

Evaluating a DSS for Irrigation Management to Optimize Water Use and Enhance Productivity: A Case Study of Qom Province

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Article Info	ABSTRACT
Article type: Research Article	Objective: The use of intelligent irrigation management decision support systems has gained significant importance as a novel approach for optimizing water consumption and enhancing water productivity in the agricultural sector. This study, as a preliminary pilot case study, evaluates the initial performance of an intelligent irrigation management decision support system (named "HooshAb") in a 20-ha silage maize field in Qom Province. The main objective was to investigate the impact of this decision support system on optimizing irrigation management and reducing water consumption under conditions of water scarcity.
Article history: Received 10 January 2025 Received 14 February 2025 Accepted 17 March 2025 Published online 22 September 2026	Methods: For this purpose, two adjacent similar fields managed by the same farmer were selected as pilot sites for implementing and operating the decision support system. In one field, irrigation followed the farmer's traditional management method (control), while in the other, irrigation was carried out according to the schedules provided by the decision support system (treatment).
Keywords: Decision Support System Smart Irrigation Management Water Productivity Soil Moisture Simulation Silage Maize	Results: The results showed that by optimizing irrigation scheduling and appropriately simulating soil moisture patterns, the decision support system reduced water consumption by approximately 6% compared to the traditional method. Moreover, the use of the system increased irrigation water productivity by 6.3%. Field monitoring of soil moisture and saturated extract salinity indicated that the decision support system had high accuracy in predicting soil moisture and was effective in optimizing on-farm water management. Soil salinity monitoring results also highlighted the importance of updating irrigation water quality data during the growing season to enhance the accuracy of the decision support system in estimating saturated extract salinity.
	Conclusions: The preliminary findings suggest that irrigation DSS may enhance water productivity and support soil-water sustainability under climate change, though multi-season and multi-location studies are needed for validation. Such systems enable precise irrigation scheduling, reduce unnecessary water use, and support long-term soil health. Regular updating of key input data, especially water quality parameters, is essential for maintaining system accuracy and reliability throughout the growing season.

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1.Introduction

Today, water scarcity is considered one of the most critical issues facing many countries—a challenge with which nations in hot and arid climates are particularly confronted. It is often stated that a significant portion of water loss in various countries is attributable to the industrial and agricultural sectors (Shemer et al., 2023; Abdi et al., 2026). Under these circumstances, the adoption of modern systems in irrigation management can contribute to the efficient use of water in agriculture. In different irrigation methods, both the amount and timing of irrigation are of paramount importance, as they are directly linked to the volume of water resources utilized and the attainment of potential crop yield (McDermid et al., 2023; Karami Moghadam et al., 2026). Imbalances in irrigation scheduling may arise from farmers' neglect or lack of knowledge regarding the crop's water requirements. This issue can directly cause substantial financial losses for the farmer and, indirectly, pose a threat to the agricultural economy and the assurance of national food security.

The first step toward increasing irrigation water productivity is to improve water management in the agricultural sector. Water specialists strive to enhance this indicator by reducing water losses in various components. One of the methods for improving water productivity is the application of intelligent irrigation management in agriculture. In this way, water is supplied to the crops at the appropriate time and in the optimal quantity, thereby facilitating the conditions for achieving potential crop yields (Lakhia et al., 2024; Sepehri et al., 2025). However, to increase the adoption rate of this technology in practice and to ensure its sustainable use, a comprehensive and specialized evaluation of these systems must be conducted through the establishment of pilot demonstration sites. Such evaluations would allow for the identification of the strengths and weaknesses of each system, enabling the development of an improved, locally adapted system for local end-users.

