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Araştırma Makalesi / Research Article

Monitoring of Groundwater Level Change with Geographical Information System (GIS), The Case of Konya Altınekin Basin

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Abstract

Among the groundwater resources in Turkey, there are quite important basins with their agricultural land use characteristics and ecological characteristics. One of them, Konya Closed Basin (KCB), along with its sub-basins, has Turkey's grain reserves. However, over the last years, over-exploitation of groundwater resources, water-level reductions have become a threat to the ecological structure of the sinkholes and the basin. In order for this process to be analysed with all its causes and measures can be taken, it is necessary to monitor and record the changes that are experienced. In this context, Geographical Information System (GIS) is important as a system that can demonstrate the change in the basin. In this study, the change of groundwater level was investigated with the help of GIS, in order to protect the ecological balance in the KCB Altınekin Basin, where significant decreases in groundwater level have been experienced in recent years. The change in the data of 2015 and 2016, which was obtained from 10 water wells where the groundwater level in this basin was identified, was analysed with the aid of GIS. It has been found that the groundwater level in the basin changes with agricultural land use characteristics, daily use, and climatic changes.

Yeraltı Suyu Seviyesi Değişikliğinin Coğrafi Bilgi Sistemi (CBS) ile İzlenmesi, Konya Altınekin Havzası Örneği

Anahtar Kelimeler
CBS;
Yeraltı suyu seviyesi değişikliği;
İklim değişikliği;
Konya Altınekin Havzası

Öz

Türkiye'deki yeraltı suyu kaynakları arasında tarımsal arazi kullanım özellikleri ve ekolojik özellikleri ile oldukça önemli havzalar bulunmaktadır. Bunlardan biri olan Konya Kapalı Havzası (KKH) alt havzalarıyla birlikte Türkiye'nin tahıl rezervlerine sahiptir. Bununla birlikte, son yıllarda yeraltı suyu kaynaklarının aşırı kullanımı, su seviyesinin düşürülmesi, obrukların ve havzanın ekolojik yapısı için bir tehdit haline geldi. Bu sürecin tüm nedenleri ile analiz edilebilmesi ve önlemlerin alınabilmesi için yaşanan değişimlerin izlenmesi ve kayıt altına alınması gerekmektedir. Bu bağlamda Coğrafi Bilgi Sistemi (CBS), havzadaki değişimi gösterebilen bir sistem olarak önemlidir. Bu çalışmada, son yıllarda yeraltı suyu seviyesinde önemli düşüşlerin yaşandığı KKH Altınekin Havzası'nda ekolojik dengenin korunması amacıyla yeraltı suyu seviyesinin değişimi CBS yardımı ile araştırılmıştır. Bu havzadaki yeraltı suyu seviyesinin tespit edildiği 10 adet su kuyusundan elde edilen 2015 ve 2016 verilerindeki değişim CBS yardımı ile analiz edilmiştir. Havzadaki yeraltı suyu seviyesinin tarımsal arazi kullanım özelliklerine, günlük kullanıma ve iklim değişikliklerine göre değiştiği tespit edilmiştir.

1. Introduction

Water is a vital component for sustaining the lives and the needs of the living creatures and the environmental structure (Başçiftçi *et al*. 2013, Tiwari *et al*. 2017). It is distributed in the forms of river water, spring water, sea water and rainwater in nature. Among these, the underground waters are expressed as an extremely important, low cost and reliable water resource type with some natural characteristics such as consistent temperature, widespread and continuous availability, quality and limited precision (Todd and Mays 2005).

Groundwater, which is used for the basic needs of living things, serves as the main water resources in the urban environment, for industrial and domestic purposes, and provide all the comfort of living things (Singh *et al*. 2014, Krishnaraj *et al*. 2015). The groundwater constitutes about 0.61% of the world's water, including ocean and permanent glaciers, despite the need for its extensive use (Tiwari *et al*. 2017). This situation is projected to be causing a water shortage in 2025 in the UNESCO report, and a 50% reduction in the amount of water available per capita is expected (Başçiftçi *et al*. 2013).

Global warming, climate change, agricultural irrigation, meteorological, hydrological and geological reasons, population growth, urbanization, food and energy security policies, globalization of trade and changing consumption patterns affect water demand (Başçiftçi *et al*. 2013, WWAP 2015, Yılmaz 2010). Along with this interaction, the groundwater level is also decreasing. For this reason, in many countries, degradation of groundwater quality and the decreasing groundwater levels are among the urgent problems (Verma *et al*. 2017, Tiwari *et al*. 2017). This threatens ecosystems and even the lives of future generations (Tsakiris 2004). In this context, the conservation and use of water resources should be planned in a long-term and sustainable manner (Jha *et al*. 2010, Çelik *et al*. 2016).

The planning process for water resources requires the changes to be recorded, monitored and the measures and policies to be developed against the threats in the face of problems. GIS is an important application tool for the rapid organization and storage of large volumes of hydrological and hydrogeological data related to this planning process, the temporal and spatial monitoring of environmental changes, and the construction and management of thematic maps (Jha *et al*. 2007, Jha *et al*. 2010, Başçiftçi *et al*. 2013, Krishnaraj *et al*. 2015).

