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Araştırma
Research

MONITORING AND ASSESSING GROUNDWATER LEVEL BY GIS: A CASE STUDY IN THE IRRIGATED SOILS OF BAFRA PLAIN IN NORTHERN TURKEY**

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ABSTRACT: This study aimed to determine monthly and seasonal ground water level variations of agricultural soils of the right-land irrigated area in Bafra Plain using Geographical Information systems (GIS). To achieve this purpose, ground water levels were monitored at 62 different points. The maps of problematic areas for drainage were developed using the highest and lowest ground water levels to determine the problems caused by high ground water level. When the map of the highest ground water level was examined, it was revealed that the ground water level was in the range of 0-1.0 meter depth in the study area covering 1513 hectares (ha). This result indicates that it is compulsory to construct deep drainage system in such areas where high ground water problems persist during the whole year.
Keywords: Ground water, Bafra plain, GIS

COĞRAFİ BİLGİ SİSTEMLERİ YARDIMIYLA TABAN SUYU SEVİYESİNİN İZLENMESİ VE DEĞERLENDİRİLMESİ; BAFRA OVASI SULAMA ALANINDA BİR ÇALIŞMA

ÖZET: Bu araştırmada, Bafra Ovası sağ sahil sulama alanında bulunan tarım arazilerinin aylık ve mevsimlik taban suyu seviye değişimlerinin Coğrafi Bilgi Sistemleri (CBS) kullanılarak incelenmesi ve problemlerinin ortaya konulması amaçlanmıştır. Bu amaçla, taban suyu seviyesi 62 farklı noktada takip edilmiştir. Taban suyundan kaynaklanan problemlerin belirlenmesi için en yüksek ve en düşük taban suyu seviyeleri belirlenmiş ve drenaj açısından problemli alanların haritaları hazırlanmıştır. Taban suyu en yüksek eş derinlik haritası incelendiğinde; 1513 ha alanda taban suyunun 0-1.0 m derinlikte olduğu ortaya çıkmıştır. Yıl boyunca taban suyu problemi ile karşı karşıya bulunan bu alanda derin drenajın yapılmasının zorunlu olduğu ortaya çıkmaktadır. Çalışma sonucunda, problemli alanlarda drenaj tesislerinin etkin bir şekilde çalışması için gerekli değerlendirmeler yapılmıştır.
Anahtar Sözcükler: Taban suyu, Bafra Ovası, CBS

1. INTRODUCTION

The main purpose of cultural measures in agricultural systems is creating the most appropriate conditions for plant growth. Despite atmospheric conditions cannot easily be modified, soil conditions can be controlled to obtain maximum yield through application of irrigation and drainage (Demir, 1985).
In Turkey, large areas are affected by ground water (GW) problems as a result of irrigation. The Bafra Plain Right land irrigated area, covering 1% of the total irrigated area, is one of the largest irrigation and drainage projects in Turkey (Cemek et.al., 2006a).

Ground water level has a significant effect on plant growth. Shallow ground water has negative effect on plant growth, since it constrains rooting area and oxygen supply. Irrigation practices become more important if the ground water is located closer to surface. Nourishment of ground water before irrigation is generally low in arid environment. Precipitation and deep percolation of is the only source of ground water. Deep percolation consists of 20-30% of the irrigation water under such conditions. Ground water level might be too high. It is possible to find irrigation areas where the ground water level rises up to 1 to 2 m dept from 20 to 30 m within 10-15 years (Erözel, 1994).

Plant root may die if the ground water table level rises and moves to the root zone. In this case, soil, water and air balance will be lost. Wet soil is generally considered as cold soil. It is also difficult plowing wet soil. If the soil is not tilled on time, soil would be too hard for sowing. A local wet point in a field causes the field to be cultivated irregularly. The roots of plants which are grown under high ground water table conditions are shallow. In dry periods of summer, when the water level goes down in a short period, shallow root system cannot adjust to the new conditions and can be easily damaged (Luthin, 1978).

A successful and economical irrigation and drainage project depends on controlling the water used and the correct use of extra water. In irrigated agriculture areas, in order to efficiently use soil and water resources, a specific balance should be maintained between plant, soil and water. But the use of extra water, application of wrong irrigation methods and insufficient drainage conditions raise the groundwater level (Kara and Arslan, 2004).

In order to determine the priorities in the maintenance service programs, ground water level should be monitored regularly to detect whether the drainage systems work properly, whether the existing drainage systems need additions or whether the areas

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with no drainage system need new drainage (Gündoğdu et. al.,1998).

