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Productivity analysis based on fuzzy logic on paddy area irrigated by varied water sources

B. Aydin and Y. Ahi*
Water Management Institute, Ankara University, 06135 Ankara, Turkey
* *e-mail: ysmahi@ankara.edu.tr*

Abstract: This study aims to determine the quality of water resources used in four paddy areas selected in Meriç-Ergene Basin of Turkey and find out the effects of these waters on soil productivity using Fuzzy Logic which have recently been used both in Turkey and in the world. Primarily, quality parameters of different water resources which are the water from River Ergene, ground water, the water from River Meriç and dam lake water were determined and analyzed in the running of the model. Changes in the properties of water resources are modeled and interpreted in terms of soil productivity with Fuzzy logic. Chemical analysis of samples obtained from water resources examined in the study is done according to standard methods. In the analysis of water samples saltiness (EC, pH, Na), trace element (Mn, Zn, Fe, Cu), and heavy metal (Pb, As, Cd, Ni, Cr, Co) parameters were examined. In the model, these parameters which directly effects soil productivity are considered as input variables, and productivity is considered as output variable. Soil productivity profiles (%) of the region consisting different soil types have been determined by obtaining the fuzzy values related to these parameters. Soil productivity values differ between 40-60%. According to the obtained results; it can be said that Fuzzy Logic model which is used in many sciences should be useful in agricultural field studies.

Key words: Fuzzy logic, water quality, macro and micro elements, modelling

1. INTRODUCTION

In many parts of the world, factors such as rapid population growth and migration (approximately 400,000 people every year), misuse of land, disorganized structuring within drainage basins, industrial consumption (ground water consumption, transferring of untreated waste water to water sources), excessive use of fertilizers and pesticides in agriculture as well as climatic changes are threatening water sources. In Thrace region, especially the Meriç-Ergene basin which covers 14,657 km^2 of land, water and therefore soil sources are getting increasingly poorer in terms of both quality and quantity. The quality of soil, depending also on the type of plant production, is changing day by day.

It is necessary that we, first of all, ensure water and soil and therefore food production in sufficient quality and amount. Within this scope, it is a must that we define, protect and improve the conditions of the region we inhabit. The most important surface water sources of Meriç-Ergene basin, one of the 25 basins in Turkey, are River Meriç and River Ergene and their arms. Basin area consists of 11,000 km^2 and total water potential is 1.71 billion m^3/year. Total ground water reserve in the Ergene basin is 0.376 billion m^3/year (Anonymous, 2015). The basin contains approximately 1.24 million hectares of cultivable agricultural land and 1.05 million hectares of this area is irrigable. The terrain in this basin provides approximately 50% of the country's rice production. Using up most of agricultural water, the rice plant is cultivated under water throughout the season or under saturated conditions. Under constant water load conditions, the quality of water being used causes an additional burden on soil and produce quality.

In this study; it is aimed that the quality of different water sources used on 4 different rice production fields within the Meriç-Ergene basin is determined and that the complex conclusions arrived at in explaining their effects on soil productivity, are cleared by way of using any one of the fuzzy logic models. To this end, it is aimed that a fuzzy logic model that has been used in many recent agricultural studies carried out both within and outside of our country (McBratney and Odeh, 1997; Mitra et al., 1998; Chang et al., 2001; Altunkaynak et al., 2005; Lermontov et al., 2009; Duru et al., 2010; Karadavut and Akkaptan, 2012; Gharibi et al., 2012; Ambuel et al., 2013; Dökmen and Aslan, 2013) be used.

The notion of fuzzy logic was first suggested by Lotfi A. Zadeh (1965), by way of expressing some ambigous expressions mathematically. It is based on the Fuzzy Set Theory by which the true and false values are determined. There is again the values of (1) and (0) here, as in traditional logic. However, fuzzy logic goes beyond these values and by making use of intermediate values, tells us, for example, not only if a certain distance is far or near, but also how far or near it is (Odabaş et al., 2009). In this context, with the use of Fuzzy Logic model, complex conclusions derived of various parameters were evaluated all together.