There are many studies in the literature about the measurement of changes in the groundwater resources with GIS. GIS is used in reviewing the quality and pollution of groundwater created by a particular agricultural production preference and urban land use changes in the urban area (Babiker *et al*. 2004, Almasri and Kaluarachchi 2004, Nas and Berktay 2010, Krishnaraj *et al*. 2015), the determination of groundwater levels and fluctuations and the mapping of protected areas in general (Jha *et al*. 2010, Başçiftçi *et al*. 2013, Chandra *et al*. 2015, Tiwari *et al*. 2016, Chandan and Yashwant 2017, Arya *et al*. 2018, Çelik and Hamidi 2018, Çıldır *et al*. 2019, Anand *et al*. 2020), in the examination of groundwater level changes arising due to use and land cover change in special areas such as agricultural areas (Dinka *et al*. 2013, Çelik *et al*. 2016, Balasubramani *et al*. 2019) and the development of a three-dimensional groundwater flow model (Gossel *et al.* 2004). GIS is an important tool in recent years, especially for the mapping of risks to the spatial registration, consolidation, and prevention of losses in groundwater for the development of a groundwater information management system' in the sustainable management of groundwater resources (Papatheodorou *et al*. 2017).

In this study, in addition to the studies reviewed in the literature, changes occurring in the groundwater level, at Altınekin Basin, one of the literature's attractive study areas in the province of Konya in Turkey, have been discussed. Here, the change in groundwater level, which threatened human life and settlements, was analysed using GIS, precipitation, climatic and environmental factors. As a result, the cause of this change was determined, and the measures and strategies to be taken were put forward.

2. Material and Method

Sustainable use of the country's water resources should be developed at all levels of local, regional, national and international level. The basins that contain water resources at almost all levels are areas that are important for the continuity of water assets, with their characteristics of being open or closed. In Turkey, KCB is a large closed basin and has about 17% of the country's groundwater potential (Int. Rsc. 1).

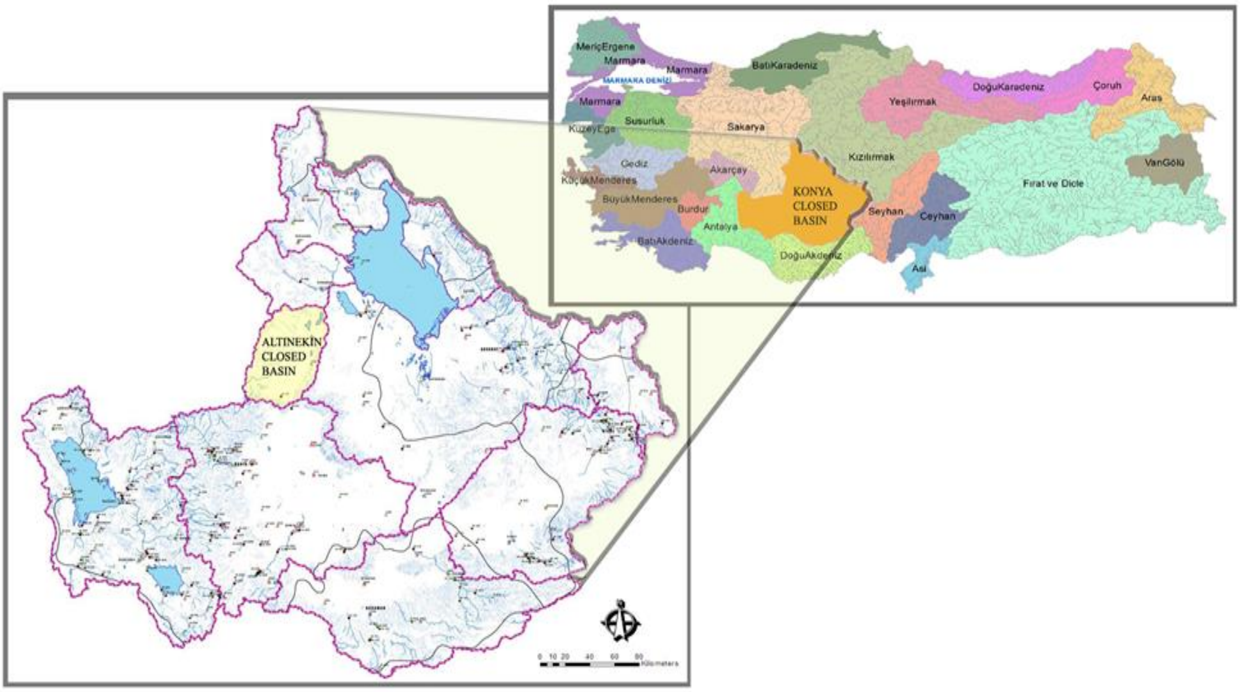

Figure 1. The location of Konya Closed Basin (Int. Rsc. 2, Okka *et al*. 2018)

KCB carries an offshore basin characteristic that does not drain its waters into the sea, which is rare in the world (Figure 1). This feature is due to the fact that it is surrounded by volcanic mountainous areas of 3,534 meters, expressed in the Digital Elevation Model and the Geological Structure, indicating the topographic structure of the KCB, and the limestone feature of the water holding basin (Figure 2).

