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# Determination of Groundwater Sensitivity Potential Using Geography Information System (GIS) Based DRASTIC Model: A Case Erzin Plain (South of Turkey)

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**Abstract.** Today, due to the rapidly increasing world population and urbanization, the amount of water is increasing exponentially in areas such as drinking, irrigation, energy, industry, etc. There is a great increase in the use of water in agriculture, especially due to the food needs of human beings. For this reason, human beings need water; They obtain water almost everywhere from above ground (springs, dams, ponds) and underground (drilling wells) water sources. Usage of groundwater is quite common in the plains, where surface water resources are insufficient. This situation; While increasing the use of pesticides and fertilizers for agricultural purposes due to irrigation, it also creates the risk of contamination of groundwater. In this study; contamination potential of groundwater in Erzin Plain was determined using Geography Information System (GIS)-based DRASTIC model. Seasonal and annual field sensitivity levels were determined by integrating current land use into this model. Accordingly, in the dry seasons of August-2006, November-2006, while the Mediterranean coast has high EC values in the vicinity of the Mediterranean coast, the area around the resort sites and the settlement area, the mountainous areas, the north of the plain and the west of Gokdere have low EC values. It has the lowest EC values by decreasing towards the north and northeast and other parts of the plain. In the study area; Although $NO_3$ concentration varies seasonally, it is especially high in citrus growing segments with high permeability. On this change; Factors such as rainfall recharge, evaporation effect in the dry period, irrigation water recharge with the effect of land use, and the depth of groundwater depending on topography played an important role.

**Keywords:** erzin plain, DRASTIC Model, Geographic Information System (GIS), Groundwater (GW), sensitivity

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## 1. Introduction

The natural hydrologic cycle has been altered in much of the world due to climate change and human land development [1]. Urban development limits the permeability of ground surfaces; precipitation that would normally the reach natural land surface and infiltrate into the underlying aquifer instead runs off, over paved areas or areas with low surface soil permeability until it evaporates, or enters surface water bodies or stormwater management facilities [2].

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Numerous studies have shown that groundwater and drinking water contamination from drywells can be avoided if drywells are used in appropriate locations and properly maintained. The effectiveness of dry wells for aquifer recharge depends on the hydrogeologic setting and land use surrounding a site, as well as influent stormwater quantity and quality [3]. According to the hydrogeological study of the Erzin-Dortyol plain by the general director of state water works [4], rocks such as conglomerate, sand, and gravel of different ages and structures form the lithology of the plain. Surface flow and rivers due to precipitation form the feeding of the plain and the discharge is rivers. While the aquifer flow direction tends from northeast to southwest, that is to the sea, it was determined that the permeability level of the alluvium in the middle part of the field is good. In the study conducted by Doyuran [5], it was stated that especially Pliocene and Quaternary aged rocks allowed the formation of free aquifers, and the hydraulic and hydrogeological conductivity of different formations varied. He emphasized that it has an important potential in terms of groundwater management.

Doyuran [6], in his study, determined that the feeding and discharge processes from the good hydrographs of 7 sample observation wells matched very well with the dry and rainy periods. He stated that the aquifer discharge is on the Mediterranean coastline and will not cause any problems in terms of operation. Çetin [7], in his study, examined the water change levels of the wells at the beginning and end of the season in the plain and emphasized that the wells where water is taken from the basalt layer are safer. Karahanoglu et al. [8], on the other hand, evaluated the freshwater-saltwater interference wedge with simulation, geophysical, hydro-geochemical analyzes and determined that there was no significant interference from the sea to the aquifer under current conditions. Examined the period of about 25 years between, Eroğlu [9] determined that the groundwater level was 100 m in the east and 5-6 m in the southwest by using the variables and criking method in the plain. Doygun et al. [10] determined the change in the land use/cover of the plain between 1972-2000 with the help of satellite images, aerial photographs and Geographic Information Systems (GIS), and determined that while dune vegetation, agricultural areas, coastal dunes, summer residences increased, swamp-reed areas decreased, respectively. suction. The general director of state water works [11] defined the plain soils as medium, heavy, partially light textured and prepared a land class and drainage report as non-irrigable and irrigable.