An intelligent irrigation system refers to irrigation carried out using smart systems and controllers capable of scheduling irrigation based on geographical location, weather conditions, temperature, and relative humidity of the environment. The controllers embedded in these modern irrigation systems are able to monitor ambient weather conditions, assess the water uptake by plants, and plan irrigation schedules by taking into account the evapotranspiration rate. In general, intelligent irrigation systems schedule irrigation based on various methods and tools. These methods can be broadly divided into three categories: those based on soil moisture, those based on meteorological data, and those based on plant indices (Bwambale et al., 2022). In soil-moisture-based irrigation scheduling, controllers equipped with soil-moisture sensors are used. These controllers incorporate sensors that assess and record soil moisture levels using various state-of-the-art technologies. The system can then intelligently plan irrigation for the field based on the moisture-related data received from these sensors. In weather-based irrigation scheduling, the system employs controllers that operate according to weather conditions and evapotranspiration parameters. These evapotranspiration controllers, referred to as ET controllers, perform intelligent irrigation scheduling based on meteorological parameters

(temperature, wind, relative humidity, and solar radiation). Finally, in irrigation scheduling based on plant indices, indicators such as leaf temperature and leaf color can be used to determine both the timing and the amount of irrigation (Ahmed et al., 2023).

Polinova et al. (2019) utilized the SWAP model to optimize irrigation under conditions of limited water availability. In their study, they integrated modern and conventional irrigation management strategies for cotton cultivation. Although this approach was unable to account for the effects of water deficit during phenological stages on yield reduction, the designed strategy allowed for the prevention of critical stress in cotton and the distribution of water in accordance with agronomic practices. Overall, water use efficiency is an important issue, and various researchers are seeking ways to enhance it. It should be acknowledged that studies of this type are fundamental investigations that will lead to the design of various models in the field of irrigation.

Abdelhamid et al. (2025) designed and evaluated a solar-powered smart rooftop irrigation system for peppermint cultivation in urban areas, comparing conventional drip irrigation with a smart irrigation system. The smart system integrated real-time monitoring of soil moisture, humidity, PV panel temperature, and electrical parameters, achieving 28.1% reductions in both water and energy consumption compared to conventional irrigation. Additionally, the smart system reduced CO₂ emissions from 0.252 to 0.181 kg CO₂/m²/year and demonstrated economic viability with a payback period of 5.6 years. The study highlights the potential of solar-powered smart irrigation to enhance food security, conserve resources, and mitigate carbon emissions in sustainable urban agriculture. Ercan Oguzturk et al. (2025) investigated the effects of an AI-supported irrigation system on the cultivation of *Geranium psilostemon* (Black-Eyed Crane's-Bill), a natural plant species native to Turkey, comparing it with manual irrigation. The AI-supported system continuously monitored air humidity and soil moisture levels, optimizing irrigation strategies and enabling instant adaptation to seasonal variations. Results showed that the AI-supported system provided more efficient and effective plant cultivation than manual irrigation, minimizing water losses while preventing soil salinization. The study concludes that AI-supported irrigation systems hold great potential for water conservation, ecological balance, and sustainable agricultural and landscape practices.

Gong et al. (2022) proposed an intelligent irrigation system integrating a data fusion model based on Long Short-Term Memory (LSTM) networks and a Long-Range (LoRa) wide-area network. The system uses multi-source heterogeneous data (historical weather, irrigation logs, forecasts, and sensor data) to simulate and predict optimal watering demands. A self-powered LoRa network with energy-autonomous nodes (using waterflow-based power generation) and a cloud platform with a mobile application interface were developed. In a landscape watering case study, the proposed system achieved an average water-saving efficiency of 94.74% compared to conventional manual methods. Navarro-Hellin et al. (2016) introduced an intelligent and automated irrigation system that was tested in a citrus orchard in Spain. They