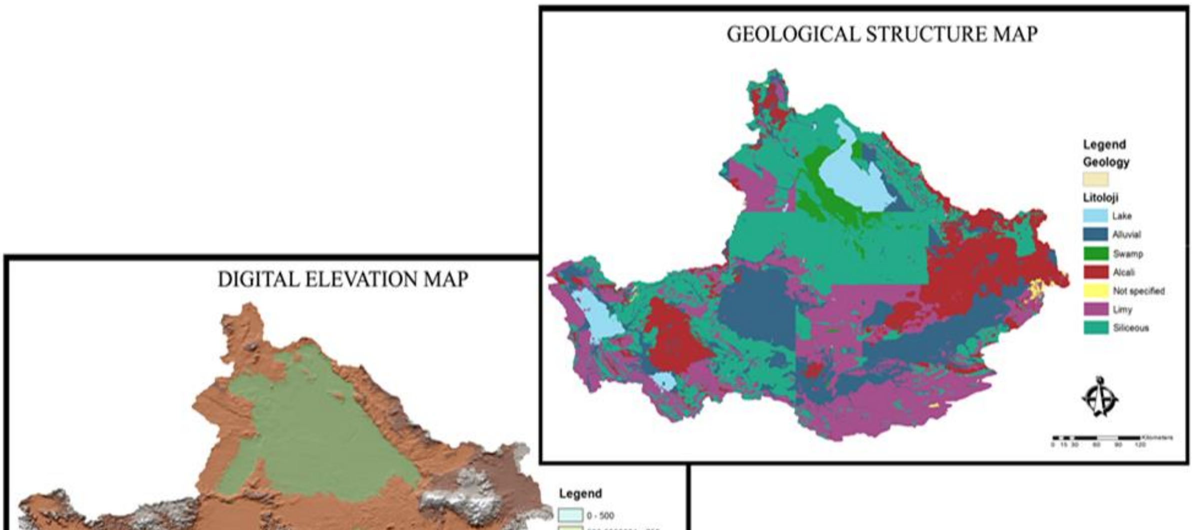

Figure 2. Digital elevation model of KCB and its geological situation

KCB is one of Turkey's areas that has the least rainfall and the average annual precipitation is 300-350 mm (Şen and Başaran 2007) (Figure 3).

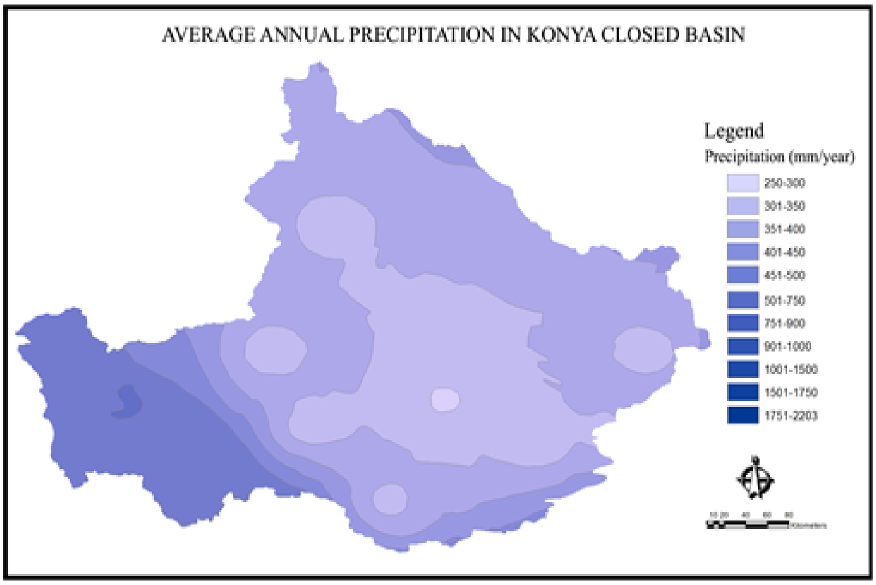

Figure 3. The average annual precipitation in KCB

Given the increasing human population, extreme water use for agricultural and industrial purposes, and other factors, it has been observed that over the last 30 years there has been a decline of 10-25 mm per year in rainfall over the Basin. Underground water level measurements of 24 wells operated by the 4th Regional Directorate of State Hydraulic Works confirm this concern. In all of the 24 wells, a decrease in groundwater level was observed (mean 0.77 m). 30-40 years of significant declines groundwater level reaching up to 1m in certain areas in KCB, which highly contributes to Turkey's agricultural and industrial inputs, cause the formation of ecological and environmental disasters such as sinkholes (Üstün *et al*. 2007, Bozyiğit and Tapur 2009).

KCB is divided into 9 different basins in itself. Within the KCB, in the Altınekin Subbasin there are negative conditions in the ecological balance due to the decrease in the amount of rainfall received in recent years and the amount of groundwater drawn above the reserve for agricultural production purposes. In order to measure these adverse conditions and to be able to take measures, Altınekin Subbasin was determined as the study area. The Altınekin Subbasin is located in the northwest of the KCB (Figure 1).