Soil productivity is affected by soil physical properties that play a crucial role in planning drainage systems. Improper planning of drainage systems can create high water table problems, and in turn, an unsuitable environment for plant growth. Therefore, drainage systems should be well planned and monitored regularly. It is labor-intensive and time-consuming to determine the spatial and temporal changes in drainage parameters such as groundwater (GW) depth, elevation, hydraulic gradient and salinity by conventional methods over large areas. Geographic information systems (GIS) and geostatistical analysis can be used to assess the spatial and temporal changes efficiently and rapidly (Çetin and Diker, 2003).

The aim of study is to determine the ground water table problems in Bafra Plain that has partly irrigated areas and where some of irrigation studies are still continuing. Observation wells were opened in the work area and the data from wells were evaluated. The areas with ground water table problem were detected and solutions were proposed.

Bafra Plain's right-land-irrigated area is one of the largest irrigation and drainage projects in Turkey. Excessive irrigation water use, seepage from canals, poor irrigation efficiencies, and inadequate drainage systems have resulted in local areas with elevated saline groundwater, increasing the risk of soil salinity. Cemek et al. (2006) indicated that cauliflower, radish, and leek production in Bafra plain increased and beans and corn production considerably decreased due to the increased ground water salinity (GWS) during irrigation season. Arslan et al. (2007) also reported 10% yield loss in the Bafra Plain due to the high electrical conductivity (EC) of ground water.

Salinity buildup in the root zone depends on several factors such as GWS, quality of irrigation water, irrigation strategy, crops being grown, soil type, and ground water depth (GWD) (Prathapar and Qureshi, 1999; Ali et al., 2000). The irrigation strategy is an important factor affecting the depth and elevation of the groundwater as well as salinity buildup in the root zone.

Cemek et. al. (2006c.) showed that salinity and alkalinity deteriorated in the study area because of irrigation and also indicated that 30% of the study area was free of salt, 53% slightly was salty, 16% salty, and 1% extreme salty, 80% was not alkaline, and 20% was alkaline in Bafra Plain.

2. MATERIALS AND METHODS

Study area is about 8000 ha and located on the right coast of Bafra Plain. A part of the study has already been opened for irrigation while the construction is still being continued. Study area is in the Middle Black Sea Region between 41° 10' - 41° 45' north latitude and 35° 30'- 36°15' east longitude in the Kızılırmak Delta plain.

Bafra Plain Irrigation Project, the total irrigation area is 47727 ha, was started in 1993. Water source of the project is the Derbent Dam established on Kızılırmak. The project consists of two parts named Bafra Plain Right Coast and Left Coast Irrigation. The construction of Right Coast Irrigation was started in 1993. By the end of 2003, 6500 ha agricultural field was opened for irrigation and irrigation and drainage studies are still continuing in the area.

The main water source of Bafra Plain is the Kızılırmak River. If the field cannot be irrigated by channel, then water is pumped from drainage canal and drilling wells of 8-10 m depth. Conventional irrigation systems involving different methods are used for the crops grown in the region, but mostly furrow or border irrigation methods are used. In some places, sprinkler irrigation system is also used. Drip irrigation method is not used in the Plain. The plants grown in the study area are various, but vegetables are the most widespread grown crops. In summer, watermelon, melon, tomato, pepper are the crops grown, whereas in winter following wheat, leak, cabbage, radish are grown as second crop. Corn is also grown in the area as first and second crop. An extreme increase in rice cultivation has been observed recently with the starting of irrigation.

According to the long years approximate observation results taken from the Bafra Meteorology Station, the rainiest month is December while the driest month is July. Mean total annual rainfall is 722.5 mm. The hottest month is July and the coldest month is January. Throughout the study, 60 ground water table observation wells were opened, and also 2 village wells were used in observations. One observation well was opened in every 130 ha. Distance between the wells was about 750 m. To keep the observations healthy and continuant, the observation wells were selected in vicinity of rice fields. The wells were generally opened as 4 m depth, but at some points due to the pebbles, wells were dug shallower. In wells, PVC pipes were used with a diameter of 63 mm and with holes of 4 mm diameter and 5 cm spaces around. The locations of observation wells were recorded with a GPS. Measurements were started in September 2003, and samples were taken in the last week of every month. They were continued until August 2004. Groundwater level was monitored with an electronic level measurer (Figure 1).

