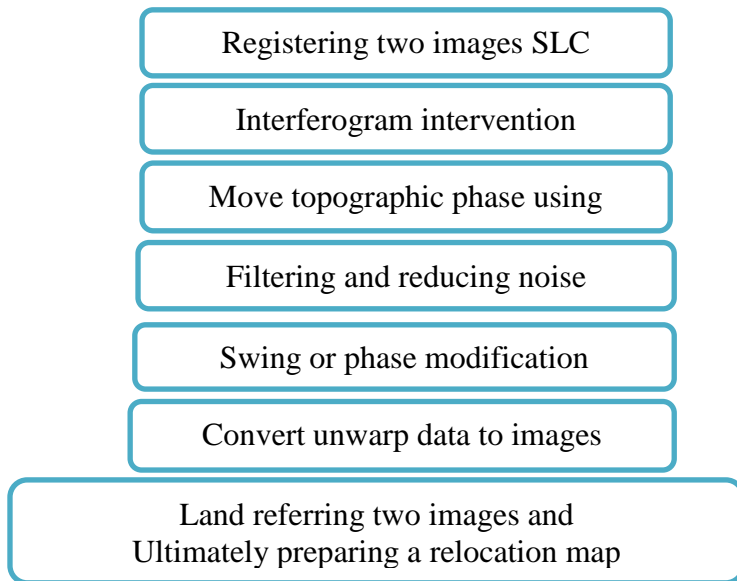


Chart 1. The stages of processing and producing subsidence and collapse maps

In this article, the description and justification of the concepts of basic words that underlie the foundation of the research are proposed, such as the patterns and techniques that can be helpful in understanding this research, the following can be mentioned:

So far, geomorphologists have tried to explain the geomorphic phenomena within the framework of the causality law (Shimoni, et al., 2017). Whereas in geographic space, contrary to classical geography, there is no requirement for the existence of relations between phenomena to be public, and only the proposed relations are of a generic type that can justify causality (Pourkhosrowani et al., 2012). And, of course, the generic relationship with what is called the correlation has a fundamental difference. Dual can be duality and duality can be doubled, a term which also implies the concept of implicit contrast, and conjunction of two phenomena. Duality can contain the symmetry of two phenomena, operating in vice versa, and specify some ratios. The design of the theory of duality in geomorphology, which is hereinafter referred to as "geodesy", is not the simple concept and expression of its implications in geomorphology, but stimulate the researchers in this field to generalize a review of how to manage, control and monitor much data of the phenomenon of geomorphology (Harvey, 2001). In describing this idea, an attempt has been made to rely on empirical-analogical approach and the interferometry-wave technique of the wave (ratio) (and its effects on geomorphology analysis). In general, the results of using this concept show that analyzing them can be in the framework of the theory of geo-duality which can create complete cause to the classical analysis in geomorphology. Although the concept of dual with concepts like coupling and duality have false similarity, and similarities can be found in the technical domain, there is an analysis of the numbers and their equivalence, but with a significant difference. Dual should not be understood by the concept of equivalent duality (Pourkhosrowani, 2015), but from the philosophical point of view, a term that can carry its meaning in Persian, one should use the paired terms. Land subsidence due to groundwater extraction is known as a major problem with environmental impacts in many areas. The creation of a subsidence phenomenon due to inappropriate groundwater abstraction, geological factors, Samadimoghadam, 2016) and the following factor comes from the porosity of soil aggregates, density, type, composition of layers, pumping method and ground structure.

