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DETERMINATION OF SPATIAL VARIATION OF REFERENCE EVAPOTRANSPIRATION CASE STUDY OF SEYHAN BASIN

Ismail Tas [1]*, Y. Ersoy Yildirim [2], Cenk Aksit [3], K. Aytac Ozaydin [4], Zeki Gokalp [5]

[1] CanakkaleOnsekiz Mart University Agriculture Faculty, Department of Agricultural Structures and Irrigation, 17020 Terzioglu Campus Canakkale, Turkey
[2] Ankara University Agriculture Faculty, Department of Agricultural Structures and Irrigation, 06120 Diskapi Campus Ankara, Turkey
[3] Republic of Turkey Ministry of Food, Agriculture And Livestock, General Directorate of Agricultural Reform, Department of Land Rehabilitation and Irrigation Systems, Cankaya, Turkey
[4] Republic of Turkey Ministry of Food, Agriculture And Livestock. Field Crops Central Research Institute, Ankara, Turkey

Abstract
Geographic Information Systems (GIS) are computer-based tools for mapping and analyzing features and events on earth. GIS technology integrates common database operations such as query and statistical analysis with the unique visualization and geographic analysis benefits offered by maps Evapotranspiration mapping with classical methods may take months and even years based on the size of the area to be mapped. However, recently developed methods decreased the time consumed for such mapping practices to minutes. Geostatistical methods are the most commonly used methods for mapping over large areas in a short time. In present study, Reference Evapotranspiration (ETo) values were calculated by ASCE Standardize Penman Monteith method using long-term climate data in the Seyhan basin. The calculated ETo values were mapped for April, May, June, July, August, September and yearly total by using geostatistical methods. It was used 7 stations in basin and 9 stations out of basins for calculation. In the production of geostatistical maps, cokriging was used as interpolation method and spherical model was used for model of semi-variogram. At the end of the study, it was determined that ETo maps could be produced with reliable this method and model.

Keywords: Geostatistical, Reference Evapotranspiration, Seyhan Basin.

1. INTRODUCTION

Evapotranspiration (ET) in the Amazon rainforest exerts large influences on regional and global climate patterns (Spracklen et al., 2012; Maeda et al., 2017). Although exact figures vary, it is broadly known that the Amazon River basin transfers massive volumes of water from the land surface to the atmosphere every day, thereby having massive influence on the global energy budget (Hasler and Avissar, 2007; Aragão, 2012; Christoffersen et al., 2014; Restrepo-Coupe et al., 2016; Maeda et al., 2017). ET is also an indicator of ecosystem functioning, given its intrinsic association with CO_2 fluxes during the transpiration process. Hence, any modification of ET over Amazon tropical forests would likely alter the global carbon cycle and further feedback to the rate of a changing climate. Nonetheless, the spatial and temporal characteristics of ET across the Amazon Basin, as well as the relative contribution of the multiple drivers to this process, are still uncertain. This may be attributed to the lack of high-quality validation data over the full range of ecoregions

*Corresponding author, E-mail address: tas_ismail@yahoo.com

across the basin, and the thus far unclear influence of climate on vegetation functioning. Recent studies suggested that vegetation phenology, as indicated by leaf demography (Restrepo-Coupe et al., 2013; Lopes et al., 2016; Wu et al., 2016; Maeda et al., 2017), further increases the complexity of quantifying the relative importance of biotic and abiotic drivers of ecosystem functioning over the Amazon. These uncertainties are reflected in simulations by land surface models (LSMs) and global circulation models (GCMs), hindering the delineation of more reliable climate change scenarios (Werth and Avissar, 2004; Karam and Bras, 2008; Restrepo- Coupe et al., 2013, 2016; Maeda et al., 2017).