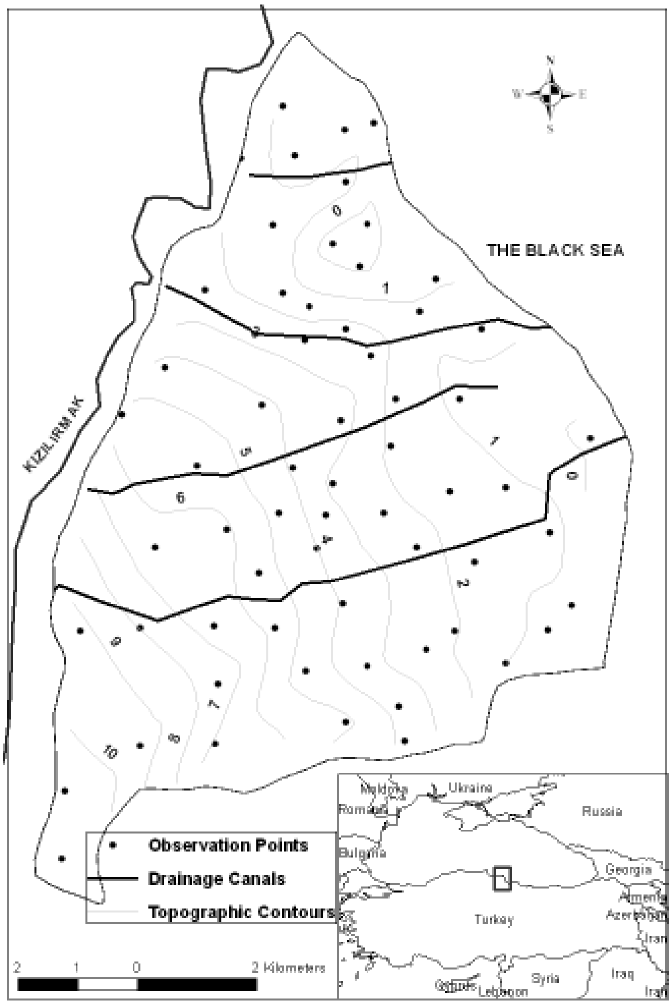


Figure 1. Location and general layout of the study area of topographic contour map with 1.0 m contour interval.

Ground water level maps were prepared to monitor the groundwater level. One year measurements were used in preparing ground water depth maps. The highest and lowest ground water levels were determined for each well following the 12 month measurements. Ground water depth map of July was prepared to determine the effect of irrigation. Ground water depth equal level curves were drawn for July and the flow direction was determined. GW depth and elevation were used in ArcGIS 8.3 (ESRI, 2001) to visually analyze the spatial relationships among the variables.

Ground water level values were evaluated by making use of the analysis functions of GIS. Observation values were interpolated using Inverse Distance Weight (IDW) method and data layers of 20 m cell size were produced. These data layers were evaluated with GIS and underwent examination and classification for the purposes set.

3. RESULTS AND DISCUSSION

Monthly ground water level fluctuation maps are presented in Figure 2. Figure 2 shows that ground water levels in September, October and December were more than 3 m in the Plain (Table 1). The measurements obtained in September revealed that ground water depth was high in this month. Optimum ground water depth requirement for sugar beet is 80 cm, for wheat and corn is 100 cm and for vegetables is 75 cm [6]. The ground water depth in 3633 ha of the area (45% of the study area) was between 0-100 cm (Figure 2.1).

When the ground water depth for October was examined, it was determined that ground water depth was between 0-100 cm in 2437 ha (30% of the total area). There was a decrease in ground water depth despite rainfall extended the period of September. The reason for that irrigation period in the study area ends in September and the effect of irrigation in the measurements is reflected in September (Figure 2.2).

None of the area was found in November with a ground water depth of 3 m. In November, ground water depth was between 0-100 cm in 5057 ha (62%). The results revealed that ground water table problem in the majority of the Plain increased in November, because plant water usage decreased and there was no any effective drainage system (Figure 2.3).

