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# Usability of Shallow Groundwater in Irrigated Agriculture: A Case Study From Turkey

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**Abstract:** Controlled drainage supports to save fresh water by providing part of the consumptive use through the capillary rise from shallow water tables. However while using groundwater, monitoring water table level (WTL) during irrigation season is required in terms of plant growth and environmental conditions. Ground water conditions can best be analysed by plotting ground water data on maps. WTL maps (WTMs) are prepared for some typical conditions e.g. the lowest or highest WTL dependent time and location. In the lowest water table map (LWTM), the areas with WTL at a depth between 0 and 1.00 m indicate that ground water is in the plant root zone in all year. In the present study, relationship between ground water level and irrigation water quantity (IWQ) tried to be determined using LWTMs and yearly amount of IWQ between 1992 and 2009 water years in Erzincan irrigation project area. The monthly data taken from 116 observation wells are used to draw LWTM to determine the interaction between WTL and IWQ, and then the long–term data were analysed using Pearson Correlation test and SPSSWIN 10.0 software. Statistical inferences indicated that shallow ground water is potentially valuable source of additional water supply to meet crop water requirements in Erzincan irrigation area.

**Keywords:** Shallow Groundwater, Water Saving, Watertable, Irrigation Practices, SPSSWIN

## Introduction

National governments, research institutes, farmers' organizations, private agencies and many organizations like ICID (International Commission on Irrigation and Drainage) are focusing their efforts in developing and applying various water saving measures. In this context the idea of controlled drainage and shallow drainage has been developed. Controlled drainage supports to save fresh water by providing part of the consumptive use through the capillary rise from shallow water tables. Shallow ground water is considered as a resource to meet crop water demands for supplemental irrigation depending on the crop and shallow ground water quality, appropriate techniques are used with varying degrees of success and there are management challenges associated with each method (Ayars et al., 2006).

Thinking of controlled drainage and shallow drainage developed aims to prevent excessive drainage and benefit more from ground water. A lot of work in the world shows that plants benefit from the significant amount of ground water.

Many studies have been done to show that in situation of exploiting of ground water will be needed less irrigation water in the period when water consumption reach the peak level.

In field studies, Grimes and Henderson (1984) are reported that the use of shallow saline ground water is a function of depth and salt content and taking of water provided from ground water at a rate of %14-45 for alfalfa and %27-60 for cotton.

Kruse et all.(1985), in a study at lysimeter, are reported that corn provided water requirement from ground water which salinity is 6.0 $dSm^{-1}$ and depth is 0.6 m at a rate of %55. Also, Meyer et all. (1996) notice that alfalfa provided water requirement from ground water which depth is 0.6 m at a rate of % 13-55 according to soil type and water salinity.

Nwadukwe et al. (1989) are reported that the one-week irrigation frequency gave significantly higher root length density and fruit yield than the other irrigation frequencies at the deep water table location. And at the shallow water table location the two-week irrigation frequency gave higher fruit yield than the one- and three-week irrigation frequencies. There was a significant positive correlation between root length density and fruit yield.

In the model study, was used to simulate several theoretical and experimental situations for forage corn, Torres and Hanks (1989) showed that the production function reaches an optimal yield when the best combination of soil, air and water is obtained. Capillary rise has a negative effect on yield, at high irrigation level. At low irrigation level, the best combination of air and water was obtained when ground water table depth was about 1 m below surface.

To determine the relationship between ground water level and irrigation practice; is a need to know fluctuations in water table during the irrigation season and changes in water table levels on long-term courses from the beginning of the irrigation works.

Controlled drainage makes it possible to vary the drainage intensity with the variation in drainage requirement during irrigation season by controlling the height of a riser in the drain outlet. During periods with low drainage demand, the riser in the drain outlet can be raised and the watertable level in field will rise up to the level of the riser before the discharge takes place (Wesström, 2001).

Water table maps should be prepared in order to determine the distribution of water table levels and salinity for time and location and its horizontal and vertical move. WTMs are prepared for some typical conditions e.g. the lowest or highest WTL dependent time and location (Mahajan, 2008). These maps are depth to lowest water table maps; depth to highest water table maps, depth to map irrigation is maximum and water table salinity map. With this distribution maps were compared and evaluated based upon irrigation water quality, soil salinity and crop patterns.