A simple definition with Evapotranspiration (ET) is the combined processes of evaporation of water from the soil and plant surfaces and transpiration of water through the plant tissues. Why is Evapotranspiration Important? A change in any one part of the Soil-Plant-Atmosphere Continuum (SPAC) will also change the requirement of when and how much to irrigate a field. Other tools, like soil moisture sensors, can inform you about only one facet of the SPAC. Evapotranspiration integrates the SPAC and accomplishes this over a broad area of a crop field. Any of the following with cause a change in the ET: a) A change in water availability in the soil, b) A change in the ability of the plants to keep up with atmospheric demand for water, c) A change in the ability of the atmosphere to pull water through the plant.In other words, a change in any component of the Soil-Plant-Atmosphere Continuum will influence ET.

If there is insufficient water available in the soil, then the ET will decrease as the plants physiologically regulate their water use. If the plants are hedged, then the ET will decrease because there is less leaf area intercepting light and losing water to the atmosphere. If there is a heat spell, the ET will increase because the atmospheric demand has increased and can more strongly pull water through the plants.

Irrigation scheduling involves different works and processes used to determine irrigation timing and quantity. The ETo values calculated for this purpose is used to estimate plant water requirements. Regional evapotranspiration values are required to estimate crop yield and quality and required also for efficient water use and management, environmental impact assessments. Ordinary Kriging, regression Kriging and cokriging-like geostatistical methods are employed for ET estimations in regions with significant variations in topography (Martinez-Cob and Cuenca, 1992; Philips et al., 1992). Performance of geostatistical methods largely depends on variables in consideration and spatial configurations of the data (Creutin and Obled, 1982; Weber and England, 1994). Therefore, each interpolation methods is good for certain conditions (Isaaks and Srivastava, 1989).

In present study, Reference Evapotranspiration (ETo) values were calculated by ASCE Standardize Penman Monteith method using long-term climate data in the Seyhan basin. The calculated ETo values were mapped for April, May, June, July, August, September and yearly total by using geostatistical methods. With the resultant values, ETo maps of Seyhan river basin were generated for relevant months.

2. MATERIALS AND METHODS

Seyhan River Basin is one of the major land and water resources basins in Turkey. The Seyhan River is located in the Eastern Mediterranean Region of Turkey and the drainage area of the basin is about 21750 km2 extending between 37º 13’ - 40º 12’ N and 35º 03’-37º 56’ E. The Seyhan River with a length of 560 km originates from Taurus Mountains, runs through the city of Adana and outfalls to the Mediterranean Sea (Figure 1). As of 2017, approximately 210000 ha area was irrigated. In the next decade (2027), this value is expected to reach 327000 ha.There are four dams already in operation fed by Seyhan River and its tributaries, and the biggest Seyhan Dam serves besides hydropower and flood control for irrigation of 13400 ha in present, however the irrigated

*Corresponding author, E-mail address: tas_ismail@yahoo.com

area is planned to be enlarged up to 174000 ha in near future. The physiography of the Seyhan Basin varies from south to north, the lowlands characterizing the south while the north is represented by harsh topography as seen in figure 1.

