Monitoring of Anthropogenic Groundwater by Using GRACE Satellite Gravimetry Data

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November 22, 2022

Abstract

In this research, GRACE satellite data have been used in order to investigate the possibility of estimating the amount of groundwater used in agriculture. The level-2 data of the GRACE satellites have been used to estimate the monthly groundwater level changes in central plateau catchment in Iran during the period of 2003 to 2013. One degree grid is used along with corrections of soil moisture, canopy, rainfall and snowfall from GRACE satellite data with the CLM4 hydrology model. The results revealed the amount of current groundwater in Iran and agricultural usage from groundwater have been determined (the largest consumer of groundwaters). verification of the results has been done by comparing the GRACE satellite data and piezometric wells data. Furthermore, ArcMap (ArcGIS) software were used for data analysis.

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This presentation participates in OSPP
Outstanding Student Poster & PICO Contest

Photography encouraged

EGU 2019

Abstract

In this research, GRACE satellite data have been used in order to investigate possibility of estimating the amount of groundwater used in agriculture. The level-2 data of the GRACE satellites have been used to estimate the monthly groundwater level changes in central plateau catchment in Iran during the period of 2003 to 2013. The results indicate a sharp decline in groundwater levels in all 6 Iran's main catchment areas. One-degree grid is used along with corrections of soil moisture, canopy, rainfall and snowfall from GRACE satellite data with the CLM4 hydrology model. The results revealed the amount of current groundwater in Iran and agricultural usage from groundwater have been determined (the largest consumer of groundwaters).
verification of the results has been done by comparing the GRACE satellite data and piezometric wells data. Furthermore, ArcMap software were used for data analysis.
The verification results show that these two series of data are in good consistency. The following conclusion can be gained that, by using the GRACE satellite data, not only the amount of groundwater resources could be estimated but also, the contribution of agriculture in these water resources could be achieved with good accuracy.

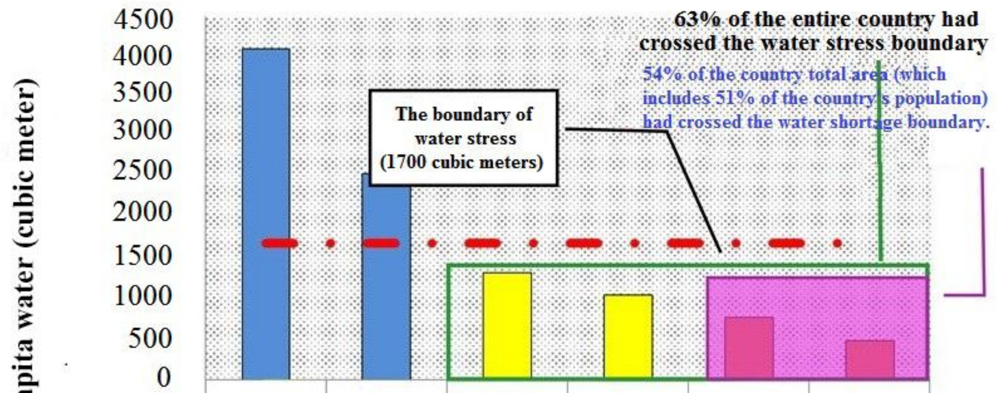
Background

Approximately 2 million people rely on groundwater as the primary source of drinking water and agriculture [Alley WM et al., 2002] [1]. However, in many parts of the world, groundwater resources are under pressure due to a number of factors, including salinization, pollution and rapid discharge [Wada et al., 2010]. When there is pressures on climate change and population growth, groundwater consumption in Iran will increase in the coming decades. Despite its importance for fresh water supply, groundwater resources are often heavily monitored, so that a consistent image of their access is difficult and sometimes impossible. In addition, water drainage from wells is often unrestricted and with lack of supervision, and making more effort to estimate groundwater consumption make it more complicated. In short, there is no comprehensive framework for monitoring groundwater resources in the world at the moment. [3]
The negative environmental impacts of groundwater harvesting include stable flows decline, which may result in the drying up of wetlands and rivers, land collapse, saltwater infiltration, increased pumping costs, and reduced water resources for some agricultural areas in the world, which exposed the production of sustainable crops In jeopardy. Careful monitoring of the pattern of groundwater harvesting is necessary to provide logical policies for achieving the goals of preserving agricultural production and managing sustainable sources of underground resources. [4]

