Detecting Methods of Ground Water Storage Changes from the Different Date Sources in Kafr Elsheikh Governorate, Egypt.

Mahmoud El-Mewafi, Fawzi Hamid Fawzi Zarzoura and Heba Basyouni Ibrahim*

ABSTRACT- Gravity monitoring is used to detect the groundwater storage changes, over traditional techniques that are very costly and require strong workers, which are very difficult. The Gravity Recovery and Climate Experiment (GRACE) measures Terrestrial Water Storage (ΔTWS) for a regional area, it is the total mass of water found in the soil column (such as, surface water, soil moisture, snow, and groundwater). In this study, Grace Data was used to calculate the changes in groundwater storage (ΔGWS) in both 2005 and 2010 in Kafr El-Sheikh, Desouk and fwa by selecting four random points in each of them and calculating the terrestrial water storage from GRACE, though global land date assimilations systems (GLDAS) soil moisture was calculated and subtracted from the terrestrial Water Storage to calculate the groundwater. In this study, data on the changes in groundwater reserves were obtained by contour maps and thus the data obtained from GRACE were verified by comparing them where the maximum values and the lowest values of the differences respectively are 20.76 and -3.68 mm.

Index Terms GRACE, Gravity, Traditional, GLDAS, Soil moisture, Storage

1. INTRODUCTION

WAter is considered an important resource in Egypt for many water users. The next fight will be on water because of the rushing need to increase the proportion of cultivated areas. . The groundwater are existing in wells, springs and caves, The groundwater can be described as water stored between the piles of sedimentary rocks formed across Time and source of this water is the water of rain or rivers, permanent or seasonal, as well as melting ice above the surface of the earth and the infiltrator into the interior. It is also possible to know the groundwater of the plant index where the existence of plants is a definitive evidence of the existence of groundwater in the layers Valley of the surface of the ground, where the presence of plants dry indicates the presence of small amounts of underground water. However, there are currently no major networks to monitor the significant changes in groundwater stock. Generality groundwater level measure only local estimates reflect of groundwater storage. Remote sensing will solve this difficulty But modern techniques based on indirect measurements of the changing part of hydrographic water {1} (e.g., plants over the springs, fractional rocks, surface displacements, etc.). While increasing awareness and thought, we must expand our ability to quantify groundwater and its flow from a distance significantly. There is a new opportunity to monitor changes in groundwater stocks from space From the Gravity Recovery and Climate Experiment (GRACE) mission {2}.

The quantity of water that infiltrate into the land changes widely from site to other, based on the soil type, slope of the land, , vegetation, and amount of rainfall like, leakage rates in sandy soil are higher than clay soil or pavement. Recharge is higher in the spring because the plants do not exhaust great amount of water {3}.Not each precipitation becomes groundwater recharge several of it still on the land surface to streams or storm, some of it become steam, and some is absorbed by plants {4}. The GRACE mission supply monthly changes in (ΔTWS) by measuring the Earth's global gravity field {5, 6}.

Before this period for new gravity mission, Earth-orbiting satellites were tracked to measure the long wavelength of the Earth's gravitational field. The monitoring had varied quantity and quality. It had minimum spatial covering distribution. In the past little years, our understanding on the gravity field of the Earth had increased {7}. The essential science objective of GRACE was to evaluate the Earth's gravity field and its period variability with unmatched accuracy. The period scales from months to years. Temporal gravity differences are actually because of water mass redistribution in the liquid surface above /in or inside Earth. The variations measured monthly of gravity occur by monthly mass difference. It can convert temporal changes to a quite thin water layer on the surface, with various thicknesses with time. The vertical changes of thin layer of water are evaluated in centimeters {8}.

Groundwater is considered since a long time as an Instrument to indemnity regional water lack. Farmers who have land located near the end of the irrigation canals should use additional water from wells {9, 10, and 11}. Must be combined surface water and groundwater where they can work through them integrated management of water resources and to help irrigation systems that have low efficiency and also problems of sanitation {12}.