Aller et al. [12] developed a method called DRASTIC to detect the contamination potential of groundwater in any hydrogeological basin in the USA. This developed DRASTIC model has been used in many parts of the world to determine groundwater pollution and sensitivity. To briefly state the regions where the DRASTIC model is used in the world; Lynch et al. [13] in South Africa, Navulur and Engel [14] in India, Secunda et al. [15] in Sharon district of Israel, Osborn et al. [16], Oklahoma, Added et al. [17] in Tunisia, Demirkıran [18], in Ankara-Kazan region of Turkey, Al-Damat et al. [19], in Arcot region of India, Babiker et al. [20], in the

Kakamigahara mountains of Japan, Yıldırım [21] in Izmir-Bornova part of Turkey, Hamza et al. [22], in the north of Tunisia, in the metline coastal part, in Almasri [23], in the western part of Israel in the Gaza sher, Remasen [24], West Bengal (India) as in many parts of the world applied in many places.

Groundwater vulnerability assessment is a measure of potential groundwater contamination for areas of interest. The main objective of this study is to modify the original DRASTIC model using four objective methods, Weights-of-Evidence (WOE), Shannon Entropy (SE), Logistic Model Tree (LMT), and Bootstrap Aggregating (BA) to create a map of groundwater vulnerability for the Sari-Behshahr plain, Iran [25]. Our paper presents the possibility of applying the DRASTIC model as a useful tool to support the process of local and regional development planning. The results of the study revealed that the modified DRASTIC model gave more accurate predictions than the traditional model [26]. The objective of the study is to estimate groundwater vulnerability against contamination in Bhiwadi region of Rajasthan by applying Geographical Information System (GIS)-based DRASTIC model which considers seven hydrogeological parameters of an aquifer: depth to water (*D*), net recharge (*R*), aquifer media (*A*), soil media (*S*), topography (*T*), the impact of vadose zone (*I*), and hydraulic conductivity (*C*) [27]. In recent years, one of the major concerns is groundwater contamination by industrial wastewater. In this regard, a GIS-based DRASTIC model is used to delineate vulnerability to agricultural applications [28].

Thus, the DRASTIC model, which has been successfully applied in many parts of the world and offers satisfactory results in terms of application results, has been chosen as a suitable method to determine the sensitivity potential of the groundwater of the Erzin plain. In this study, the groundwater sensitivity of the Erzin Plain will be determined by processing the materials of the field with the help of various geostatistics and Geographic Information Systems (GIS) within the scope of the DRASTIC model.

## 2. Materials and Methods

### 2.1. Study Area

Working area; It is within the borders of the Mediterranean region of Turkey and covers an area of 101.65 $km^2$ in the river basin of the Asi River. The site is between the Amanos mountains and the Mediterranean in the east and northeast of the Iskenderun Bay, within the borders of the provinces of Hatay (Erzin, Dortyol districts) and Osmaniye (Toprakkale district), 36°45'-37°01' north latitudes and 36°03'-36°46' It is located between eastern longitudes (Figure 1).