Similarly, the current trend in the removal of groundwater resources in Iran is an unsustainable process, and then in future, the irreparable damage will seriously affect the quantity and quality of aquifers. All these issues are of extraordinary importance to groundwaters and the need to pay more attention to this issue. [1]
In this paper, estimating the amount of groundwater consumption in the largest catchment area of Iran using GRACE satellite data has been studied in order to investigate Iran's situation in this field.
In following this discussion, according to Chart 1, the water per capita allocation by using the Falkenmark index shows that when the per capita consumption reaches below 1700 cubic meters, the situation is called critical, more than 1700 water is sufficient, between 1,000 and 1,700 water stresses, there are between 500 and 1000 water shortages and less than 500 severe water shortages. [5]

Graph 1-Classification per capita renewed water resources by using of the Falkenmark index [9]

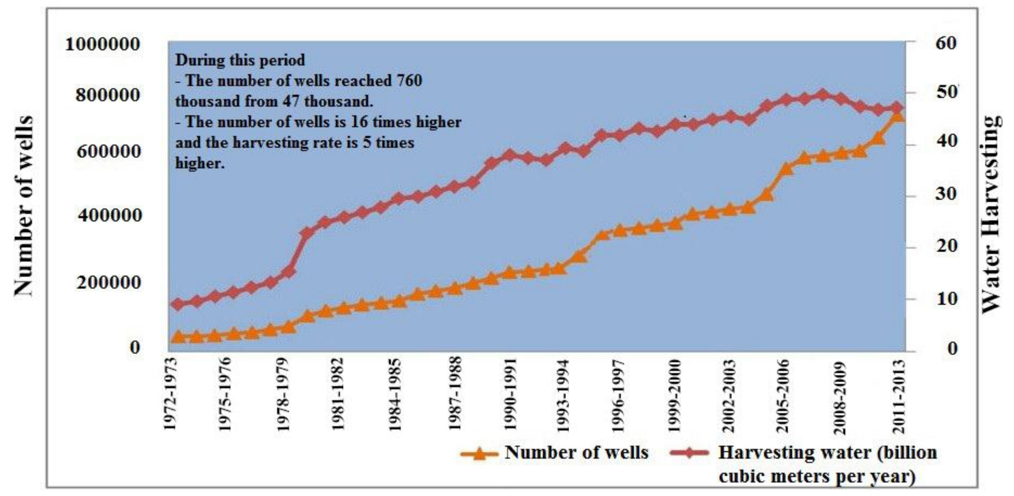
In discussing water per capita in the catchment areas, with regarding the graph 2, the central plateau as the largest water catchment area of the country with a per capita of 790 has crossed the boundary of water stress. The red dashed line is 1700 cubic meters, which is considered as the global standard as the boundary of water stress, that is, if the region or country is below 1700 cubic meters, it has been subjected to water stress and 63% of the country's area has such a situation. 54% of the total area of the country is in the water deficit situation. The central plateau area is considered as a water deficit area. (5)



	Persian Gulf and Oman Sea	Caspian Sea	Urmia lake	Eastern Border	Central Plateau	Qara Quom
Per capita water	4104	2567	1337	1069	791	502
People in square kilometers	41	69	107	16	42	95