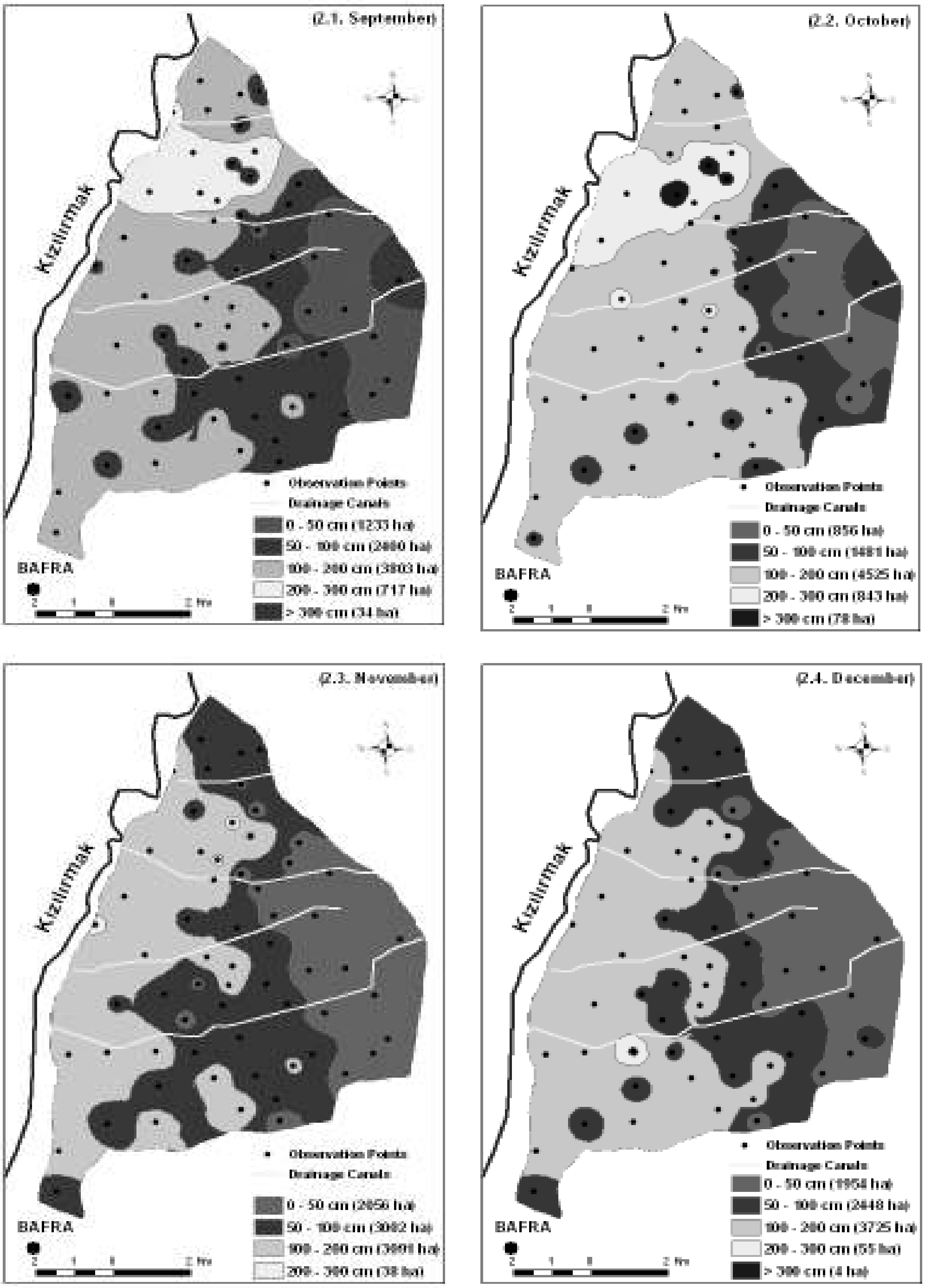


Figure 2. The spatial distribution maps of the monthly ground water depth in the study area

The ground water depth problem was determined in a big part of the Plain in December as a result of reasons similar to November (Figure 2.4). The decrease in January affected ground water depth directly and caused the areas in which water deepness is between 0-100 cm to lessen (Figure 2.5).

Measurements in February showed a decrease in ground water depth (Figure 2.6). Total area between 0-50 cm depth, which is important for plant growth, was about 664 ha, and the area between 50 to100 cm depth, which causes decrease in plant yield, was 2399 ha. This shows the effect of rainfall on ground water depth.

In March, the total area in which ground water depth between 0-50 cm was 110 ha. This was consequence of less rainfall occurred in the previous months. The area consisting of 50 to100 cm depth was 2599 ha, whereas 100 to 200 cm depth was 5439 ha (Figure 2.7). As it can be seen from the depth map for April, there is an increase in ground water table, parallel to the increase in rainfall. The ground water