Area of the region, hydraulic conductivity of the layers, rainfall and temperature are the factors affecting subsidence of the earth (Akbari et al., 2009). Unnecessary groundwater extraction causes loss of water levels and decreases the fluid pressure and thus increases the intermediate particle pressure which leads to the formation of the phenomenon of subsidence of the earth. The uneven drop in groundwater levels, the heterogeneity of tissue, sediment, and alluvial characteristics of the area also causes the irregular subsidence of the earth and creates gaps in the earth's crust. Land subsidence has been reported in many plains from dry and semi-arid areas of central and eastern Iran with a sustained decline in groundwater levels. The statistics of the country's plains, facing this phenomenon has reached 751 plains. This phenomenon is observed in other plains of Iran such as Arak, Nahavand, Khomein, Natanz, Yazd, Abarkuh, Kashmar plain in Khorasan Razavi province which is under development (Ghani ardakani Maleki, 2016). The frontier effects resulting from the development of land surfaces can be reduced by precise planning and conservation matters. The environmental consequences of the subsidence phenomenon (Sun et al., 2017) includes damage to

man-made structures such as buildings, streets, bridges and power lines, creating gaps on the surface of the earth and the flood. In all the subsidence that occurs in Iran, extraction of underground water is the only factor or the main cause of subsidence. To measure the phenomenon of deformation, one needs to study the time series in a study area. Therefore, several images should be available at different time intervals of that area and several interferogram between different time periods embedded to calculate the deformation rate in the calculations (Yarahmadi et al., 2015). This method is known as interferometric technique since the received phase is as the fraction of the phase needed to estimate the displacement implemented as a phase retrieval phase.

3. Results and Discussion

The data used in this research are of two categories: one the data Piezometric area of the region which according to the map piezometric wells area (Figure 2) of the water level height in wells in the years 1983 to 1993 were examined and evaluated which observed a 10 to 20 meter water level drop in between years. Due to this amount of water loss in the region, definitely the subsidence of the earth's surface has also been observed.

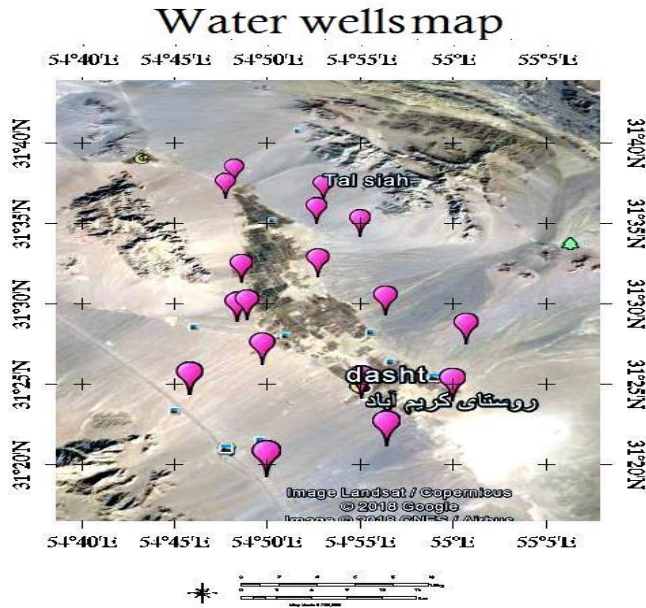


Figure 2. Map of wells in the study area

In this research, using a land survey method, the subsidence model was developed based on the following tables in the GIS and SPSS software.

Linear regression and modeling of land subsidence

Table 1. Modeling Model Summary^b

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics				
					R Square Change	F Change	df1	df2	Sig. F Change
1	.367 ^a	.135	.124	38.132	.135	13.371	1	86	.000

a. Predictors: (Constant), groundwater extraction

b. Dependent Variable: subsidence

Table 2. Liner Regression ANOVA^a

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	19441.573	1	19441.573	13.371	.000 ^b
	Residual	125045.870	86	1454.022		
	Total	144487.443	87			

a. Dependent Variable: subsidence

b. Predictors: (Constant), groundwater extraction

Interpretation of Table 2-ANOVA-: A single-variable linear regression model is meaningful between the rate of groundwater extraction and land subsidence

Linear regression coefficient B

Table 3. Linear regression coefficient

Model	Unstandadized coefficients		standadized coefficients	t	Sig.	95.0% Confidence Interval for B		Collinearity Statistics	
	B	Str.Error	Beta			Lower Bound	Upper Bound	Tolerance	VIF
1(Constant)	62.884	13.402		4.692	.000	36.242	89.525	1.000	1.000
groundwater extraction	1.538	.421	.367	3.657	.000	.702	2.375	1.000	1.000

a:Dependent Variable :Subsidence

T distribution in this table with 0.421 indicates that there is no distribution and it is significant.