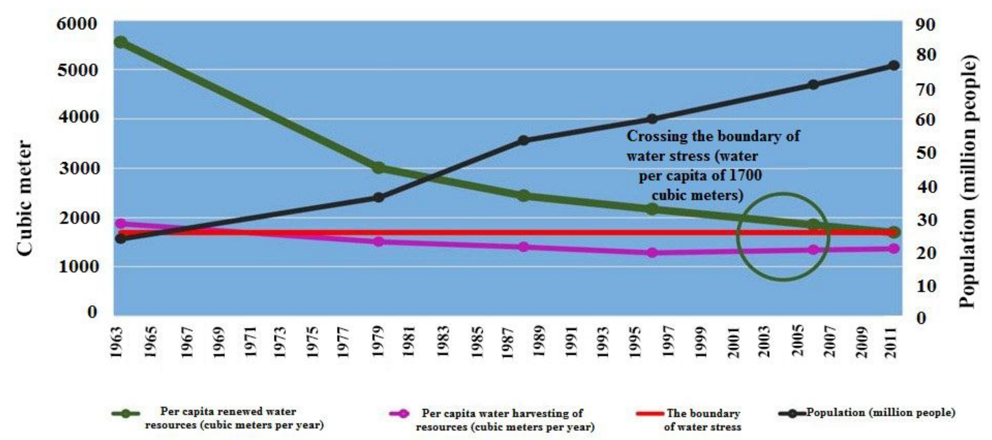
Graph 2-Water per capita status in 6 main basins of the Iran [5]

Investigating the process of water extraction from underground wells in graph 3, in the last 40 years, has shown that in the year 1972 the number of wells was about 47 thousand, and in the year 2012 it has reached 750 thousand wells, but the amount of water extracted from these wells was relatively reduced and have reached from 50 billion cubic meters to 45 billion cubic meters. Between 2005 and 2012, two catastrophes occurred that led to the construction and drilling of uncontrolled wells, some of which were illegal and another part was delved with the license. Despite the construction of the wells, Due to the fact that the reservoirs did not have capacity, there was no harvesting, rather reduce had observed that in water management this called as a disaster. In total, the amount of well drilling in this period has increased by 16 times and the harvesting rate has increased 5 times. (5)



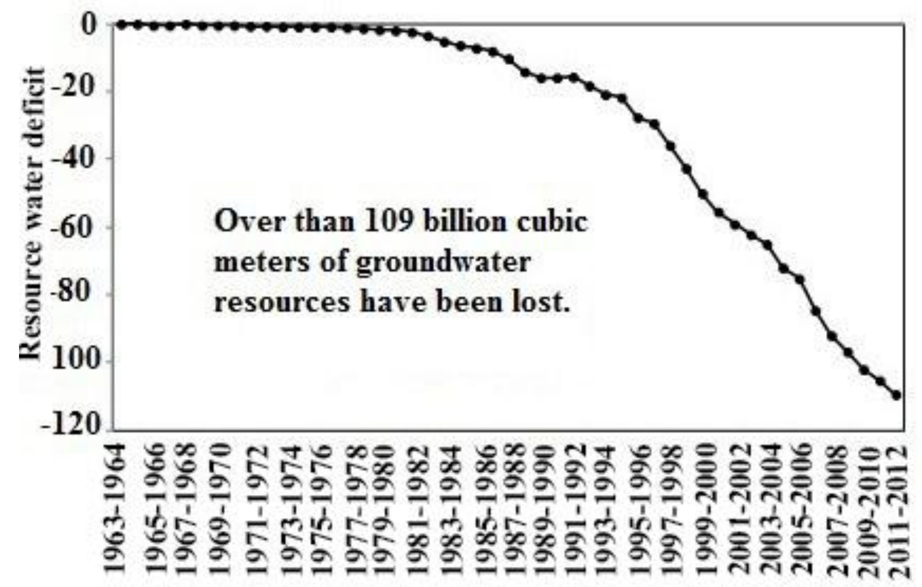
Graph 3-Process of exploitation of groundwater resources of the Iran country (wells) over a period of 40 years (5)

In Figure 4, the black curve represents the population, which was about 20 million in the year 1965 and reached 75 million in the year 2011. The green curve is the renewable water sources per capita in the year 1965 which were 5500 cubic meters per year in Iran and has reached 1,600 cubic meters in the year 2011, which That way the red line has crossed of the water stress line. The result is that this process has led the country to the crisis. [5]