collected data through sensors placed in the air and soil, as well as weather forecasts, and after real-time analysis by the intelligent system, irrigation was carried out. The results showed that the deployed intelligent system was capable of determining the plant's water requirement during irrigation and notifying the user to stop irrigation. Gutiérrez et al. (2015) employed an automated irrigation system for the purpose of optimizing water use. This system utilized a network of soil moisture and temperature sensors in the plant root zone. By leveraging the capabilities of the automated system in a stevia field over a 136-day experimental period, water savings of up to 90% were achieved compared to conventional irrigation in the region. Todorovic et al. (2016) believe that by using intelligent irrigation systems, more economical food production can be achieved. In their view, the use of traditional irrigation methods or even non-intelligent modern irrigation systems increases water consumption, leading to runoff at the end of the field or deep percolation. This not only results in water loss but also increases fertilizer consumption and raises crop production costs. Shahrokhnia et al. (2015) compared the application of several irrigation scheduling tools, including tensiometers, infrared thermometers, soil moisture sensors, gypsum blocks, and the national water document, against the traditional management practices of orchard owners in two orange orchards in Fasa County, Fars Province. In this study, water consumption decreased by 56% and 46% in the two orchards, respectively, compared to traditional management, while irrigation water productivity increased by 110% and 54%, respectively. Masseroni et al. (2018) conducted a study aimed at the automatic control of irrigation in a rice field in Italy. The results showed that a reduction in water consumption was not demonstrated (2000 to 3700 mm) and that no significant increase in crop yield (approximately 8 tons per hectare) was observed, no mechanical failures occurred during the irrigation season. The use of the intelligent irrigation system made it possible to significantly reduce the time spent by workers on water level monitoring and irrigation flow adjustment. Given the willingness of farmers to innovate, the price of the automatic irrigation system (ranging from 638 to 689 euros per hectare) appears to be appropriate for its development. Touati et al. (2013) developed a fuzzy logic-based irrigation system equipped with a wireless data acquisition system for field-scale cultivation under drip irrigation. The amount of water lost through evapotranspiration was estimated using the Penman-Monteith equation, and future water requirements were determined accordingly. A soil moisture sensor determined whether irrigation was needed. In this case study, irrigation was initiated if soil moisture fell below 11%. The fuzzy inputs included air temperature, radiation, and soil moisture, while the output was the duration of irrigation.

Carucci et al., (2023) evaluated a system called PlaSoMan for the simultaneous monitoring of plant water status and soil moisture in processing tomato irrigation. The results of this system were compared with an evapotranspiration-based irrigation method (IrriMan) and traditional farmer management (FarMan). The PlaSoMan system achieved water savings of approximately 30% and 7.5% compared to FarMan and IrriMan, respectively, with corresponding yield losses

of only 10% and 2.5%. While attaining the highest crop quality indicator (combining total yield and Brix degree), this system was introduced as an efficient solution for areas with limited water resources. Mao et al., (2025) investigated the relationship between cotton leaf color (RGB values) and plant water content to enable rapid, non-destructive moisture monitoring for precision irrigation. A two-year experiment revealed that R and G values of the third and fourth leaves from the apex between 2:30 p.m. and 5:00 p.m. showed the strongest positive correlation with plant water content. Using univariate and bivariate linear regression models, the study established that a 72% plant water content threshold achieved the highest cotton yield and irrigation water use efficiency. The authors concluded that integrating leaf color-based diagnosis with the 72% irrigation threshold provides a robust foundation for real-time, large-scale precision irrigation management. Kumar et al., (2023) proposed a cost-effective automatic irrigation system based on the Internet of Things (IoT) for water conservation in Indian agriculture. Soil moisture sensors detect changes in soil moisture and send signals to a Node MCU, which automatically activates or deactivates the irrigation motor. The system significantly reduces human intervention, saves time and money for farmers, and alerts users about soil moisture levels via mobile phone. Implemented on a campus, the proposed smart irrigation system effectively conserves both energy and water, offering a practical solution for resource-limited regions. Bazaluk et al. (2022) proposed a low-cost smart irrigation system based on satellite monitoring as an alternative to expensive commercial systems. Over five-year field experiments on wheat, corn, sunflower, and rapeseed, the system increased water-use productivity by 4.09% for wheat and 9.8% for sunflower, and yields by 5.72% for wheat and 13.42% for corn. The payback period varied by crop, with corn, sunflower, and rapeseed showing very short payback periods (3 to 12 months), while wheat required up to 82 months. The study concluded that the satellite-based smart irrigation system offers significant advantages and can be recommended as a low-cost solution for improving agricultural water management.

The literature review indicates that, overall, irrigation management utilizing intelligent irrigation scheduling Decision Support Systems (DSS) has become a topic of interest among irrigation specialists and researchers worldwide in recent years. Numerous studies have reported the success of these systems in reducing water losses and improving water productivity. While most of these evaluations have been conducted over limited time periods and geographical areas, the present study contributes to this body of knowledge by providing a preliminary assessment of a locally developed DSS under the specific agro-climatic conditions of Qom Province, while acknowledging the need for broader validation. To further develop intelligent irrigation systems and promote this novel technology in practice, a precise and comprehensive evaluation of intelligent irrigation management decision support systems is essential. To this end, the present study investigated the locally developed intelligent irrigation management decision support system named "HooshAb" and evaluated its efficiency in

optimizing water consumption and enhancing water productivity in a silage maize pilot farm in Qom Province. The evaluation of this locally developed decision support system for intelligent irrigation management enables the identification of the system's strengths and weaknesses. Furthermore, it can significantly assist end-users in making informed choices, as well as support decision-makers in the national water industry at the macro level in policy-making and planning regarding the allocation of government support, capacity building, farmer training, technology dissemination in the field, and collaboration with the private sector.