In the scope of the study, first of all, the digital elevation model which shows the topographical structure of Altınekin Basin was created with the help of ArcGIS 10.3.1 software. According to the slope analysis carried out over the digital elevation model, it is determined that the basin is surrounded by high mountains and that the middle parts are of plain characteristic (Figure 4). The minimum height for the basin is 938 m around the Bulak Lake and the maximum elevation is 1300 m in the mountains surrounding the basin.

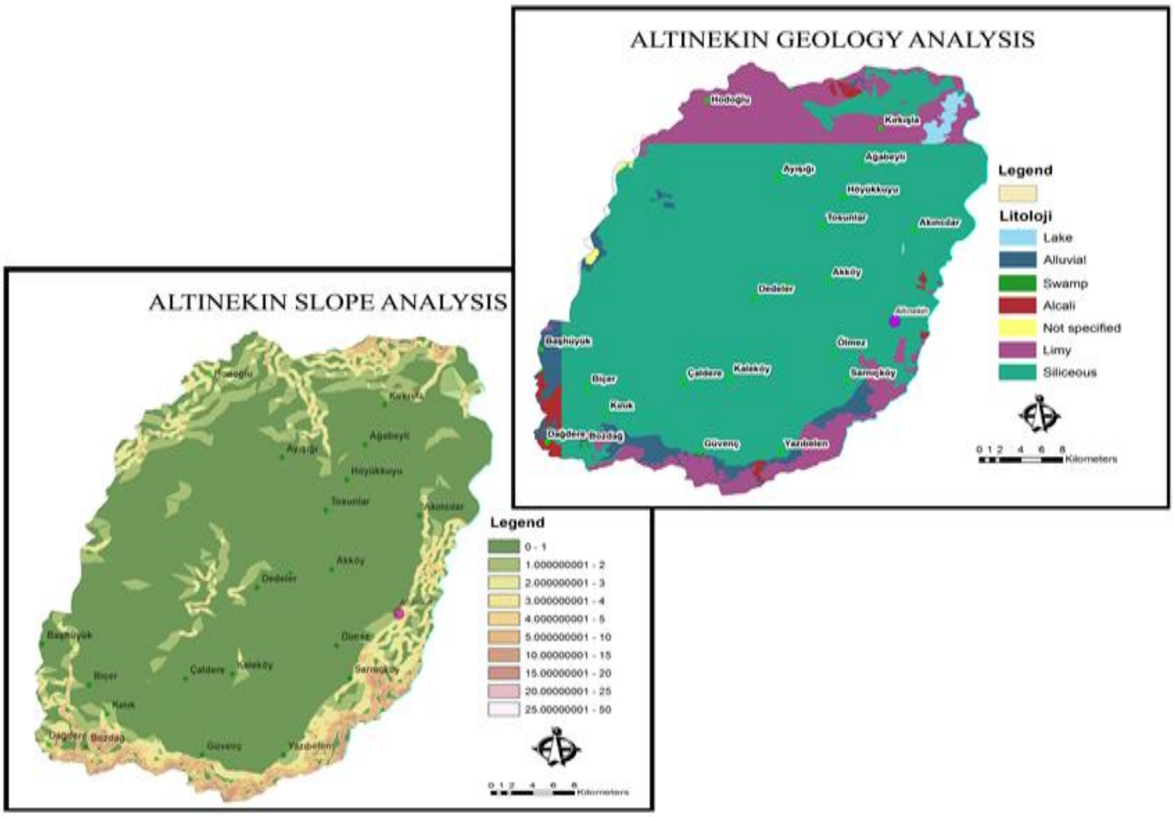

Figure 4. The slope and geologic situation in Altınekin Basin

The geological structure consists of neogene, limestone, claystone, conglomerate, neogene clayey limestone, mesozoic limestone, pliocene clayey sand and alluvium pliocene strata (Figure 4). The topographical structure and geological structure of the basin are important for forming a closed basin by holding groundwater. However, the topographical structure of the basin is not suitable for the establishment of facilities for the storage of water.

The Altınekin Basin land use situation was evaluated according to the data prepared by the CORINE program. The land cover/use data, which was generated by the computer-assisted visual interpretation method over satellite images according to the Land Cover Usage Classification determined by the European Environment Agency, was regulated according to the needs of the study (Figure 5). Altınekin Basin consists mostly of non-irrigable and arable land at the proportion of %47, irrigable and arable area of 3%, 33% maquis and herbaceous plants and sparse plant areas, 7% forest and pastures. Other land use features make up 10% of Altınekin Basin. Since the topography of the basin does not allow the establishment of facilities for the storage of water, water is drawn from the wells in order to irrigate the non-irrigable plots of arable land which negatively affects the groundwater level change.