The soil salinity is highest in the lowest water table level. Upon entry irrigation water or rainfall into the soil, while salinity decrease water table level starts to rise again (Smedema and Rycroft, 1983).

In this study, the relationship between ground water level and amount of water used in irrigation has been determined to by benefiting from spatial distribution of the data of depth to lowest water table maps of Erzincan irrigation Project area water-years for 1992-2009 and yearly amount of water used in irrigation.

## Materials and Methods

### *Location*

Part of 10723 ha of Erzincan irrigation project was selected as research area which gradually drained and allowed for irrigation by the State Hydraulic Works since 1964. Research area is situated in the left bank of the Euphrates River. Irrigation area is located between 39º 30' – 40º 00' East latitude and 39º 25'-39º 44' north longitude. The average altitude of irrigation area is 1100 meters.

### *Climatic features*

Continental climate type is prevalent in the study area. Winters are hard end cold, summers are hot. Springs are rainy, summers are dry. According to long-term meteorological data (1926-2017), annual mean temperature, total annual precipitation averages and mean sunshine duration are 10.9 ºC, 373.5 $kg/m^2$ and 81 hour, respectively (DMI, 2017).

### *Water sources and availability of irrigation*

Irrigation practices were started gradually in 1967 as a stage in the field of research. Water sources of the study area are Kom stream and Left Bank main canal deriving water from the Euphrates. With Şıhlı regulator have been made on Kom stream are taken into area 1.783 $m^3$ of water per second (Topraksu, 1984). The capacity of left bank main canal that is other water source of research area is 3,950 $m^3sec^{-1}$ in upstream and is 0,146 $m^3sec^{-1}$ in downstream. Irrigation water is taken from the streams during periods of insufficient water in the area. In the year 2009 irrigation season, was determined as irrigation rate of 44%, irrigation productivity of 1% (DSI, 2010).

***Drainage systems***

In the study area introduced into irrigation step by step classic open drainage system was established together with the irrigation network. Construction of the closed drainage system, on the other hand, started in 1980's and has been taken into operation segment by segment. Open drainage systems are composing of the main drainage channels and in connection with this gatherer and tertiary drainage channels and surface drainage channels. Left bank main drainage channel is 22 062 m in length and connected to Euphrates rivers. Natural drainage channels are connected in the main drainage channel in upstream of the channel. There is collecting drainage channels associated with these drainage channels. Small streams are discharged to left bank main drainage channel. Depth of main drainage channel is 2.50-3.00 m in downstream. Depth of their tertiary drainage channels ranged from 1.20 to 1.50 meters. Also, after start of irrigation where needed the surface drainage channels are opened in parallel with the tertiary irrigation channels.

Surface drainage network systems consist of discharge and collector canals linked with secondary drainage canals. Secondary creeks flow into main discharge canal. Main discharge depth ranges from 2.50 to 3.00 m in the lower parts while the depth of collector and secondary discharge canals are 1.20 to 1.50 m. In addition to secondary canals needed after the opening of the irrigation facility, there are also surface drainage canals. Drains consisting of subsurface drainage network are concrete pipes lain under the surface. Depth of the drains ranges from 1.5 to 2.0 m. Inner radius of the drains ranges from 16 cm to 20 cm. Drainage constant for the study area is 0.0017 m $day^{-1}$ and the distance between subsurface drains in the fields is between 100 and 120 m (Topraksu, 1984).

***Soil features***

Periodic floods played a role in the soil formation of research area. Plain soil is alluvial and colluvial soil that has formed sediments brought by runoff water and its depth is moderate.

***Vegetation***

Cropping pattern mainly consists of wheat, beans and sugar beet in the research area. And vegetables and fruits are also grown. Some crops grown in Turkey and their optimal levels of water table as Table 1. (Güngör and Erözel, 1994).

Table1. Optimal levels of water table for different crops in Turkey

| Plant species | Depth to watertable (cm) |
|---|---|
| Wheat | 140 |
| Barley | 100 |
| Coton | 90 |
| Sugar Beet | 80 |
| Corn | 90 |
| Alfalfa | 100 |
| Tomatoes | 75 |

***Analysis and evaluation methods***

The most important factor in increasing soil salinity is the rise of saline water table. After the rise of ground water with capillarity, is composed of accumulation of salts in the soil with evaporation and transpiration. High salt content of water table near the soil surface in the case, there is the possibility that evaporation, salinization is inevitable.