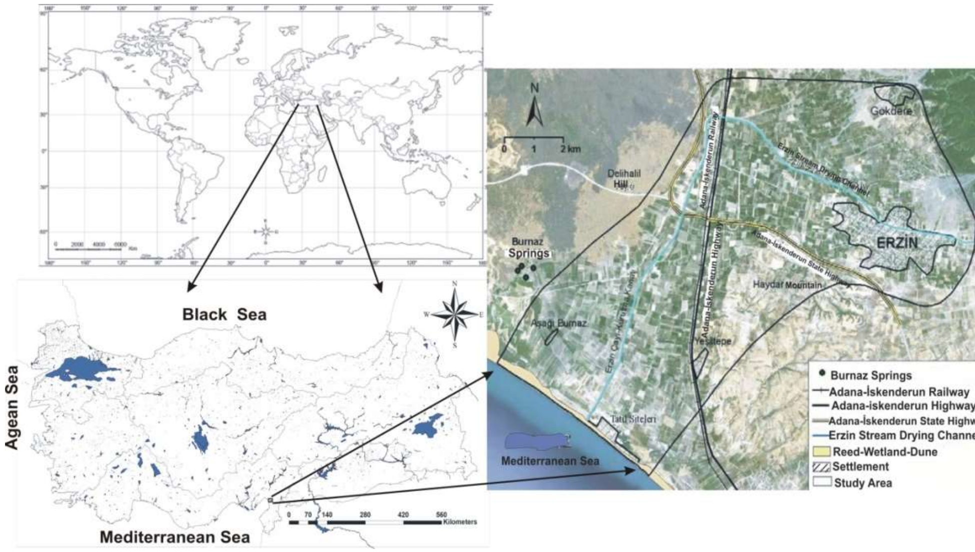


**Figure 1.** Study's Location

Erzin Plain is bordered by Delilhalil Hill (450 m), Hama Hill (182 m), Haydar Mountain (226 m) in the north-northwest, Amanos Mountains in the east, and the Mediterranean coastline in the west and south (Figure 1).

## 2.2. Material

General geographical characteristics of the research area (Figure 1), topography (Dem), climate (Table 1) and hydrological characteristics, soil characteristics and agricultural situation (Table 2), geological and hydrogeological characteristics, land use characteristics, GW observation data, GW depth data and GW quality data constitute the materials of the research area.

**Table 1.** Climate Data of the Study Area (Precipitation (1951-2002), Average Temperature (1951-2023), Highest Temperature (1987-2003), Lowest Temperature (1987-2003), Average Total Evaporation (1971 -2004), Humidity (1987-2003), Wind Speed (1987-2002), [29] (It was benefited)

| Climate Data | Months | | | | | | | | | | | | Annual |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | |
| Average Total Precipitation (mm) | 116.2 | 115.0 | 106.7 | 98.1 | 67.5 | 29.0 | 17.2 | 12.5 | 31.3 | 74.3 | 98.7 | 122.2 | 888.7 |
| Average Temperature (ºC) | 8.7 | 9.8 | 12.9 | 17.1 | 20.7 | 24.4 | 27.1 | 27.6 | 25.3 | 21.1 | 14.4 | 10.2 | 18.3 |
| Highest Temperature (ºC) | 22.1 | 26.0 | 29.0 | 36.0 | 41.6 | 40.8 | 40.7 | 42.2 | 41.8 | 38.0 | 31.6 | 23.6 | 42.2 |
| Lowest Temperature (ºC) | -5.0 | -5.3 | -2.2 | 0.6 | 7.0 | 13.3 | 16.6 | 16.1 | 9.6 | 7.0 | -1.6 | -3.4 | -5.3 |
| Average Total Evaporation (mm) | 34.9 | 46.7 | 75.4 | 101.9 | 136.9 | 165.5 | 189.3 | 187.4 | 150.4 | 104.3 | 55.0 | 35.0 | 1267.1 |
| Average Month Ratio Humidity (%) | 58 | 56 | 56 | 58 | 58 | 58 | 61 | 59 | 52 | 50 | 56 | 62 | 57 |
| Average Wind Speed (m/sn) | 2.0 | 2.1 | 2.1 | 2.0 | 2.0 | 2.0 | 1.8 | 1.7 | 1.9 | 1.9 | 2.0 | 1.9 | 1.9 |

Table 2 as seen as below, shows soil and plant patterns, areas and ratios of the research area.

**Table 2.** Soil and Plant Patterns, Areas and Ratios of the Research Area [29], (It was benefited PhD Thesis)

| Large Soil Group | Symbol | Area (Hectares) | % |
|---|---|---|---|
| Alluvial Soils | A | 4633.4 | 48 |
| Colluvial Soils | C | 3207.4 | 33 |
| Hydromorphic Soils | H | 479.8 | 5 |
| Brown Soils | B | 1040.7 | 11 |
| Non-Calcareous Brown Soils | N | 95.6 | 1 |
| Basaltic Soils | B | 161.8 | 2 |
| **Plant Type** | **Planting Rate (%)** | **Yield(kg/da)** | |
| Citrus | 68 | 3000 | |
| Cereals | 22 | 350 | |
| Vegetables | 5 | 3500 | |
| Onions | 2 | 3000 | |
| Peanuts | 2 | 300 | |
| Cucumbers | 1 | 3500 | |
| Corn (2nd Product) | 5 | 700 | |

## 2.3. Method

In the study; Geography Information System (GIS), Remote Sensing (RS), Geography Information System (GIS)-based DRASTIC model and model parameters (GW Depth, GW Recharge amount, Aquifer, soil, topography, vadose zone materials, hydraulic conductivity, Drastic Index (DI), data analysis and mapping (hydrogeochemical analysis, Geostatistical analysis) are the methods used (Figure 2).