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The GRACE mission supply monthly variations in terrestrial water storage (TWS) on the footing of mensuration of the land global gravity area. TWS, as conclude from the gravity gauge, perform a vertically inserted gauge of water stock that contains soil moisture, groundwater, surface water, snow and ice, and biomass. Thus, so deduce one component from TWS (e.g., groundwater storage), other ingredients (like, surface water, soil moisture) requirement to be measured or evaluated. A lot of studies have validated GRACE derived TWS with results from other models like land surface models and with observe soil moisture and groundwater storage variations. These studies displayed that GRACE TWS can be applied to estimate ground water {13, 14}

2. STUDY AREA

The study area is a part of the Nile Delta in the north which is the governorate of Kafr El - Sheikh which consists of fine sand and clay, the center and south of the province cover the sediment of the modern geological age (the Holocene era), dark brown structures consisting of clay sediments, clay and sandstone, These sediments are deposited above the old sea sediments, which date back to the Pleistocene era, These sediments are deposited above the old sea sediments , which date back to the Pleistocene era {14}. They are describe by yellow color, consisting of coarse sand, fine gravel, or rocky. The northern coastal area is a low sandy coast of soft, Belongs to the ages of Pleistocene and Hadith as shown in figure (1).

Figure (1): The location of KFS governorate, Egypt

3. Methodology

Synthetic Aperture Radar (SAR) microwave radiometry or Thermal Infra-Red (TIR) imagery has the ability to detect shallow groundwater inwards a little centimeters of the surface. However, if the depth of the water is less than one meter, the groundwater can't be detected in this case and it is usually monitored using gravity {15}.

GRACE gives you the time-variable component of the gravity field, which can be written /expressed in terms of changes in the total water storage. Total water storage includes surface water, groundwater, snow water, canopy water, and soil moisture. Identify the relevant compartments of total water storage for your region of interest is important. Then remove estimates of these water compartments from Total water storage change from GRACE. For example: GW = TWS - Soil moisture - surface water - canopy water, for a semi-arid region {16}.

TWS is considered the single parameters affecting on climate case by diverse methods. SM is a major source of water for the atmosphere {17} and plays a sub part in the climate case {18}Assessment of SM is too benefiting for seasonal predictions, and is shown to increase forecast of air temperature {19, 20}

GRACE can use gridded data from various centers, GFZ, JPL CSR or process the spherical harmonic coefficients and remove various components such as soil moisture... However, the results (accuracy and the spatial resolution) would be affected by the post-processing methods used, Monthly GRACE TWS data is available for free, the groundwater storage changes was calculated from the TWS changes, TWS is considered a vertically integrated measurement of water storage variation that clarify the total of groundwater, snow, soil moisture, surface water, snow, and ice {21}. Variations in groundwater stock (ΔGW) are studied as shown:

$$\Delta GW = \Delta TWS - (\Delta SM + \Delta SWE + \Delta SW) \quad (1)$$

Where Δ is indicate to monthly or yearly variation. ΔGW is the changes in Groundwater storage, ΔTWS is the variance in Terrestrial water storage, ΔSM indicates to the changes in volumetric soil moisture content, SWE Snow water equivalent and SW Surface water. In study area Kafr Elsheikh government is located in Located in the far north of Egypt in the Nile Delta, there is no Snow water or it is found in a very small amount so it is neglected, too Surface water is ignored because of narrow width. For that, the equation can be expressed as:

$$\Delta GW = \Delta TWS - \Delta SM \quad (2)$$

In this study, the changes in groundwater storage will be compared with GWS changes derived from traditional methods.

4. Database used in the study

There are three sources of data used in this study:

4.1. Data from Grace

The GRACE monthly water height was downloaded for study area from Center of Space Research (CSR). In this study, Release-06 of GRACE (GRACE-RL06) is applied to conclude the TWS for 2005 and 2010, an example shown in figures (2, 3).GRACE-RL06 is extra precise than previously released products, date available at (http://thegraceplotter.com/)

4.2. Global land date assimilations systems (GLDAS)

GLDAS/Noah is considered one of the most closely used global continental hydrology models {22}. The NOAH model with 1° decision in 2005 and 2010 was utilized according to the available date from grace, an example shown in figures (4, 5).
The model of GLDAS is obtainable at
(http://gdata1.sci.gsfc.nasa.gov/daacbin/G3/gui.cgi?instance_id=GLDAS10_M)

4.3. Traditional methods

Two contour maps for 2005and 2010 were made for the availability of water levels from peering in this period and to see the developments in the groundwater level and the compatibility of these results with data obtained from GRACE.