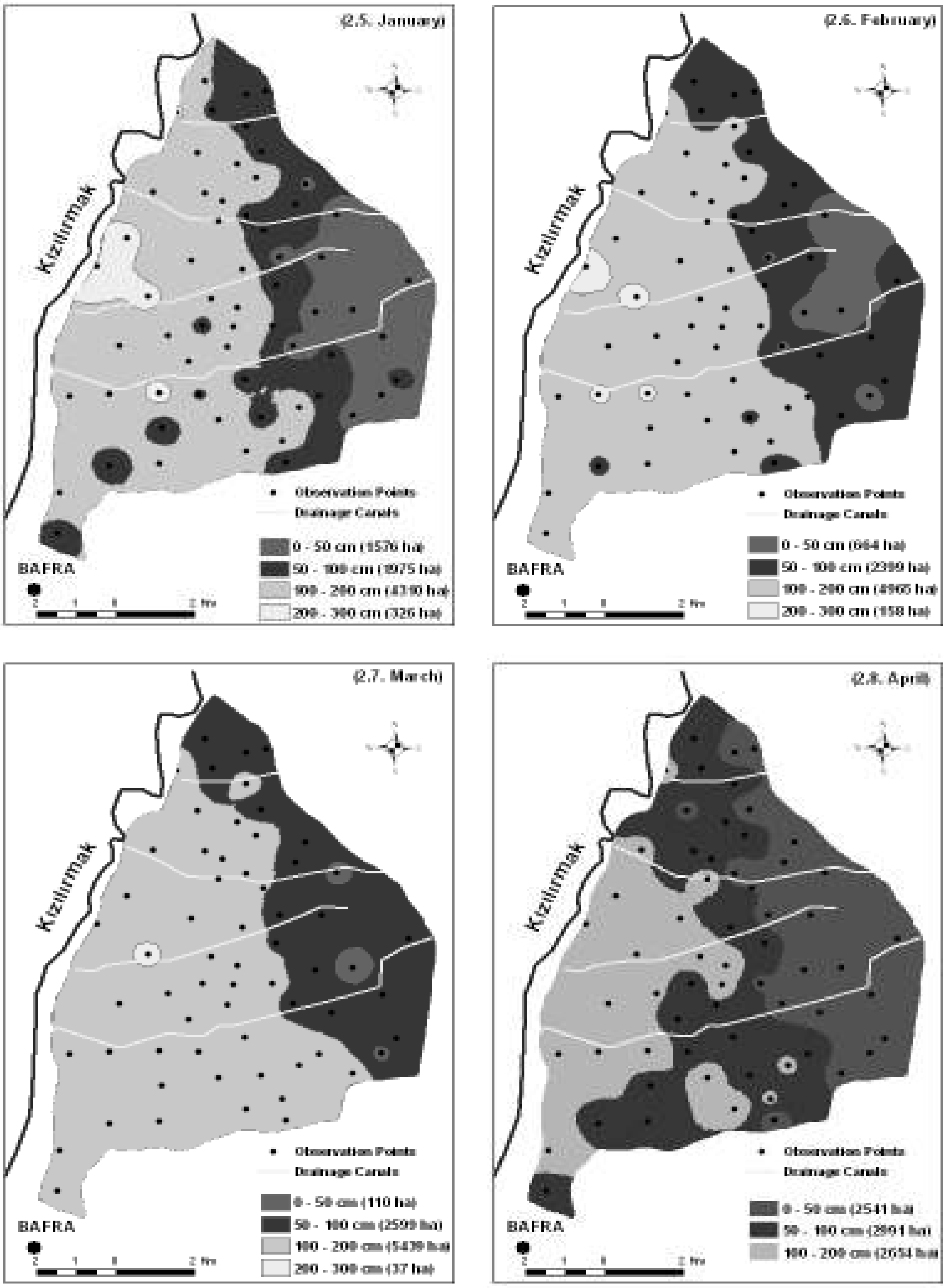


Figure 2 (continue). The spatial distribution maps of the monthly ground water depth in the study area

depth between 0-100 cm makes up of 68% of the study area. Ground water depth was not less than 200 cm because of the rainfall (Figure 2.8).

Following the first week of May, water was supplied from Derbent Dam. From this month, irrigation and rainfall were taken together while examining the change in ground water table level. Rainfall amount in May was measured as 78 mm (Figure 2.9). Since rainfall was quite high in June, irrigation canals were closed. Rainfall compensated to the plant need and this prevented rising the ground water level. The area consisting of ground water depth of 100-200 cm reached to 5933 ha (Figure 2.10).

To know the effects of irrigation on ground water table, ground water depth values for the months, in which the need for water and irrigation is the greatest, were drawn on a map, and a map of equal depth was prepared for the month in which irrigation was the greatest.

The driest month in Bafra Plain was July with an average of 26.3 mm precipitation and the highest evaporation took place in this month with 200.9 mm. Therefore, July is the densest irrigated season in the plain (Kara and Arslan, 2004). In this month, the ground water level in 24% of the study area is in a depth that may affect the plant growth negatively (Figure 2.11). In August, a similar characteristic was observed at the end of the measurements. The area in