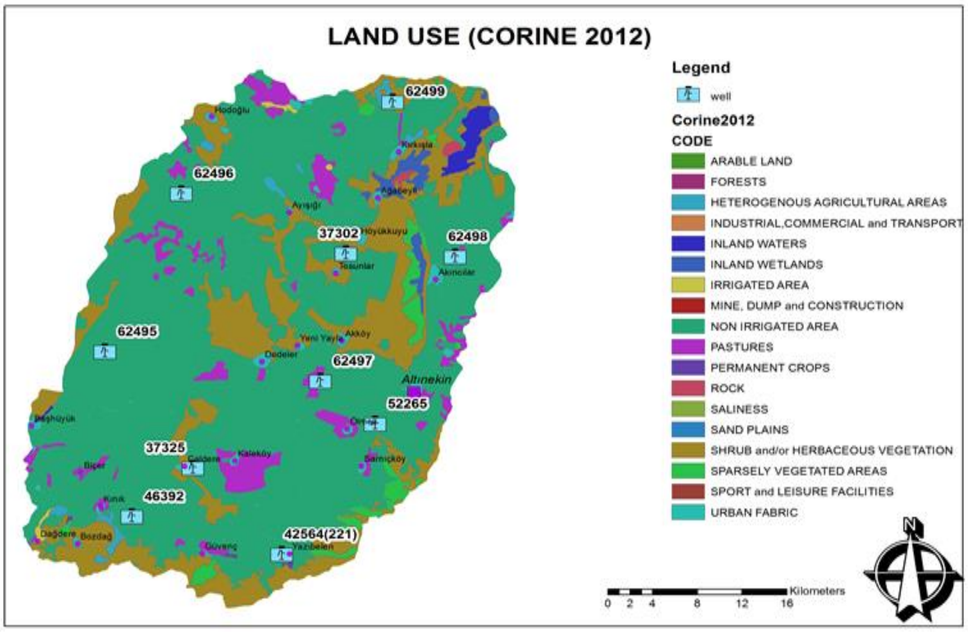

Figure 5. Land use in Altınekin Basin (Int. Rsc. 3)

This is due to the land use feature in the basin and when the area is analyzed by the amount of precipitation change, the danger that the groundwater level falls is clearly visible. When meteorological data between 1973 and 2012 are examined, the total rainfall average is calculated as 458.06 mm. Between 2009 and 2016, this value has fallen to around 275 mm. Apart from that, in the Basin, in many settlements, the need for potable and usable water is also met by the wells in this area. As a result, in terms of groundwater in the region, the safe reserve was 71 hm^3/year while the withdrawal amount was 158.44 hm^3/year.

Considering the topographical structure, geological structure, and land use characteristics of the Altınekin Basin, it is seen that the basin has a great deal of importance for the sustainability of water resources. For this reason, it is necessary to examine the risks involved in the protection-use balance of the basin.

For the determination of these risks, rainfall, temperature and water table data for the years 2015 and 2016 were obtained from 10 wells located in the basin and coordinates were determined from the State Hydraulic Works 4th Regional Directorate. For the spatial modeling of these data, a database was created in ArcGIS 10.3.1 software and analyzes were performed using the Inverse Distance Weighting (IDW) interpolation technique. The changes in the groundwater level from the analyzes were evaluated with respect to the distance to the settlement, water consumption for agriculture and types of vegetable production.

3. Result and Discussion

In the Altınekin Subbasin, there are 10 wells that were measured. In the scope of the study, the well no 62564 (221) has the characteristic of being the oldest well that can be measured in the basin. Observations were made in this well from 1968 until today. It was observed that the amount of groundwater decreased by 32.17 m, according to the data from this well.

Groundwater monitoring wells should be monitored at regular intervals (monthly or quarterly) to provide useful information (Crisan and Ioan 2012). In the study, the years (2015 and 2016) in which measured values were taken at specific intervals were chosen in order to determine the change of groundwater level by creating a significant spatial model. According to the monthly data obtained from the database, the water level change in the wells is as shown in Figure 6.

Spatial modelling (IDW) analysis was conducted to examine the change in groundwater level. For this, for the years 2015 and 2016, primarily the data of the March, when water reached the maximum level, and the data of September when it was in the minimum level were used. Differences between these data were taken and the change in groundwater level was determined (Figure 7).