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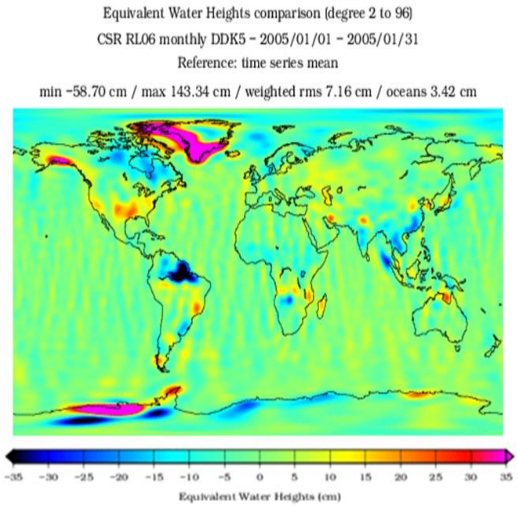

Figure (2). Equivalent water heights in 2005 from GRACE

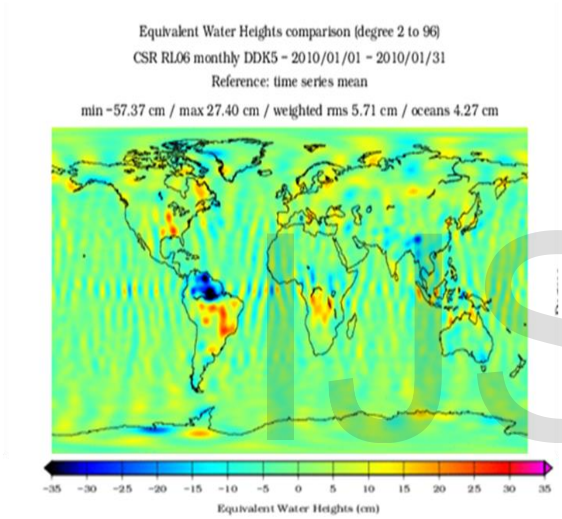

Figure (3). Equivalent water heights in 2010 from GRACE

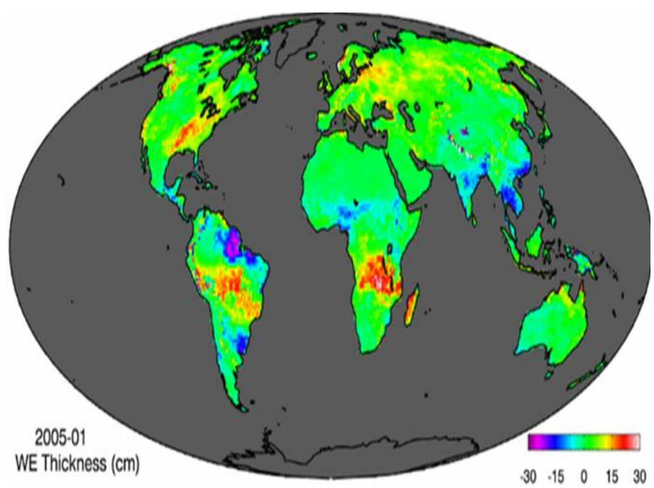

Figure (4). GLDAS Mass (cm) in 2005

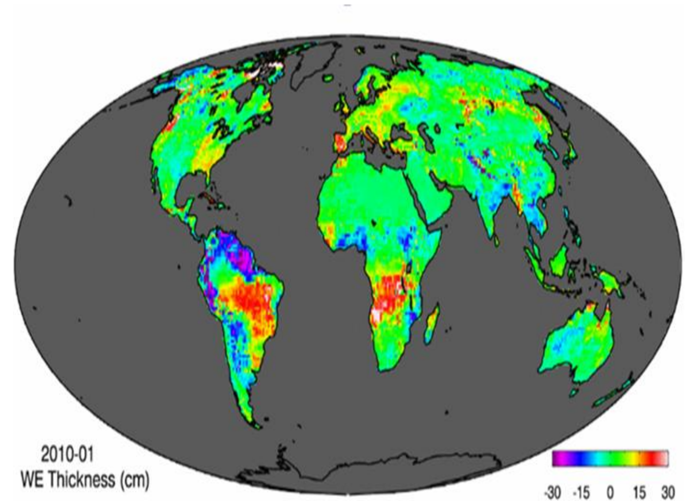

Figure (5). GLDAS Mass (cm) in 2005

5. Analysis results and discussions

The Grace data is containing the total water storage of Kafr El-Sheikh Governorate, which extends from Φ =31° to 31° 37´ N and λ = 30° 20´ to 31° 20´ E. Four points were selected in the center of Desouq, Fwa and Kafr El-Sheikh. The total water storage was obtained for each month in 2005 and 2010, afterwards subtracting ΔSM (mm) acquired from GLDAS from ΔTWS to get ΔGW. The mean values of the three values were calculated for all available months for the study period. These steps are performed to the three centers for each of both years as shown in table (1). You can find out if the area is rechargeable or dischargeable by subtracting the New Year values from the old year. The positive value is means rechargeable and negative value is dischargeable area.

The storage of land water in GLDAS model is contains the soil moisture. Wherefore, the variation in groundwater storage was calculated by subtract the variation in total water storage from ΔSM for the identical area from GLDAS, its resolution is 1o and its average values are similar to 12 and 10 mm for 2005 and 2010 respectively.

The results show that the period from 2005 to 2010 was recharged at an average value in the center of Desouk, Fowa, and Kafr El Sheikh with 64.24, 63.86 and 66.7 mm respectively.

The data obtained from the previous excavations from peering's the only data available to us for Desouk, fowa and Kafr Elsheikh in the years 2005 and 2010 as shown in tables(2,3 and4), an example of counter map in Desouk city as shown in figures(6,7)

