Carpathian Journal of Earth and Environmental Sciences, August 2020, Vol. 15, No. 2, p. 515 – 531; Doi:10.26471/cjees/2020/015/149

MONITORING AND SURVEY OF SNOW CLIMATOLOGICAL PARAMETER AREA USING REMOTE SENSING DATA IN ZAGROS MOUNTAINS RANGE, LOCATED ON THE EASTERN BORDER OF IRAQ

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Abstract: As snowfall plays a vital role in the supply of water resources to all living things on the planet, its wasting must be avoided by careful planning. In recent decades, with the rising temperatures of the Earth and the melting of mountain snow, many scientists have taken the view of this natural hazard, so it is important to address this issue. The purpose of this study is to monitor and analyze the snow area and depth in the Zagros mountain range. For this purpose, TERRA - MODIS satellite image data for Iran were used. The timeframe of the selected images is between 2000 and 2019. Tips for selecting images are taken into account, with an averaging three months (Jan, Feb and Mar) image of winter in each year. Based on the results, the decreasing trend of groundwater aquifer trend with the amount of snowfall in the study area is highly correlated at the level of 0.94% and this decrease has been highly correlated since 2007 onwards. The largest decline in groundwater use by the CSR model was in November 2017 with 18.29 cm. The maximum average of three-month snowfall variations (January, February and March) in the study area during the period (2000 to 2019) was 55.16 cm in 2008. Average quarterly snow depth variations (January, February and March) fluctuated in the study area, the most severe between 2007 and 2014, with 2008 snowfall averaging 110.21 cm. According to the comparisons made during the study period, the lowest snow cover area was for the winter quarter (Jan, Feb and Mar) of 2018 with a value of 3919.423 km^2 and the highest was obtained for the quarter of 2007 with the amount of 86515.925 km^2. These results imply that the relevant authorities in the study area must adopt careful planning in water resources management.

Keywords: Terra Satellite Data, Snowfall, NDSI Index, GRACE Sensor, Groundwater aquifer, Iran.

1. INTRODUCTION

Although a small portion of the Earth's surface is covered by mountainous areas, but this small amount has a significant impact on the watershed's hydrological landscape. Since the water crisis is a serious issue in arid and semi-arid regions of Iran, monitoring the amount of snowfall in the mountainous parts of these areas is very important. Due to the importance of snowfall in mountainous water supplies, accurate estimation of snow equivalent water as well as changes in its cover levels are effective in agriculture, energy, reservoir management and flood warnings. Precise statistics about snow damage in Iran are not available. This phenomenon occurs in the northwest of the country during the cold season due to the synchronization of the synoptic systems of the atmospheric balance with surface low-pressures each year or several years depending on the specific conditions of the region (Molazadeh et al., 2014; Jahanbakhshasl et al., 2015a; Abdam et al., 2016; Khoshkho, 2016; Bahrami et al. 2016; Keikhosravikiani & Masoudian, 2016b and Darghiyan & Alijani, 2016; Sobhani & Safarianzengir. 2019a). Heavy snowfall is one of the atmospheric hazards that is very important in predicting its intensity and location. Iran is known as a country with arid and semi-arid climates, where the problem of dehydration has always been one of its environmental issues. Therefore, snowfall and its cover is the best factor in water supply during the warm seasons. Snow is one of the major sources of water in most parts of the world and estimation of runoff from its melting is one of the most important activities of hydrologists (Ghaffarian et al., 2016; Rostaee et al., 2016; Ibrahimi et al., 2016; Massoudian & Keikhosravi, 2018; Khoshhaldastjerdi & Kamyar, 2018; Sobhani et al. 2018; Safarianzengir et al. 2019; Safarianzengir & Sobhani. 2020). One of the most important sources of water in mountainous areas is snow storage, which can provide the water needed for agricultural, drinking, and environmental uses for most of the year. Snow is one of the forms of rainfall that due to the nature of the delay in turning it into a runoff, it is very different from other components of water balance. It is an important factor in climate change in an area. Snow blizzards are an atmospheric hazard, with disruptions to the transmission network and damage to the energy transmission grid. Snowmelt plays a major role in supplying water for agricultural, natural resources, industrial, and human activities, especially in mountainous areas. Snow is one of the components of the water cycle in many mountainous basins in the (Karamoz & Iraqi-nezhad, 2014; Haghizadeh et al., 2018; Khoshhaldastjerdi & Kamyar, 2018; Entezami et al., 2018 and Sobhani & Safarianzengir. 2020). Snow is a divine blessing as one of the main sources of water balance, spring surface currents, groundwater aquifers, rivers and springs. On the other hand, this process has caused numerous problems and adverse conditions in snow-covered areas in many years. Reduced horizontal visibility during snowfall, snow accumulation, snowstorms, glaciation and road surface slippage are both inter-urban and road blocks that require rapid response and corrective action (Mirmosavi & Sabouri, 2012; Jahanbakhshasl et al., 2015b; Jamalzadeh et al., 2015; Kashki & Mohammadi, 2017; Sobhani & Safarianzengir. 2019b; Sobhani et al. 2020b). Information on snow cover as one of the providing sources of groundwater, drinking and agriculture water is important for optimal management of water resources. One of the most important information sources for snow surface detection is the MODIS satellite imagery from which the snow surface product is produced on a regular basis. Snowfall although it is an atmospheric phenomenon similar to the size of atmospheric rainfalls, but it has its own effects and classes due to its physical nature. With all the benefits of snow for dry and semi-arid climates, Iran has its own limitations. Heavy rainfall events often cause irreparable life and financial losses. Therefore, the ability and predictability of these events to occur correctly is crucial for the rapid alert organizations of different countries (Tasdighian & Rahimzadegan 2018; Shadpour et al., 2018; Khansalari et al, 2018; Sobhani et al 2019c; Sobhani et al. 2020a). Snowfall, especially in arid climates, is considered to be a very important environmental event and has a specific hydrological behavior and has a different impact on the environment than other precipitations. Assessing the impact of climate change on the change of snow cover and melting is very important in managing the water resources of snow-fed rivers. Such changes have a direct impact on the hydrological regime and water resources management. In mountainous regions, seasonal snow, as an important component of the hydrological cycle, causes winter water storage and release in spring and summer, thus provide requiring water in various sectors, such as agriculture, industry and urban consumption. Supplies (Ozdogan, 2011; Montazeri, 2018; Falahati et al., 2018; Keikhosravikiani & Massoudian, 2016a, 2016b; Khosravi et al., 2018; Sobhani et al. 2019b; Sobhani et al. 2019a). Snow is one of the essential sources of fresh water supply and an important component of the aquatic cycle. The presence of snow in the basin has a significant impact on the moisture content of the surface and consequently the runoff. Blizzard has an impact on agriculture, transportation infrastructure and utilities, trade, postponement of office and school work, demolition of unsafe buildings and threat to human health and it can cause severe damage to human communities. A spatial and temporal survey of the extensive blizzard in the United States during the period 1959–2014 showed that 711 people were killed and 2044 were injured during this period (Takeli, 2012; Berezowski et al., 2015; Coleman & Schwartz, 2017; Shadpour et al., 2018; Baghbanan &

Hosseini, 2018; Hoshyar & Javanbakht, 2018; Safarrad et al. 2019).