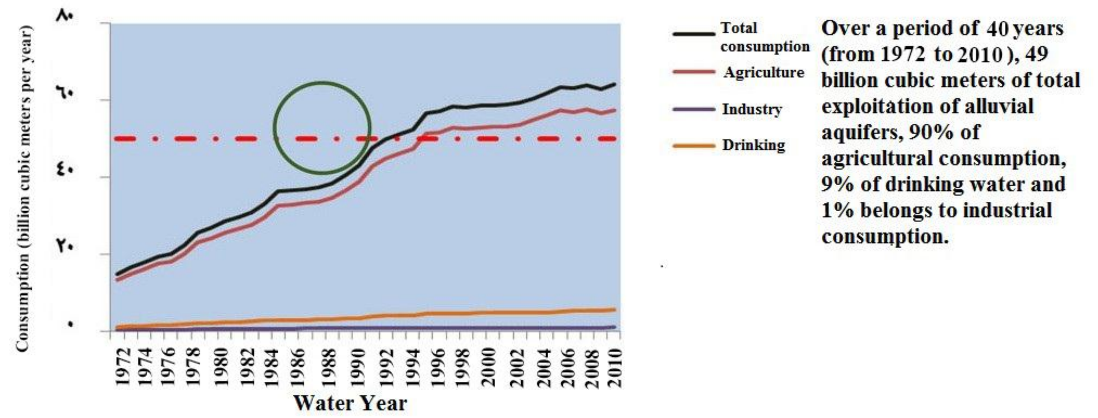
Graph 4-Changes in renewable water per capita and water harvesting per capita relative to population increase [5]

The increase in harvesting from reservoirs and groundwater in 1968, 1982, 2005, 2010, 2013 respectively is about 0.1, 2.2, 65.2, 97, 109 billion cubic meters, which has caused a serious crisis for underground water supplies (Figure 5). The chart shows a reservoir deficit the volume of groundwater resources in different years. [10]



Graph 5-Deficit of the volume of groundwater resources in different years

Figure 6 shows the groundwater resources from 1972 to 2008. The blue line, which is almost on the horizontal axis, is the trend of consumption of the industrial sector over the past 38 years. The brick curve shows the amount of drinking water, the pink curve shows the agricultural consumption and the black curve shows the total consumptions. If the max of consumption of about 50 billion got taken into account, it can be understood that the harvest is currently 65 billion cubic meters, which is about 15 billion more than the capacity of underground aquifers, which is the reason of the criticality of groundwater aquifers.