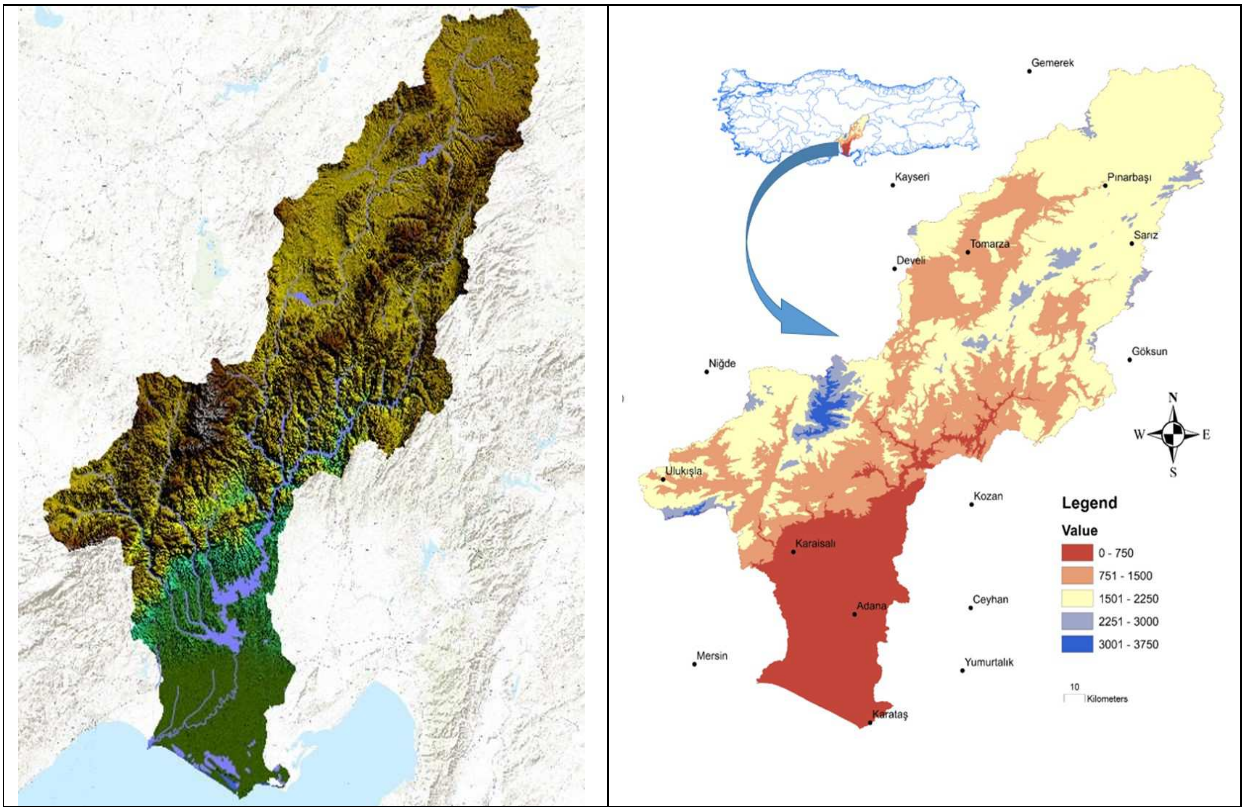

Figure 1. Topographic Maps of Seyhan Basin

The climate in the basin is under the influence of the Mediterranean climate, with hot and arid summers and mild and rainy winters. Grain production is dominating in the lower part of the basin, and among the grains, wheat is grown under rain fed conditions while maize grown as first and second crop is irrigated. Industrial plants such as cotton and fresh fruits particularly citrus and vegetables are taking also significant place in the cropping pattern of the region. In the upper part of the basin dominates mixed forest, meadow and pastureland (Topcu et. al., 2008).

Table 1. Total Water Resources Potential in Seyhan Basin

Surface Water Resources	Water volume (hm³)	Ground Water Resources	Water volume (hm³)	Total Water Resources	Water volume (hm³)
Zamantıa	2.031	Zamantı	405	Zamantı	2.436
Göksub	1.811	Göksu	419	Göksu	2.230
Seyhan	2.295	Seyhan	322	Seyhan	2.617
Total	6.137	Total	1.145	*SeyhanDam*	*7.282*

There are four dams already in operation fed by Seyhan River and its tributaries. As of 2017, approximately 210 000 ha of land are irrigated. In the In the future this figure is expected to reach 327000 ha. In the seyhan basin, the biggest dam is Seyhan Dam which serves besides hydropower and flood control for irrigation of 134000 ha in present, however the irrigated area is planned to be

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enlarged up to 174000 ha in near future.The climate in the basin is under the influence of the Mediterranean climate, with hot and arid summers and mild and rainy winters.