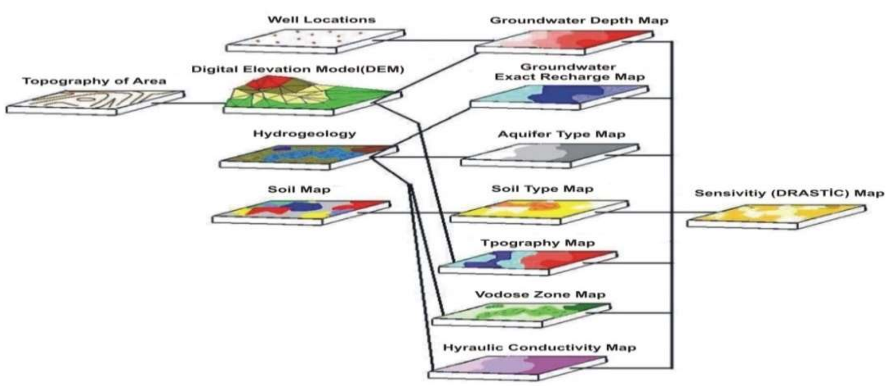


**Figure 2.** Representation of DRASTIC (D: depth to water, R: net recharge, A: aquifer, S: soil, T: topography, I: the impact of vadose, C: hydraulic conductivity) Model Parameters Flow Chart [29], It was benefited the PhD Thesis)

## 3. Results and Discussion

### 3.1. Geostatistical Analysis Result

The GW depth and quality (*EC* and $NO_3$) observation results of the observed boreholes were mapped by geostatistical method. As a result, seasonal and annual GW isomorphic maps and GW *EC* and $NO_3$ distribution maps were developed.

### 3.1.1. Seasonal and annual GW peer level in erzin plain

Erzin Plain is located at a certain angle with the north due to its location. For this reason, experimental semivariograms depending on the Euclidean distance of the GW wells in the study area were created by considering the 45° direction in order to create the GW isometric maps. By taking the angle tolerance of 90°, maximum sample pairs were tried to be analyzed. Bandwidth was kept at 0.5 level in order to clearly see the semivariogram patterns of the GW elevation variable. It was decided that the experimental semivariogram structures of the GW elevation variable were suitable for the spherical type theoretical semivariogram model [29]. Eroğlu [9] applied geostatistical analysis to the GW elevation values obtained from the general directorate of state hydraulic works reports in order to develop the Erzin Plain GW isometric map, and used the GAS data to the Gaussian semivariogram model. After the semivariogram model parameters were determined, the point values of the regions without observation were obtained by the Criging estimation method [29]. According to these results; In the period of August 2006, while the GW elevation values around Erzin and Gokdere settlements are 75-104 m, it is at zero (0) elevation, that is, at sea level, around Aşagı Burnaz and resort sites (Figure 4). It even falls below sea level. It can be thought that this situation is caused by the GW shots in June, July and August (Figure 3). In the period of November 2006, it was determined that there was an increase in the levels of GW with the end of the irrigation period and the beginning of the precipitation at the same time (Figure 3). In the period of February 2007, while the level of the groundwater increased from the southwest to the northeast of the field in accordance with the topography level, it was observed that it decreased to -1.3 m below the sea level in the areas close to the sea. This may be due to GW withdrawals or measurement errors [29]. In the period of May 2007, the GW elevation changes in accordance with the topography and is below the sea level around the Aşagı Burnaz settlement (Figure 3).

In summary, the fact that the south of Aşagı Burnaz settlement falls below the sea level in an area of approximately 10-15 $km^2$ according to the GW equivalent levels for the August, February and May periods supports the idea of a level error in the maps created based on the digital elevation model [29].