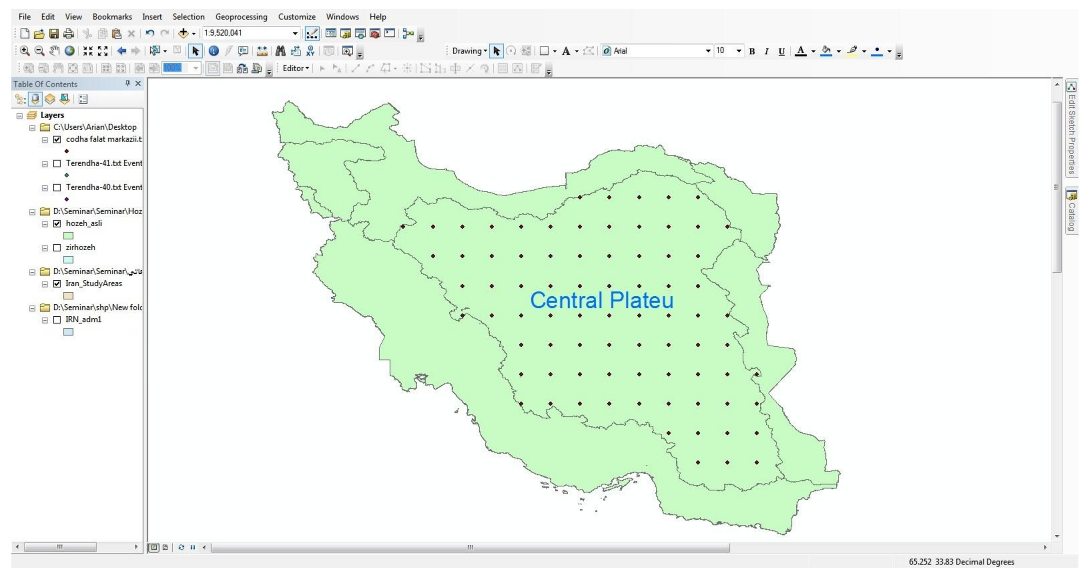


Graph 6-Changes in the amount of different type of consumptions of groundwater resources in the last 37 years [5]

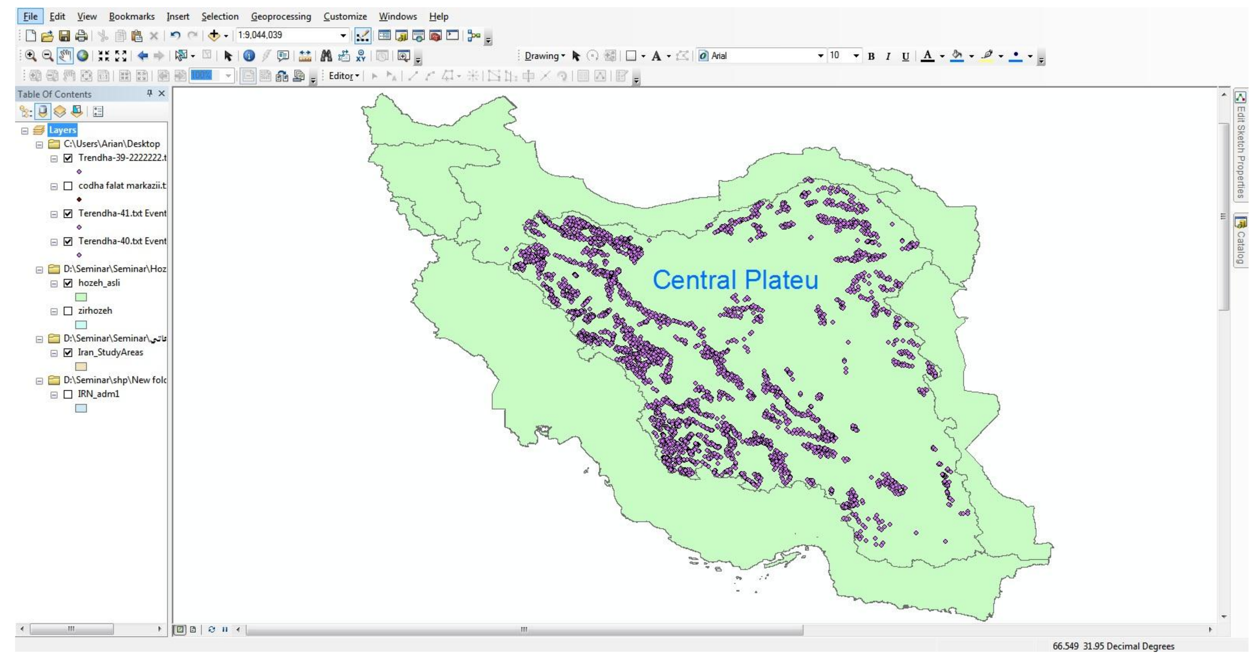
All of this and the upcoming crises in the Iran country about groundwater highlights the importance of further work on this issue. The problem of water scarcity and water crisis are a global problem that the whole world faces, which will require further consideration.
In Iran, 90% of the groundwater is used for agriculture, so all the results obtained from the GRACE satellite can be considered as the used groundwater in agricultural consumption.