In present study, Reference Evapotranspiration (ETo) values were calculated by ASCE Standardize Penman Monteith method using long-term climate data in the Seyhan basin. It was used 7 stations in basin and 9 stations out of basins for calculation.The general form Penman-Monteith equation (Allen et al., 1998) is:

$$ET_{sz} = \frac{0.408\ \Delta\,(R_n - G) + \gamma\,\frac{C_n}{T+273}\,u_2\,(e_s - e_a)}{\Delta + \gamma\,(1 + C_d\,u_2)}$$

where ET is the reference evapotranspiration, (mm d^{-1} or mm h^{-1}); Rn is the net radiation, (MJ m^{-2} d^{-1} or MJ m^{-2} h^{-1}); G is the soil heat flux, (MJ m^{-2} d^{-1} or MJ m^{-2} h^{-1}); (es - ea) represents the vapor pressure deficit of the air, (kPa); es is saturation vapor pressure of the air, (kPa); ea is the actual vapor pressure of the air, (kPa); ρa is the mean air density at constant pressure, (kg m^{-3}); cp is the specific heat of the air, (MJ $kg^{-1}$$^{o}C^{-1}$); Δ is the slope of the saturation vapor pressure temperature relationship, (kPa$^{o}C^{-1}$); γ is the psychrometric constant, (kPa$^{o}C^{-1}$); rs is the (bulk) surface resistance, (s m^{-1}); ra is the aerodynamic resistance, (s m^{-1}); λ is latent heat of vaporization, (MJ kg^{-1}); Ktime is a unit conversion, (86400 s d^{-1} for ET in mm d^{-1} and 3600 s h^{-1} for ET in mm h^{-1}).

In the production of geostatistical maps, cokriging was used as interpolation method and spherical model was used for model of semivariogram. The calculated ETo values were mapped for April, May, June, July, August, September and yearly total by using geostatistical methods. At the end of the study, it was determined that ETo maps could be produced with reliable this method and model.

3. RESULTS AND DISCUSSIONS

Cokriking methods as interpolation methods and spherical model as semi-variogram generally yield better outcomes for ETo calculation and mapping (Noshadı and Sepaskhah, 2005; Yıldırım et al., 2017). Such recommendation of these previous researchers were taken into consideration and ETo maps of the research site were generated. Statistical parameters calculated while generating ETo maps are provided in Table 2. The maps generated for April-September months and annual total are presented in Figures 2-5.

In April, ET values changed between 80-110 mm in the study area.In the North-eastern part of the basin, where the height region in the basin, ET is lowest and it changed between 80-90 mm.In the southern part of the basin, that is, in the regions close to the Mediterranean where is the highest, it changed between 100-110 mm.

In May, ET values changed between 110-140 mm in the basin.In the North-eastern part of the basin, where the height region in the basin, ET is lowest and it changed between 110-120 mm.In the southern part of the basin, that is, in the regions close to the Mediterranean where is the highest, it changed between 135-140 mm.

In June, ET values changed between 135-170 mm in the basin.In the North-eastern part of the basin, where the height region in the basin, ET is lowest and it changed between 110-120 mm.In the southern part of the basin, that is, in the regions close to the Mediterranean where is the highest, it changed between 135-140 mm.In July, ET values changed between 140-200 mm in the basin.In the North-eastern part of the basin, where the height region in the basin, ET is lowest and it changed between 165-175 mm.In the southern – southern West part of the basin, that is, in the regions close to the Nigde province, where is the highest, it changed between 135-140 mm.

Table 2. Values of some statistical parameters related to prepared maps

Parameters	**April**	**May**	**June**	**July**	**August**	**September**	**Yearly Total**
Count	16	16	16	16	16	16	16
Min	78.0	108.5	136.5	141.1	138.9	95.4	78.0
Max	107.1	139.8	168.0	193.8	176.1	138.3	107.1
Mean	-0.11	-0.12	-0.45	-0.08	0.03	-0.03	-1.24
Root Mean Square	2.25	4.1	7.10	6.82	6.32	6.85	41.3
Mean Standardized	-0.02	0.01	-0.04	-0.01	-0.01	-0.01	-0.01
Root Mean Square Standardized	0.48	0.61	0.74	0.62	0.67	0.75	0.63
Average Standard Error	4.6	6.78	9.7	11.14	9.52	9.27	67.1

In August, ET values changed between 140-180 mm in the basin.In the North-eastern part of the basin, where the height region in the basin, ET is lowest and it changed between 140-160 mm.In the southern – southern West part of the basin, that is, in the regions close to the Nigde province, where is the highest, it changed between 170-180 mm.

