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The Analysis of Landscape Irrigation Systems in a Neighborhood Park: The Case of Prof. Dr. Erol Güngör Park

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Abstract: In landscape implementations, the required water volume for the plant should be provided through an appropriate system and irrigation program. The use of inappropriate irrigation systems can result in the wasteful consumption of water resources that are already in limited supply. It is therefore crucial that irrigation systems are designed by experts following the relevant standards. The objective of irrigation system designers in urban areas is to guarantee the year-round health of landscapes. Accordingly, designers and users need to pay more attention to water management. The goal of water management is to keep landscapes healthy throughout the year while minimizing the amount of water and energy used for irrigation on an annual basis. This study aims to investigate landscape irrigation systems, which are critical to the sustainable use of green spaces in urban areas, at the scale of neighborhood parks. The study area was selected as Prof. Dr. Erol Güngör Park with an area of about 9000 m^2 in Konya, Türkiye. The research involved observing the irrigation systems used in the park, studying their technical specifications in detail, and analyzing data such as the amount of water used and the frequency of irrigation. It is found that over-irrigation in the park results in the annual waste of 8.963 m^3 of water, which corresponds to an approximate cost of 6.665 US dollars per year. The results of the study show that significant water savings can be achieved through the design of automatic irrigation systems and the conscious preparation of irrigation schedules.

1. Introduction

Water is the most basic resource that all living things need to survive. Although approximately 3/4 of the world is covered with water, the amount of usable water is very limited and continues to decrease day by day. For this reason, it is necessary to act with a

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holistic approach in order to effectively use the water consumed in agriculture, industry, households, and urban green areas. Currently, water use in agriculture and industry is mostly kept to a minimum due to commercial concerns. The avoidance of waste in domestic water use, a type of water consumption in urban areas, is associated with the raising of awareness among individuals. On the other hand, landscape irrigation, which is outside of these uses, should be considered as part of urban water management policies; meeting the water needs of vegetation should be harmonized with the efficient use of water resources. In this context, the provision of sustainable irrigation solutions to support landscape areas is of paramount importance in addressing the issue of urban water scarcity. The design of an irrigation system and the formulation of an irrigation program for urban green spaces should be undertaken by a team of experts with relevant technical expertise. Irrigation system design in landscape areas basically involves field surveys and calculation of water needs according to plant characteristics. In the context of an effective irrigation program, it is imperative to consider evapotranspiration rates, water flow rates, and the uniform distribution of water to optimize water use and minimize wastage.

The presence of urban green areas and the effective management of water resources in a nation are considered to be among the most significant indicators of economic development and social welfare. In this context, policies for the sustainable use of water in urban green areas should be developed [1]. A review of the literature on this topic reveals that previous studies have focused on the design and management of irrigation systems. The studies emphasize the importance of irrigation design based on climate, soil, and hydrogeological factors and suggest various methods to improve the efficiency of water distribution and irrigation programs [2]. Hydraulic calculations play a critical role in the optimal performance of landscape irrigation systems [3]. Furthermore, the use of appropriate irrigation management and technologies is emphasized to increase water savings and protect plant health [4, 5]. In particular, the integration of soil moisture sensors and weather data into irrigation programs stands out as an important step to minimize water waste [6]. Shurtz et.al. (2022) [7] found that many water users irrigate beyond the optimum point, suggesting that there is water conservation potential without loss of aesthetics. Some studies, such as the work of AlHalim (2020) [8] have focused on the importance of the xeriscape concept in terms of water conservation in landscape areas. In conclusion, these studies cover a wide range of factors that need to be considered in the design of sustainable and efficient irrigation systems [9, 10].

A review of the extant literature on the irrigation of landscape areas which was evaluated in the context of this research, reveals some studies that have been carried out in Türkiye as well. It was determined that the main topics addressed in these studies were the techniques used in irrigation system design, water consumption, and efficiency criteria, performance and quality indicators, and comparative irrigation approaches. Bayramoğlu, et al. (2012) [11] examined the principles that should be taken into consideration regarding drip irrigation systems, intending to utilize water at maximum level in landscape areas. According to Bayramoğlu, et al. (2013) [12], new irrigation approaches should be developed to make cities more livable by saving irrigation water, especially in recreation areas. Yetik and Ünal (2024) [13] determined the weights of water use efficiency, system cost, plant type, technical knowledge of the irrigator, water availability, climate, soil type, traditional habits, slope, and water quality criteria for the evaluation of irrigation methods. Demirel, et al. (2006) [14] found that up to 50% water saving can be achieved by designing and implementing the irrigation system in their study area according to certain rules. Altay and Demirel (2019) [15] examined the irrigation systems of 12 large-scale landscape areas within the scope of their study and encountered deficiencies and problems related to irrigation systems in almost all of the examined areas. Demirel, et al. (2024) [16] found that despite the superior water application efficiency of subsoil drip irrigation systems, sprinkler irrigation systems were found to be a more cost-effective solution.