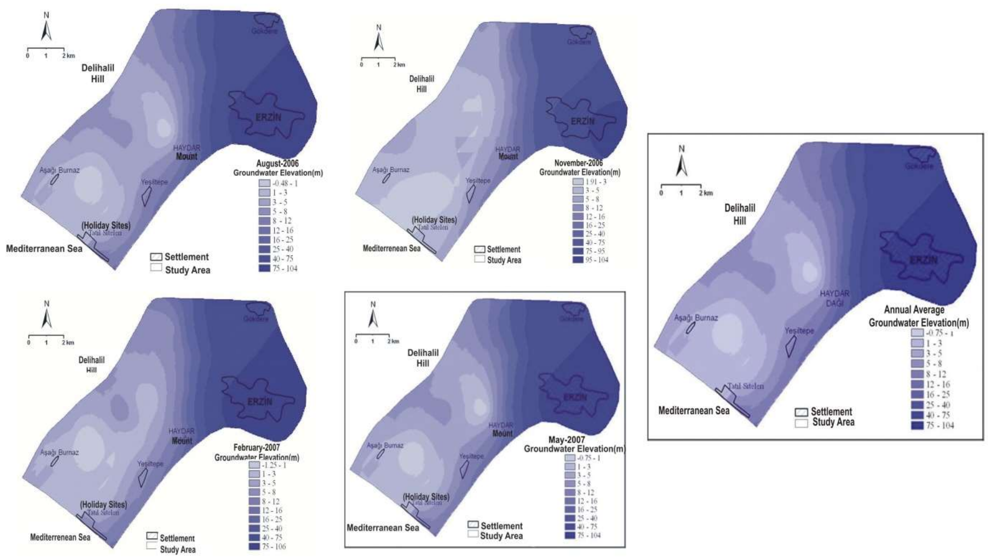


**Figure 3.** August-2006, November-2006, February-2007, May-2007, Annual Average GW Equivalent Maps [29], It was benefited from PhD thesis)

### 3.1.2. Seasonal GW EC and $NO_3$ distribution Maps

Spatial distribution maps of salinity (EC) and nitrate ($NO_3$) concentrations, which are observed seasonally for 4 periods in the study area, were produced by geostatistical method.

According to the August 2006 period, GW EC distribution, high EC values (1.53 - 1.63 dS $m^{-1}$) were obtained near Yesiltepe settlement. While EC values are at the level of 0.73 - 0.85 dS $m^{-1}$ in the northern parts of the field, it is understood that the GW EC distribution in the November 2006 period increased from the land to the sea, but was lower in the study area compared to the August 2006 period. Low EC values at the level of 0.63 – 0.69 dS $m^{-1}$ (Class II irrigation water) are observed around wells 12845 and 8340. In the Cerrahoglu Farm well, the values of 1.05 dS $m^{-1}$ and 0.97 dS $m^{-1}$ and 46814 numbered wells were observed to be the highest in November. The lowest EC values were found in wells 8340 and 12845 (0.57 – 0.66 dS $m^{-1}$) in the north of the study area (Figure 4).

According to the GW EC distribution for the period of February 2007, the highest EC values determined in the study area were observed in the well no 10434 with 2.3 dS $m^{-1}$ in the four seasons GW sampling. It has been determined by Piper and Schoeller diagrams that the water in this well is different from other wells and has a different origin (Figure 4). The reason for the low EC values in the northern parts of the study area is interpreted as the dilution of the groundwater salinity with the effect of precipitation in the regions where the groundwater table is deep, and thus the decrease in the EC values.

During May 2007, EC values were high in the south and southeast, similar to the EC distribution of August 2006 and February 2007; It was observed that it was low in the northern parts. In the southern parts of the study area, high EC values are observed. It was observed that the EC values were low (0.703 – 1.51 dS $m^{-1}$) throughout the study area due to the relatively low EC values towards the north and the effect of precipitation compared to other periods (Figure 4).