2. MATERIAL AND METHODS

2.1 Material

The research was carried out throughout the 2015-2016 cultivation season, on four different rice plant fields within the Meriç-Ergene basin, which are Uzunköprü-Merkez, Aslıhan, Eskiköy and Delibedir, and with 4 different water sources which are respectively the water from River Ergene, ground water, the water from River Meriç and dam lake water.

The soil in Aslıhan and Eskiköy research area is in general sandy, whereas the soil in Eskiköy and Delibedir research area is generally clay; organic matter content is poor, non-calcareous and there are no such problems as saltiness or excessive sodium in ground water.

In all research areas, the technique of agriculture, the type and amount of seeds, timing and amounts of fertilization and spraying as well as all other inputs were studied and recorded, making sure the data is homogenized.

In the research, Fuzzy Logic and Matlab R2015a modules were used in order to perform fuzzy logic applications. Throughout the research, the irrigation water to be applied to borders has been chemically examined and additionally, heavy metal analyses were made both for the soil and for the water.

2.2 Methods

2.2.1 Determining the physical and chemical properties of soil samples

In each research area, field treatment plots of 5 da were selected as sampling areas. In each plot, all sampling and measuring applications were performed with at least 3 repetitions.

At the beginning and the end of the cultivation season, disturbed soil samples were taken from a depth of 0-30, 30-60 and 60-90 cm from each field treatment plot. The samples taken were dried in the shade, sifted through a 2 mm filter and so prepared for analysis. Soil texture was measured with a hydrometer as explained in Bouyoucos (1962).

2.2.2 Determining the physical and chemical properties of water sources

Irrigation water samples were taken at the source point, or at the plot entrance to put it differently, twice a month, with 3 repetitions and the samples were brought to the lab. In the water samples brought to the lab, anions, cations, organic and inorganic pollutant parameters were determined and then, their limitedness was determined according to the Quality Criteria Based on Intra-Continental Water Source Classifications, Irrigation Water Quality Criteria for the Classification of Irrigation Waters that are found in the Technical Procedure Communication (Anonymous, 1991) and the quality criteria prescribed in the food legislation.

Water samples brought to the lab were analysed with the methods below:

Chloride (Cl^-), sulfate (SO_4^{-2}), nitrate (NO_3^-), nitrite (NO_2^-) were determined according to the Standard Method-4500 Ion Chromatographic Method; carbonate (CO_3) and (HCO_3) were determined according to the fundamentals indicated in Tüzüner (1990), with titration; Cations (Na+, Ca++, Mg++, K+) and total phosphorus (P) were determined according to the Standard Method-3500, on an ICP-OES device.

Inorganic Pollutant Parameters; Cadmium (Cd), lead (Pb), copper (Cu), chrome (Cr), cobalt (Co), nickel (Ni), zinc (Zn), iron (Fe), manganese (Mn), boron (B), selenium (Se), aluminium (Al); were determined on the ICP-OES device according to the Standard Method-3500.

Organic Matter was determined with the Potassium Permanganate Method, according to Eltan (1998). In addition, pH and saltiness levels (EC) were measured respectively with a pHmeter and electrical conductometer (Ayyıldız, 1983). Analyses were verified with certified standard water samples.

2.2.3 Application of fuzzy logic model

An effort was made to evaluate all analysis results by taking into account average values, based on Fuzzy Logic System.

After the membership functions and rules were established of the system whose input and output variables were identified, values of pH, saltiness, thrace elements etc. that were measured in each water source were fed to the system as input values and fuzzy values were acquired in return.

Fuzzy Logic system was built by making use of MATLAB R2015a. The steps taken in this stage can be expressed as below:

1. It was identified what the input and output variables of the system will be. pH, saltiness, lime and organic matter, etc. values were taken as input variables as they are factors which directly effect the soil productivity and productivity was taken as an output variable in return.
2. Membership functions and threshold values were determined concerning the input and output variables.
3. In this step, in line with the interactions of input variables with each other, an effort was made for setting rules concerning the possible outcome.