In the study of Ünlükaplan and Tiğiz (2023) [17], it was stated that the implementation of projects based on xeriscaping principles is imperative to minimize water consumption costs, and the reuse of water collected from impermeable surfaces will achieve substantial savings in irrigation. As a result of the work of Ayanoğlu and Demirel (2023) [18], 54% savings in water consumption, 36% savings in electricity consumption, 64% savings in maintenance costs, and 5% savings in implementation costs were achieved in designs created with xeriscaping approach compared to designs created according to classical landscape principles. Demirel, et al. (2020) [19] emphasized that the design of irrigation systems in landscape areas should be done by experts in the field, taking into account factors such as the soil structure of the land, water consumption of plants, flow rate of water source, soil infiltration rate, wind speed. Kamer Aksoy, et al. (2022) [20] provided solutions to the problems of incorrect irrigation techniques and insufficient irrigation systems in their study area. Within the scope of the study of Ak and Erdoğan (2022) [21], the presence of vegetation forming the landscape area and the importance of determining the optimal water requirements of this vegetation were clearly emphasized, and it was seen that a remote sensing-based approach is an important step in the determination of water stress. According to Demirel, et al. (2018) [22], studies on the evaluation of irrigation projects prepared by municipalities or private companies in Turkey should be increased. Within the scope of this study, the current status of the irrigation system and the irrigation schedule implemented in a neighborhood park in the city of Konya (Turkey) were examined. The analyses have yielded two key outcomes. Firstly, a novel irrigation system has been designed that shows how water usage can be enhanced. Secondly, an appropriate irrigation schedule based on an evaluation of the working area's conditions and the water requirements of the plants have been formulated. A comparative analysis was conducted between the proposed project and the extant irrigation system. Furthermore, an evaluation was made of the proposed and the implemented irrigation schedules, with the objective of ascertaining the presence of any water wastage in the area. In this context, suggestions were developed on the basis of the identified errors/deficiencies. The findings of this study have the potential to serve as a model for similar areas, contributing to the enhanced efficiency of water resources management by raising awareness of local governments on the subject.

2. Materials and Method

2.1. Materials

The study area, Prof. Dr. Erol Güngör Park, is in the Yazır neighborhood of Konya city. It is 8540 m^2 in size and is located approximately 3 km south of Selçuk University Alaeddin Keykubat campus (Fig. 1). The Park contains nineteen pergolas, one dedicated children's playground, and sporting equipment for use by visitors. In the western sector of the park, residential properties are in use by members of the academic staff at Selçuk University. The Park is located 100 meters from the tram stop on the eastern side and approximately 1 kilometer from the Higher Education Girls' Dormitory on the south side. The equipment employed in the study comprised an unmanned aerial vehicle (UAV), a laser distance meter, a digital camera, and a GPS receiver. The DJI Phantom 4 unmanned aerial vehicle (UAV) was employed during the aerial photography and video recording phase of the study. The Leica Disto D810 laser distance meter was utilized for the measurement of various parameters, including distance, area, and height. The Nikon D500 camera was used to take photographs and video recordings of the study area. The Garmin 680 handheld GPS device was utilized to record the coordinate data of the required locations (Fig. 1).

The materials of the study consist of aerial photographs of the study area, Autodesk AUTOCAD 2022 software used in the preparation of existing and proposed irrigation projects, Microsoft Word, Excel 2022 software used in the digitization of the obtained data, and literature on the subject.