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Table (1) Difference in GW changes2005 &2010 from GRACE and GLDAS

Country	Global Coordinate		Mean for year 2005			Mean for year 2010			Difference in ΔGW2005& ΔGW2010 (mm)
	Last	Long	ΔTWS (mm)	ΔSM (mm)	ΔGW (mm)	ΔTWS (mm)	ΔSM (mm)	ΔGW (mm)	
Desouk	31.13N	30.65E	-25.78	12	-37.78	36.54	10	26.54	+64.32
	31.14N	30.64E	-25.66		-37.66	36.51		26.51	+64.17
	31.12N	30.65E	-25.8		-37.8	36.48		26.48	+64.28
	31.15N	30.65E	-25.66		-37.66	36.53		26.53	+64.19
Fowa	31.25N	30.55E	-24.34	12	-36.34	36.46	10	26.46	+63.8
	31.24N	30.54E	-24.34		-36.34	36.41		26.41	+63.75
	31.22N	30.55E	-24.53		-36.53	36.38		26.38	+63.91
	31.20N	30.55E	-24.63		-36.63	36.34		26.34	+63.97
Kafr ELsheikh	31.11N	30.95E	-28.24	12	-40.24	36.58	10	26.58	+66.82
	31.11N	30.93E	-28.1		-40.1	36.45		26.45	+66.55
	31.10N	30.92E	-28.1		-40.1	36.48		26.48	+66.58
	31.10N	30.96E	-28.3		-40.3	36.53		26.53	+66.83

Table (2) Difference in GW changes2005 &2010 in Desouk city

City	Diff in GWL(mm)		
	Max	Min	Mean
Desouk	170	0	85

Table clarify the ground water changes between 2005 and 2010, the maximum and minimum value for Desouk city are 170mm and 0 mm respectively with mean value 85 mm

Table (3) Difference in GW changes2005 &2010 in Desouk city

City	Diff in GWL(mm)		
	Max	Min	Mean
Kafr Elsheikh	120	0	60

Table clarify the ground water changes between 2005 and 2010, the maximum and minimum value for Kafr Elsheikh city are 120mm and 0 mm respectively with mean value 60 mm.

Table (4) Difference in GW changes2005 &2010 in Desouk city

City	Diff in GWL(mm)		
	Max	Min	Mean
Desouk	160	10	85

Table clarify the ground water changes between 2005 and 2010, the maximum and minimum value for Kafr Elsheikh city are 160mm and 10 mm respectively with mean value 85 mm.