Interpretation: in Table 3, coefficients shows that there is a direct and significant relationship between the amount of groundwater extraction and the land subsidence, so that for one unit of increase in water extraction, the average land subsidence increases by 1.5 units.

Charts

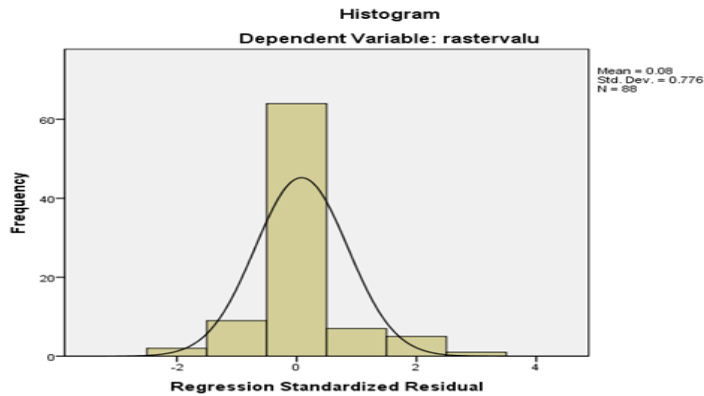


Chart 2. Normal distribution

The linear regression in Table 2,3 assumption is that the remainder of the model has a normal distribution, which, as we can see, assumes this assumption.

The significance of the regression is also shown in the table that the level (Sig = 0.00) is 99% less than 0.05. It can be deduced that the ratio of two variables is significant.

Based on linear regression, the amount of subsidence (Y) can be predicted through the rate of water harvesting (x).

$$Y = a + bx \tag{2}$$

Y= the amount of predicted dependency (the amount of land subsidence), a= constant value (the amount of dependent variable at the time when the independent variable is zero) b= Line slope or regression coefficient, " X "is the independent variable values (piezometric wells)

$$Y = 62.884 + 1.538 * X$$

X: water extracting rate Y: subsided pictures

For each unit the variation in water extraction, 1.538 variations are created in height.

- The model derived from the following formula, the components of which were described above, were analyzed by SPSS software and concluded that the correlation coefficient between the two parameters is as Equation (2)

- The correlation coefficient of the two parameters is positive with each other, which means that in the space where the study is done, the increase of a parameter with the increase of the other parameter, and also the reduction of that parameter, is accompanied by a decrease in the other parameter. In this model, changes and extraction from the water surface can predict 0.367 percent of the subsidence.

The quantity r^2 or R^2 , also called the determination coefficient, is the ratio of the variables (variables) defined to the total variables (variables). (This measure allows us to determine how much it can predict a reliable model or diagram.) The value of the determination coefficient is in the range $0 < r^2 < 1$ which represents the percentage of recruits that are closer to the regression

line. For example, when $r^2 = 0.797$, this means that 79% of the total variation of y can be obtained through the linear relationship between x and y through the defined equation, and 21% of the y variables are not defined- Adjusted coefficient: The important difference between the coefficient of determination and the adjusted coefficient of determination is that the coefficient of determination assumes that each independent variable observed in the model explains the changes in the dependent variable. Therefore, the percent represented by the coefficient of determination assumes the effect of all independent variables on the dependent variable. If the percentages indicated by the modified coefficient are only due to the actual effect of the independent variables of the model, then not all independent variables. The other difference is that the suitability of the variables for the model cannot be determined by the coefficient of determination even with a high value, if the value of the estimated adjusted coefficient can be trusted.