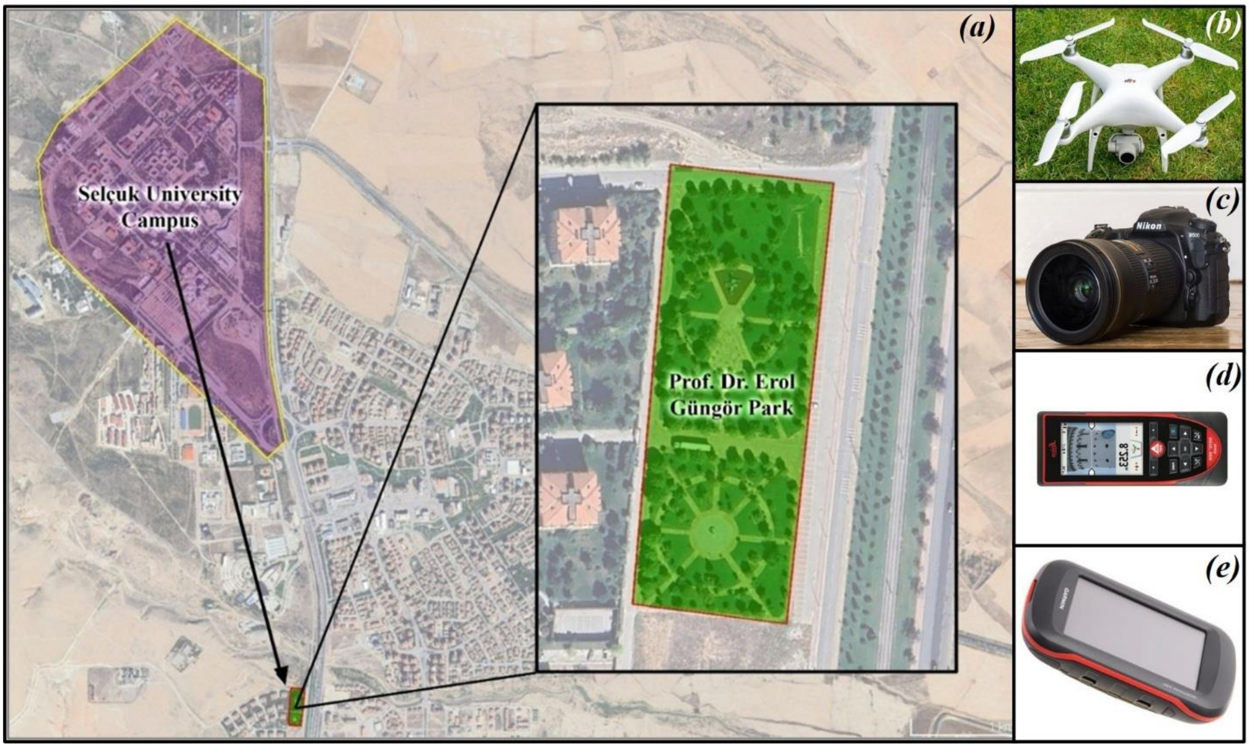

Fig. 1: (a) Location of the study area, (b) UAV, (c) Photo camera, (d) Laser meter, (e) GPS

2.2. Method

The methodology of this study is comprised of five distinct stages. These stages and their sub-stages are shown in Figure 2, which summarizes the flowchart of the study. In the initial phase, the project for the existing irrigation system in the park was drafted on a computer. During the project's preparation phase, the irrigation system in the area was activated, and visual documentation was obtained from both aerial and ground-based perspectives, utilizing a drone and a camera, respectively. In addition, the models of the sprinkler heads were determined through field observations. The required information was obtained from the local government and a project for the location of the sprinklers in the existing irrigation system was prepared. Following observations made during the operational phase of the irrigation system and a thorough examination of the project documentation, deficiencies, and errors were identified and recorded. In the following stage of the study, the irrigation schedules implemented in the park were obtained from the Parks and Gardens Department of the Konya Metropolitan Municipality. Utilizing the aforementioned schedules, the quantity of water consumed in the park was calculated separately for each month during which the irrigation system was in operation. In the next stage, the water requirements of the vegetation in the park were calculated for each month based on the precipitation data of the region. In the third stage, deficiencies/errors in both the irrigation project, and the irrigation schedule were evaluated, and decisions regarding the required revisions were documented. At this stage, a proposed irrigation system design project was prepared for the park. Furthermore, a series of calculations were made on the existing irrigation system, and a proposed irrigation schedule was prepared for implementation by the local government.

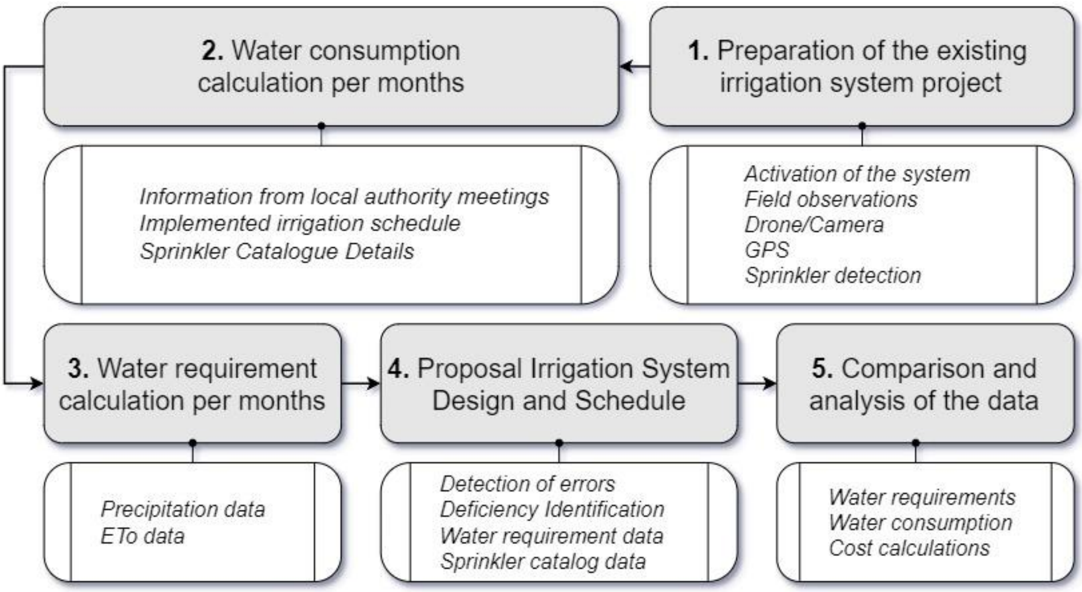

Fig. 2: Flow-chart of the study

In the last stage, the water requirements of the vegetation, calculated previously (in the third stage), were compared with the amount of water consumed in the park, calculated (in the second stage) from the irrigation schedule implemented by the local government. Following a comparison of the data, deficiencies in the irrigation schedule were identified. Based on the data obtained as a result of these comparisons, both the amount of water wasted in the area and the annual cost of this waste were revealed.