Ground water conditions can best be analysed by plotting ground water data on maps. Water table maps are drawn to monitor the changes in water table level and groundwater quality. These maps are depth to lowest water table maps; depth to highest water table maps, depth to map irrigation is maximum and water table salinity map. By the way of LWTM, changes that take place in the groundwater are evaluated with the critic values at which groundwater depth is the lowest (DSI, 2005). LWTMs are obtained by taking the lowest groundwater values measured from each well during the irrigation season (Akkaya and Gundogdu, 2007). In LWTM, the areas with WT at a depth between 0 and 1.00 m indicate that ground water is in the plant root zone in all year.

While monitoring of water table, water table observation wells are utilized. In De Ridder (1994) are indicated that will be needed the 100 observation wells for the field size of 10,000 ha and 300 observation wells for the field size of 100,000 ha. There are 116 observation wells in the field of research. In the study, 1992-2009 watertable reports which are provided by DSI (General Directorate of State Hydraulic Works) are used. *ArcGIS* Software is usedin formed the LWTM and salinity maps that are used for basic layer, developing *TIN* (triangulated irregular network) for each year. In the study, for determine the effect of the water table level depth on the amount of used water for irrigation, SPSSWIN 10.0 statistical software was used. As an independent variable, spatial distrubution of different depth on the LWTMs and as a dependent variable, the amounts of water used in irrigation are also used. After the transfer of the data to digital data form, *t* test was performed to interaction between the water table level and the quantity of water used in irrigation by using SPSSWIN program.

***Results and Discussion***

In this study, the relationship between water table level and used water in irrigation is determined by using long annual data. For this purpose, it was used to LWTMs created for each year. The LWTM map created for the year of 2009 developing TIN model in ArcGIS is shown Figur 1. Finally, all data was analysed by Pearson Correlation test using the SPSSWIN 10.0 program. The result of Pearson correlation analysis of the dependency between the used water for irrigation and the spatial distributions of watertable depth to 0- 0.5 m, 0.5-1 m and 1-2 m is given in Table 2 where N shows the number of years when study of analysis was done.

Table 2. Results of Statistical Analysis between the used water for irrigation and the spatial distributions of WT depths.

| Statistical Parameters | | | |
|---|---|---|---|
| Depth (m) | N | Pearson Correlation | Significant(2-tailed) |
| 0.0-0.5 | 18 | -0.549 | 0.018 |
| 0.5-1.0 | 18 | -0.741 | 0.000 |
| 1.0-2.0 | 18 | 0.594 | 0.009(0.01) |

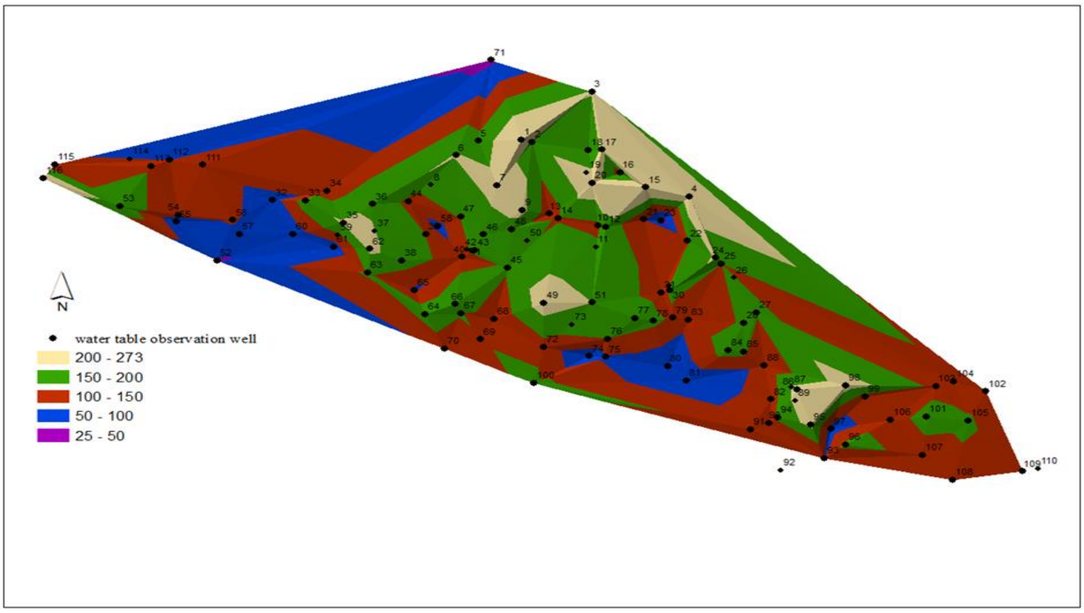


Figure 1. LWTM for the year of 2009 (spatial distribution water table depth as cm)