In September, ET values changed between 90-140 mm in the study area.In the North-eastern part of the basin, where the height region in the basin, ET is lowest and it changed between 95-105 mm.In the southern part of the basin, that is, in the regions close to the Mediterranean where is the highest, it changed between 125-135 mm.

In September, ET values changed between 900-1300 mm in the study area.In the North-eastern part of the basin, where the height region in the basin, ET is lowest and it changed between 900-1000 mm.In the southern part of the basin, that is, in the regions close to the Mediterranean where is the highest, it changed between 1200-1300 mm.

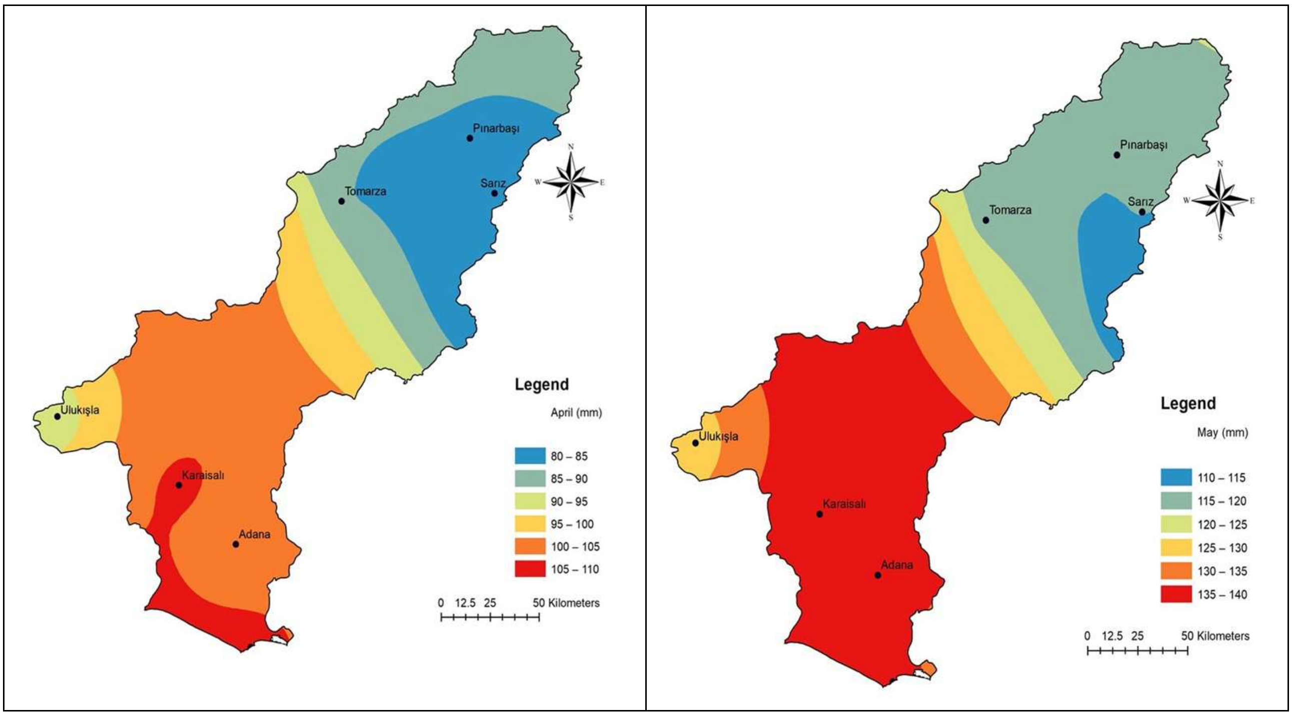

Figure 2. ETo maps of April and May

*Corresponding author, E-mail address: tas_ismail@yahoo.com

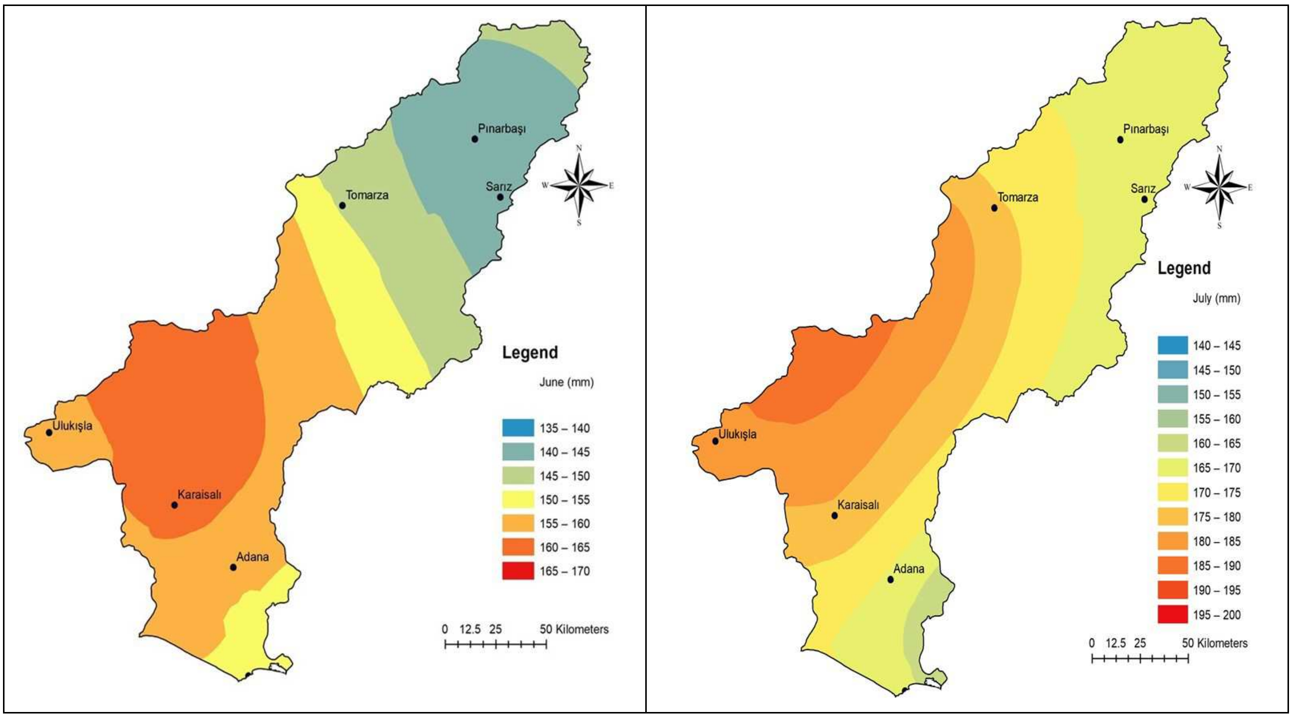

