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IRRIGATION SCHEDULING AND DETERMINATION OF IRRIGATION WATER REQUIREMENT OF PADDY RICE WITH DRIP IRRIGATION USING TAGEM-SUET MODEL

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Abstract: Nowadays, as the pressure of drought on water resources increases, new approaches regarding paddy rice irrigation, which has the highest water consumption rate, need to be taken into consideration.One of these approaches is the drip irrigation method, which saves significant amount of water in paddy rice irrigation. In this study, 4 different irrigation programs (25%, 50%, 75% and 100%) in drip irrigation method and ponding methodfor paddy rice in Edirne were examined in TAGEM-SUET. As a result of the study, the evapotranspiration of paddy rice during the production season was calculated as 692.83 mm, the amount of irrigation water was calculated as 162-648 mm in drip irrigation. In the model, it was measured that the optimum drip irrigation program would not cause a decrease in efficiency despite saving 38% of water compared to the ponding method. It is thought that TAGEM-Suet can be a good tool for irrigation planning and management of paddy rice, depending on climatic conditions.

Keywords: Irrigation scheduling, Modelling, Paddy rice, Water deficit

TAGEM-SuET Modeli Kullanılarak Damla Sulama ile Çeltiğin Sulama Programlaması ve Sulama Suyu İhtiyacının Belirlenmesi

Öz: Kuraklığın gün geçtikçe su kaynakları üzerindeki basksının arttığı günümüzde en çok su tüketimine sahip olan çeltikle ilgili yeni yaklaşımların dikkate alınması gerekmektedir.Bu yaklaşımlardan biri de çeltik sulamasında önemli miktarda su tasarrufu sağlayan damla sulama yöntemidir. Bu çalışmada Edirne için çeltikte damla sulama yönteminde 4 farklı sulama konusu (%25, %50, %75 ve %100) ve göllendirme yöntemi TAGEM-SUET'te incelenmiştir. Araştırma sonucunda çeltik üretim sezonundaki bitki su tüketimi 692.83 mm, sulama suyu miktarı ise damla sulama konularında 162-648 mm hesaplanmıştır. Modelde optimum damla sulama programının, geleneksel göllendirme yöntemine göre %38 oranında su tasarrufu sağlamasına rağmen verimde düşüşe neden olmayacağı belirlenmiştir. TAGEM-SuET'in çeltik bitkisi özelinde iklim koşullarına bağlı olarak sulama planlaması ve yönetimi için iyi bir araç olabileceği düşünülmektedir.

Anahtar Kelimeler: Sulama programlama, Modelleme, Çeltik, Su kısıtı

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1. INTRODUCTION

Paddy rice is the fourth most produced grain product in Türkiye after wheat, maize and barley. It is produced in an area of 120.000 ha in Türkiye. Edirne covers more than 38% of paddy rice agricultural areas in Türkiye (TÜİK, 2022).

Paddy rice farming is done by traditional ponding method in Türkiye, like it is applied globally (Sürek, 2002). In this method, the entire cultivation area is covered with water throughout the development period of the crop. The biggest disadvantage of this method is the uncontrolled and excessive use of irrigation water (Nar et al., 2018). Nowadays, with global warming, there is a significant decrease in water resources. Therefore, techniques that can use less and more effective water are needed (He et al., 2013).

Pressurized irrigation systems have the potential to increase water efficiency by reducing surface runoff and deep drainage losses. In addition, they provide significant water savings by allowing the paddy rice to be grown in most land conditions (Xu et al., 2012; Tan et. al., 2014; Parthasarathi et al., 2017; Spanu et al., 2020). Drip irrigation, contribute to increasing productivity and preventing excessive irrigation water usage as they provide water as much as the plant needs (Tas et al., 2022; Çolak et. al., 2022;). When planning this irrrigation system, it is necessary to estimate crop water consumption (ETc) and determine the amount and time of irrigation water. These results, which emerge as a result of a series of calculations, facilitate the management of irrigation systems (Köksal et al., 2018).