A comparison was made between traditional methods and GEACE/GLDAS and the results shown in table (5).

Table (5): The variations in ΔGWS from both traditional and GRACE-GLDAS methods

City	Traditional mean different in gwl (mm	Grace/glades Mean different In gwl (mm	Diff between Traditional and Grace/glades
Desouk	85	64.24	20.76
Kafr Elsheikh	60	63.9	-3.86
fowa	85	66.7	18.3

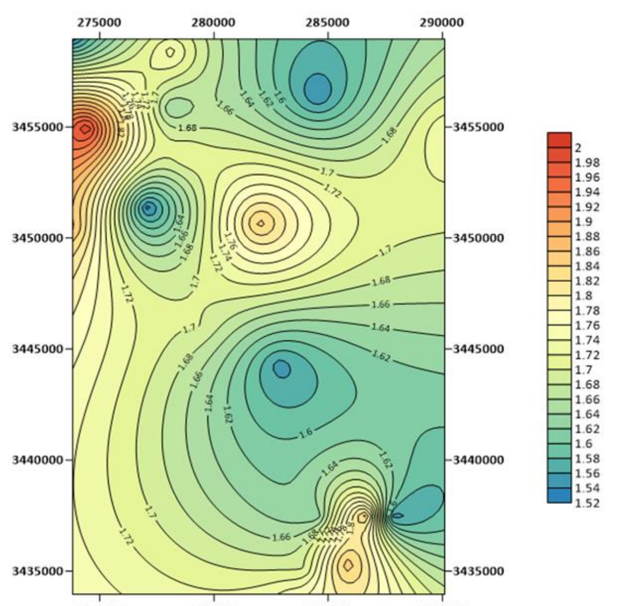
The previous table show that the Diff between traditional and GRACE/GLDAS in Desouk, Kafr Elsheikh, fwa was 20.76 , -3.86, 18.3 mm respectively, Its indicates that the governorate of Kafr El-Sheikh was subject to rechargeable in the centers that studied, and also the compatibility of the results between the traditional way and GRACE/GLDAS as shown in figure(8). These results correspond with the main hydrogeological units in Egypt (RIGW 1988) which show that the Nile Delta aquifer is rechargeable {23}.

Otherwise, in the city of Kafr Elsheikh the results are inconsistent but the common behavior of governorate is rechargeable for the surface and subsurface award to RIGW adjective for the main hydrological units in Egypt that published by (El Tahlawi. M. R., Farrag. A., 2008), which is mention that the GRACE-GLDAS results are more dependable.

Attia (1954) and Farid (1980), shows that the Rosetta branch is a discharge for groundwater at Kafr El-Ziyat and Tamalay cities, however.it rechargeable in the Edfina and Desouq region.

The Research Institute for Groundwater (RIGW) and the Drainage Research Institute (DRI) shows that the leakage rate ranges from 0.25 to 0.80 mm / day and this is leakage from waterways and irrigation water leakage (RIGW, 1980; DRI, 1989) Central and South Delta.

According to the Initiative of Nile Basin (NBI), 2012, there is a difference in recharge the groundwater systems in the Nile region, with value ranging from a few millimeters to over 400 mm/ year