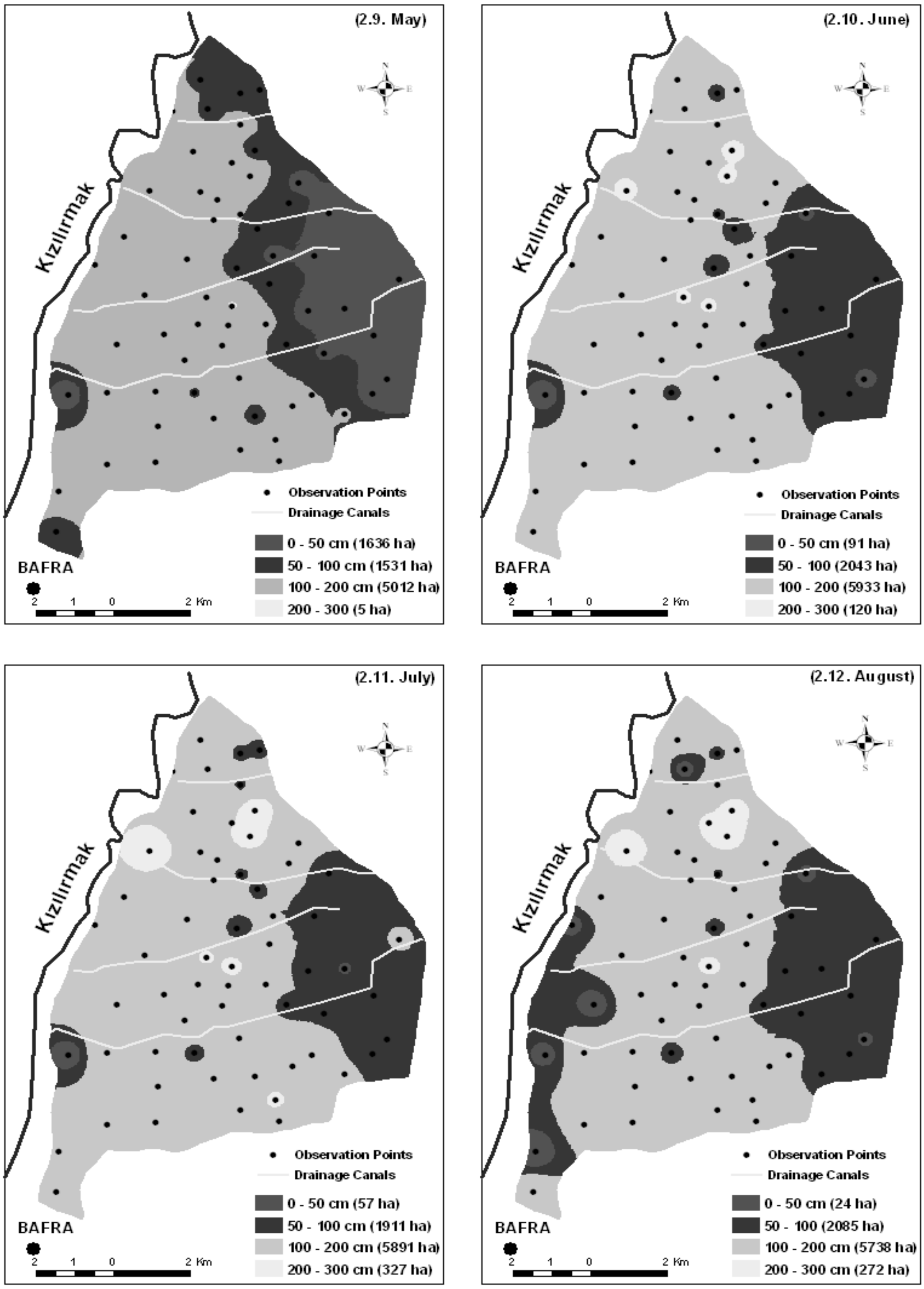


Figure 2 (continue). The spatial distribution maps of the monthly groundwater depth in the study area

Table 1. The spatial distribution of the monthly groundwater depth in the study area

	Groundwater level (cm)									
	0-50		50-100		100-200		200-300		>300	
Month	Area	%	Area	%	Area	%	Area	%	Area	%
September	1233	15.1	2400	29.3	3803	46.5	717	8.8	34	0.42
October	956	11.7	1481	18.1	4828	59.0	843	10.3	78	0.95
November	2055	25.1	3002	36.7	3091	37.8	38	0.5	-	
December	1954	23.9	2446	29.9	3727	45.5	55	0.7	4	0.05
January	1576	19.3	1975	24.1	4310	52.7	326	4.0	-	-
February	664	8.1	2399	29.3	4965	60.7	158	1.9	-	-
March	110	1.3	2599	31.7	5439	66.4	37	0.5	-	-
April	2541	31.0	2991	36.5	2654	32.4	-	-	-	-
May	1638	20.0	1531	18.7	5012	61.2	5	0.1	-	-
June	91	1.1	2043	25.0	5933	72.5	120	1.5	-	-
July	57	0.7	1911	23.3	5891	72.0	327	4.0	-	-
August	94	1.1	2085	25.5	5736	70.1	272	3.3	-	-

which ground water depth was less than 50 cm was 94 ha while the area between 50-100 cm was 2085 ha (Figure 2.12).

In a period of 12 months, the values when ground water table is the closest and the furthest to the soil surface in every well were detected (Anonymous, 2005). During the year, the highest value of the well was drawn on a map and a map of ground water table and critical highest equal depth curves were prepared.