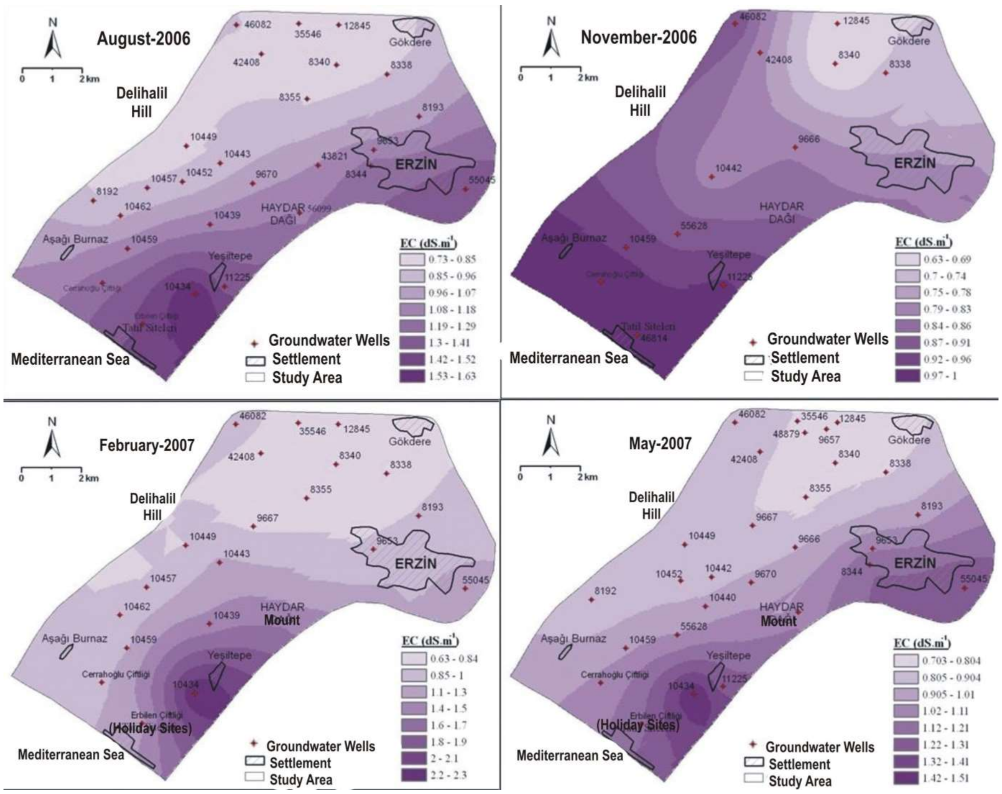


**Figure 4.** August-2006, November-2006, February-2007, May-2007 GW EC Distribution Maps, [29], (It was benefited from PhD thesis)

In the distribution of GW $NO_3$ in the study area for the period of August 2006, high $NO_3$ concentrations were observed with values of 13.29 mg $L^{-1}$ in well 10457 and 14.62 mg $L^{-1}$ in well 10462 in the middle parts of the study area. In addition, the $NO_3$ value measured in the well no. 9653 in the Erzin settlement is 16.17 mg $L^{-1}$. In the period of November 2006, higher $NO_3$ values were observed in the north of the field compared to the south, while in February, it was similarly high in the northern parts; It shows a low distribution in the southern parts. $NO_3$ value varies between 0.5 – 12 mg $L^{-1}$ (Figure 5).

In the period of May 2007, the highest $NO_3$ value with 15.95 mg $L^{-1}$ is seen in the well no. 10449 in the middle part of the field. The lowest $NO_3$ value of 0.31 mg $L^{-1}$ was found in well no 11225, located in the southeast of the study area (Figure 5). According to DWS 266 drinking water standards (DWS)-2005, it is seen that it is not at dangerous levels in terms of drinking water standards. It is observed that GW $NO_3$ concentrations are generally high, especially in regions where citrus cultivation is intense and soil layer is permeable.