Today, irrigation programming is possible with the opportunities provided by computer and software technologies. Some of these software are CROPWAT and AQUACROP (FAO, 2009; Köksal et al., 2018). Song et al., (2015), stated that the CROPWAT program could help farmers increase paddy rice crop yield by providing compatible results according to FAO-Penman Monteith for different irrigation seasons. Hossain et al., (2017), investigated ETc and irrigation planning during the production season of rice using CROPWAT in Bangladesh. They reported that CROPWAT can be used in planning irrigation projects by determining the paddy rice irrigation need by taking soil and weather conditions into consideration. Shekhar et al., (2018), examined the best irrigation planning for paddy rice in India that could be calculated using a mathematical model. They stated that CROPWAT can appropriately estimate ETc and effective precipitation parameters and is a good tool for irrigation planning for climatic conditions. Ahmad et al., (2021), investigated the effect of global warming on the ETc and irrigation water needs of paddy rice in CROPWAT. As a result of the study, they showed that the crop irrigation water requirement varied between 965-1000 mm. Porras-Jorge et al., (2020), reported that the alternative wetting and drying (AWD) irrigation technique in paddy rice in the Aquacrop program showed good performance on crop yield and could be used under drought conditions. Markovska and Dudchenko (2021), determined the ETc and wate use efficiencyunder drip irrigation conditions. As a result of the study carried out using 2 different paddy rice seeds, they stated that the water production amounts were in the range of 1.27-1.29 kg/m^3 and drew attention to the potential of drip irrigation. Akbar et al., (2022), examined the irrigation water efficiency and irrigation water savings of 3 different irrigation methods (furrow irrigation, drip irrigation and flood irrigation) in Pakistan with Aquacrop model. They stated that although drip irrigation reduced crop yield by 7.5%, it increased irrigation water efficiency and water savings by 2.4% and 73%, respectively. As can be seen, although studies on paddy rice irrigation based on different models have been carried out in international studies, studies in Türkiye are limited.

In this study, the performance of drip irrigation in paddy rice for Edirne were examined in the Irrigation Management and Crop Water Consumption Decision Support System (TAGEM-SuET)model developed by the General Directorate of Agricultural Research and Policies of Turkey (TAGEM).

2. MATERIALS AND METHODS

2.1. TAGEM-SuET

TAGEM-SuET is an application developed to ensure efficient irrigation in the right amount at the right time, to increase water use efficiency and to contribute to water resources management. It allows technical personnel and producers who support water management in agricultural production to calculate crop water consumption, irrigation water need, irrigation programming, irrigation module, flow rate and water source needs required for the design and operation of irrigation systems. In addition to the data contained in the "Crop Water Consumption Guide of Irrigated Crops in Türkiye" in the SUET database, it includes some new and updated data regarding crops, soil and irrigation systems required in irrigation management. SUET database contains 30 years of meteorological data. Different techniques have been devised so far to estimate ETc theoretically. TAGEM-SuET offers 7 different alternative methods for ETo, ETc, irrigation programming and irrigation module calculations. These methods vary depending on the use of climatic parameters. SUET is able to perform these methods even in case of limited meteorological data available. It is the "Standardized Penman Monteith" method recommended by the system (TAGEM, 2024).

The FAO-Penman Monteith is the most widely used method for determining ETc worldwide. The technique in issue is based on crop coefficient (Kc) associated with the stages of crop development and reference evapotranspiration (ETo), both of which can be computed using comprehensive meteorological data (Allen et al., 1998). The flowchart of the model is shown in Figure 1.