By bringing together as related groups the input variables, 4 different sets of input variable parameter groups were formed for water. These groups are; salinity parameter group (Sodium (Na), electrical conductivity (EC) and pH); Trace element parameter group (Manganese (Mn), Zinc (Zn), Iron (Fe) and Copper (Cu)) and also Heavy metal parameter group (By half-life; first one is Lead (Pb), Arcenic (As), Cadmium (Cd) and second one is Nickel (Ni), Crom (Cr), Cobalt (Co)).

3. RESULTS

By making use of Fuzzy Logic model program, with the purpose of determining the effects of the quality of the water source used in the selected farming lands on soil productivity and of observing the collective effects of multiple elements within the framework of fuzzy logic, firstly the input and output variables for each parameter group were established. The model stages that were attained for saltiness parameters have been provided in the paper so that they serve as a model. Also, the conclusions for all parameter groups are summarized.

3.1 Productivity analysis results of the parameters determined in irrigation waters

3.1.1 Results of the irrigation water saltiness parameters

Input and output variables, membership functions and threshold values of the saltiness parameters that were determined by making use of MATLAB R2015a are shown in Figures 1, 2, 3 and 4. Of the membership functions, two were decided to be trapezoids and others to be triangles.

After the establishment of membership functions and rules of the system whose input and output variables were identified, pH, EC and Na values that were measured in different water sources were fed to the system as input values and productivity was taken as the output varible in return.

In line with membership functions, the rules were established. A total of 48 rules were written for this parameter group. In line with the interactions of input variables with each other, some of the rules that were written concerning what the output could be are shown in Figure 5.