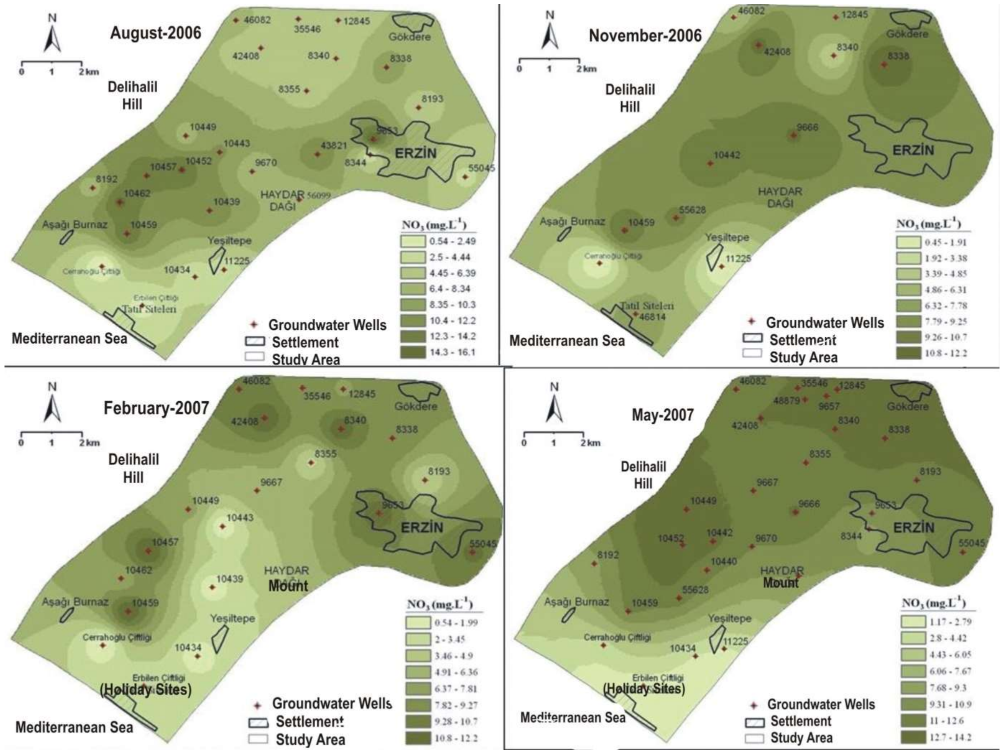


**Figure 5.** $NO_3$ Distribution Maps for August-2006, November-2006, February-2007, May-2007 Periods, [29], (It was benefited from PhD thesis)

### 3.1.3. Land Use (LU) and Groundwater Sensitivity (GWS) of Erzin plain

Land use in the Erzin plain has significant effects on groundwater sensitivity. Because in any stream basin or plain; It plays an important role in the contamination of groundwater in all sectoral activities from agriculture to settlement, from settlement to industry. In the Erzin plain, groundwater sensitivity was tried to be determined by integrating the land use characteristics of the field into the DRASTIC model. Accordingly, based on the studies of Secunda et al. [15] and Al-Adamat et al. [19], a weighted land use map was created by first classifying the land use parameters and assigning values, in order to determine the effect on the sensitivity of the groundwater. This weighted sensitivity map was integrated into geographic information systems and a corrected annual GW sensitivity map was produced (Figure 6B).

Comparing the annual GW sensitivity Drastic İndex (DI) map with the corrected annual GW sensitivity map, it is understood that the sensitivity areas on the corrected annual GW sensitivity map show an increase compared to those on the DI map. In particular, while 49% of the study area was low sensitivity in the DI map, the low sensitivity area in the corrected annual GW sensitivity map decreased to 2.6%, on the other hand, there was a 24% increase from the DI map to the corrected annual GW sensitivity map in the medium sensitivity area. The most striking difference between the DI map and the corrected annual GW sensitivity map; Although the very high sensitivity area was seen in an area of 2.9 $km^2$ on the DI map, the very high sensitivity area on the corrected annual GW sensitivity map increased to 21.9 $km^2$ with an increase of 18.7%.

Areas with low pollution potential were included in medium, high and very high areas with the correction made. Therefore, a more realistic distribution is obtained (Figure 6).