Feng & Hu (2007) studied changes in snowfall in the United States during the winter. Results in the northwestern US have reduced snowfall and replaced it with rainfall. Changvon et al., (2008) studied snowstorms in the Ohio River Valley. The reason for this phenomenon is due to the strong compressive shive between the Canadian cold front and the warm, humid mass in the south of the region. Hossos & Lolis (2008) studied the synoptic conditions of heavy rainfall formation in Greece. The results show that the different circulation patterns of the show that the location and intensity of high atmospheric synoptic systems had the most influence on its occurrence. Jianqi et al., (2010) studied the spatial and temporal characteristics of heavy snowfall events in China. Results show that there is a decreasing trend of precipitation in eastern China and a rising trend in Xinjiang in northwest China and the eastern Tibetan Plateau. Also, the outputs of meteorological models show that in the 21th century, there was a decrease in the frequency variation of snow (first with increasing and then decreasing) in the southern regions and the northern regions. The Bodnores have studied the synoptic conditions of heavy snowfall and its persistence in the Central European Plateau. According to the results, the reasons of snowfall in southwestern Europe are cold fronts of cyclones along the Nave and low-pressure over the Baltic Sea, cyclones crossing Central Europe, low-pressure Iceland, and high-pressure deployment in the North Atlantic. Also, the persistence of snow in Europe is associated with high-pressure Europe except for southwest and at the same time high-altitude in the North Atlantic and Scandinavian. Akyurek et al., (2011) investigated the snow under the area in the Karasu basin in eastern Turkey during the period 2000 to 2009. The results obtained during this period do not show a decreasing trend in the snow area of this zone. Brown & Robinson (2011) studied the trend of snow cover in the Northern Hemisphere during March and April during 1922 to 2010. During this time, snow zones have experienced a significant downward trend. And over the past 40 years, this slope has been accelerating. Zhang et al., (2012) investigated the snow cover trend test in the time interval of 2001 to 2010 in the Tibetan Plateau. Richards & Xiuping (2006) have investigated the occurrence of early snowfall in northeast China. According to the results, the reason for this event is the location of a deep basin with a 5-geopotential anomaly over the study area that permeates the cold north air over northeast China and Mongolia. Fahiminejad et al., (2012) studied snowstorms in the northern part of the country in 2004 and concluded that the presence of blockages was a major contributor to heavy snowfall in the region. Drexen & Brown (2012) studied the trend of snow cover in the Northern Hemisphere for April to June for a period of 2000 to 2011. According to the results, during the period, the amount of snow cover in June was negative. The rate was -17.8 percent per decade. Brown & Derksen (2013) studied the trend of snow cover in Eurasia in October for years 1982-2011. The results show that the range of snow is increasing at a rate of 580000 km^2 per decade. Dargahian & Alijani (2013) have examined the effect of blocking on the occurrence of heavy and continuous snow in Iran. The results obtained that the formation of blocking with continuity of more than 4 days play a role in the occurrence of heavy and continuous snow in Iran. Tang et al., (2013) examined the trend of snow days in the Tibetan Plateau. The results showed that about 34% of the study area had a decreasing trend during this period, but only 5.5% of the findings had a significant decreasing trend. Merino et al., (2014) examined the decrease in snowfall in the Iberian Peninsula. The results show a negative trend in the number of snow days in most of the studied stations. Ke & Liu (2014) examined the trend of snow cover in the Xinjiang region of China. The results of the snow cover trend for different heights and different seasons of the year was different. Jin et al., (2014) examined the trend of snow cover on Luis Plateau in China. The results showed that only in 7.16% of this area there was a significant decrease in the number of snowy days.

Irannezhad et al., (2015) investigated the factors controlling winter climate and snowfall reduction in Finland at three stations of south, centre and north of Finland, and according to the results, the Finnish winter precipitation fall is in relation to the East- Atlantic and West Russia indices, the polar oscillation and western Pacific. Also, the decrease in atmospheric flux declines of Finland has been associated with an increase in temperature of 4 degrees during this century. Atif et al., (2015) studied the trend of snow cover changes in upstream of the Indus basin for periods of 2003 to 2013. The results do not show a significant trend in snow cover changes. Dariane et al., (2017) studied the central Alborz mountainous region in northern Iran. The results showed that the level of snow in the central Alborz mountainous region has been drastically reduced over a short period of 13 years. Quantification of snow cover changes and related phenology in global mountain areas has not been consistently addressed, despite the well-known importance of the snow in this environment. Air temperature is the main driver for snow onset and melt, while a combined effect of air temperature and precipitation dominates the winter season. These changes have multiple implications on water resources, ecosystem services, tourism, and energy production (Notarnicola, 2020). Based on the above studies and sufficient information on the study of snowfall, it was undertaken to monitor and analyze the snow area and gravimetry in the Zagros Mountains, in the western part of Iran.

2. MATERIALS AND METHODS

2.1. Study area

The data used in this study include TERRA - MODIS satellite images for Iran. The timeframe of the selected images is between 2000 and 2019. Tips for selecting images are taken into account, for each year an averaging three months (Jan, Feb and Mar) image of winter is considered. This time frame is intended to allow snow to fall and after that date, almost all snow-covered surfaces will melt due to rising temperatures and the monitoring work will be fruitless. The study area is presented in Figure (1).

2.2. Pre-processing of satellite images

In the first step, radiometric and geometric correction of images were performed. In this study, the following three indices were selected for image monitoring, and by examining each of them, the best method for image monitoring was selected. These three indicators are: (NDSI index, Unsupervised classification and Supervised classification)

2.3. NDSI index

In this method, first, the dual-reflectance criteria (i.e., the reflectance value of the pixels in the six-band greater than 11% and the pixel-reflectance value in the band 4 equal to or greater than 10%) and the condition of NDSI> 0.4 (1) was used according to equation 1. In the next step, conditional triple tests are performed based on equation (1) to derive NDSI values (Normalized Difference Snow Index). The NDSI index is one of the appropriate and sufficient indicators for estimating the depth and area of snow, which is approved by researchers (Choudhury & Chang, 1981; Hall et al, 1995).