3. Results and Discussion

3.1. Findings Regarding the Existing Irrigation Project

As a project for the irrigation system in the park could not be obtained from the relevant local authorities, the irrigation system in the area was activated and visuals were recorded with the assistance of a drone and camera (Fig. 3).

Fig. 3: Various images from the study area

The photographs and videos recorded from the air by the drone camera at perpendicular angles to the ground of the park were used as the primary source for the preparation of the plan illustration of the park. In case of encountering parts that could not be perceived in these images, which had to be recorded from a certain height, images recorded relatively closer and with a perspective suitable for human scale by walking in the park were utilized. In addition to the images obtained by both methods, measurements of length were taken from specific reference points within the designated park area. Concurrently, the models and locations of the sprinkler heads used in the park were also recorded through measurements and observations. As a result of the computerization of the data obtained from field observations and measurements, a plan image showing the arrangement of sprinkler heads in the existing irrigation system in the park and the wetting areas was prepared with Autodesk AutoCAD 2022 software (Fig. 4).

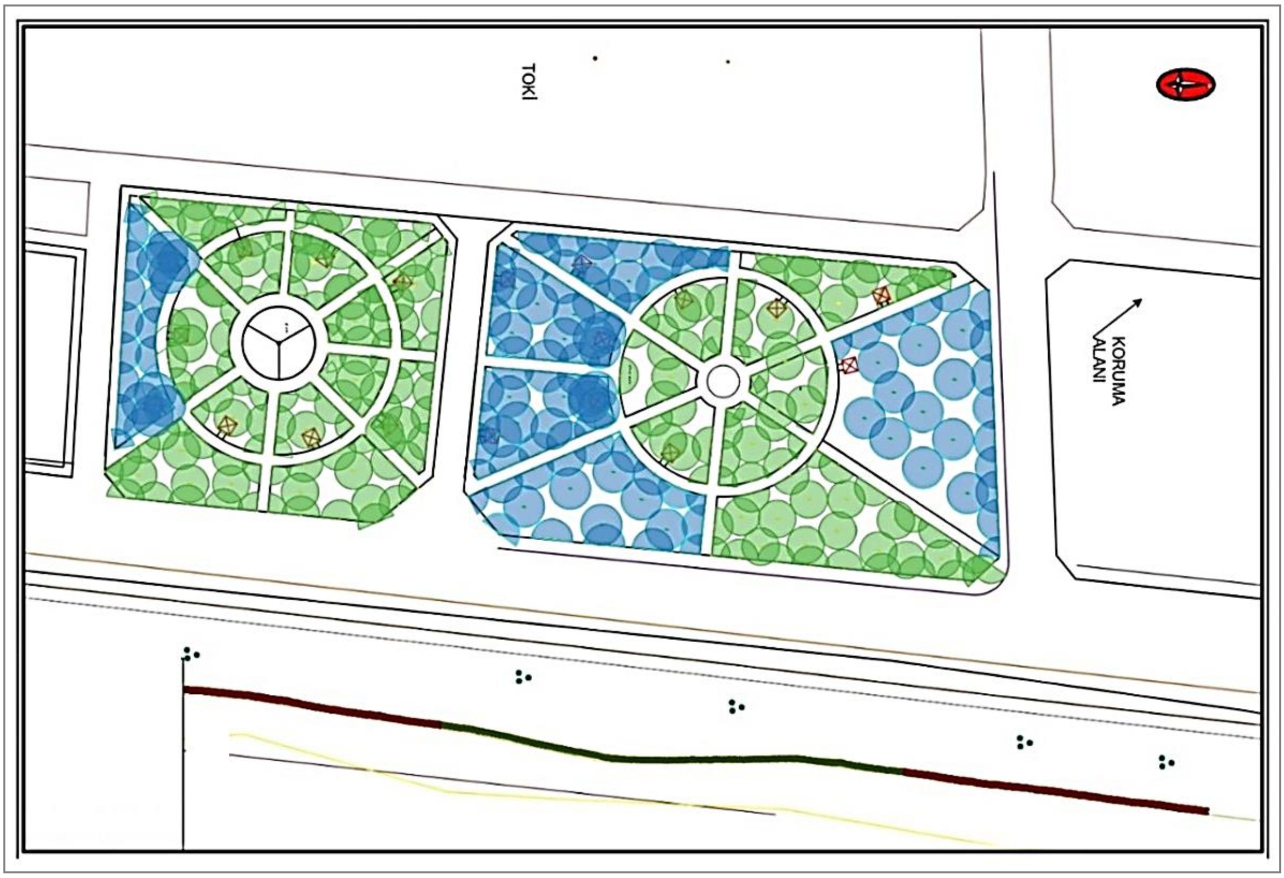

Fig. 4: Existing irrigation system design of the park

A review of the current project indicates that uniform water distribution throughout the area is not assured. In certain regions, irrigation is administered at levels exceeding the requirements. Moreover, it was ascertained that the irrigation of pedestrian pathways and pergolas was also compromised due to the improper adjustment of the sprinkler head rotation angles.