2. Method

2.1. Study Area

Qom Province covers an area of 11,240 square kilometers, equivalent to 0.68% of the country's total area. The province lies at latitudes ranging from 34°8' N to 35°11' N and longitudes from 50°6' E to 52°3' E. The average annual rainfall in the province is approximately 151 mm, with a maximum average annual rainfall of 220 mm and a minimum average annual rainfall of 115 mm. The seasonal distribution of rainfall across the province indicates that 72.4% of the annual rainfall occurs in winter and spring, while summer accounts for only 1.2% of the annual rainfall, representing the lowest seasonal rainfall in the province. The average annual temperature in the province is 17.5°C, ranging between a maximum of 20.1°C and a minimum of 13.2°C. The pilot study site for this research was a 20-hectare silage maize field located at latitude 34.843182° N and longitude 50.673138° E, equipped with a drip tape irrigation system. The water supply for the study field was sourced from groundwater, and based on water quality classification, it fell into class C2S2. The soil texture of the field was clay loam, and the electrical conductivity of the saturated soil extract at the beginning of the silage maize growing season was approximately 6 dS/m.

2.2. Evaluation of Irrigation Scheduling by the Decision Support System

To evaluate the efficiency of the intelligent irrigation management decision support system, two adjacent silage maize fields managed by a single farmer were selected. One of these fields was irrigated according to the farmer's traditional management and was considered the control field. In the second field, irrigation was carried out in accordance with the schedule provided by the decision support system, and this field was considered the treatment field. The implementation, monitoring, and evaluation of this system were carried out in several stages as described below (Sepehri et al., 2026):

- ✓ Stage One: In this stage, the HooshAb decision support system was implemented in the field. This system is a web-based platform with a three-tier architecture (presentation, logic, and data). The data entry interface comprises five main sections: (1) field information (geographical location, area, crop type, planting and harvest dates), (2) soil properties (texture, bulk density, field capacity, permanent wilting point, organic matter, EC, pH), (3) water quality (source, EC, SAR), (4) irrigation system design (type, flow

rate, efficiency, pressure, emitter specifications), and (5) crop management (rotation). Upon receiving the input data, the system simulates crop water requirement using the FAO-Penman-Monteith method, daily soil moisture using a water balance model, and soil salinity using a salt balance model, and subsequently generates an optimized irrigation schedule based on the allowable moisture depletion threshold. The user interface includes a management dashboard for real-time monitoring, reporting tools, and an interactive map displaying field status with color-coded indicators. The required information was then completed online through the system's data entry forms. The information required at this stage included determining the geographical location and precise area of the field, as well as defining the field's characteristics in the Google Earth Pro system. In this way, the decision support system will be able to design a local virtual weather station for each field, based on available meteorological data from the nearest weather stations to the pilot study site. Subsequently, it is necessary to complete the information layers within the decision support system, including the physical and chemical properties of the soil, water quality and source, irrigation system design specifications, fertilizer application rates, the farmer's desired crop rotation and planting pattern, the user's water rights status, as well as historical records of crop yield for the target field. Soil samples were collected from different layers up to the root development depth in both disturbed and undisturbed forms to determine physical and chemical properties, as well as key soil moisture constants. Field capacity (FC) and permanent wilting point (PWP) were determined in the laboratory using the pressure plate apparatus at suctions of 0.33 bar and 15 bar, respectively (Cassel & Nielsen, 1986). These measured values were then entered into the HooshAb system. Furthermore, in the case of simultaneously cultivating diverse crop patterns, various scenarios under conditions of limited water availability—particularly during peak consumption periods—should be defined so that the decision support system can redefine and optimize intelligent irrigation management in response to these boundary conditions when necessary.