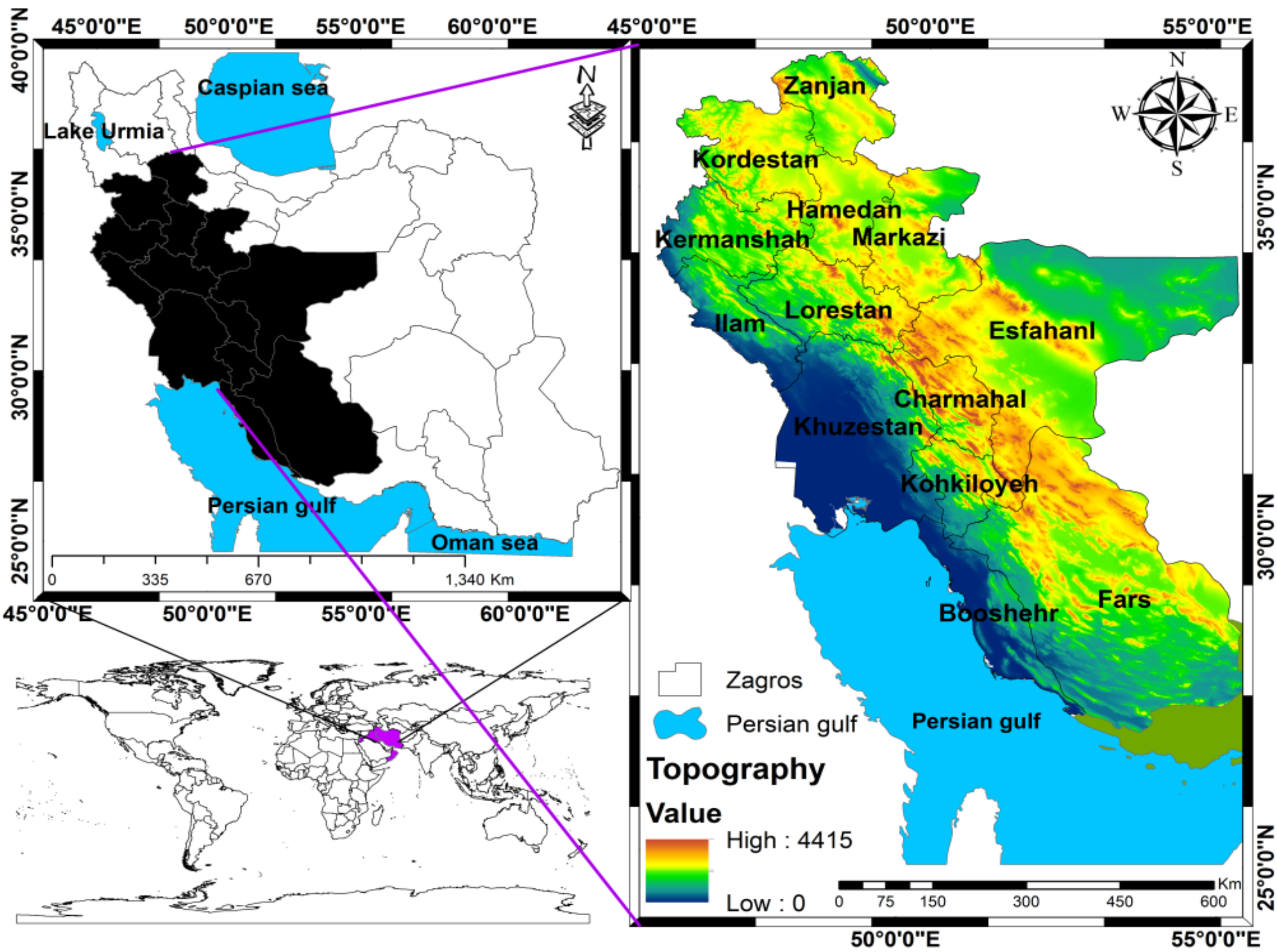


Figure 1. The study area location

Applying the NDSL index will result in the creation of pixels with a value of 1- to +1, with values ranging from -1 to 0, indicating areas where there is no snow and 0 to +1 includes areas where snow has positive coefficients due to its lightness and depth (depending on its depth) (Nolin & Liang, 2000; Blosch & Parajka, 2008). The greater the depth of snow, the closer the number to 1 and the lower the depth to 0. The MODIS snow map algorithm from bands 4 and 6 of this sensor is automatically implemented to extract the differential thermal snow index (NDSI) and is calculated based on the following equation (1), (Emre and et al., 2005):

$$\text{NDSI} = \frac{MODIS_{Band4} - MODIS_{Band6}}{MODIS_{Band4} + MODIS_{Band6}} = \frac{\text{green} - \text{SWIR}}{\text{green} + \text{SWIR}} \quad (1)$$

In the above relation, the band of 4 (0.545- 0.665 µm) has a reflectance equal to or greater than 10% and band 6 (0.841-0.876 µm) has a reflectance of more than 11%.

2.4. Unsupervised classification

Another method used to separate snow cover from other coatings is the unsupervised classification method. In the unsupervised classification method, no repository information is entered into the classification system. This method is based on classification analysis techniques. The basis of the categorization task in unsupervised classification is a clustering method. In the clustering method using the unsupervised classification method, the pixels are assigned to specific clusters based on the degree of brightness. Snow cover also falls into one or more clusters based on the brightness degree of the pixels, depending on the depth of the snow cover. In the process of unsupervised classification, the basis of the user is group classification. Putting pixels in a class in remote sensing based on their spectral properties similar to them is a process that they are called clustering (Richards & Xiuping, 2006). The reason for choosing this classification method is many, including the inability to select training areas, especially when it is difficult to obtain training data. By using MAXSET (Maximum set basic probability classifier), which is an automated method, you can classify different input bands. In this method, only the number of clusters and the maximum number of iterations are required. This method is a fast method that has considerable accuracy in identifying and classifying snow and ice.

2.5. Supervised classification

In this method, the training points are first removed from the snow cover and introduced to the system. In this method, samples of each type of cover are taken. The sampling in this study is limited to 4 cases including snow cover, water, vegetation, and rock and soil surfaces. For a more accurate sampling of these effects, a false-colour image of the target image is first obtained. By combining 3 different bands and assigning each colour of the 3-primary red, green and blue (RGB) colours to each band, the colour image is made. In the False Color Image (FCC), red is assigned to the infrared band, green to the red band, and blue to the green band, therefore vegetation that has maximum reflectance in the infrared band with red colour, water with blue and bare soil with brownish-grey. If the false colour images are properly and accurately represented and the histograms of the bands used are similar in appearance, the resulting image will be well-combined and highly interpretable (Richards & Xiuping, 2006). The goal is to select the right bands to create colour images, minimize undervalued data, and maximize the use of user information. select of band composition is done in different ways. A way is eye comparison of images from different combinations is usually very difficult and time-consuming. Another approach is based on the statistical criteria used in the colour images creation (Mousavi & Sabour, 2014). One of the methods used to select the band composition of optimal index factor (OIF), determine the maximum variance-covariance matrix and analyze of the principal components (Richards & Xiuping, 2006).

2.6. GRACE Groundwater Model

In this study, GRACE satellite data were used to estimate changes in water reserves in Iran. To obtain groundwater level changes, the GRACE model estimates the moisture content of the soil, water of snow and rivers (surface waters) and deduces from GRACE observation water reserves. Human changes in groundwater are also calculated by subtracting the natural changes in groundwater predicted by the CLM4 model from the groundwater level.

2.7. GRACE satellite

In this study, we use GRACE satellite data from 2002 to 2017 from version 5 of the CSR data processing centre to investigate changes in water reserves in Iran. GRACE satellites data were processed based on the Swenson and Wahr (2002 and 2009) method for monthly changes in water reserves for the Iranian region. Before using the Stokes coefficients obtained from the GRACE satellites, we replace the first-order harmonic coefficients obtained from the study by Swenson et al., (2008) and the second-degree zonal harmonic coefficient estimated by SLR geodetic satellites. The first-order Stokes coefficients are related to the position of the Earth's mass centre relative to the

Inertia coordinate system. Since the coordinate system is defined so that its centre always corresponds to the centre of Earth-mass. This term is also considered zero in examining the changes in the gravity field obtained from the GRACE satellites. The C20 coefficient obtained from the GRACE data is not very accurate due to the geometry of the orbits of the GRACE satellites which is less sensitive to this coefficient. The effects of GLA in this area are very small and negligible. GLAs are not created because of glaciers melting right now, but because of Earth's reaction to several kilometres of thick ice sheets, which cover much of North America and Europe. The effect of the GLA is that some parts of the earth are rising and some parts are falling (such as the bottom of some oceans). Then it can be calculated the monthly change of water level (EWH) using relation (2), (Rodell et al., 1999; Swenson & Wahr, 2002; Gert, 2013; Forootan, et al., 2014; Swenson et al., 2008).

$$EWH(\varphi,\lambda) = \frac{\alpha\rho_{ave}}{3p_w} \sum_{1=0}^{\infty} \sum_{m=0}^{i} \frac{2_l+1}{1+K_l} \tilde{P}_{lm}(\sin\varphi)[\Delta C_{lm}\cos(m\lambda) + \Delta S_{lm}\sin(m\lambda)] \quad \textbf{(2)}$$

In this respect $Pav = 5517\, {kg}/_{m3}$ is mean earth density, a= 7 3 6; the radius of the Earth, $Pw = 1000\, {kg}/_{m3}$; water density, Ki; lav number of I, C_{lm} and S_{lm}; monthly variations of spherical and harmonic coefficients. P_{lm} is Legendre's normalized functions. To estimate equivalent water level changes. The coefficients difference of the monthly geopotential models is calculated from the average of the total models and estimated by placing in the above equation (Swenson & Wahr, 2009)

3. RESULTS AND DISCUSSION

In order to select the most efficient method for monitoring snow cover, NDSI (Normalized Difference Snow Index) maps were first extracted for the intended months, and then snow boundaries were separated from other constraints. In order to monitor the changes of snow cover by unsupervised classification method, after clustering the pixels, clusters containing snow pixels were separated from other clusters. For the application of the supervised method, sampling of the spectral value of the pixels of the image is performed according to the spectral reflections that are distinguished on the images by different colours. In this study, which studied the snow area and depth. The fluctuations of the 3-months high snowfall variations (January, February and March) were 35.06, 35.17, 55.16, 31.09 and 55.08 cm in 2005-2007-2008-2009 and 2014). In the rest of the studied years, the snow fluctuations were uniform and at the same depth, with the highest amount of snow falling in 2008 with 55.16 cm (Fig. 2). Average quarterly snow depth variations (January, February, and March) in the study area fluctuated between 2000 and 2019, in which the most severe was between 2007 and 2014, with the 2008 snowfall of 110.21 cm (Fig. 3). According to the results, snow equivalent water according to the snowfall depth in the study area in 2008 is 2.5 kg / m 2. Changes in snow equivalent water are correlated with changes in snow depth. The higher the depth of snow, the higher the snow equivalent water (Fig. 4). It covers a maximum snow volume of 54% in North Korea and a maximum snowfall of up to 44% on Earth each season. Water supply At least one third of the water consumption from snowmelt is supplied. Also, water from melting snow has 3% water in water supply. Therefore, by holding the teeth, they do not fall into the air and are protected against cold weather.