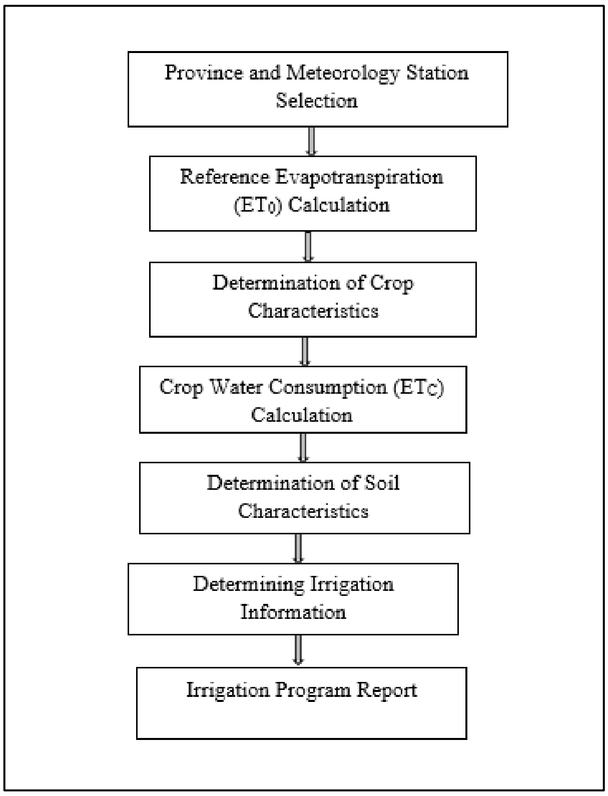

Figure 1:
Flowchart of the model

2.2. Study Area

Edirne province is in the northwest of Türkiye and is located at 41.6771 latitude and 26.5557 longitude (Figure 2). There are Istranca Mountains in the north, Ergene Basin in the middle, mountains and plateaus and the Meriç Delta in the south. A continental climate prevails in Edirne. The winter months are very cold and long, and the summer months are hot. It rains the most in spring (Deveci and Kaptan Ayhan , 2023).

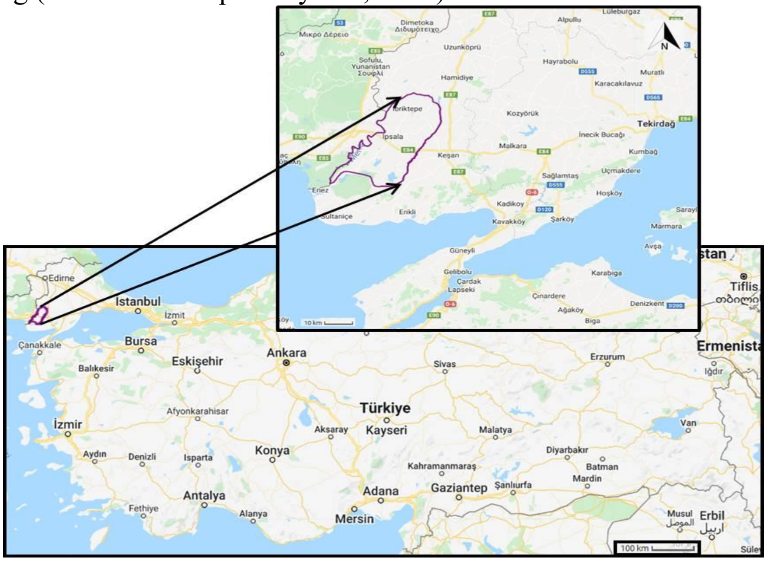

Figure 2:
Study area

2.3. Meteorological Data

Minimum and maximum temperature, sunshine duration, wind speed and precipitation values of the research area for the last 30 yearsand monthly reference evaporation (ET$_o$) values calculated with the TAGEM-SuET computer software with the help of these data are given in Table 1. The annual ET$_o$ found 970.12 mm in the model (Figure 3).

Table 1. Edirne province monthly meteorological data and ETo values

Months	Maximum Temperature (°C)	Avarage Temperature (°C)	Minimum Temperature (°C)	Sunshine Duration (h)	Wind Speed (m/s)	Total Precipitation (mm)	Avarage ET$_o$ (mm)
January	6.7	2.6	- 0.6	2.4	4.11	65.2	0.58
February	9.4	4.4	0.4	3.6	4.28	52.8	1.05
March	13.3	7.6	2.8	4.5	4.03	50.1	1.77
April	19.3	12.8	7.1	6.2	3.67	47.9	2.89
May	24.8	18.0	11.7	8.0	3.27	52.3	4.10
June	29.2	22.2	15.5	9.2	3.22	47.3	5.00
July	31.9	24.7	17.4	10.3	3.50	32.0	5.34
August	31.9	24.5	17.3	9.8	3.58	23.3	4.78
September	27.4	20.1	13.5	7.5	3.44	36.2	3.21
October	20.7	14.4	9.2	5.2	3.67	57.4	1.70
November	14.2	9.2	5.2	3.2	3.86	66.8	0.82
December	8.5	4.6	1.4	2.2	4.10	70.6	0.52