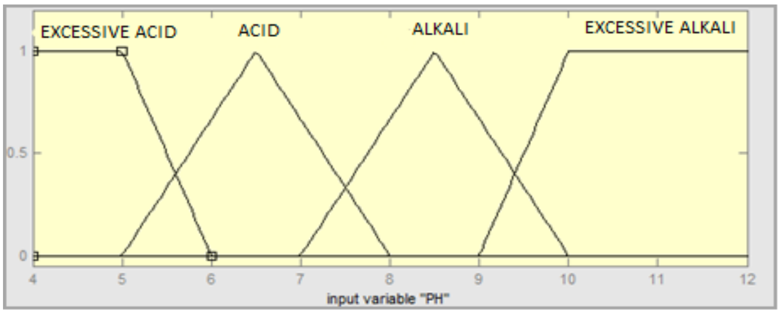

Figure 1. The membership function of pH variable

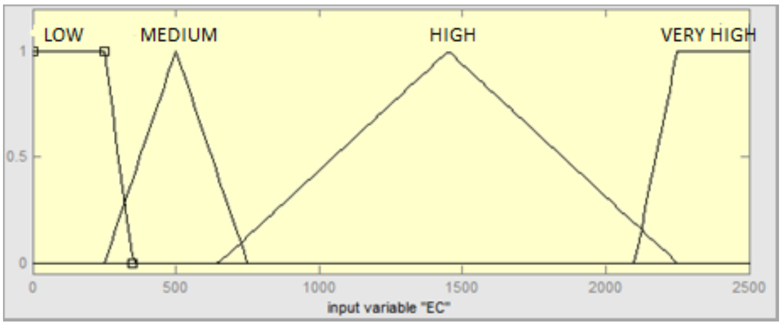

Figure 2. The membership function of EC variable

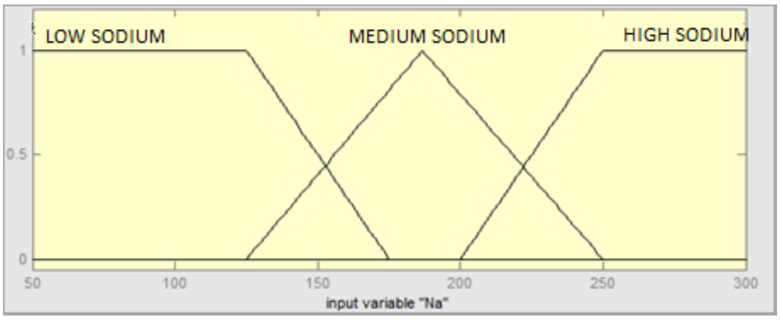

Figure 3. The membership function of Na variable

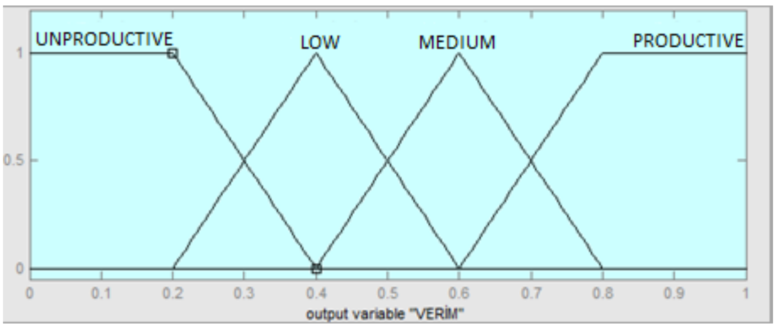

Figure 4. The membership function of productivity

3D demonstrations for the selected parameters that set up the rules are on Figure 6a,b,c. On Figure 6a are productivity, the changes seen in EC and pH in relation to each other; and on Figure 6b are productivity and 3D demonstrations of the rules that show the changes in pH and Na in relation to each other. The system evaluates four different input and output variables together, but only the rules concerning three selected variables can be seen on the 3D demonstration.

1. If (pH is ACID) and (EC is LOW) and (Na is LOW-SODIUM) then (PRODUCTIVITY is PRODUCTIVE)
2. If (pH is ACID) and (EC is LOW) and (Na is MEDIUM SODIUM) then (PRODUCTIVITY is PRODUCTIVE)
3. If (pH is ACID) and (EC is LOW) and (Na is HIGH SODIUM) then (PRODUCTIVITY is MEDIUM)
4. If (pH is ACID) and (EC is MEDIUM) and (Na is LOW SODIUM) then (PRODUCTIVITY is PRODUCTIVE)
5. If (pH is ACID) and (EC is MEDIUM) and (Na is MEDIUM SODIUM) then (PRODUCTIVITY is PRODUCTIVE)

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45. If (pH is EXCESSIVE-ALKALI) and (EC is HIGH) and (Na is HIGH SODIUM) then (PRODUCTIVITY is LOW)
46. If (pH is EXCESSIVE-ALKALI) and (EC is VERY HIGH) and (Na is LOW SODIUM) then (PRODUCTIVITY is LOW)
47. If (pH is EXCESSIVE-ALKALI) and (EC is VERY HIGH) and (Na is MEDIUM SODIUM) then (PRODUCTIVITY is LOW)
48. If (pH is EXCESSIVE-ALKALI) and (EC is VERY HIGH) and (Na is HIGH SODIUM) then (PRODUCTIVITY is UNPRODUCTIVE)

Figure 5. A part of the rules of the salinity parameter group in irrigation water