Based on the results of groundwater aquifers using GRACE model (which has three types of algorithms CSR centre, GFZ of Germany, JPL of USA and the data of this method can model changes in the gravity or groundwater table indicates that the amount of groundwater aquifers in the study area has declined over the years. It is worth noting that the

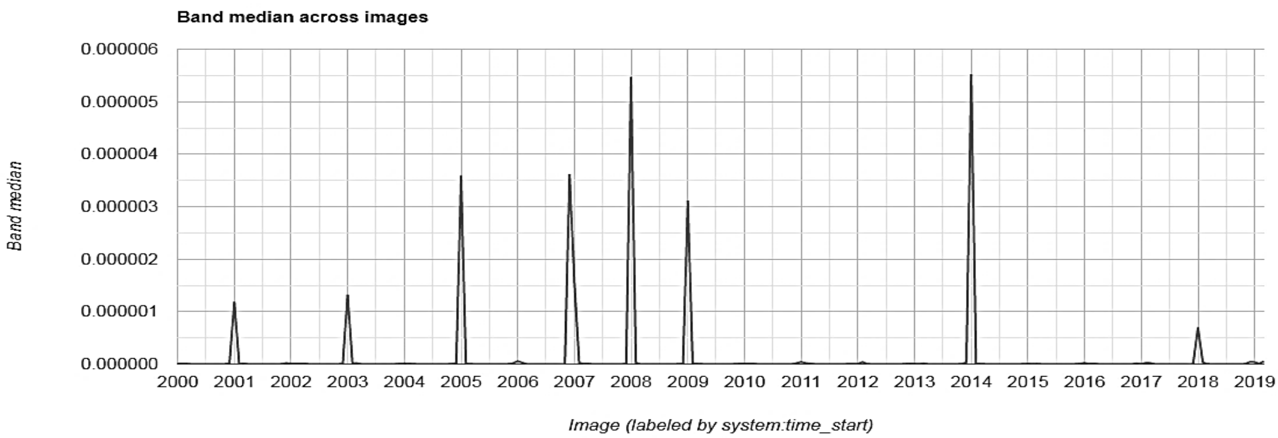


Figure 2. Diagram of snowfall changes based on MODIS data over a 20-year period (2000–2019)

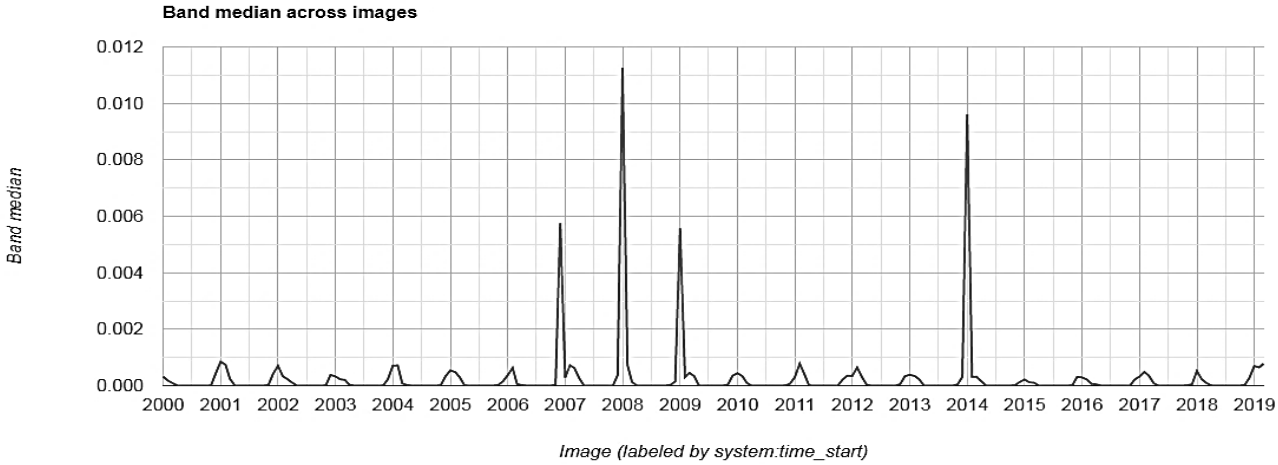


Figure 3. Diagram of snow depth changes based on MODIS data over a 20-year period (2000–2019)

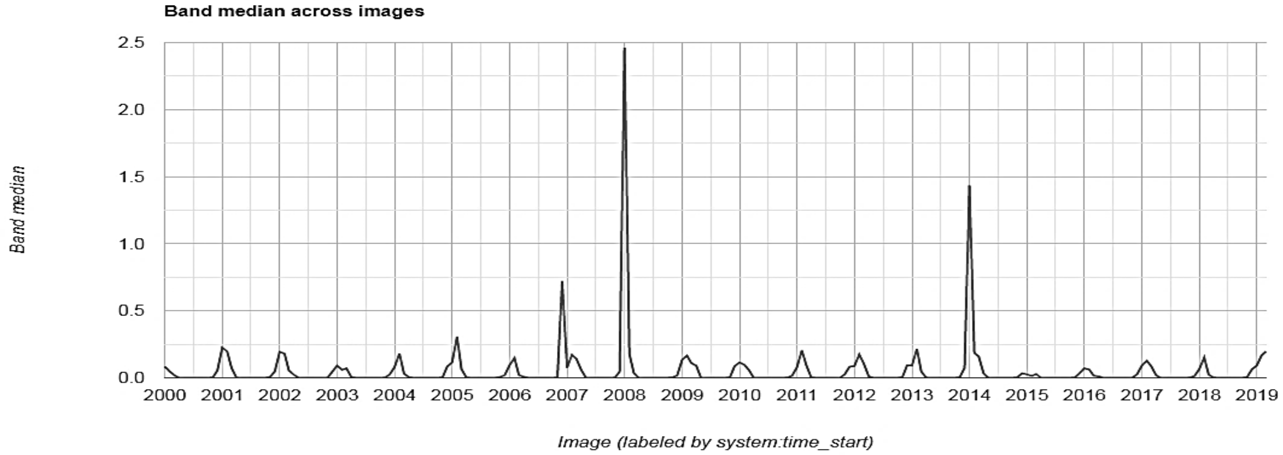


Figure 4. Diagram of equivalent snow water changes based on MODIS data over a 20-year period (2000–2019)