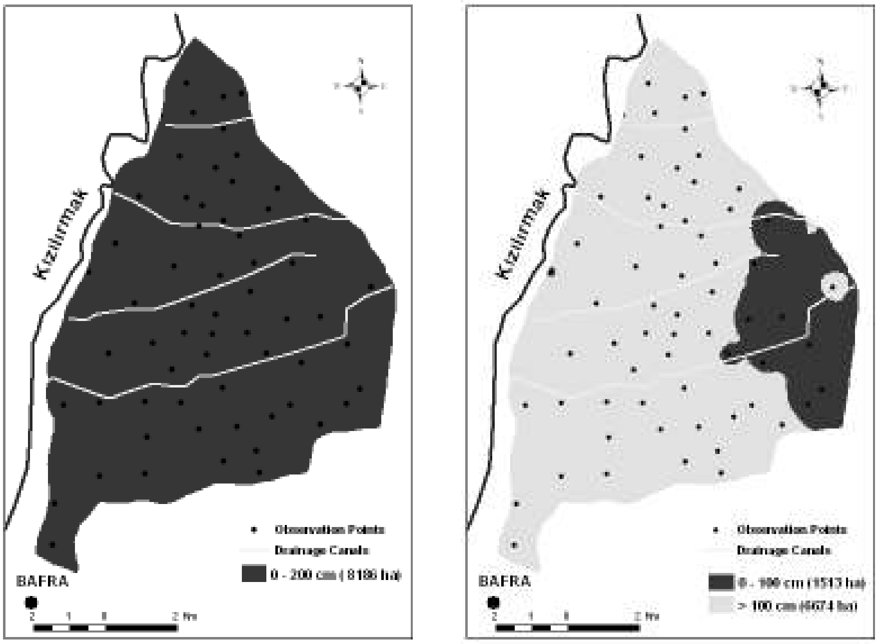
This map shows the highest level of ground water in the irrigation area in a year. On this map, the area that ground water depth is between 0-2 m was detected by the borders of the areas which had drainage problems.

The highest values for 62 ground water table observation wells were found out, and the highest equal depth map of ground water table was prepared accordingly. When the map was examined, ground water depth was between 0-2.0 m in the whole study area for 12 months. Consequently, there was drainage problem in the whole area studied.

By using the highest values of 12 months measurements, the critical lowest equal depth curve maps were drawn. The maps show at which level the most ground water level falls down to in irrigation area in one year. On this map the areas where groundwater level is between 0-1 m of depth shows the areas where groundwater level is around plant root zone throughout the year, in other words, the areas where farm drainage should be made.

The map prepared shows the highest ground water levels. When the map was examined, ground water level was at plant root zone throughout in 1513 ha land (Figure 3). The area which had problem was located in the northern part of the plain. Ground water table problem was seen in this area and caused great losses in plant yield. Rice in the husk is grown mostly in these areas in order to decrease the losses. However, since the lands are wet at the time of the harvest, rice cannot be harvested on time and this causes important economic losses.

Ground water depths for July were determined by drawing equal level curves, and the curves were made with 1 m intervals (Anonymous 2005). As it can be seen from Figure 4, ground water depth equal level curves were suitable for the topographic structure of the land. The flow of ground water was in southwest-northeast direction. Equal level curves were seen more on the southwest part of the area. This shows that the ground water table flow speed is high. In the northeast of study area, the distance between the equal level curves was greater. This shows that the ground water table flow speed in this area is low. When the ground water depth maps were examined, the areas in which groundwater level problems were occurred in this area.



(a) (b)

Figure 3. (a) The maps of the highest groundwater depth
(b) The maps of the lowest groundwater depth

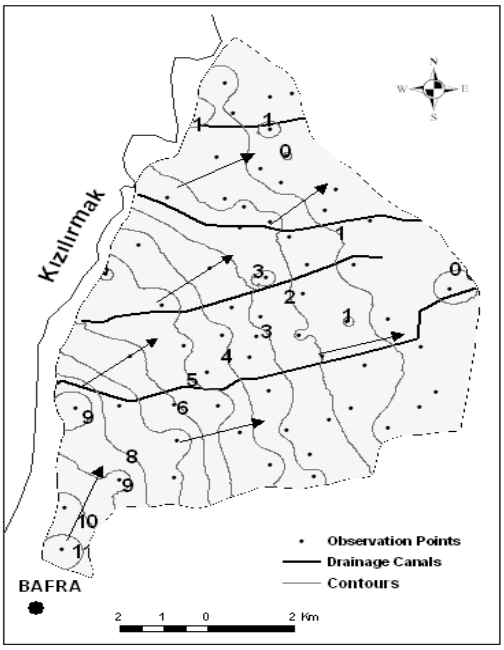


Figure 4. The maps of groundwater flow direction

4. CONCLUSIONS

The highest and the lowest equal depth maps regarding to groundwater depth were prepared using one year data. When the groundwater level for the highest equal depth map was examined, groundwater depth was observed between 0-1.0 m in an area of 1513 ha.