Figure 3. ETo maps of June and July

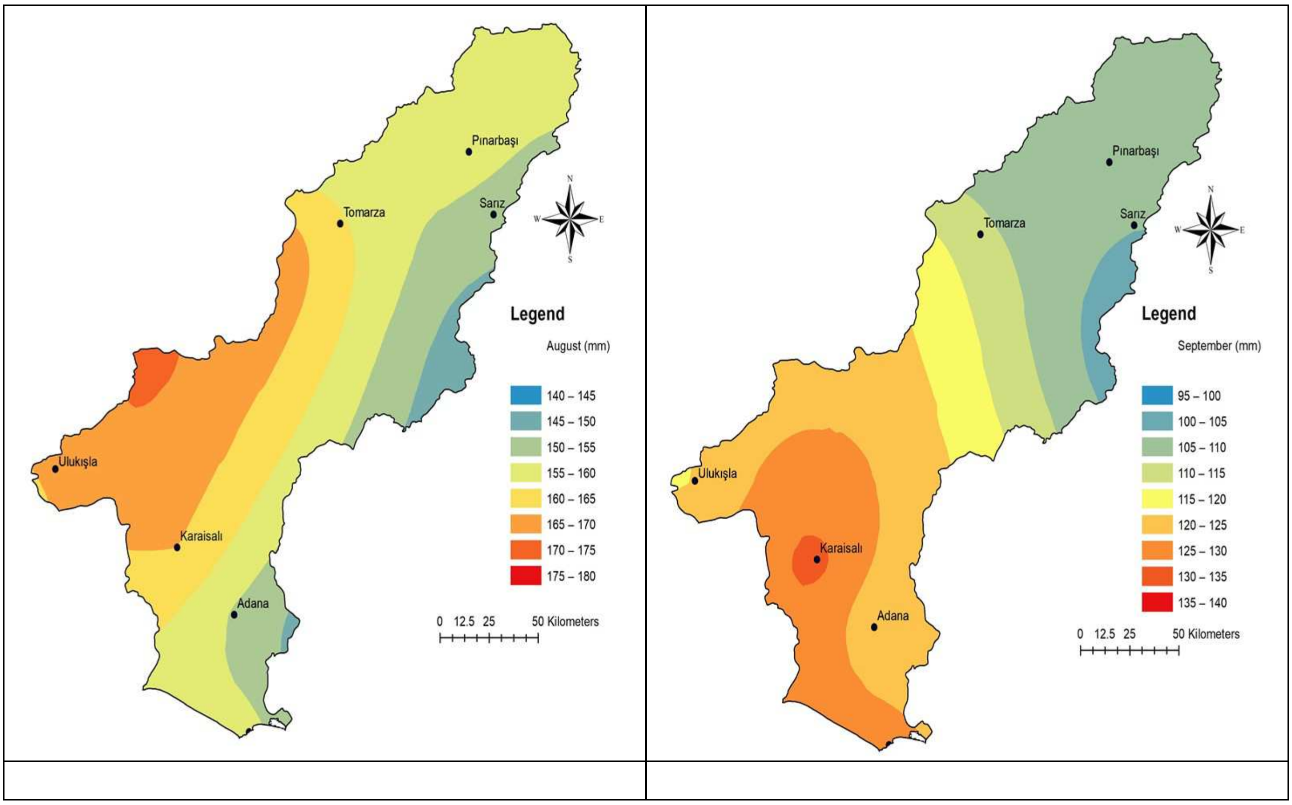

Figure 4. ETo maps of August and September

*Corresponding author, E-mail address: tas_ismail@yahoo.com

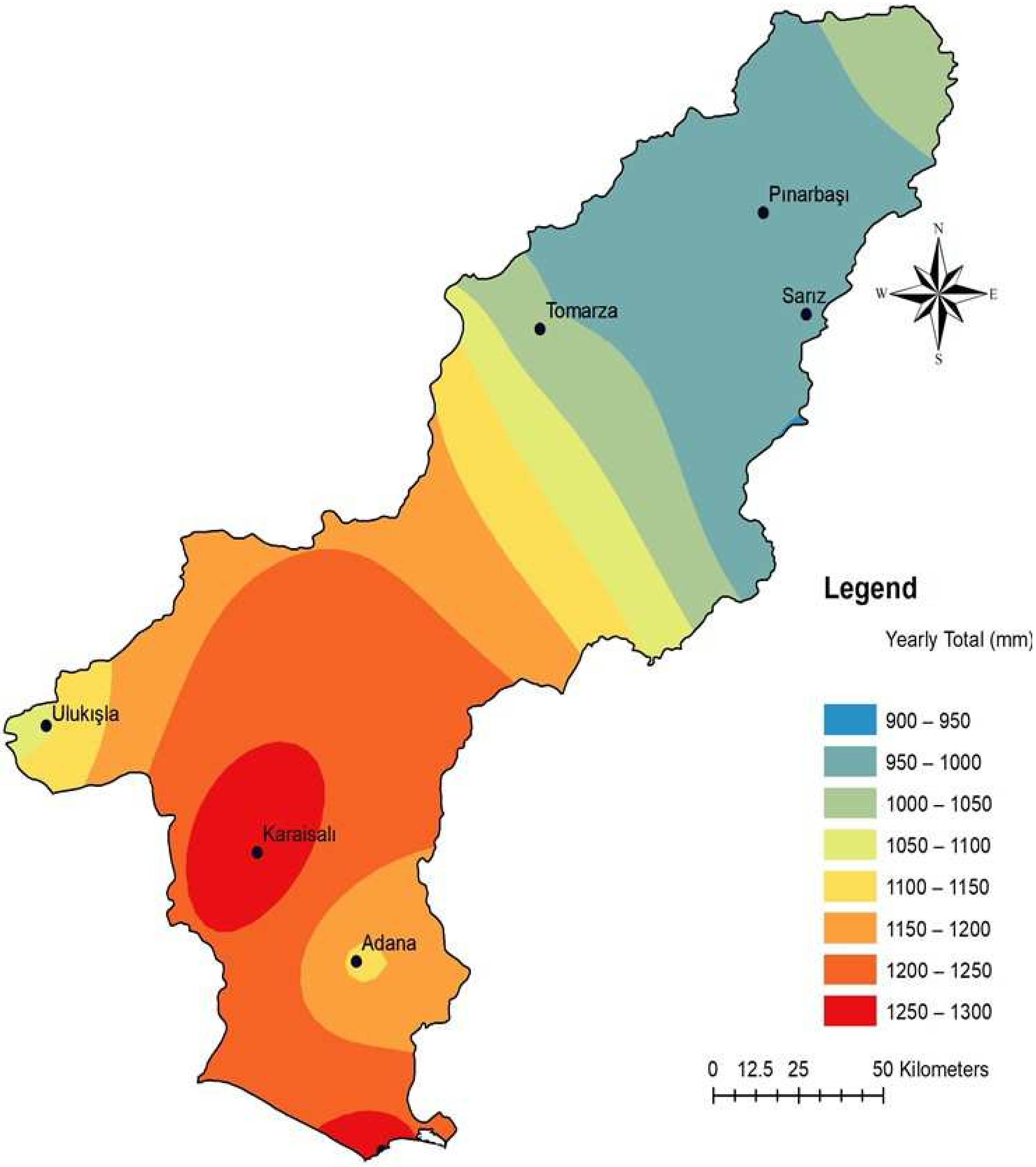

Figure 5. ETo maps of annual total

Measuring and monitoring of evapotranspiration is both times consuming and costly in conventional methods. Thanks to the developing technology in recent years, measurement and monitoring methods have improved. Determination of reference evapotranspiration in the spatial, regional, basin and even the national scale and preparation of their distribution maps are important contributors to the creation of practical irrigation schemes. The values obtained as a result of the calculations made from land tests or with proven reliability methods are very useful and useful for the producers if they are analyzed