3.2. Findings on the Amount of Water Consumed in Irrigation

Monthly water consumption was calculated from irrigation schedules obtained from local authorities in charge of park irrigation and from existing irrigation project data generated in the previous phase. According to the information received from the authorities, the irrigation system is not operated in December, January, February, and March; it is operated for 15 minutes per day in April and November; 20 minutes per day in May, June, September, and October; and 30 minutes per day in July and August. Based on this data, the following equation (Eq. (1)) was created. It shows the mathematical expression of the operations used to calculate the monthly water consumption of Prof. Dr. Erol Güngör Park.

Equation 1: Monthly water consumption for park irrigation

$$WC_m = f_s \times n_s \times t \times 30$$

WC_m = *Water consumption per month* (m^3)
f_s = *Flow of a sprinkler head* (m^3/min)
n_s = *Number of the sprinkler heads*
t = Irrigation time per day (min)

The flow rate of a sprinkler head was obtained from the catalog of the relevant product. Data concerning system pressure and daily irrigation duration were supplied by the local authority responsible for the maintenance of the park. The number of sprinkler heads was extracted from the project prepared for the existing irrigation system. As irrigation was not utilized in January, February, March, and December, a separate set of calculations was performed for the remaining months of the year (Fig. 5).

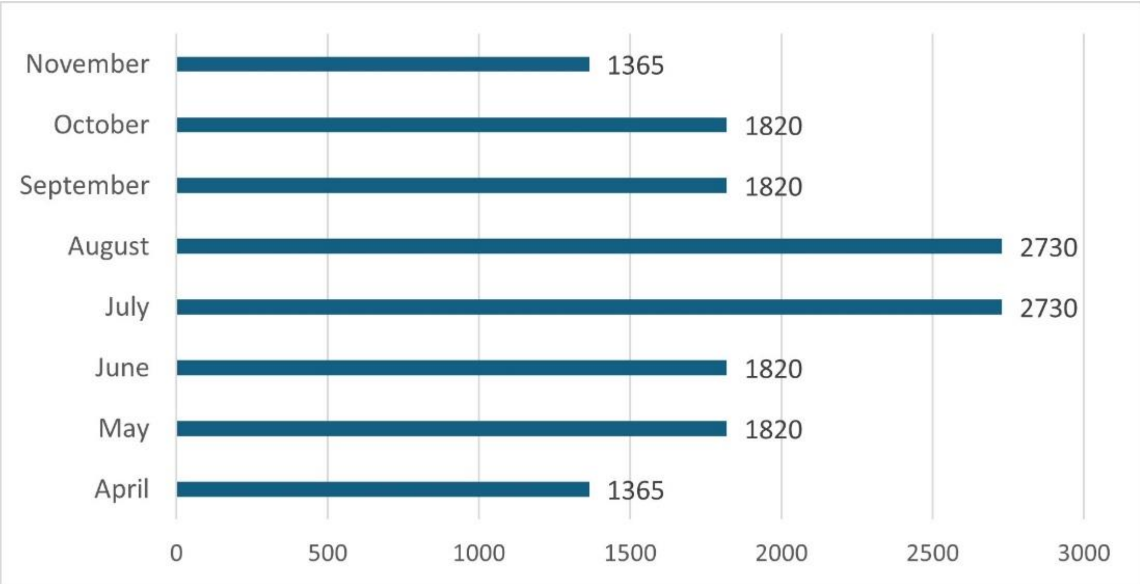

Fig. 5: Amount of water supplied per month to the area (m^3)

An examination of the data obtained for monthly water consumption reveals that the lowest recorded amount is 1365 m^3, while the highest is 2730 m^3, under the current irrigation schedule. As would be anticipated, the volume of water supplied increases in proportion to rising temperatures during the summer months.

3.3. Findings on the Determination of Plant Water Requirement

In determining the plant water requirement in the park, calculations were made in accordance with the information obtained from the *"Plant Water Consumption of Irrigated Plants in Türkiye Guide"* [23], which was published by the 'General Directorate of Agricultural Research and Policies', and the 'Directorate General for State Hydraulic Works'. In this context, the following equation (Eq. (2)) was derived to show the mathematical expression of the processes applied in the calculation of plant water requirement.

Equation 2: Monthly amount of irrigation water required by plants in the park

$$IW_m = (ETo_K - AP_K) \times I_a$$

IW_m = *Irrigation water requirement per month* (m^3)
ETo_K = *Reference Evapotranspiration (ETo) in Konya (mm)*
AP_K = *Average precipitation in Konya (mm)*
I_a = *Irrigated area* (m^2)

Data on reference evapotranspiration (ETo) and long-term precipitation averages for Konya City were obtained from the specified guide (Table 1). An analysis of the values in the table shows that the highest monthly precipitation of 45 millimeters was recorded in December. The lowest value was recorded in August with 5 mm. Analyzing the reference evapotranspiration (ETo) data for Konya, which has a total annual precipitation of 311 mm, it is found that the total annual water requirement is 1077 mm. The difference of 766 mm between these two values indicates the annual amount of water that should be provided by irrigation, in addition to the part of the plant's water requirement met by precipitation.