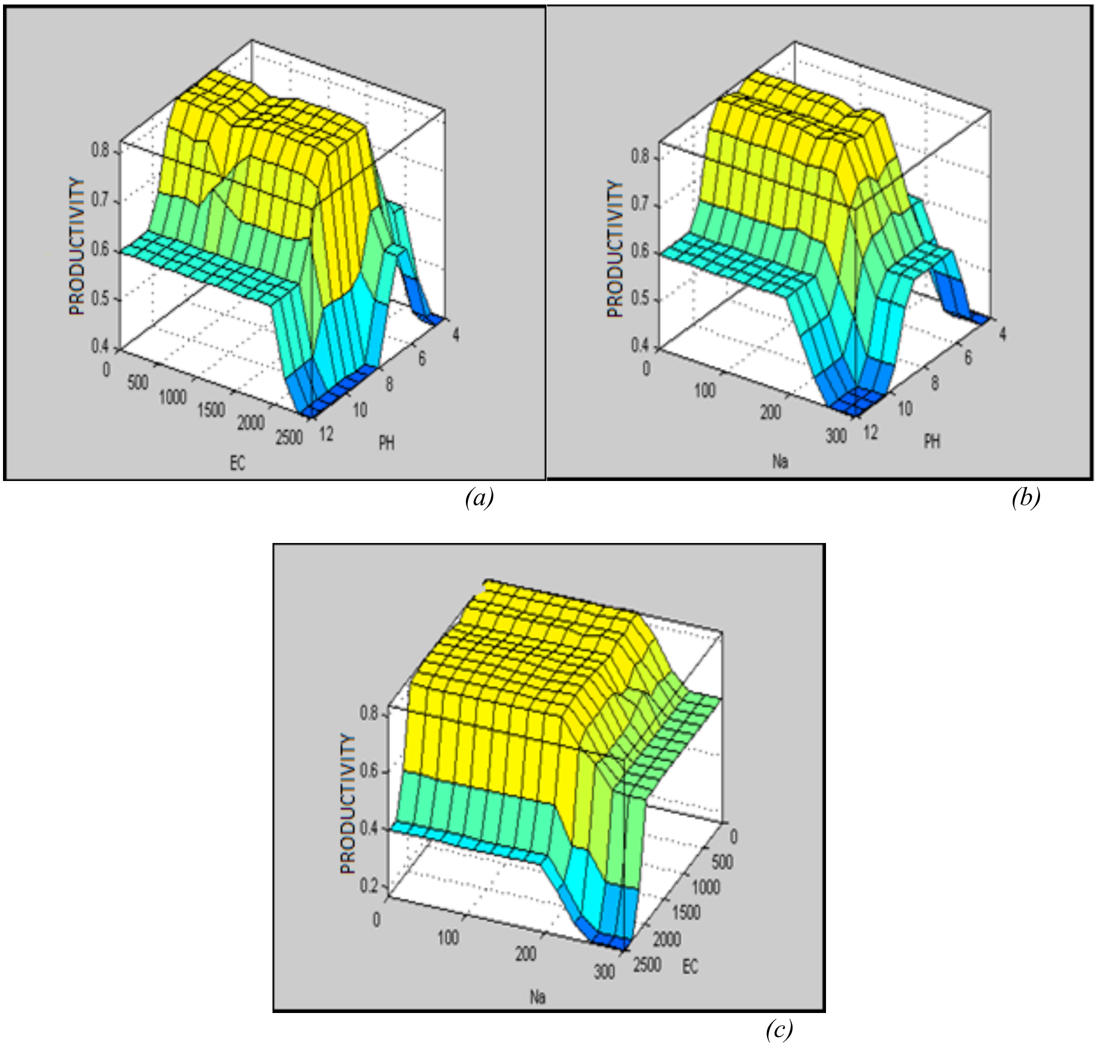

Figure 6. Three-dimensional presentation of the rules relating to the selected three variables (a), (b), (c).

The saltiness parameters whose average values are given on Table 1 (EC, pH, Na) were fed into the system as input variables and soil productivity values for each region were obtained (Table 2).

As can be tracked on the table, the variance in productivity levels based on water quality is very obvious. The highest productivity (82%) was seen in the region Aslıhan where the water source used was ground water, whereas the lowest productivity (26%) was seen in the region Uzunköprü where the levels of pollution and saltiness were quite high. In Eskiköy terrains where the water from River Meriç was used, the soil productivity was 59% and in Delibedir where the dam water was used, it was 71%.

Table 1. Results of analysis as mean of salinity parameters by regions

Parameter	Months	Region			
		Aslıhan	Eskiköy	Uzunköprü	Delibedir
pH	May	6.80	7.20	7.68	7.09
	June	6.97	8.08	7.90	8.02
	July	8.07	7.39	7.42	7.74
	August	7.56	7.03	7.38	7.48
	September	7.05	-	-	-
	Average	6.80	58	7.60	7.58
EC (µS/cm)	May	945	1069	3610	998
	June	767	3020	8690	2398
	July	1261	2846	7510	2072
	August	1808	2462	2921	1925
	September	1614	-	-	-
	Average	945	2349	5683	1848
Na (ppm)	May	26.37	43.48	408.15	50.40
	June	26.35	62.23	459.56	59.04
	July	21.69	57.93	415.59	50.65
	August	25.53	52.72	398.97	54.32
	September	25.26	-	-	-
	Average	26.37	54.09	420.57	53.60