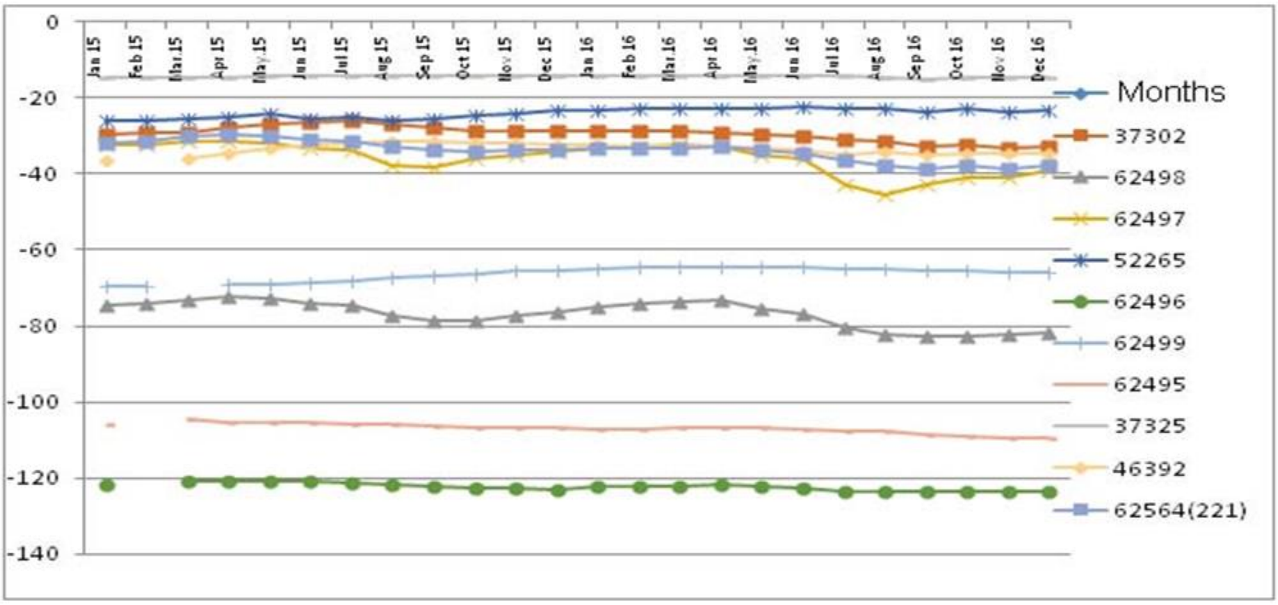

Figure 6. The water level change in wells according to the months

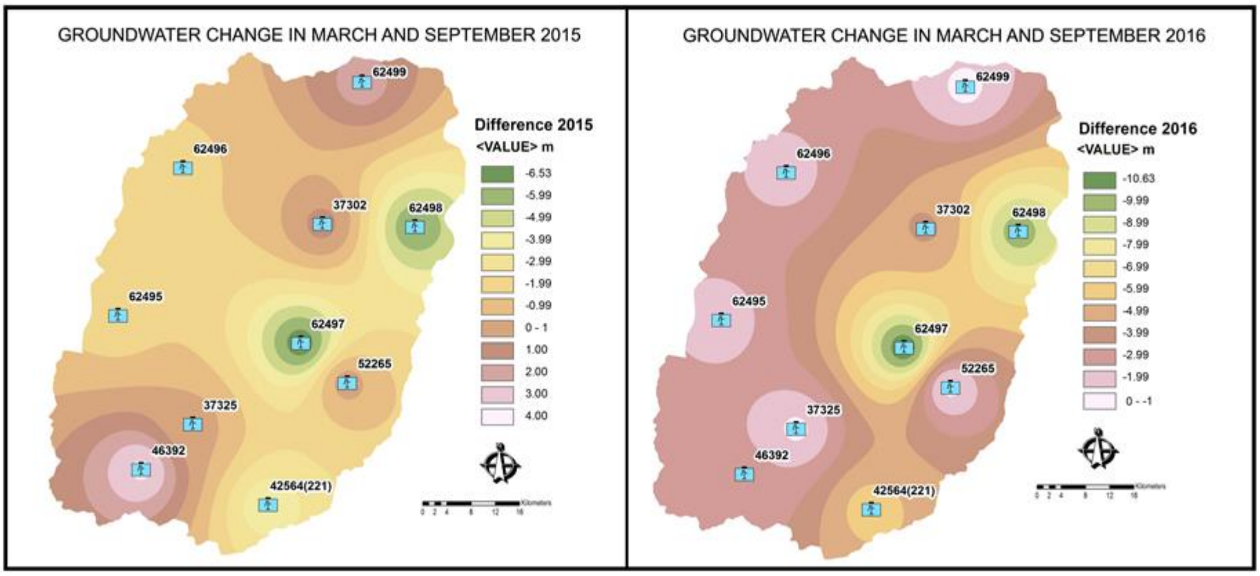

Figure 7. The groundwater change in March and September of 2015 and 2016.

When the groundwater change in March and September of 2015 was examined, a maximum reduction in the amount of groundwater was found at 6m at wells 62498 and 62497 and 3m at 42564, from which data were taken. Similarly, when the groundwater change in March and September of 2016 was examined, a maximum reduction in the amount of groundwater was found, at 10m in wells 62498 and 62497 and 5m in 42564 wells. Only in 2015, there was an increase in wells 46392 and 62499, which was not seen in 2016. When the condition of the wells is examined with the land use structure given in Figure 5, it is determined that the land around these wells has the characteristic of non-irrigable and arable area, with respect to the land use characteristics. The decrease in groundwater in these wells, observed both in March and September of 2015 and 2016, indicates that agricultural irrigation in the summer period has drawn more water than their reserves. In addition, excessive use of groundwater resources as a result of cultivating the crops such as corn, sugar beet and sunflower, which need more water, are being cultivated in these areas, causing water resources in the Basin to decrease (Int. Rsc. 1).

Secondly, the change between average groundwater levels between 2015 and 2016 was determined in Figure 8.