Table 1: Reference evapotranspiration and long-term precipitation averages for Konya [22]

Month	January	February	March	April	May	June
Precipitation (mm)	30	23	26	36	39	20
ETo (mm)	20	31	64	94	129	161
Month	**July**	**August**	**September**	**October**	**November**	**December**
Precipitation (mm)	8	5	11	30	39	45
ETo (mm)	186	164	113	64	30	18

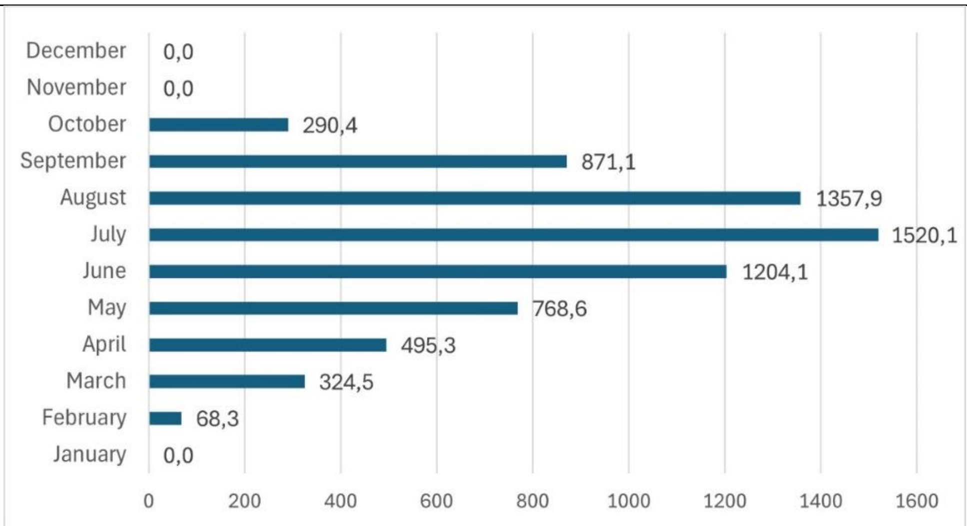

Fig. 6: Amount of irrigation water required by the plants (m^3)

The size of the irrigated area was determined from field measurements and the project prepared. The monthly water requirements of the plants in the park that should be supplied by the irrigation system were calculated from all this data (Fig. 6). Since the precipitation in the months of January, November, and December covers the water requirements of the plants, the irrigation system does not need to be operated during these months. It was determined that the highest water requirement was 1520,1 m^3 in July.

As can be seen from the graph, water requirement increases in summer when the temperature and evaporation are high. Similarly, as temperature and evaporation decrease in the autumn, water requirements also decrease.

3.4. Findings on the Proposed Irrigation Project and Schedule

Up to this stage of the study, the project of the existing irrigation system was prepared, and the amount of water consumed as a result of the irrigation schedule being implemented was calculated in accordance with the information received from the local authority. Furthermore, defective, or missing parts of the irrigation system were identified through the analysis of field observations and recorded images. Based on this data, a standard-compliant irrigation system design project was prepared for the park (Fig. 7). Two main issues were considered during the preparation of the project. The first was to ensure a homogeneous water distribution in the area and the second was to build a more successful system in terms of price/performance during the installation phase of the project. In this context, the proposed project replaced the sprinkler models with more appropriate models where needed and updated the locations of the sprinkler heads that are currently incorrectly positioned.