The results obtained in the study from all parameter groups are shown on Table 3. When Table 1 is reviewed, it is seen that pH values have varied between 6.5-8.5 in all of the sources and that they are water sources of good quality based on the standards. EC values of irrigation water vary between 750-2000 µS/cm for the village of Aslıhan and it is a water source of utilizable quality that will not impose any limitations on rice plant agriculture. As explained in Meral and Temizel (2006), no yield loss is experienced up to 2.0 dS/m for the rice plant. For the water source in Eskiköy, it is seen that the EC values are moderately utilizable in the month of May while it is of bad quality in other months. EC values of the water source in Uzunköprü are above 2000 µS/cm and the Na value is above 250 ppm and it is IVth grade water of inutilizable quality which could decrease the yield of the rice plant and the soil quality. The relative highness of these amounts can be due to the fact that the source is River Ergene and that it is subject to quite a high dose of waste water discharge. In parallel with these results, the soil productivity values reached by the model have remained low in these areas. And in the water source in Delibedir, EC values are around 2000 µS/cm and of mid-quality according to the classification. With respect to other parameters it exhibits a quality of Ist grade water that is utilizable, according to the standards.

As can be tracked on Table 3, depending on the trace element change, the variation in the productivity levels has shown parallels with respect to different regions. Productivity was seen to be around 84% in Aslıhan, Eskiköy and Delibedir regions and 74% in the Uzunköprü region.

Based on the changes in heavy metals, the levels of productivity were found to be close to each other in average with approximately 70%. But as can be clearly seen on the table, the productivity levels have greatly varied in different months. The lowest productivity was found to be 50%, whereas the highest was 85%. This situation seems likely for Uzunköprü and Eskiköy with respect to the fact that industrial and domestic waste water is occasionally mixed with the water sources there. But it was found not to be very meaningful for the other water sources.

When the possible productivity levels based on the model results from measured parameters of water sources are examined; in the region Uzunköprü which is the region with the poorest water quality, the overall expected soil productivity level was seen to be quite low. Soil productivity levels have also varied in parallel with the variance in the quality parameters.

Table 2. Values of productivity of different water supply for salinity parameters

Region	Months	pH	Na (ppm)	EC(mμhos/cm)	Productivity
Aslıhan	*May*	6.80	26.371	945	0.820
	June	6.97	26.346	767	0.810
	July	8.07	21.693	1261	0.836
	August	7.56	25.526	1808	0.821
	September	7.05	25.260	1614	0.832
Eskiköy	*May*	7.20	43.479	1069	0.827
	June	8.08	62.227	3020	0.400
	July	7.39	57.930	2846	0.522
	August	7.03	52.722	2462	0.593
Uzunköprü	*May*	7.68	408.152	3610	0.239
	June	7.90	459.558	8690	0.189
	July	7.42	415.589	7510	0.301
	August	7.38	398.972	2921	0.311
Delibedir	*May*	7.09	50.403	998	0.823
	June	8.02	59.036	2398	0.400
	July	7.74	50.655	2072	0.814
	August	7.48	54.324	1925	0.819

Table 3. Values of productivity(%) of all parameter groups by regions

Parameter Group	Months	Region			
		Aslıhan	Eskiköy	Uzunköprü	Delibedir
Salinity	May	82	83	24	82
	June	81	40	20	40
	July	84	52	30	81
	August	82	60	31	82
	Average	82	58	26	71
Thrace Elements	May	85	83	40	85
	June	85	84	85	85
	July	85	84	85	85
	August	83	85	85	84
	Average	84	84	74	85
Heavy Metal	May	85	85	85	85
	June	85	60	60	60
	July	60	84	83	83
	August	83	57	54	51
	Average	78	72	71	70

4. CONCLUSIONS

In the light of the results attained, it was seen that Fuzzy Logic model which is made use of in many fields of science can also be used in studies performed in the field of agriculture.