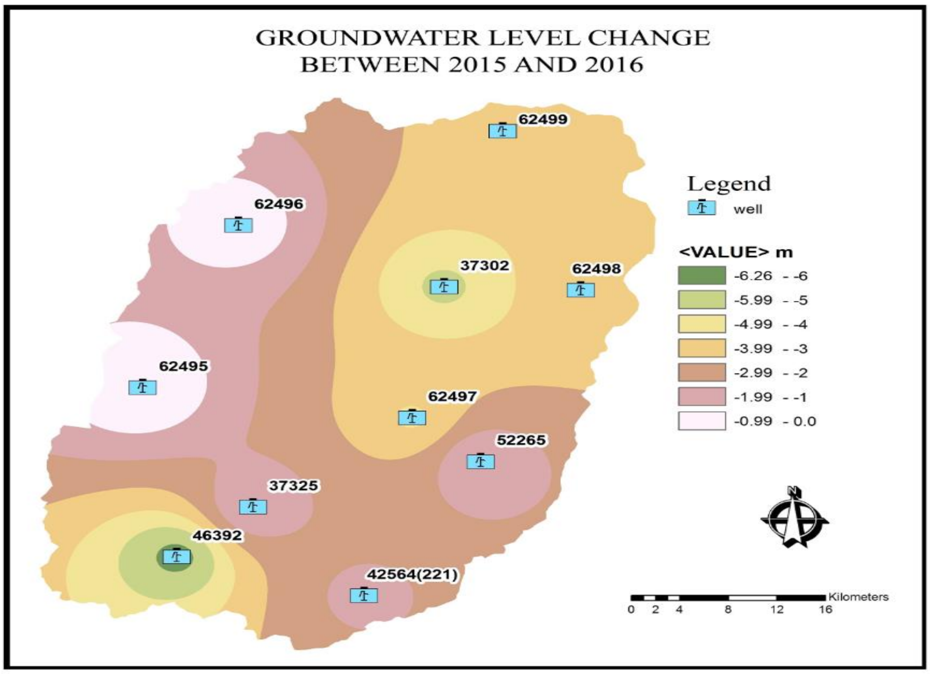

Figure 8. The change between average groundwater levels between 2015 and 2016.

According to Figure 8, it is determined that the maximum change is in the wells 37302 and 46392, where the data were taken. These wells have a slight decrease in water level during the March and September periods in 2015 and 2016, however, when the change between years is examined, this amount increases considerably. For this reason, it can be said that these wells are influenced by other uses in the average water level changes between 2015 and 2016, apart from agricultural uses. In this context, the distances to the nearest settlements of the wells in the basin were determined and the changes in these wells were examined (Table 1).

Table 1. The distances to the nearest settlements of the wells in the Altınekin Basin

	SETTLEMENT 1		SETTLEMENT 2		SETTLEMENT 3		SETTLEMENT 4	
Well Number	**Villages**	**Distance**	**Villages**	**Distance**	**Villages**	**Distance**	**Villages**	**Distance**
37302	**Höyükkuyu**	**1.89**	**Tosunlar**	**2.03**	**Ayışığı**	**6.48**	**Akıncılar**	**8.42**
37325	Çaldere	0.7	Kaleköy	3.84	Kınık	9		
42654(221)	Yazıbelen	0.7	Eğribayat	4.97	Güvenç	7.08		
46392	**Kınık**	**2.96**	**Bozdağ**	**5.5**	**Biçer**	**6.23**	**Çaldere**	**6.85**
55265	Ölmez	2.53	Sarnıçköy	4.25	Altınekin	4.68		
62495	Başhüyük	9.72	Karatepe	12.48	Dedeler	14		
62496	Hodoglu	8.03	Ayışığı	9.83	Özkent	9.96		
62497	Yeniyayla	4.06	Akköy	4.41	Dedeler	5.58		
62498	Akıncılar	2.78	Höyükkuyu	8.86				
62499	Kırkışla	4.88	Sığırcık	7.86	Karabağ	8.08		

According to Table 1, it is determined that wells 37302 and 46392, which have the greatest decrease in average groundwater levels in 2015 and 2016, are sources for more settlements than other wells in the basin. The decline in groundwater level in these wells indicates that waters are also used for daily use needs other than agricultural needs.

Finally, the change in groundwater level is examined for annual mean temperature and precipitation changes for 2015 and 2016 (Figure 9). For this, an IDW analysis was carried out that showed annual mean temperature and precipitation changes for 2015 and 2016.