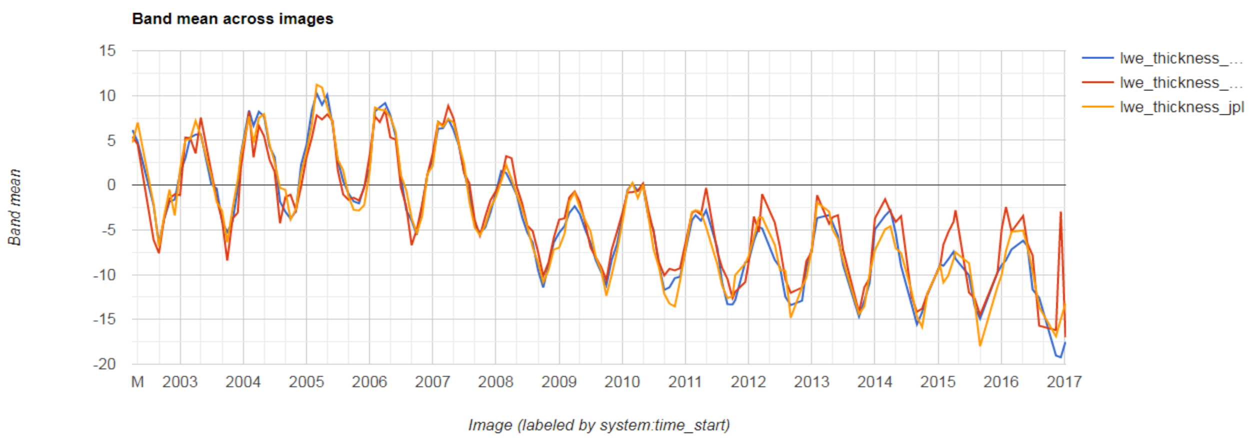


Figure 5. Groundwater aquifer diagram based on GRACE satellite data

decrease in the trend of groundwater aquifers with a decrease in snowfall in the study area is a high correlation at the level of 0.94%, and this decrease has been high since 2007. Decrease in groundwater aquifers based on the three models, namely the JPL model: in September 2015 with a value of -17.99 cm; GFZ model: in August 2017 with a value of -16.97 cm; Finally, the CSR model: in November 2017 with a value of -18.29 cm (Fig. 5). These results show that the trend of temperature changes in the coming years (20-year periods) in the study area is increasing and precipitation changes fluctuate except for the months (January, February, March). In most months decreasing trend is observed in the amount of snowfall during the year. Also, it is observed a sharp decline in groundwater resources according to the GRACE model in Zagros mountain. In the southern section of the eastern and western slopes of the study area, irrigation is used dramatically to increase agricultural productivity during drought, when precipitation levels are inadequate, reducing groundwater aquifers. Snow is more important than rain on the ground because it gradually turns into water. Snow that stays on the surface in the form of a glacier is a valuable natural resource that stores water deep in the earth. For example, 10 cm of snow usually has about 10 mm of water, and even this amount reaches 30 mm. Therefore, a 10 cm snowfall with only 10 mm of water will save 10,000 hectares of water in an area of 10 square kilometers. Snowmelt runoff plays an important role in drinking water supply and agriculture, as well as in groundwater recharge. Another value is that snow contains a lot of air, it is known as a poor conductor of heat.

The amount of snowfall area during the years under study (2000-2019) in the study area has included snowfall fluctuations, with the highest amount of snowfall in 2005, 2007 and 2014, respectively, with 78728.479, 86515.925 and 48911.981 Table (1). Changes in Snow cover level in climate change due to the importance of snow cover is as one of the important factors in simulating runoff and interaction of climatic elements number in ground surface conditions. If the temperature changes and increases, subsequently the snow cover level reduced. According to the findings, this trend and area were represented in Fig. 6 and 7. Since air temperature is the most important factor in the stability of snow cover in mountainous areas, and the lower the air temperature, the conditions for the formation of snow crystals and eventual precipitation in the form of snow will be provided. In this section, it is attempted to make a comparative judgment of the amount of snow cover and the stability of this cover by comparing the snow cover area and temperature in the study area. In general, a comparison of the changes in snow cover levels in the study area shows that year 2005 has the highest rate (86515.925 km^2) while in 2005 and 2014 which has more snow cover (78728.479 and 48911.981 respectively) than other

Table 1. Snowfall area based on MODIS data during the studied periods (2000-2019)

Year	**The average snowfall three months (Jan, Feb and Mar, (km^2))**	**Year**	**The average snowfall three months (Jan, Feb and Mar, (km^2))**
2000	17598.082	**2010**	8830.112
2001	36131.107	**2011**	37559.646
2002	33491.568	**2012**	31048.857
2003	41855.62	**2013**	10414.345
2004	31636.514	**2014**	48911.981
2005	78728.479	**2015**	7362.441
2006	22240.658	**2016**	21768.985
2007	86515.925	**2017**	22961.525
2008	43795.766	**2018**	3919.423
2009	11046.094	**2019**	34849.226

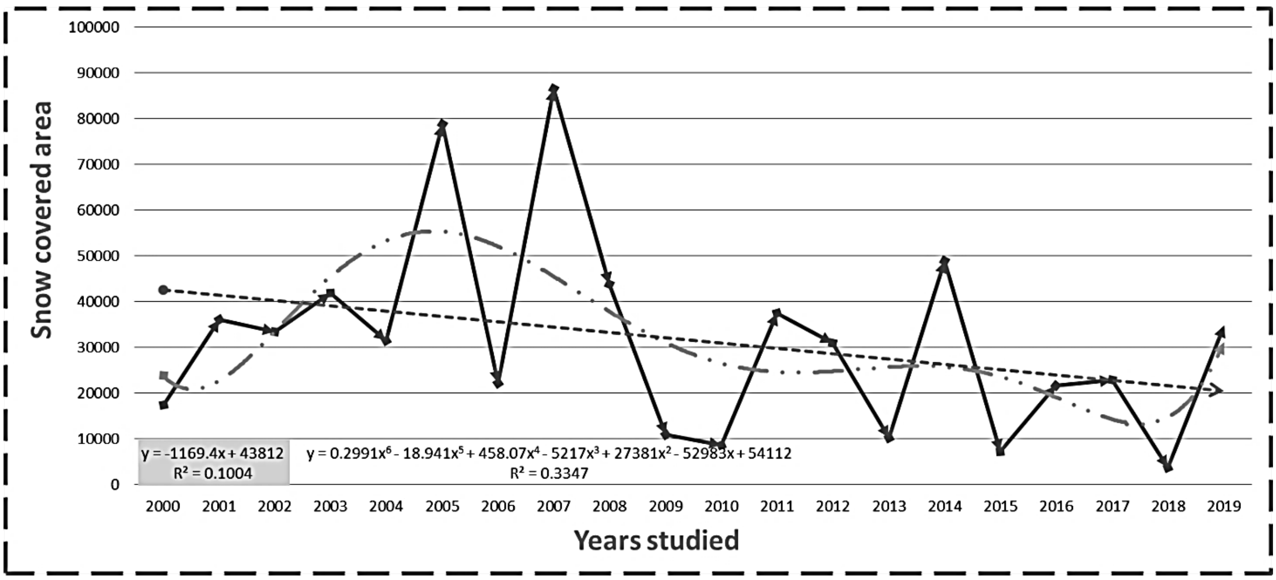


Figure 6. Diagram of snow area changes based on MODIS data over a 20-year period (2000–2019)