Determining the relations of model parameters with each other soundly and establishing the relevant rules, in environments where various variable impact factors are present is of great importance for ensuring that the model arrives at correct conclusions.

The values obtained from the triangles that are formed in fuzzy logic constitute an additional alternative application range in comparison to standard quality criteria tables. This situation brings forth fuzzy logic as an advantage in the field of agriculture. And the application ranges are seen as tolerable levels which will not effect the productivity of the rice plant negatively.

This study will constitute the basis for many future researches as it proves that fuzzy logic systems which allow the evaluation of the collective effects of many parameters in the field of agriculture yield utilizable results.

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REFERENCES

Altunkaynak, A., Özger, M., Çakmakçı, M., 2005. Water consumption prediction of Istanbul City by using Fuzzy Logic approach. Water Res. Manage. 19: 641-654.

Ambuel, J.R., Colvin, T.S., Karlen, D.L., 2013. A fuzzy logic yield simulator for prescription farming. Transactions of the ASAE. 37(6): 1999-2009.

Anonymous, 2015. DSI, the General Directorate of State Hydraulic Works. www. http://en.dsi.gov.tr/ (Accessed 27.06.2016).

Anonymous, 1991. The Official Journal of the Republic of Turkey, 01.07.1991, Issue: 20748. Available: www.resmigazete.gov.tr /default.aspx [Accessed 08.02.2017]

Ayyıldız, M., 1983. Sulama Suyu Kalitesi ve Tuzluluk Problemleri. Ankara Üniv. Ziraat Fakültesi Yayınları. No: 897, 282s. Ankara.

Bouyoucos, G. J., 1962. Hydrometer method improved for making particle-size analysis of soils. Agron. J. 53: 464 – 465.

Chang, N., Chen, H.W., Ning, S.K., 2001. Identification of river water quality using the fuzzy synthetic evaluation approach. J. of Environ. Manage. 63: 293-305.

Duru, N., Canbay, M.M., Kurtuluş, C., Dökmen, F., 2010. Soil productivity analysis based on a fuzzy logic system. J. Sci. Food Agric. 90: 2220-2227.

Eltan, E., 1998. İçme ve Sulama Suyu Analiz Yöntemleri. Köy Hizmetleri Gn. Müdürlüğü Yayınları

Gharibi, H., Mahvi, A.H., Nabizadeh, R., Arabalibeik, H., Yunesian, M., Sowlat, M.H., 2012. A novel approach in water quality assessment based on fuzzy logic J. of Env. Manage. 112: 87-95.

Karadavut, U., Akkaptan, A., 2012. Bitkisel üretimde bulanık mantık uygulamaları. Türk Bilimsel Derlemeler Dergisi. 5(2): 77-82.

Lermontov, A., Yokoyama, L., Lermontov, M., Machado, M.A.S., 2009. River quality analysis using fuzzy water quality index: Ribeira de Iguape River watershed, Brazil. Ecological Indicators 9: 1188-1197.

McBratney, A.B., Odeh, I.O.A., 1997. Application of fuzzy sets in soil science: fuzzy logic, fuzzy measurements and fuzzy decisions. Geoderma. 77: 85-113.

Meral, R., Temizel, K.E., 2006. Çeltik tarımında sulama uygulamaları ve etkin su kullanımı. KSÜ Fen ve Mühendislik Dergisi, 9 (2): 104-109.

Mitra, B., Scott, H.D., Dixon, J.C., McKimmey, J.M., 1998. Applications of fuzzy logic to the prediction of soil erosion in a large water shed. Geoderma 86: 183-209.

Odabaş, C., Pehlivan, İ., Cinal, D.M., 2009. Bulanık mantık ile güneş enerjisi uygulaması. 5. Uluslararası İleri Teknolojiler Sempozyumu. (IATS'09). Karabük, Türkiye.

Tüzüner, A., 1990. Toprak ve Su Analiz Laboratuarı El Kitabı. KHGM Yayınları, Tarım Orman ve Köy İşleri Bakanlığı, Ankara.

Zadeh, L.A., 1965. Fuzzy sets. Information and Control. 8: 338-353.