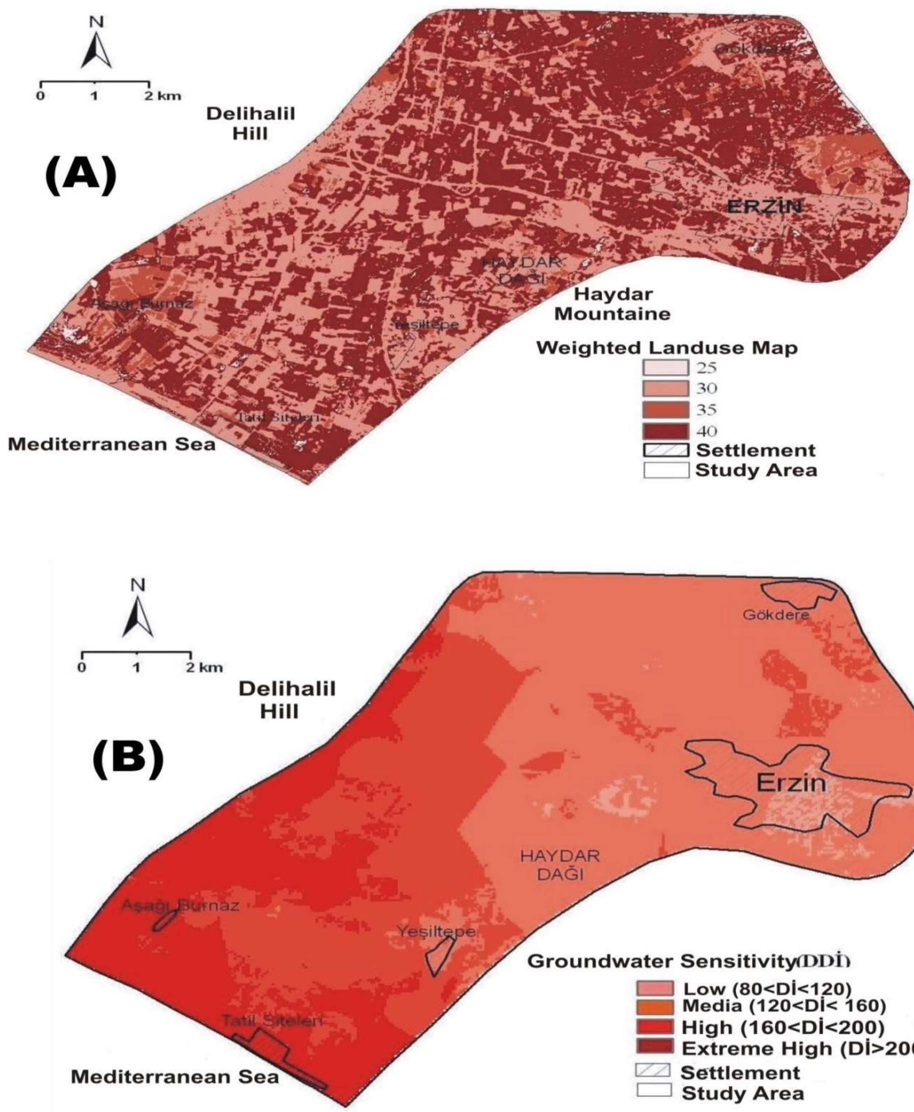


**Figure 6.** Weighted Land Use (A) and Corrected Annual GW Sensitivity (B) Map, [29], (It was benefited from PhD thesis)

## 4. Conclusions

According to the above-mentioned findings and discussions, the following conclusions have been reached in Erzin Plain and its surroundings. According to this, while the GW elevation is 75-104 m around Erzin and Gokdere settlements in the seasonal GW isometric maps for the periods of 1-August 2006, November 2006, February 2007 and May 2007, it reaches 0 elevation on the Mediterranean coast near the Aşagı Burnaz settlement and holiday sites level was determined. Again, in these periods, it was determined that the GW elevation took negative values in the areas close to the sea, that is, the GW level fell below the sea level.

It has been determined that the values vary between 0.45-16.1 mg $L^{-1}$ according to seasonal GW $NO_3$ distribution, it is suitable for irrigation water supply, and It was obtained that these concentrations are not at dangerous levels according to DWS 266 drinking water standards (DWS).

In the corrected annual groundwater sensitivity map, it has been determined that there is an increase in the degree of groundwater vulnerability and areas with the effect of land use. It was determined that while 3% of the study area in the 4-Drastic Index map was a very high GW sensitivity area, a very high GW sensitivity area increased sevenfold in the corrected GW sensitivity map. It can be argued that it is important to develop 5-Corrected annual GW sensitivity maps and that it is a correct approach to detect consistent groundwater sensitivity by integrating the real land use situation onto the groundwater sensitivity.

### Abbreviations

GIS: Geography Information System, GW: Groundwater, DWS: Drinking Water Standards, DI: Drastic Index, GWS: Groundwater Sensitivity, EC: Electrical Conductivity, $NO_3$: Nitrate, RS: Remote Sensing, *DRASTIC* Parameters: (*D*) depth to water, (*R*) net recharge, (*A*) aquifer media, (*S*) soil media, (*T*) topography, (*I*) the impact of vadose zone, (*C*) hydraulic conductivity.

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