Metod

For this project, GRACE satellite data was downloaded from Podaac site between the years 2003 to 2013. Since these level-2 GRACE data included all the water below the satellite and it was only needed to groundwater, so additional items from the GRACE satellite data should be deducted.
For doing so, the CLM4 hydrologic model was opened in all central plateau with the 1-degree gradient grade in the Arc Map software (Figure 7) and analyzed, and additional items of rainfall, snow, dew and soil moisture from data Grace satellite was deducted. Finally, for the verification of the results, the results were compared with the correct piezometric wells (Figure 8) on the central plateau.



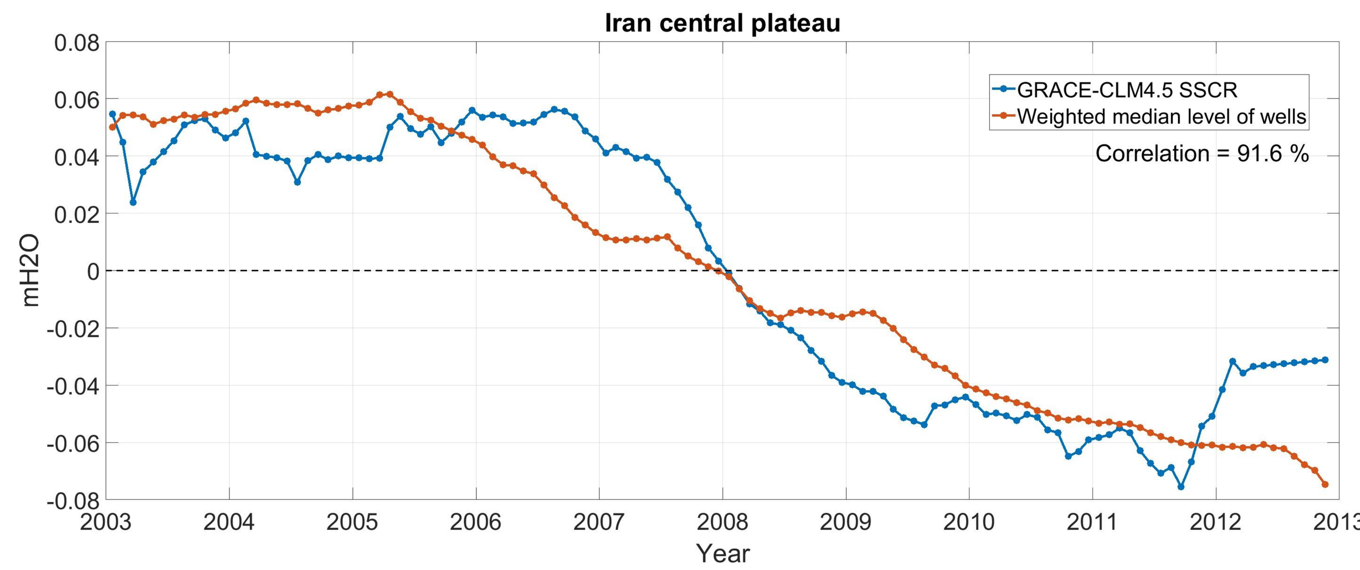
Graph 7-CLM4 data in 1-degree gradient in Arc Map software in all central plateau



Graph 8-Piezometric wells in Arc Map software in all central plateau

Results

To reach the final results, the data from the piezometric wells located in the central plateau basin were compared with The results obtained from lowering the values obtained from the CLM4 hydrologic model from GRACE satellite data. The results showed the 91.6% matching rate of these two series of results (Figure 9), which indicates the appropriate and acceptable precision for the data from the GRACE satellite.



Graph 9-Piezometric wells in Arc Map software in all central plateau

In the end, overall, it can be concluded that in large areas and in cases that are not needed very carefully, gravimetric satellites such as GRACE satellite can be used to obtain such things like groundwaters instead of using piezometric wells.
By doing so, you can save time and expense. Additionally, piezometric devices installed in these wells can be damaged and destroyed, which can lead to incorrect results from these devices.

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