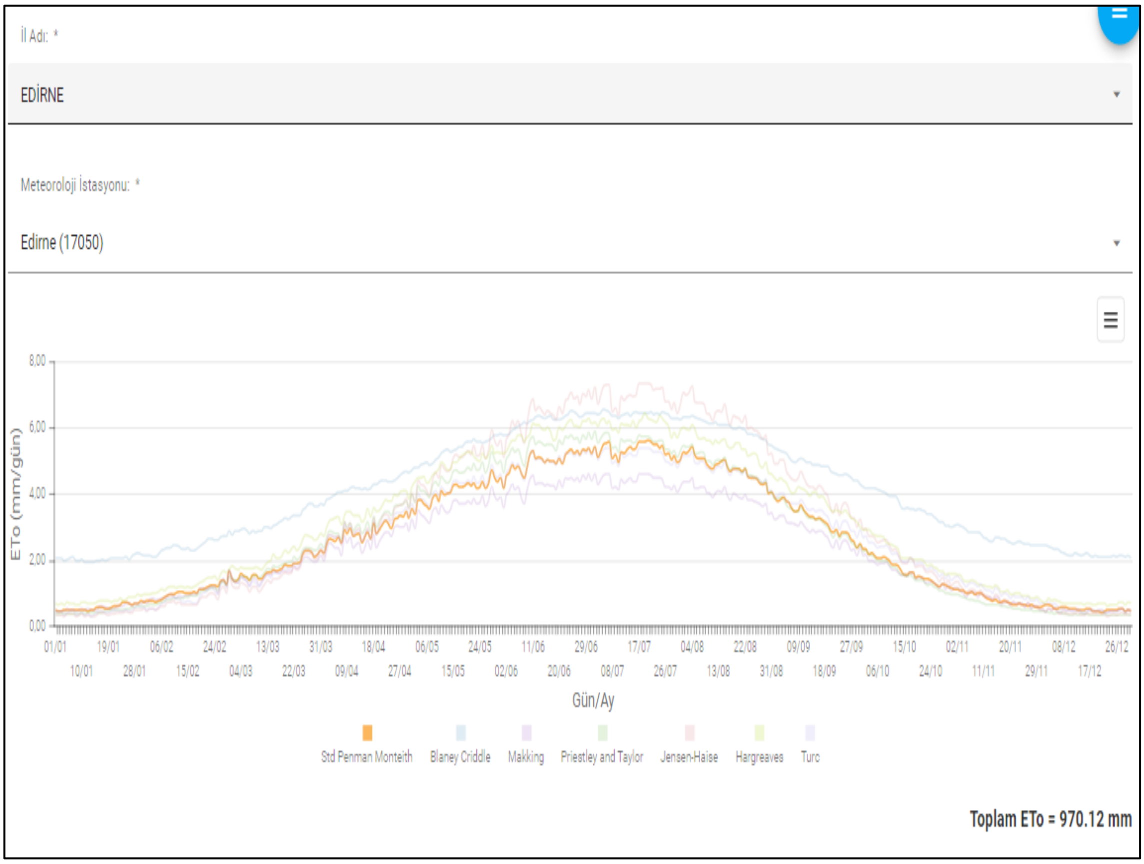

Figure3:
TAGEM-SuET ETo calculation module

2.4. Creating Irrigation Programs

The length of the growing period of paddy rice was taken as the planting and harvesting dates of the Thrace region between 15 May and 10 October. Crop coefficient (K_c), effective root depth, and the fraction of available water holding capacity allowed to be consumed were determined by Allen et al., (1998) (Table 2). The seasonal yield response factor (ky) was selected as 1.10 for paddy rice. The ET_C of the paddy rice in Edirne province is calculated as 692.83 mm in the model (Figure 4). It is estimated that ET_C of paddy rice in Türkiye varies between 810-1625 mm depending on the climate in various regions (Özgenç and Erdoğan, 1988). TAGEM (2021), reported ET_C values for drip irrigation varying between 517-625 mm.