Figure(6) Contour map in Desouk in 2005

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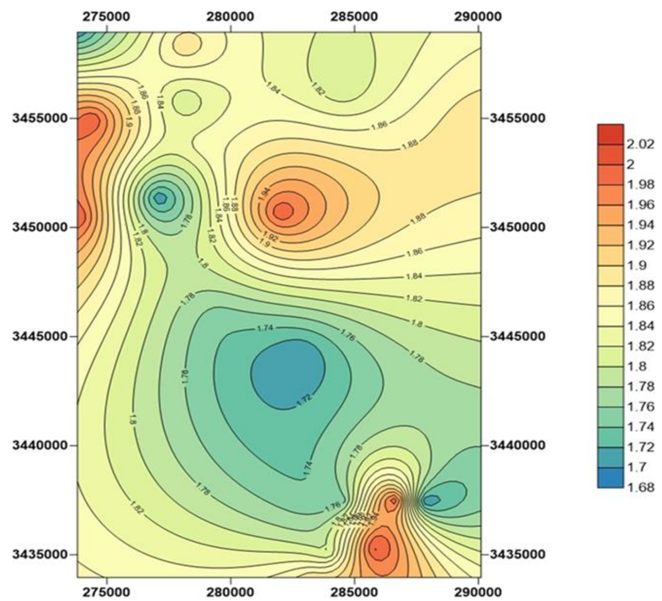
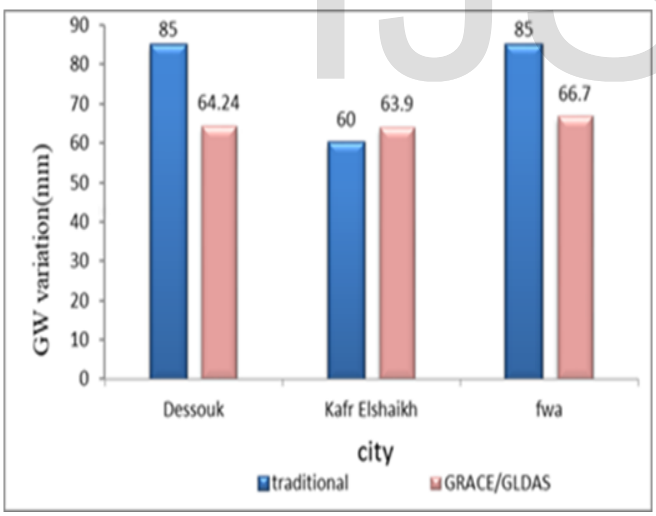


Figure(7) Contour map in Desouk in 2010

A map of Contour was prepared for the center of Desouk in the year 2005 through the coordinates of the points obtained from the site. It is shown from the Contour lines that the water level ranges from (1.7 to 2) which is consistent with previous researches such as (Survey of groundwater use in the central part of the Nile Delta)

A map of Contour was prepared for the center of Desouk in the year 2010 through the coordinates of the points obtained from the site. It is shown from the Contour lines that the water level ranges from (1.7 to 2) which is consistent with previous researches such as (Survey of groundwater use in the central part of the Nile Delta)



Figure(8) Comparison between the traditional way and GRACE/GLDAS

6. relation between land use / land cover and ground water

To define the shape of variations in urban area, directional variations were executed on urban areas of Desouk city as shown in Figures (9 to 11). The general way of spatial development was observed to the south and east trend over the periods from 2005 to 2010 and from 2010 to 2018 was in the south trend. The city ultimate spatial increase during the total studied period from 2005 to 2018 was 25.7 km2 in the south direction as shown in Table (6) and figure (12).