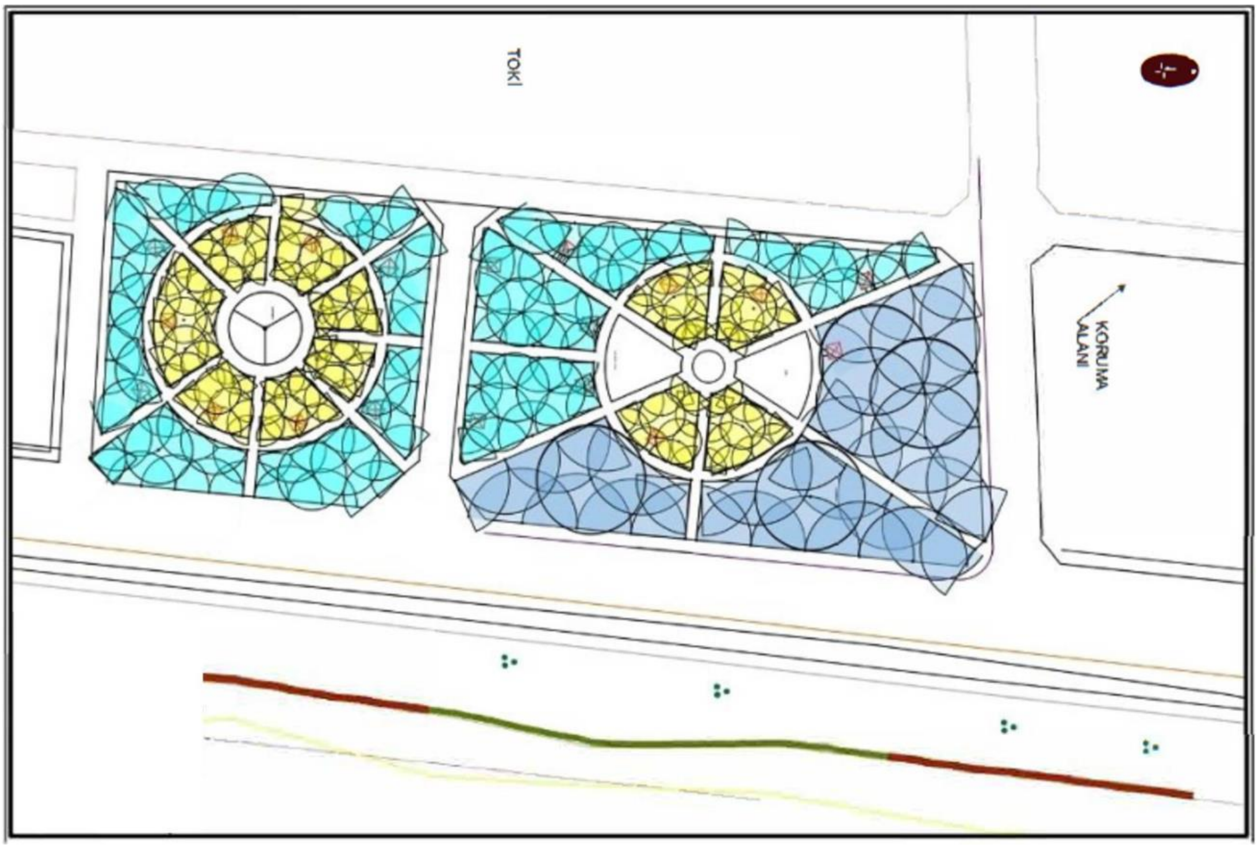

Fig. 7: Proposed irrigation system design project

In consideration of the technical specifications of the equipment utilized within the park, a proposed irrigation schedule was then prepared for the local authority (Table 2). The table also includes information on the current irrigation schedule for the purpose of comparative analysis.

Table 2: Proposed irrigation schedule

Month	Feb.	Mar.	Apr.	May.	June	July	Aug.	Sept.	Oct.	Nov.
Current Irrigation (min)	0	0	15	20	20	30	30	20	20	15
Proposed Irrigation (min)	1	3,6	5,4	8,4	13,2	16,7	14,9	9,6	3,2	0

As is apparent from the data presented in the table, it is clear that the recommended duration of irrigation for each month has been significantly exceeded. Evidence suggests that, in several instances, the recommended irrigation duration is exceeded by more than 5 times. In November, it was observed that the system was operated for a daily duration of 15 minutes, despite the absence of necessity for irrigation. This finding indicates a substantial amount of water wastage. Similarly, while only 3,2 minutes of irrigation was sufficient in October, the system was operated for 20 minutes; in April, the system was operated for 15 minutes instead of 5,4 minutes. Evidence also suggests that the irrigation system, which was meant to be operational for a limited period in February and March, was not utilized at all during these months. Consequently, it was determined that the existing irrigation schedule is not conducive to the optimal health of the park's vegetation and the efficient use of water resources.

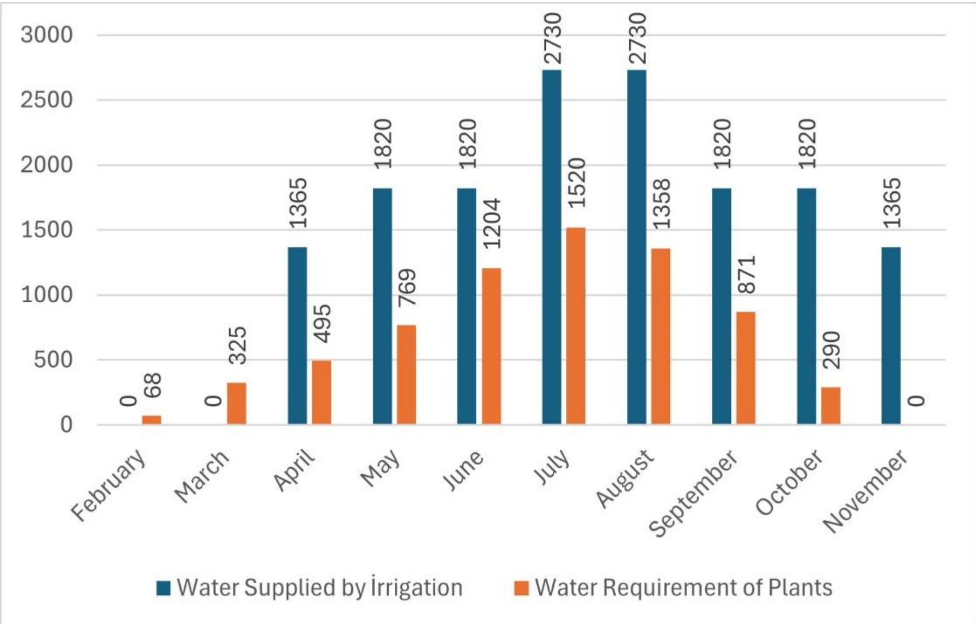

Fig. 8: Water supplied by irrigation and the water required by plants (m^3)