Table 2. Characteristic data of paddy rice

Days	Period	K_C	Starting Root Depth Based on Irrigation (m)	Maximum Root Depth Based on Irrigation (m)	(ky)
0-20	Germination	K_{cini} (0.89)	0.25	0.90	1.10
21-61	Vegetative development	K_{cini} (0.89)			
62-94	Flowering	K_{mid}(1.19)			
95-133	Maturation	K_{cend} (0.76)			

Figure4:
ET_c calculation module

Different irrigation programs were applied for drip irrigation (DI) in Edirne province and are presented in Table 3. While creating optimum irrigation programs, no water restrictions were applied and the solution was taken by accepting the actual water consumption as equal to the maximum water consumption. When the soil properties in Edine province are examined, they are generally loamy soils (Pekcan and Erdem, 2005; Bellitürk, 2011). In the study, all irrigation programs were applied according to the characteristics of medium-textured soils (Table 4).

Table 3. Irrigation treatments

Treatments	Explanation
DI100	To apply irrigation water with DI when 30% of the total available soil water (TAW) in the root zone is depleted
DI75	Restricting 75% of DI100
DI50	Restricting 50% of DI100
DI25	Restricting 25% of DI100
Ponding Irrigation (PI)	To apply irrigation water with PI when 40% of TAW in the root zone is depleted.

Table 4. Soil characteristics

Soil Texture	Soil Depth (cm)	Field Capacity (%)	Wilting Point (%)
Loam	0-120	25	12

Irrigation information according to irrigation methods in the TAGEM-SuET irrigation program is given in Table 5. Critical depletion fraction (p)for paddy rice, which is a water-sensitive of the crop, is used to be between 0.3-0.4. Irrigation efficiency values are used according to those stated in Çakmak et al., (2008).

Table 5. Irrigation information

Informations	Irrigation Method	
Irrigation Method	DI	PI
Critical depletion fraction (p)	0.3	0.4
Irrigation Efficiency (%)	85	55
Wetted Area Rate (%)	100	100

2. RESULTS AND DISCUSSION

Within the scope of the most appropriate irrigation program in which there will be no loss of efficiency in the TAGEM-SuET system, in Edirne province, the paddy rice irrigated with drip irrigation is predicted to be irrigated 19 times, the net amount of irrigation water, and the total irrigation water need are given in Table 6, Figure 5.

Table 6. Appropriate irrigation program

Date	Net Amount of Irrigation Water (mm)	Total Irrigation water (mm)
17/05/2024	6.93	8.16
21/05/2024	11.13	13.09
26/05/2024	12.15	14.29
31/05/2024	14.58	17.16
06/06/2024	19.85	23.36
12/06/2024	21.32	25.09
19/06/2024	27.45	32.29
26/06/2024	31.26	36.78
02/07/2024	32.57	38.31
09/07/2024	36.26	42.66
16/07/2024	36.04	42.40
22/07/2024	37.30	43.89
28/07/2024	36.37	42.79
04/08/2024	38.95	45.83
11/08/2024	39.48	46.45

Table 6 (continue)

18/08/2024	37.00	43.53
25/08/2024	35.43	41.68
03/09/2024	38.85	45.71
13/09/2024	37.64	44.29
Total:	550.64	647.81