Table 4. Model

Model	Correlation coefficient	Coefficient of determination	Adjusted coefficient
1	0.367	0.797	0.74

In table.5, number 6 is the coefficient of determination and number 7 is Adjusted coefficient

Table 5. Balance equilibrium

OBJECTID*	VARNAME	VARIABLE	DEFINITION
1	Neighbors	22	
2	ResidualSquares	29242.771295	
3	Effective Number	20.055553	
4	Sigma	20.7459	
5	AICc	801.237358	
6	R2	0.79761	
7	R2 adjusted	0.740849	
8	Dependent field	0	subsidence
9	Explanatory field	1	groundwater

The second group data is radar information. Radar interferometric computing in this research is based on six images ENVISAT with low imaging geometry. 6 Interferogram images with software help Sarscape and the Orbital Information Agency of the European Space Agency Specification Interferogram (Table 5) processed in the study area by considering the spatial basis. In order to reduce noise and increase the correlation between interferograms an attempt has been made to use a pair of radar images with a short period of time.

Table 6. Specifications of processed interferogram in plain Bahadoran Yazd.

Spatial base line	Secondary image	Primitive image	number
911	29/7/2005	22/6/2003	1
416	25/4/2007	10/5/2006	2
398	16/9/2011	21/2/2011	3

After the production of interferograms by applying the phase-to-gap coefficient, displacement maps were prepared in the time series of the (Table 5). The survey of displacement maps shows that the phenomenon of subsidence in the central region of the study area has almost reached the same rate and anyway to the northwest or to the elevation around the area, The subsidence will be reduced and increased by a large proportion. Radar surveys which show that the ratio of each type is between the subsidence and the extinction in the region. As it subsides in the plains, it has been relatively more frequent, but in the heights it has been observed to be relatively less.

In exploring the radar data, it clearly shows a slight relationship between subsidences and uplifting in the region of the plains and the area has fallen subsidence to a greater extent but small range of uplifting has been seen at high altitudes. The statistics in the survey suggest that the mean maximum subsidence is 0.25 meter and the mean maximum uplifting is 0.07 meter, respectively (Figure 4, 5 and 6).