The result of this study indicated that it is highly recommended to establish a drainage system in this area. In Bafra Plain, this area is named as under level +2 m. The part that has to be taken into consideration in ground water table is the lowest deepness maps which are between 0-2 meters. This area showed us the part that has drainage problem. The maps prepared for the study area indicated that the groundwater level in all of the area was between 0-2 m.

The farmers in the study area are negatively affected because of rainfall occurs during sowing and harvesting periods. This has implications for crop diversity. In these areas, rice in the husk is grown mostly because it is not affected by ground water table. In summer, drainage channels should be cleaned and prepared to decrease the effects of rainfall especially in spring and autumn. The dams which are made by farmers in front of the drainage channels in order to get water should be removed to fulfill their real posts. Besides, one of the issues of ground water table seen in the study area is salinity, a big problem in agricultural areas. Consequently, in order to prevent further problems precautions should be taken faster and the drainage system should be completed as soon as possible.

5.REFERENCES

Anonymous, 2005. Taban Suyu İzleme Rehberi, DSİ Genel Müdürlüğü, Ankara, 2005.

Ali, R., Elliot, R. L., Ayars, J. E., Stevens, E. W. 2000. Soil salinity modeling over shallow water tables. II: Applications of LEACHC. Journal of Irrigation and Drainage Engineering, 126, 234–242.doi:10.1061/(ASCE)0733-9437(2000)126 :4(234).

Arslan, H., Guler, M., Cemek, B., Demir, Y., 2007. 565Assessment of groundwater quality in Bafra plain for irrigation. Journal of Tekirdag Agricultural Faculty, 568 4(2), 219–226.

Cemek B., Demir Y., Erşahin S., Arslan H., Güler M., 2006a, Spatial Variability Of Groundwater Salinity And Groundwater Depth, Soil Salinity In Irrigated Soils Of Bafra Plain In Northern Turkey. Abstract page 250, full text in Cd. International Symposium on Water and Land Management for Sustainable Irrigated Agriculture in memory of Prof. Dr. Osman Tekinel. Adana, Turkey.

Cemek, B., Guler, M., & Arslan, H. 2006b. Determination of salinity distribution using GIS in Bafra plain right land irrigated area. Ataturk University Journal of Agricultural Faculty, 37(1), 63–72.

Cemek,B., Güler,M., Kılıç,K., Demir,Y., Arslan, H., 2006c. Assessment of spatial variability in some soil properties as related to soil salinity and alkalinity in Bafra plain in northern Turkey, Environmental Monitoring and Assessment, Volume 124, 223-234

Çetin M., Diker K., 2003. Assessing drainage problem areas by GIS: A case study in the eastern Mediterranean region of Turkey. Irrig. And Drain. 52: 343-353.

Demir A.O., 1995. Bazı Kararlı Akış Drenaj Eşitliklerinin Model Denemeleri ile Kendi İçerisinde Karşılaştırılması, Köy Hizmetleri Erzurum Araştırma Enstitüsü Müdürlüğü, Genel Yayın No:23, Rapor Yayın No:20, Erzurum, , pp. 1-14.

Erözel A.Z., Öztürk A., 1994. Sulama Suyu Kalitesi ve Tabansuyu Derinliğinin Bitki Verimine Etkisi, DSİ Teknik Bülteni. 81: 55-61.

ESRI., 2001, Using ArcView GIS. Environmental System Research Institute.Inc.:Redlans,. California.

Gündoğdu K.S., Demir A.O., Değirmenci H., Akkaya Ş.T., 1998. Arc-Info Ortamında Taban Suyu Haritalarının Hazırlanması Üzerine Bir Araştırma: M. Kemalpaşa Sulama Proje Örneği. 2. Ulusal Tarımda Bilgisayar Uygulamaları Sempozyumu., Konya.

Güngör Y., Erözel, A.Z. ,1994. Drenaj ve Arazi Islahı. A.Ü. Ziraat Fakültesi Yayınları, No. 1341, Ankara.

Kara T., Arslan H., 2004. Bafra Ovası Sulama Alanında Tabansuyu ve Tuzluluk Araştırması, Sulanan Alanlarda Tuzluluk Yönetimi Sempozyumu, DSİ Genel Müdürlüğü, Ankara,

Luthin J.N., 1978. Drainage Engineering. Robert E. Kriegger Publishing Company, Inc.Krieger Drive Malabar, Florida, USA

Prathapar, S. A., & Qureshi, A. S. 1999. Mechanically reclaiming abandoned saline soils: A numerical evalu ation. Research report 30 (p. 20). Colombo, Sri Lanka: International Water Management Institute.