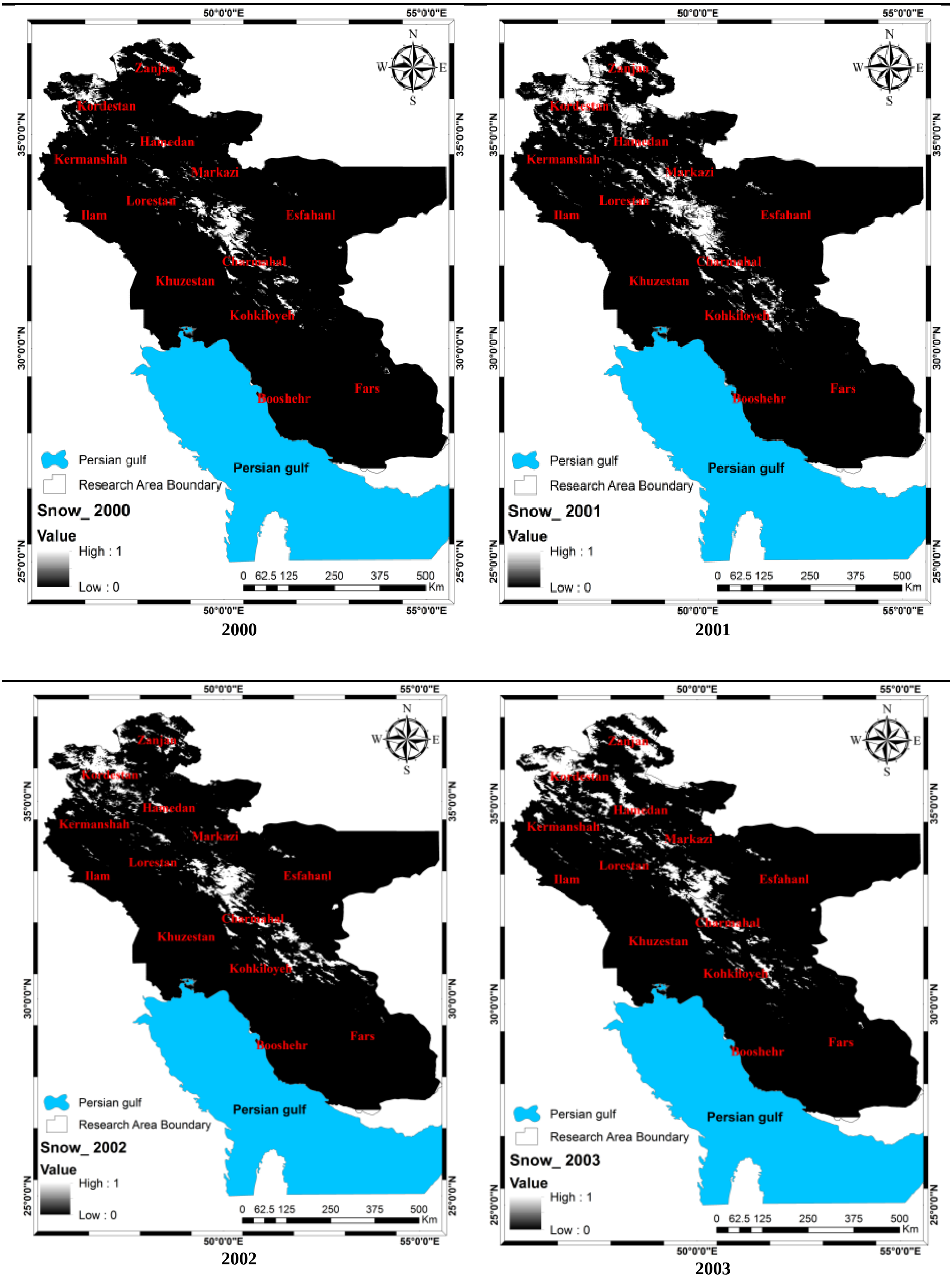
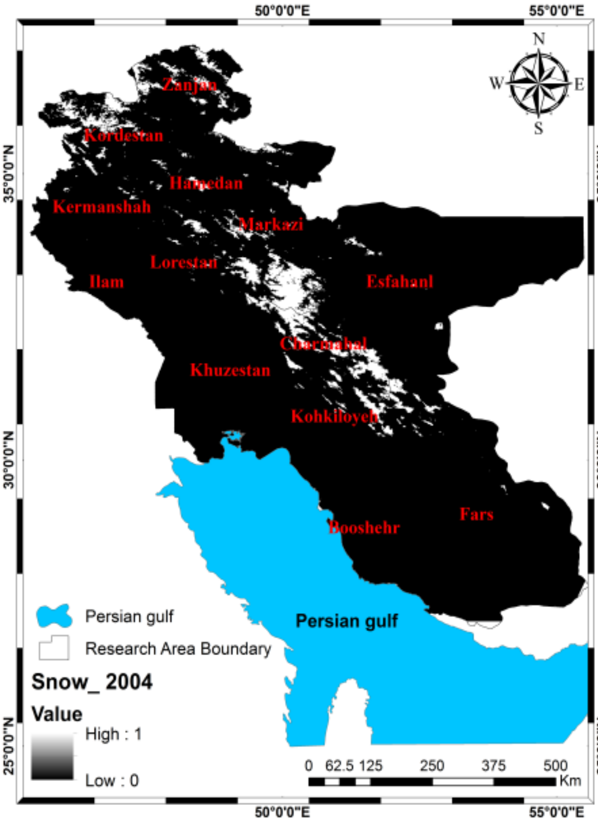
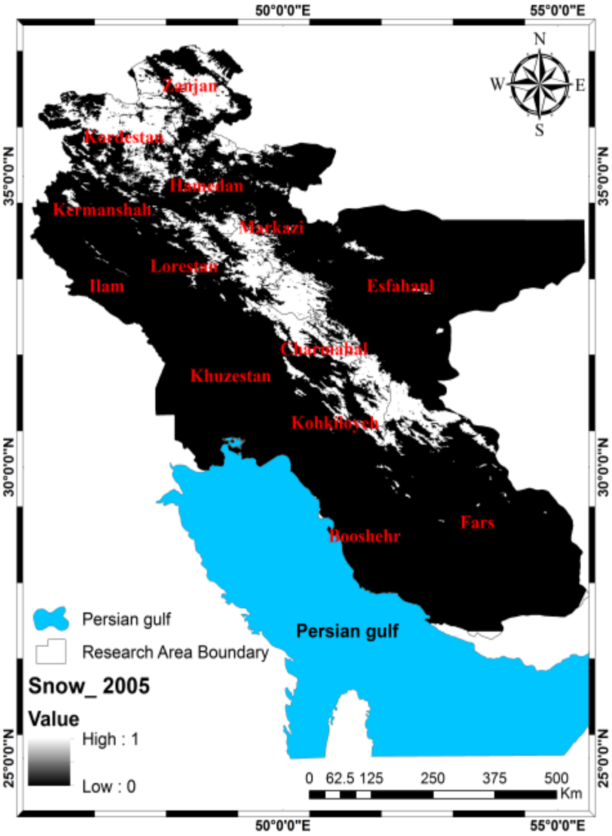


Figure 7. Shapes of Visual Changes in Snowfall Changes, Based on MODIS data over a 20 year period (2000-2019)