3.5. Findings on the Comparison of Required and Supplied Water

A comparison of the irrigation water requirements of the plants with the data obtained from the irrigation schedule reveals a significant amount of water wastage (Fig. 8). As irrigation is not required and the system is not operational in January, November, and December, these months have been excluded from the graph. During the months of February and March, it is observed that no water is provided, although a relatively small amount of irrigation is required. Another noteworthy month in the graph is November. In this month when there is no need for irrigation, a total of 1365 m^3 of water is wasted.

A subsequent analysis of the data indicates that the consumption of water is significantly higher than the amount required for all months during which the irrigation system is operational. It is seen that the amount of extra water consumed reaches 1530 m^3 per month. It was also determined that the months with the highest water wastage were August, October, and November. The total water requirement of vegetation in the park has been calculated to be 6900 m^3 per annum. However, analysis of the data indicates that the irrigation system is supplying more than double this amount, reaching a total of 15470 m^3. Additionally, an annual loss of 8963 m^3 has been recorded, which is indicative of water wastage (Table 3).

Table 3: Supplied, required, and extra water consumption per month

Month	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Total
Supplied Water (m^3)	0	0	1365	1820	1820	2730	2730	1820	1820	1365	15470
Required Water (m^3)	68	325	495	769	1204	1520	1358	871	290	0	6900
Extra Water Consumption (m^3)	0	0	870	1051	616	1210	1372	949	1530	1365	**8963**

The wasted water because of the improper irrigation schedule was also evaluated in terms of cost (Table 4). At this stage, information on the price per cubic meter of water was obtained from the municipality responsible for the neighborhood where the park is located.

Table 4: Supplied, required, and extra water consumption per month

Project/Irrigation Schedule	Annual Water Consumption Cost (TL)
Proposed Irrigation Schedule	187.818 (~5.366 $)
Current Project and Irrigation Schedule	421.093 (~12.031 $)
Loss Incurred Due to Faulty Irrigation Schedule	233.275 (~6.665 $)

Based on the calculations, it has been determined that there is an annual loss of 233.275 TL (~6.665 $). The cost of water consumed with the current irrigation schedule is 421,093 TL (~12.031 $). It was found that this cost could be reduced to 187,818 TL (~5.366 $) by implementing the proposed irrigation schedule. This situation proves that there is a significant loss not only in terms of plant health and water wastage but also in economic terms with the improper irrigation schedule applied.

4. Conclusions/Recommendations

In this study, the efficiency of the existing irrigation system in Prof. Dr. Erol Güngör Park was evaluated and the issues that need to be improved were determined. As a result of the analysis, it was found that there were various shortcomings and errors in both the project and the irrigation schedule of the existing irrigation system. The primary findings showed that the current irrigation system does not provide uniform water distribution in some areas and that there is over-irrigation in some of the zones. In addition, it was determined that pedestrian paths and pergolas were also irrigated because the rotation angles of the sprinklers were not set properly. This leads to water wastage and inefficient operation of the system. Comparing the irrigation schedule and plant water requirements, it was found that the current irrigation schedule exceeds the plants' water requirements, resulting in significant water wastage. It was determined that water wastage was at the highest level, especially in August, October, and November. In total, it was found that 8963 m^3 of water was wasted annually at a cost of 233,275 TL (~6.665 $). Based on these findings, a new proposed irrigation system for the park was designed and an irrigation schedule was developed. The new proposed project is designed to ensure uniform water distribution and to create a more efficient system in terms of cost/performance. It has been shown that annual water consumption and cost can be significantly reduced with the proposed project and schedule. In addition, if such waste of water and cost is incurred even in an area of only 9000 m^2, it will be better understood how serious the situation is when the green areas of the entire city are considered. In this context, the local authority responsible for the maintenance of the park should replace the existing irrigation system in the park with the proposed new system. This will reduce water wastage by ensuring uniform water distribution. Even if the proposed new system is not installed, at least the existing irrigation schedule should be updated and revised according to the water requirements of the plants each month. Thus, a significant amount of water will be saved just by revising the schedule. Optimizing irrigation performance through regular monitoring and data analysis should be supported by the use of advanced technologies. Training on efficient irrigation and water conservation should be organized for park maintenance staff; cooperation between local government, researchers, and environmental organizations should be encouraged. To achieve long-term sustainability goals, a plan should be developed that includes water-saving and environmentally friendly solutions. In conclusion, this study has provided recommendations for improving the efficiency of the existing irrigation system and preventing water wastage. It has also demonstrated the feasibility and potential benefits of these recommendations. Future research may focus on assessing the long-term performance of the proposed system and further developing water management strategies.

Acknowledgments

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