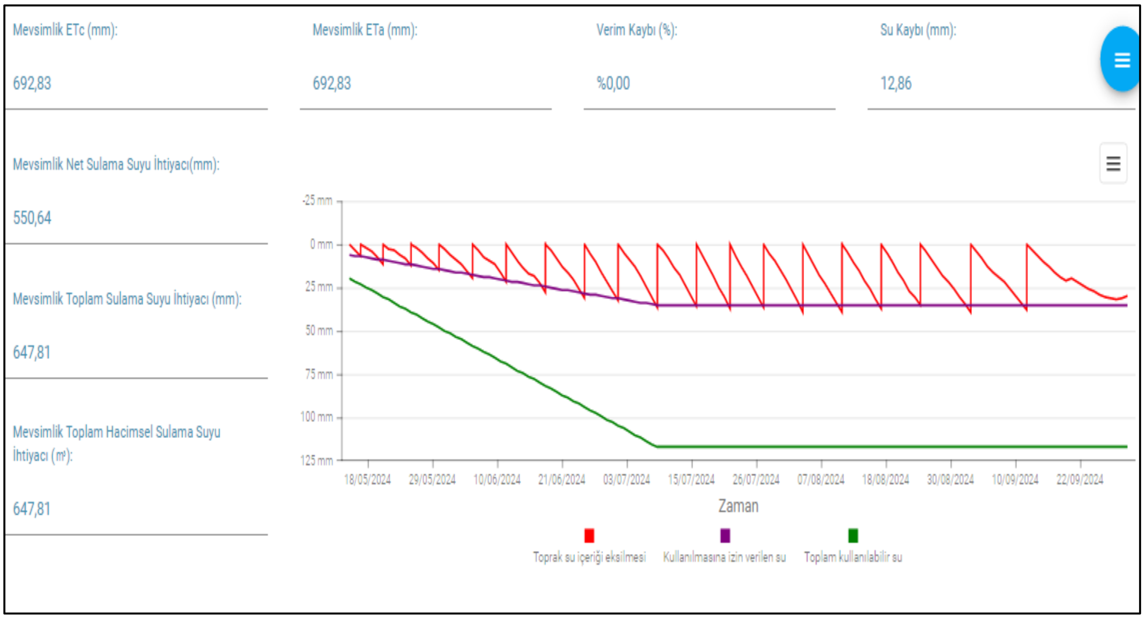

Figure 5:
The most appropriate irrigation program for drip irrigation in paddy rice for Edirne

When the studies conducted in the Thrace region are examined, TAGEM (2021), applied 719 mm of irrigation water for Epan 1.0 in its two-year study. In another study, Tuna (2012) stated that 723 mm of irrigation water was applied to Epan 1.0 in drip irrigation applications. Özer (2018), applied 876 to 1217 mm of irrigation water to drip irrigation treatments. The reason why irrigation amounts differ is that ET_C is calculated based on long-term climate parameters when making irrigation planning.In addition to the appropriate drip irrigation program, results for 4 different irrigation schedules: PI, DI75, DI50 and DI25 are given below (Figure 6, Table 7). The Table 7 shows net irrigation water, total irrigation water, and yield loss percentage values calculated by the TAGEM-SuET system for each irrigation program.