According to the result of analyses, between the amounts of irrigation water and surface width where water table is 0-0.5 m in depth a significant negative relation has been determined. So, correlation is significant at the 0.05 level (2-tailed). This situation indicated that there is significant decreasing the amount of water used in irrigation with increasing areas of water table level becoming near to the surface.

Also, as seen from Table 2., between the amounts of irrigation water and location where water table is 0.5-1 m in depth a very significant negative relation has been determined. In this case, correlation is very significant at the 0,01 level (2-tailed).

On the contrary, between the amounts of irrigation water and location where water table is 1-2 m in depth a significant positive relation has been determined according to statistical analysis results such that correlation is very significant at the level of 0.01. If water table falls below the effective root depth of plants, there will very significant increasing in amount of used water irrigation.

The results of spatial distribution obtained from salinity maps were drawn by using the results of the analysis of water samples were taken from the water table observation wells in august each year, during the study period (1992-2009), is also given in Table 3. The data of salinity (EC) obtained from DSİ reports. The salinity map developing with TIN model by using created these date for measuring spatial salinity distribution for the year 2009 has shown in Figure 2.

Table 3. The spatial distribution of water table salinity maps (ha, %)

| | Watertable Salinity Class ($dSm^{-1}$) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 0-0.250 | | 0.250-0.500 | | 0.500-0.750 | | 0.750-1 | | >1 | |
| Years | ha | % | ha | % | ha | % | ha | % | ha | % |
| 1992 | 9103 | 84.89 | 1309 | 12.21 | 282 | 2.63 | 29 | 0.02 | - | - |
| 1993 | 9920 | 92.51 | 803 | 7.49 | - | - | - | - | - | - |
| 1994 | 10268 | 95.76 | 455 | 4.24 | - | - | - | - | - | - |
| 1995 | 10201 | 95.13 | 522 | 4.87 | - | - | - | - | - | - |
| 1996 | 10654 | 99.36 | 69 | 0.64 | - | - | - | - | - | - |
| 1997 | 10580 | 98.67 | 143 | 1.33 | - | - | - | - | - | - |
| 1998 | 10580 | 98.67 | 143 | 1.33 | - | - | - | - | - | - |
| 1999 | 10594 | 98.80 | 129 | 1.20 | - | - | - | - | - | - |
| 2000 | 10586 | 98.72 | 137 | 1.28 | - | - | - | - | - | - |
| 2001 | 10710 | 99.88 | 13 | 0.12 | - | - | - | - | - | - |
| 2002 | 10196 | 95.09 | 478 | 4.46 | 48 | 0.45 | - | - | - | - |
| 2003 | 9937 | 92.67 | 710 | 6.62 | 76 | 0.71 | - | 0.01 | - | - |
| 2004 | 9653 | 90.02 | 985 | 9.19 | 59 | 0.55 | 26 | 0.01 | - | - |
| 2005 | 10014 | 93.39 | 455 | 4.24 | 103 | 0.96 | 124 | 0.01 | 27 | 0.25 |
| 2006 | 10570 | 98.57 | 153 | 1.43 | - | - | - | - | - | - |
| 2007 | 10651 | 99.33 | 72 | 0.67 | - | - | - | - | - | - |
| 2008 | 9965 | 92.93 | 746 | 6.96 | 12 | 0.11 | - | - | - | - |
| 2009 | 10541 | 98.30 | 90 | 0.84 | 92 | 0.86 | - | 0.01 | - | - |

As shown, in important part of research area, according to the US Salinity Laboratory Classification for irrigation water, ground water has been determined as Low-salinity water (C1) (EC less than 0.250 $dSm^{-1}$). Low-salinity water (C1) can be used for irrigation with most crops on most soils with little likelihood that soil salinity will develop. The low salinity of ground water, to provide less salt accumulation on the soil surface with evaporation. Few years, in a proportionately much smaller areas, medium-salinity water (C2)( EC, 0.250-0.750 $dSm^{-1}$) and high-salinity water (C3)( EC, 0.75-2.25 $dSm^{-1}$) in class were found in water. If water is medium-salinity, plants with moderate salt-tolerance can be grown in most cases without special practices for salinity control.