- ✓ Stage Two: In this stage, after completing the information layers, virtually constructing the field, and finalizing the implementation of the HooshAb decision support system, the irrigation management schedule provided by the system was implemented in the treatment field from the beginning to the end of the growing season. The control field was also irrigated during the same season under the farmer's traditional management. One of the most influential parameters in optimal irrigation management is the accurate determination of crop water requirements, as well as the pattern of soil moisture changes, which directly affect the calculation of net irrigation requirements and the determination of the optimal irrigation interval without inducing water stress, thereby

achieving maximum yield. For this purpose, these two parameters were specifically examined to evaluate the decision support system. The net irrigation requirement was determined according to the values provided by the water requirement system and compared with the values calculated by the system during the growing season. Additionally, soil moisture was monitored throughout the growing season in the treatment field and compared with the values estimated by the decision support system. Soil moisture measurements were taken at the root zone depth within three intervals: 0–30 cm, 30–60 cm, and 60–90 cm. The measurements were conducted gravimetrically, and the fresh weight of the samples was immediately measured on-site using a digital balance with an accuracy of 0.01 g. The samples were then transferred to the laboratory and dried in an oven at 105°C for 24 hours, after which the gravimetric soil moisture content was determined (Cassel & Nielsen, 1986). Volumetric water content was then calculated using the following relationship:

$$\theta_v = \theta_g \times \rho_b \quad (1)$$

where θ_v is volumetric water content (cm^3/cm^3), θ_g is gravimetric water content (g/g), and ρ_b is soil bulk density (g/cm^3). Bulk density was determined using the core method at the beginning of the growing season.

- ✓ Stage Three: The development of emerging technologies must always be aligned with the sustainability of productive resources. In this regard, the application of decision support systems should also take into account the preservation of water and soil resource sustainability. Therefore, in the present study, soil quality, with an emphasis on soil salinity as an influential parameter affecting soil sustainability, was monitored during the growing season in the treatment field.
- ✓ Stage Four: At the end of the growing season, crop yield was compared between the treatment and control fields. The volume of applied water in each field was determined using volumetric water meters installed at the inlet of the respective irrigation blocks. Based on this information and using the following equation, the applied water productivity was calculated and compared for both fields (Kassam et al., 2007):

$$WP = \frac{CY}{CW} \quad (2)$$

Where:

WP is the physical water productivity (kg/m^3 of applied water), CY is the crop yield (kg/ha), and CW is the volume of applied water (m^3/ha). Crop yield was measured at harvest time by weighing the total production from each field, and the applied water volume was measured using volumetric water meters.

3. Results

The results of soil moisture monitoring in the silage maize field are presented in Figures 1 and 2. To interpret the soil moisture simulation results by the HooshAb decision support system, the moisture values estimated by the system were first examined relative to the moisture content at field capacity and permanent wilting point (measured using the pressure plate method) (FC and PWP), taking into account the allowable moisture depletion limit of 45% for silage maize and the irrigation schedules provided by the system.