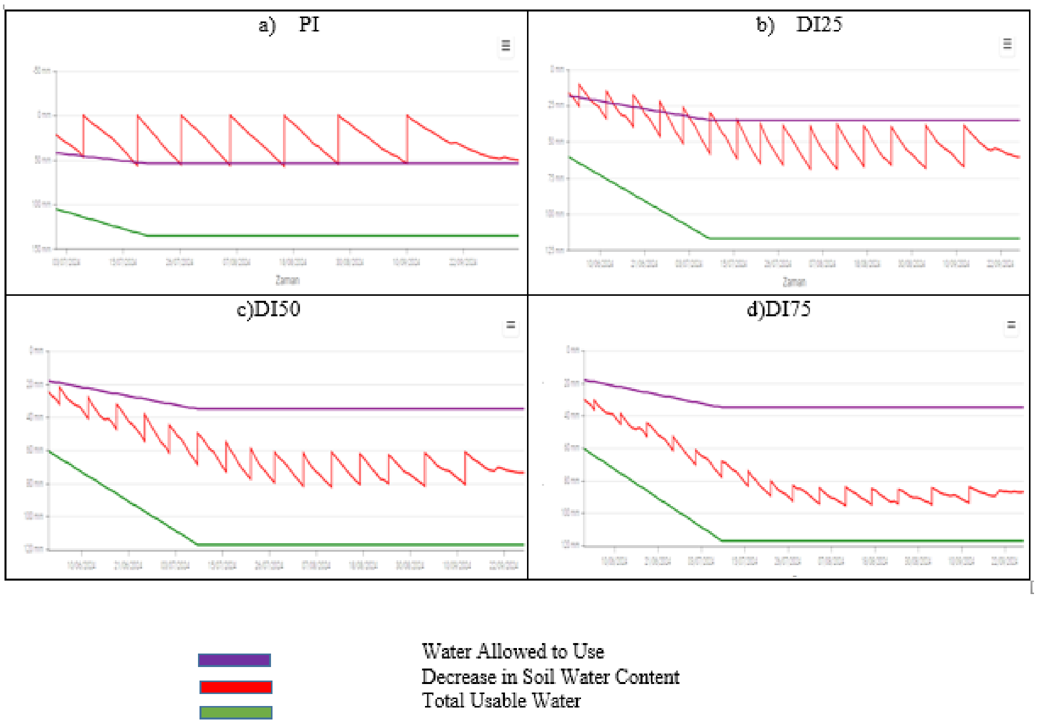

Figure 6:
Irrigation schedules

Table 7. The results of irrigation programs

Irrigation Program	Net Irrigation (mm)	Total Irrigation (mm)	Yield reduction (%)
PI	573.87	1043.41	-
DI75	137.88	162.21	55
DI50	275.76	324.42	35
DI25	413.64	486.63	15

According to the study, depending on the degree of water deficit, yield reductions happen because less irrigation water is applied than the ET_C in water-restricted programs. Upon examining Table 7, it becomes evident that potential serious reductions will be observed in yield accordance with the severity of the water scarcity.Özer (2018), obtained a yield of 6.39 t/ha with the drip irrigation method and 7.95 t/ha with the ponding irrigation method. In the study conducted by Tuna (2012), a yield of 8.14 t/ha was obtained from the field irrigated with the ponding irrigation, and 7.11 t/ha (Epan 1.50) from the field irrigated with the drip irrigation method. In the study conducted by Demirel et al., (2020) in Edirne province, 664 kg/da from the ponding method, 745 kg/da from the ponding + water barrier, 321 kg/da from the subsoil drip + water barrier anda yield of 365 kg/dawas obtained from the drip irrigation application.Taş (2022), achieved the highest yield among 24 sub-topics, 10305 kg/ha on 1.5 Epan with drip irrigation with 2 days intervals.According to the model, considering limited drip irrigation programs, crop yield losses vary between 15-55%, and the highest yield loss is predicted to be at DI75. When the appropriate drip irrigation program (DI100) was compared with PI, it was estimated that there would be no effect on yield despite the 38% water restriction.

3. CONCLUSION AND SUGGESTIONS

Taking advantage of approaches provided by technology plays an increasingly important role in terms of the sustainability of water resources. Recently, software and online platforms that enable the determination of the appropriate irrigation schedule for cultivated plants as well as in paddy rice.

In this study, the most appropriate drip irrigation program for paddy rice in Edirne province was determined and its effects on yield were investigated in the TAGEM-SuET model. This model allows obtaining the highest efficiency per unit water in paddy rice by using meteorological data. According to the results of the study, the total irrigation water requirement in the most suitable drip irrigation program that will not cause a decrease in crop yield was measured as 647.81 mm. It is calculated that although limited drip irrigation will cause a 15% to 55% loss in grain yield compared to PI, it will provide irrigation water savings between 45% and 85%. The results clearly show that the irrigation program of the TAGEM-SuET model will help both producers and technical personnel in paddy rice cultivation with drip irrigation. In future study, it is planned to develop an irrigation-automation system integrated with paddy rice cultivation under drip irrigation based on the outputs of the model.

CONFLICT OF INTEREST

The authors declare that there is no conflict of interest regarding the publication of this article.

AUTHOR CONTRIBUTION

Hakkı Fırat ALTINBİLEK: Determining and implementing the modeling process, literature review and writing the article.

Ünal KIZIL: Analysis, interpretation, editing and compilation the article.

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