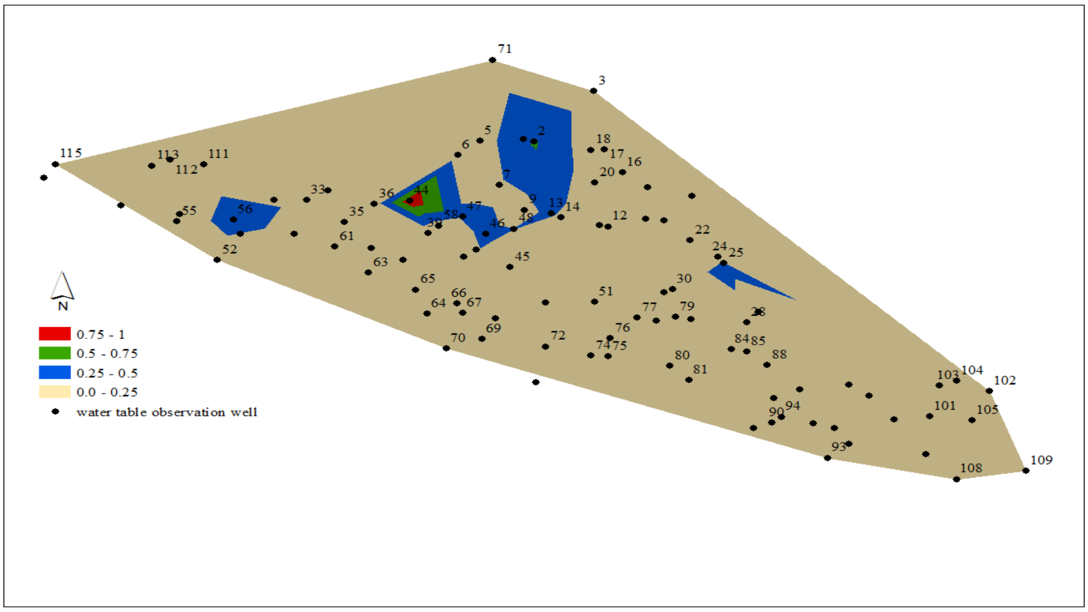


Figure 2. Salinity map for the year of 2009 (spatial distribution EC, $dSm^{-1}$)

High-salinity water (C3) cannot be used on soils with restricted drainage. Even with adequate drainage, special management for salinity control may be required and plants with good salt tolerance should be selected. In the research area, there is no problem in terms of water quality. These results indicate that plant's water consumption and intake has increased in irrigated area, if the water table falls below 1 m. The plants benefit from ground water at the most, if the water table locates between 0.5-1 m. In the situation that the water table level is between 0,5-1.00 m., plant roots better develop downward. So, the better development of the roots, provide better water intake from ground water.

In this case, irrigation water quality should be taken into consideration. However, high water table level will cause decay of the plant's roots, therefore should not be permitted to access this level which changes for different plants as seen Table 1. Also, while determining the permissible depth of water table, should not be ignored the fact that will be salt accumulation on the soil surface by evaporation.

**Conclusion**

The decreasing of used water in irrigation with increasing of areas of the lowest depth of water table level becoming near to the surface in a year in the other words as the water table approches the soil surface, shows that ground water is used in supplying of water requirement to plants. İn this situation, in order to normal development of plants, is required that water table level is below the effective root dept. However, with carefully planned and managed water table management systems, can be provided that plants to take advantage of ground water do not contain much salt in certain levels.

It is very important that, while using groundwater, monitoring water table level during irrigation season is required in terms of plant growth and environmental conditions.

With the right balance of water, water table can be controlled. With providing a good water balance, the salinity problem will disappear (Smedema, 1990). For providing a good water balance, amounts of water rising from high water table with capillarity should be taken into consideration in making the irrigation program.

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