Displacement maps of the study area at different time intervals

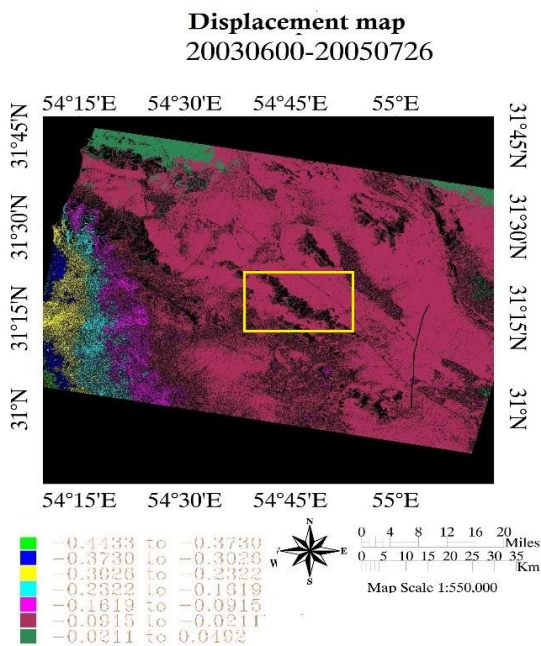


Figure 4. Displacement between 2005 and 2003

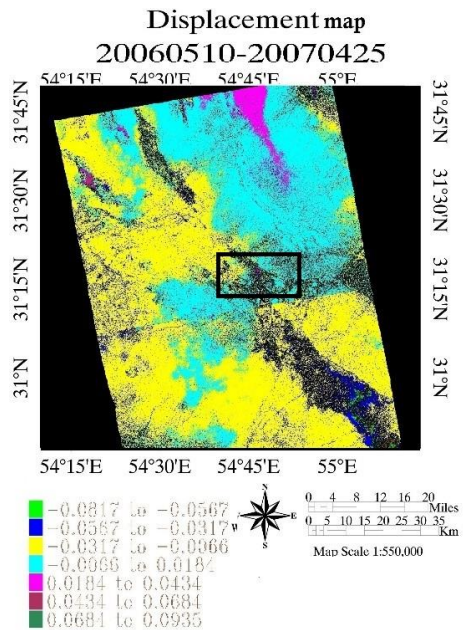


Figure 5. Displacement between 2007 and 2006

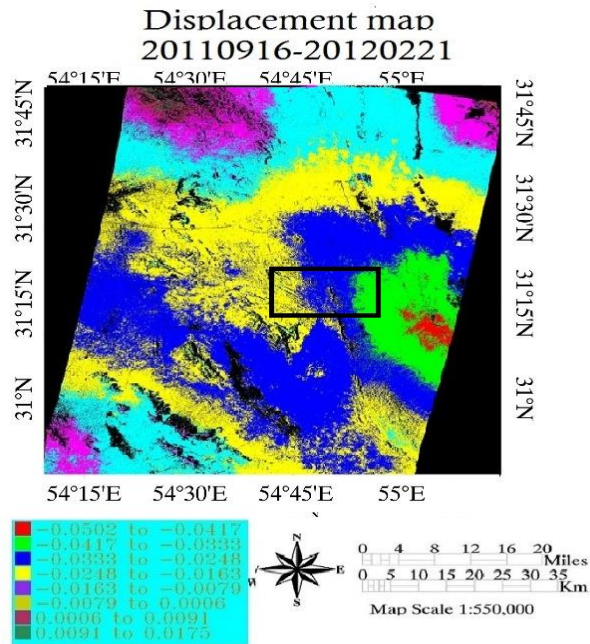


Figure 6. Displacement between 2011 and 2012

The subsidence and uplifting variations on the maps of the study shows that the largest subsidence in the plain has occurred in the flat zones and the most uplifting is seen on the high mountains overlooking and in the surrounding mountains.

According to the results specified in the data mining section, the use of the radar interferometry method shows the proper capacity of its capabilities in determining the range of subsidence at the levels. The dry climate of the study area decreases the effect of the phase shift caused by atmospheric compounds to the viscosity of the humidity, providing an accurate measure of the phase difference resulting from surface displacement. Also, the lack of co-incident vegetation in the phase of radar images in the C band is the least. It was possible to measure phase change over the annual time interval for the C band data, which indicates that the displacement numbers are close in two maps with different wavelengths. Groundwater harvesting has reduced the piezometric pressure which this reduction of the piezometric pressure causes an imbalance and increased pressure from the upper sediments. So that the porosity of the sediments is reduced and the density increases, which is one of the factors of subsidence if the pores are filled with rain water or temporary rivers and this will prevent collapse in the area.

4. Conclusions

The results of this research show that the study of duality has been proved in the domain of geomorphologies function. This review calls the general thinking in question that is associated to the complete cause of subsidence which is reduced groundwater and has been claimed by scholars and researchers because by monitoring the causes, the breaks in this area have reached over 60

years while the mechanical extraction of groundwater has short lifespan. Therefore, it can be concluded that the movements of the earth's crust has important and fundamental causes of uplifting and subsidence. Secondly, the subsidence and uplifting can be explained and defined in the duality of geomorphology. These ups and downs caused by the unnecessary extraction of groundwater witnesses the crust movements in the plains and the adjacent peaks which indicates the crust motions in order to achieve the crustal balance. Whereas, the subsidence occurred alone, as no line of equilibrium observed on the heights. Displacement maps were prepared according to the time series in Table 5. The evaluation map of the displacement rate demonstrates the phenomenon of subsidence in the boundary of the central region of the case study for the evaluated years and as far as the center of the Bahadoran plain to the north western and other regions around the area comes from the rate of the subsidence declined and slightly added to uplifting. In exploring the radar data, it is clear that there is a slight relationship between subsidence and uplifting as in the region of the plains and the area has fallen subsidence to a greater extent. But small range of uplifting were observed at high altitudes. The survey statistics suggest that the mean maximum subsidence is 0.25 meter and the mean maximum uplifting is 0.07 meter, respectively (Figure 4, 5 and 6).

As a result, the hypothesis of this research can be verified by experiments because the direct relation between the subsidence and uplifting by radar interferometry has a significant correlation.

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