by the correct geostatistic methods and preparing the maps and the subject experts. The use of the appropriate geostatistical methods in the preparation of maps directly affects the accuracy of the generated maps.

*Corresponding author, E-mail address: tas_ismail@yahoo.com

The ASCE Standardize Penman-Monteith method used to calculate the reference evapotranspiration gave good results for the Seyhan basin. In addition, cokriging as an interpolation method in the preparation of ETo maps by the geostatistic method; it was determined that the use of the spherical model as the semivariogram is appropriate.

4. CONCLUSIONS

Evapotranspiration is a quite significant value for optimum use of limited water resources, sustainable water management and agricultural production. The irrigation water requirement of culture crops is determined only with the aid of accurately and precisely calculated ET values by appropriate methods. Spatial, regional, watershed-scale and even country-scale ET values may have great contributions in preparing irrigation programs. The data coming from either field experiments or generated through reliability-proven methods should be analyzed through appropriate geostatistical methods. Resultant maps may have great contributions to area-experts and producers. ET maps can be generated with the aid of geostatistical methods in short time. The primary issue in ETo mapping is to use proper interpolation method and semi-variogram model. Such cases directly influence the accuracy of the maps. In ETo calculation and mapping, cokriking as an interpolation method and spherical model as a semi-variogram generally yield better outcomes.

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