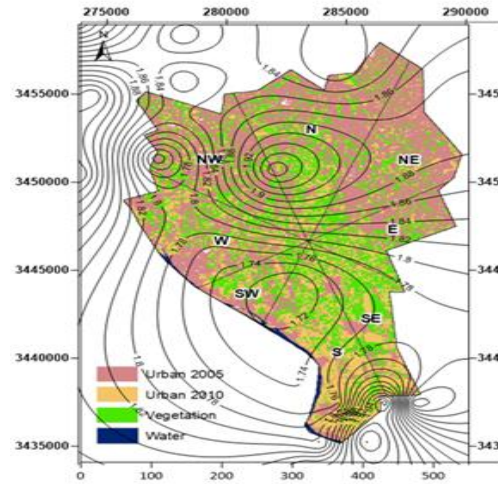


Figure (9) Directional changes in urban Areas in Desouk from 2005 to 2010

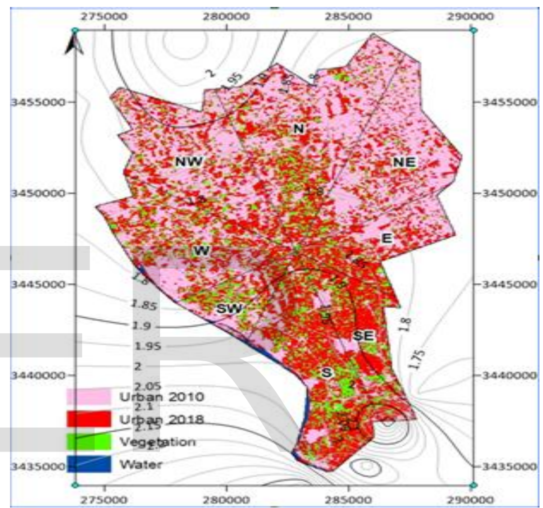


Figure (10) Directional changes in urban Areas in Desouk from 2010 to 2018

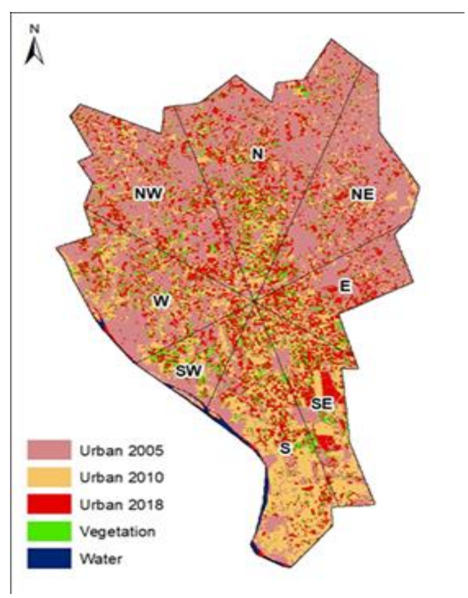


Figure (11) Directional changes in urban Areas in Desouk from 2005 to 2018

Table (6) Directional changes in urban Areas in Desouk from 2005 to 2018

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DIRECTION	Urban from 2005 to2010	Urban from 2010 to2018	Urban from 2005 to2018
N	10.1	10.6	20.7
NE	5.7	5.9	11.6
E	4.9	5.7	10.6
SE	11.5	5.2	16.7
S	23.6	1.7	25.4
SW	4.5	1.6	6.1
W	10.7	5.2	15.9
NW	7.7	8.5	16.2
SUM	78.8	44.5	123.2

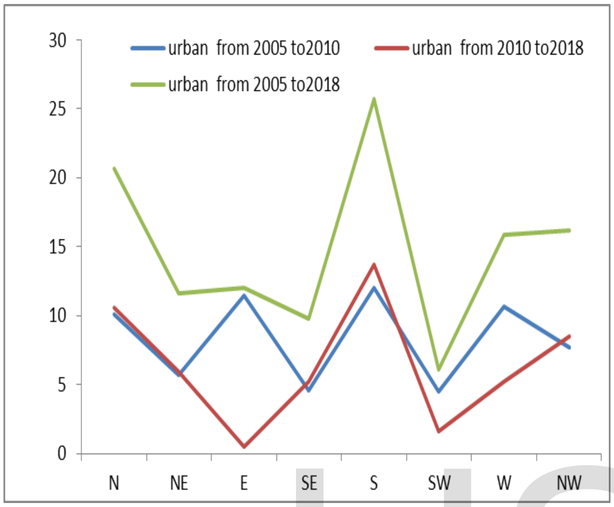

Figure (12) graphical clarification of direction spatial expansion in urban area of Desouk city from 2005 to 2018

7. CONCLUSIONS

In this paper, the GRACE date used to calculate the change in total water storage, GLDAS date to calculate soil moisture and traditional methods in the year 2005 and 2010 to calculate the change in groundwater in Kafr Elsheikh governorate. From the above results, it can be concluded that

1. The results obtained from GRACE and GLDAS are consistent with the data derived from the traditional method at the site where the maximum and the minimum value of the differences respectively are 20.76 and -3.86mm.
2. Monitoring can be used using gravity at the field level without the need for wasted time and high cost. in estimating changes in total groundwater storage (ΔTWS) which enabled us to obtain groundwater storage (ΔGWS) by subtracting the soil moisture obtained from GLDAS from the total water storage.
3. There is a close correlation between urban change and rising groundwater
4. The governorate of Kafr El-Sheikh is subject to rechargeable in the centers that studied.

Recommendations

- Use GRACE Data to determine sea level changes along the Egyptian coasts. Therefore the coastal cities will protect by predicting with improve the global gravity models.
- Future studies on the impact of urban developments on groundwater quality and recharge to make the stable model for different aquifers in Egypt.
- We recommend that you study more intensive data, whether field or any other methods to infer a clear model to indicate the groundwater stock in any study area.

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