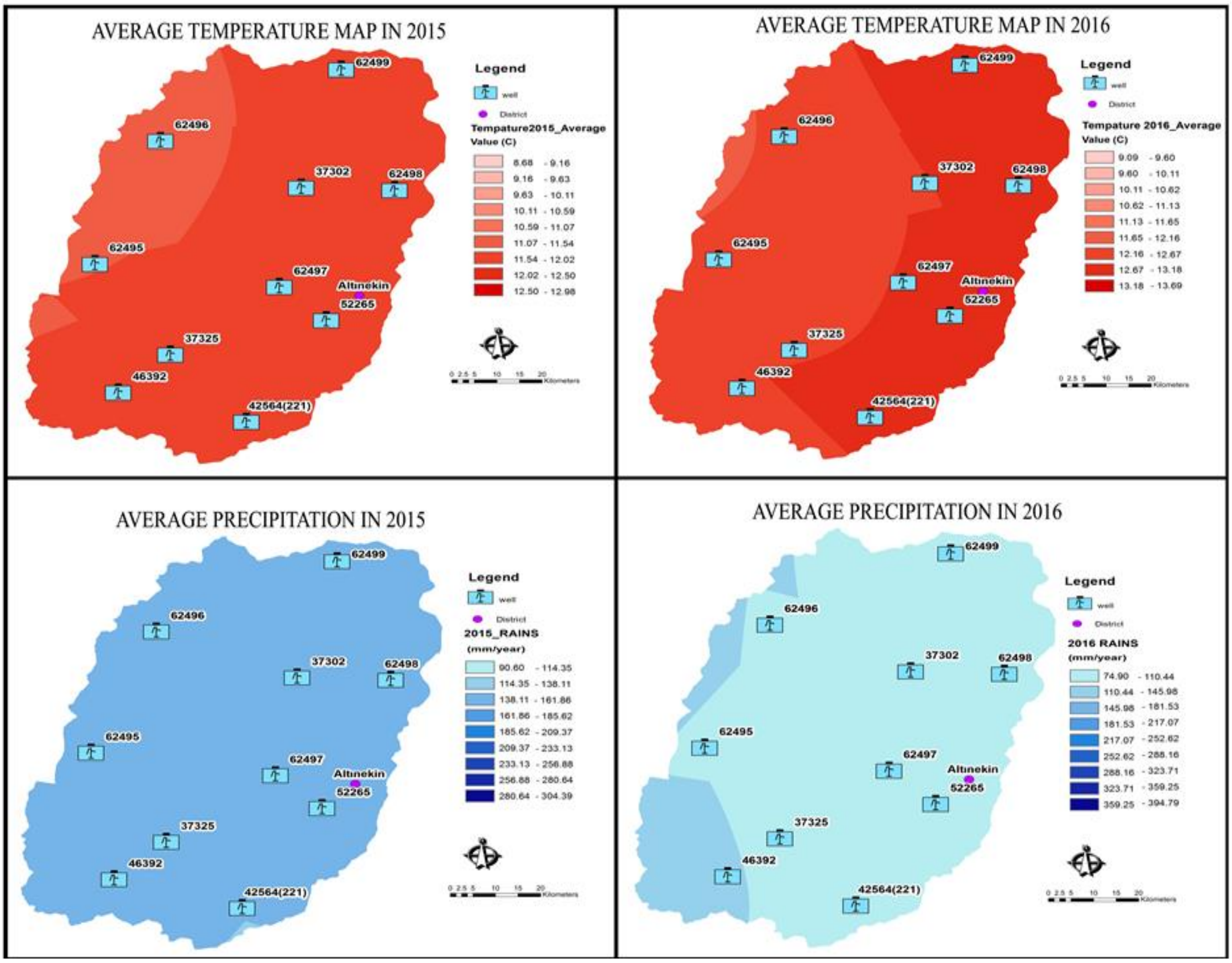

Figure 9. The annual mean temperature and precipitation changes for 2015 and 2016.

In 2015, the temperature was lower in the western part of the basin where the slope is elevated, and higher in the district center and around the villages. It has been determined that the amount of precipitation is the same for everywhere in the basin. In 2016, it was determined that temperature values increased in the whole basin and the precipitation decreased in the entire basin.

According to the water table data of the year 2016, the decrease in the groundwater level in the wells is higher than the year 2015. This can be expressed as the irrigation of non-irrigable and arable land around the wells, or the reduction of the amount of precipitation and the temperature increase that occurs in the whole basin.

4. Conclusions

Altınekin Basin, which is a subbasin of KCB, an important centre of agricultural production for Turkey, the decline in recent years in the amount of groundwater requires an analysis of the protection and use process for the sustainability of the basin's ecological balance.

Within the scope of this study, the measurements obtained from 10 observation wells in this basin were analysed with ArcGIS 10.3.1 software. In the measurements made, the changes detected in groundwater were evaluated within the scope of land use structure, temperature, precipitation variables and distances to settlements. When the change is examined by analyses made using graphs and GIS software, changes in water level during the year and for the last 2 years have been determined. It has been determined during the years following the study that negative conditions may occur in terms of the ecological balance of the basin due to the decrease in the amount of precipitation received by the basin, the increased temperature values, the amount of groundwater drawn above the reserve for agricultural production purposes.

In terms of the sustainability of groundwater resources, this study reveals:

- The necessity of monitoring and recording water level changes,
- The necessity of making rural development plans for the rural land use, plant cover, changing climatic conditions and the status of water assets,
- The fact that ecological structure needs to be protected against the driving force of the growing agricultural economy
- The fact that measures and policies need to be developed in the face of identified problems.

Effects such as the decrease in winter precipitation, increase in summer temperatures, frequent droughts and soil degradation due to climate change threaten the existence of groundwater. One of the most important effects of climate change is the change in groundwater quality. Due to climate change, the precipitation that feeds groundwater has decreased, and thus groundwater levels have fallen. As the average temperature is expected to increase rapidly in the basin after 2030, along with the decrease in the precipitation, the futures of natural life and agriculture are threatened. The importance of the water for the vital activities of living beings to be continued and the ecological continuity to be achieved is a well-known fact because it has an end and it is a sensitive resource. For this reason, for the groundwater management, the water resources need to be monitored for a certain period of time, taking the local climate, and land conditions and characteristics into consideration. A groundwater monitoring network is established by the State Hydraulic Works by taking the opinion of the relevant institutions and organizations for monitoring activities. In this way, the amount and chemical status of groundwater and its long-term changes caused by natural conditions and human activities are determined.

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