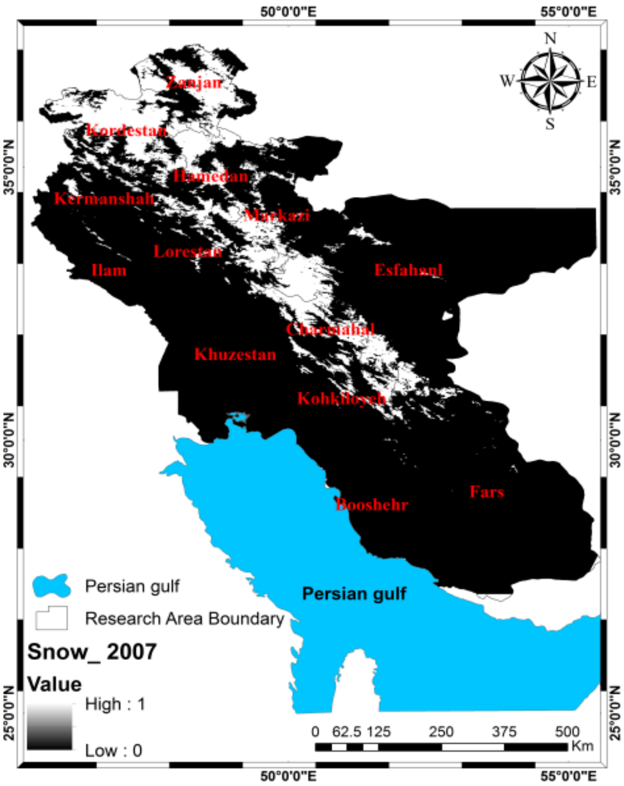


2004



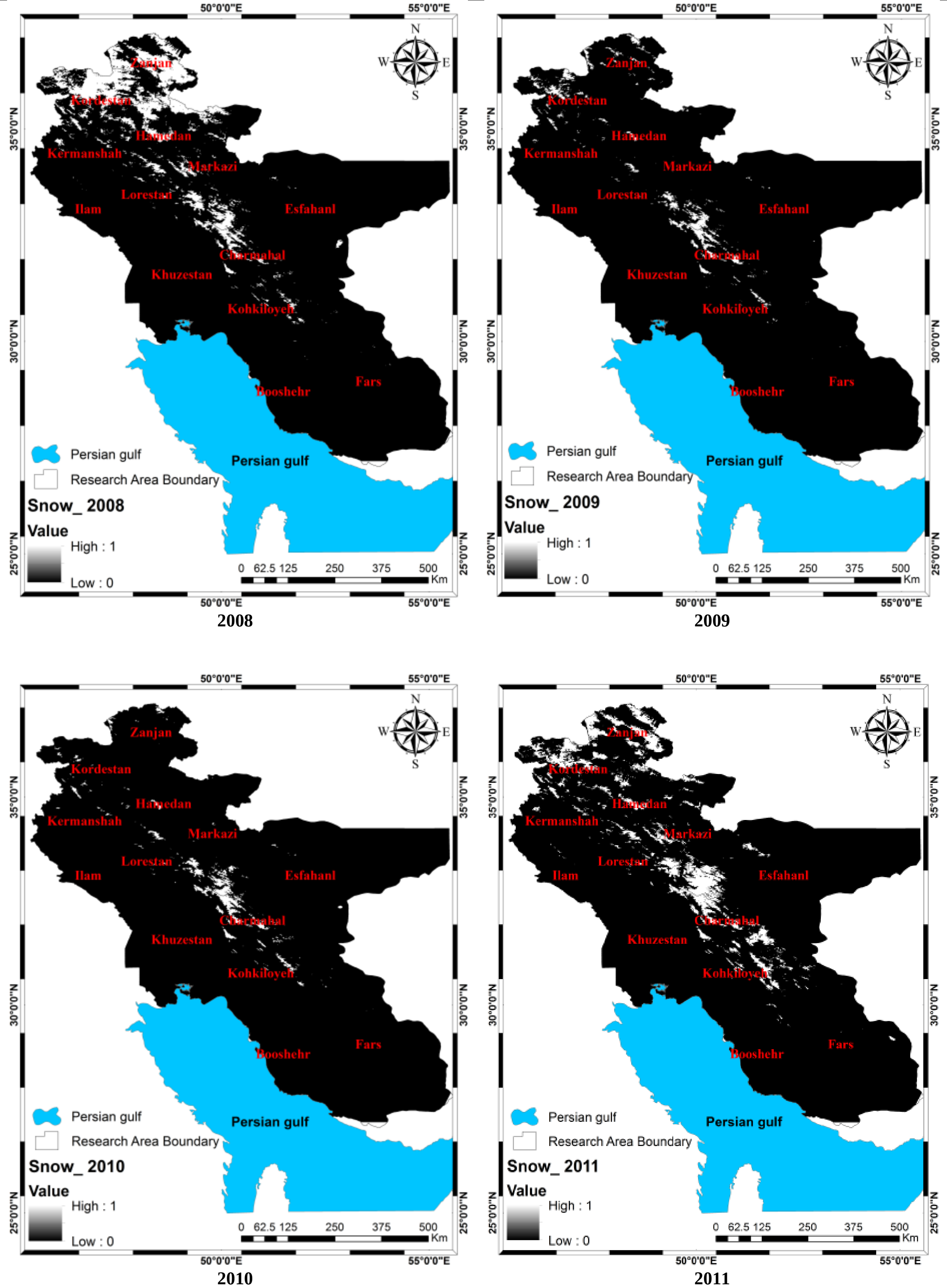
2005

2006

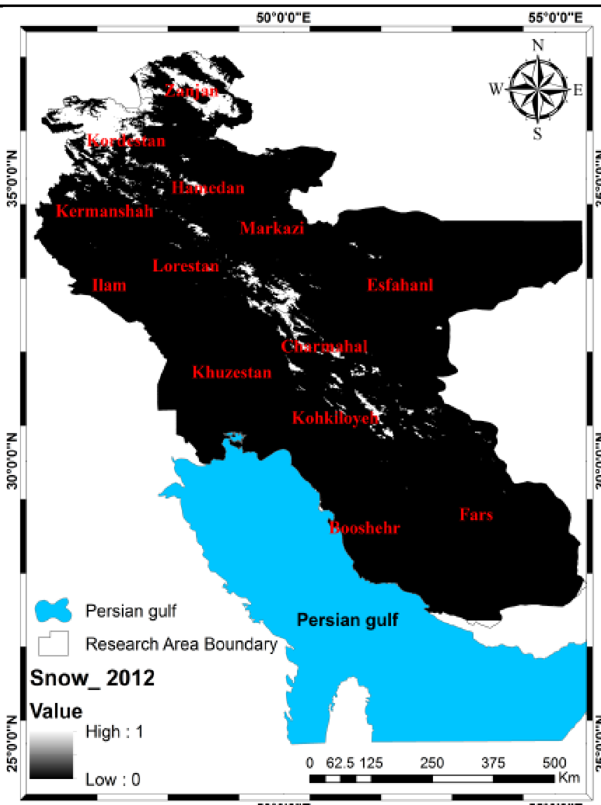


2007

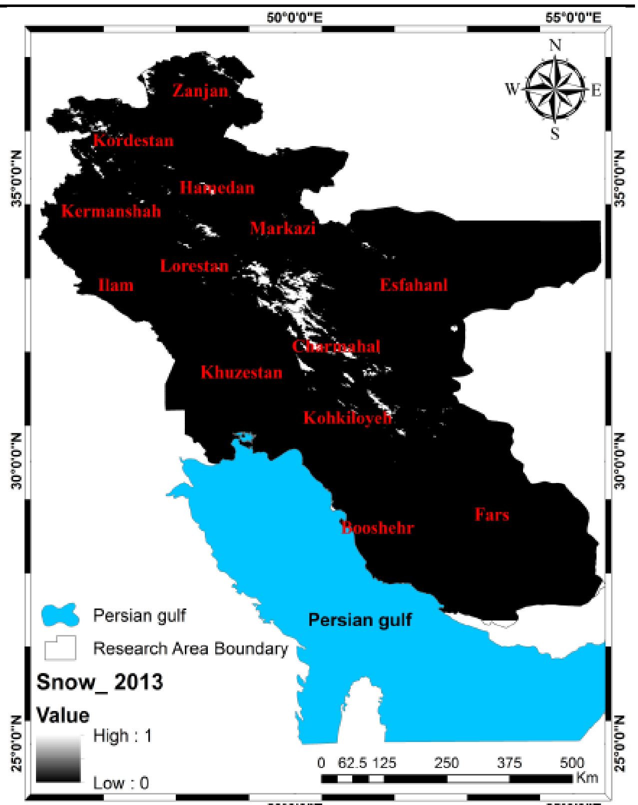
Continue Figure 7. Shapes of Visual Changes in Snowfall Changes, Based on MODIS data over a 20 year period (2000-2019)



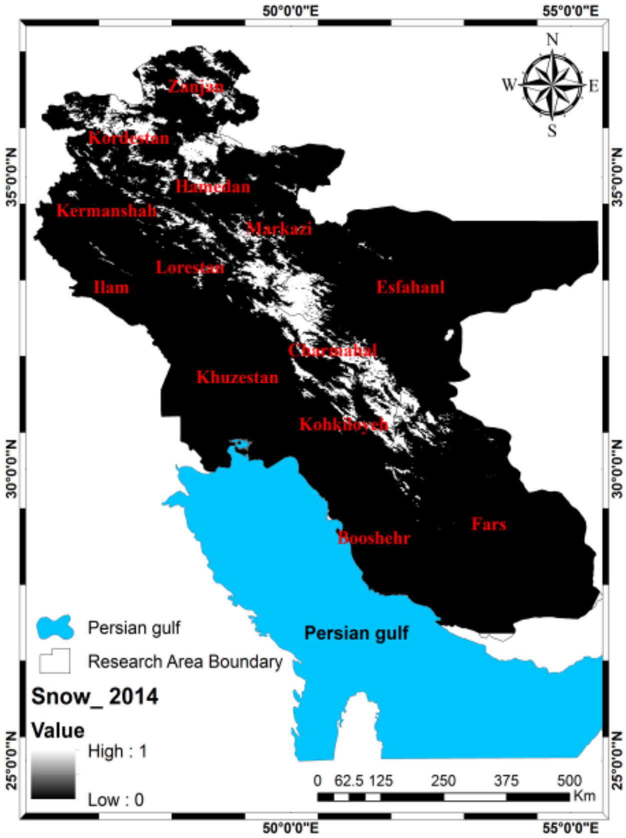
Continue Figure 7. Shapes of Visual Changes in Snowfall Changes, Based on MODIS data over a 20 year period (2000-2019)



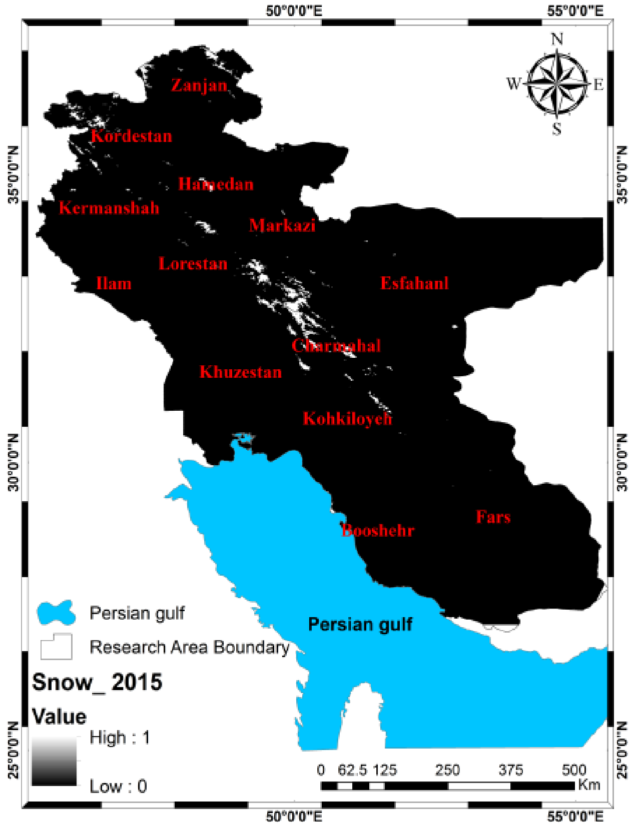
2012



2013

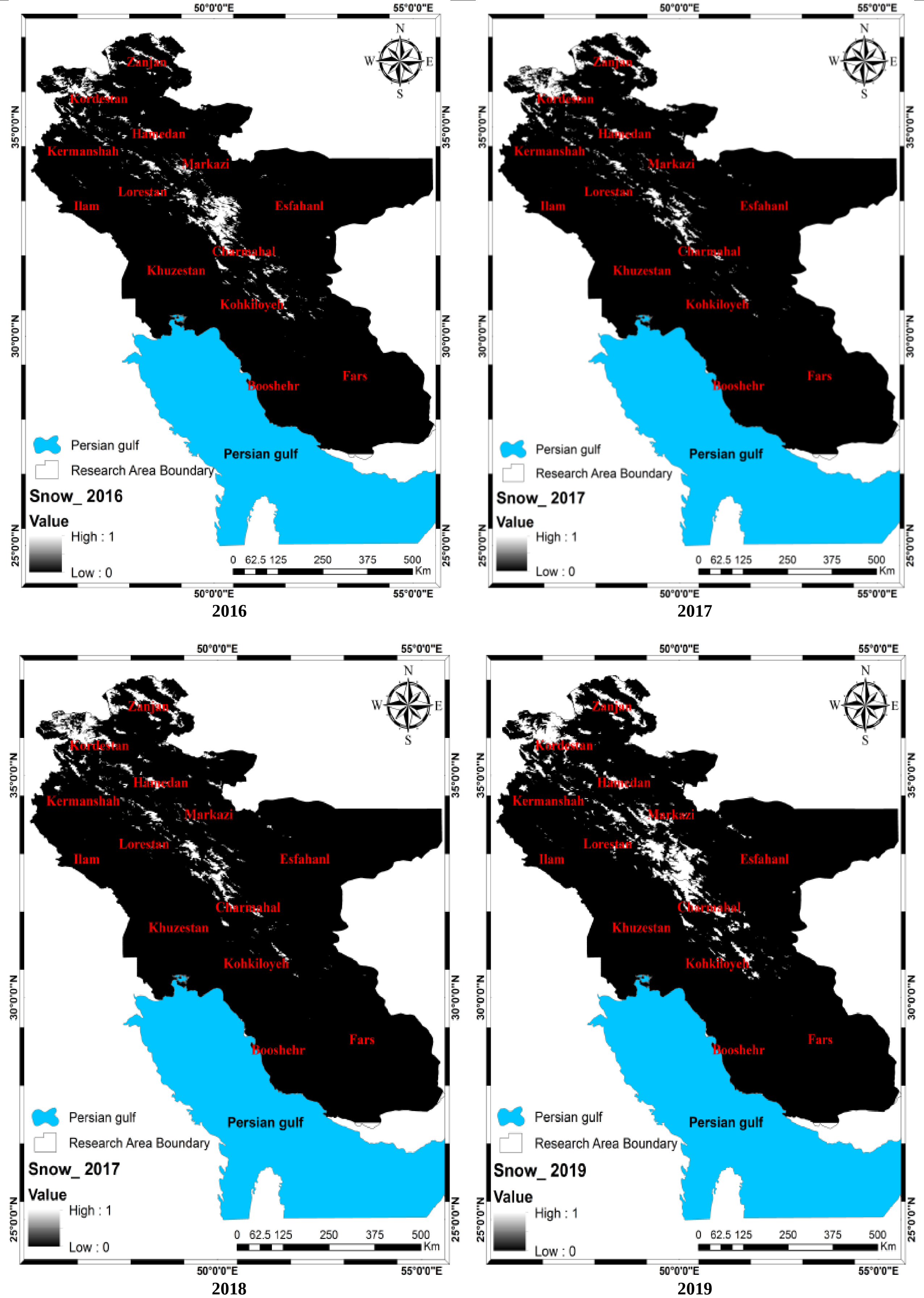


2014



2015

Continue Figure 7. Shapes of Visual Changes in Snowfall Changes, Based on MODIS data over a 20 year period (2000-2019)



Continue Figure 7. Shapes of Visual Changes in Snowfall Changes, Based on MODIS data over a 20 year period (2000-2019)

years. This indicates the extent of high variation in snow cover in the study area and the existence of exceptional years in terms of snowfall conditions. Also, comparisons of snow cover changes in the studied years show that there is a decreasing snowfall sequence in several years and relatively high snowfall in the following year.

4. CONCLUSION

In this study, the area and depth of snowfall and changes in groundwater aquifers were assessed. The studies showed that despite the increase in snow melting potential with increasing air temperature due to the decrease of snow cover according to increased temperature and unnecessary use of surface water in the coming years, snowfall and groundwater levels and increased runoff will occur due to snowmelt. Overall, the main results of this study including the study of three unsupervised, NDSI, and supervised methods for monitoring snow cover variations showed that the supervised classification method due to false colour maps provided accurately and separately for different bands and no disadvantages of other two methods are considered as an efficient way to monitor snow cover changes in the study area. Surveying maps of snow cover changes over the years 2000 to 2019 showed that during the period under study, the lowest amount of snow cover related to the year 2018 with an area of 3919.423 km^2 and the highest area for the year 2007 with an area of 86515.925 km^2. This represents a 98% change over the decade in the amount of snow cover in the Iranian region and indicates the vulnerability of snowmelt-dependent water resources in the study area for some years. The probable result in this study is a one-year sequence among low and high snow cover in the study area. So that with one-year alternation, a few years of low coverage and the following year, high coverage occurred. This can also be taken into account in forecasting low or high snow cover years. The findings showed that the amount of natural groundwater depletion was higher than the abnormal groundwater level, indicating the severe effects of drought in the study area. Forecasts from this study suggest that future droughts in the study area will cause more severe groundwater depletion. Another advantage of snowfall, in addition to soil protection, is the protection of plant roots. In other words, snow acts as an insulation on the surface of plants to protect plants from sub-zero temperatures so that the roots of the plant are not damaged, otherwise if the cover is not insulated, the roots of the plant will be damaged. Also, as snow travels from the sky to the ground in the atmosphere, it carries nitrogen and sulfur. When melted, these elements are released from inside and enter the soil and are absorbed by the plant. Nitrogen is a necessary nutrient for plant growth. Snow storage in mountainous areas is an important source of water, so that 60% of the surface water and 57% of the country's groundwater is located in snow-covered areas.

Acknowledgements

We acknowledge the Grace Satellite and TERRA-MODIS personnel and scientists for their efforts, data sharing and for the production its.

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Received at: 23. 07. 2020
Revised at: 12. 08. 2020
Accepted for publication at: 27. 08. 2020
Published online at: 28. 08. 2020