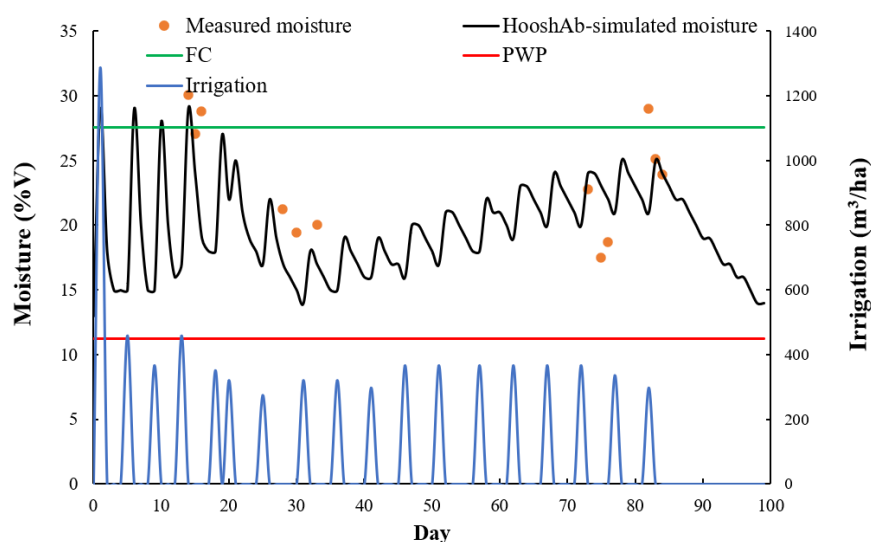


Figure 1 - Soil moisture monitoring in the treatment field

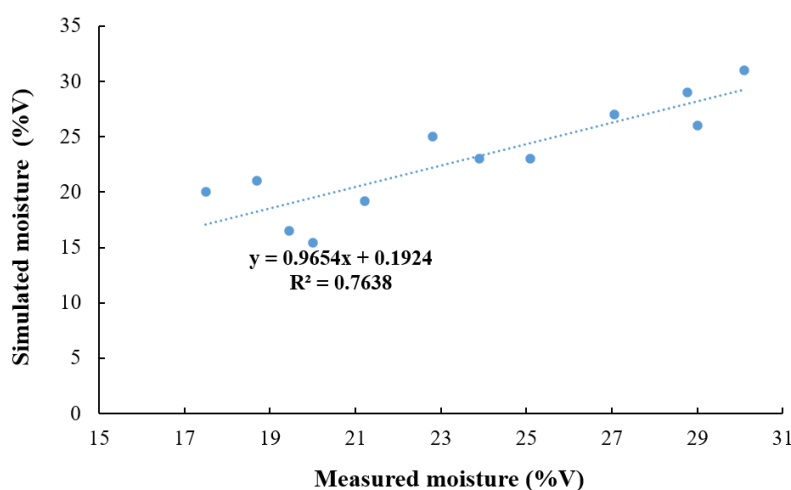


Figure 2 - Relationship between moisture simulated by the decision support system and moisture measured in the treatment field

As shown in Figure 1, in the silage maize field, the moisture simulated by the decision support system lies within the range between FC and PWP, and the allowable moisture depletion limit has been respected. The comparison of simulated moisture values on irrigation days indicates appropriate simulation performance by the system. Field monitoring of soil moisture during the growing season (Figure 2) shows an R^2 value of 0.76 between the moisture

simulated by the decision support system and the moisture measured in the field. The results of monitoring the saturated extract salinity in the treatment field and its comparison with the values simulated by the decision support system (Figure 3) indicate a relative increase in salinity in the study field.

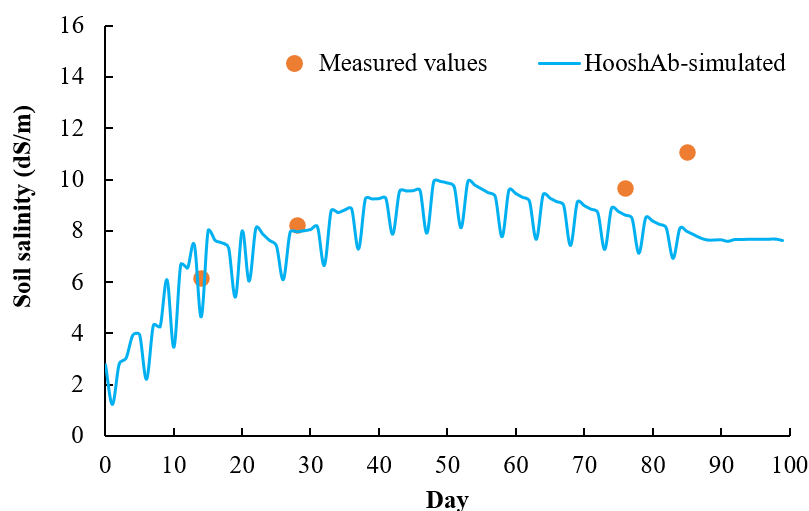


Figure 3 - Monitoring of soil saturated extract salinity in the treatment field

Further investigations revealed that wheat and silage maize were cultivated in rotation in the study field, with wheat being irrigated using surface irrigation while silage maize was irrigated using a drip tape irrigation system. This finding may provide a reasonable explanation for the low values of saturated extract salinity observed at the beginning of the silage maize growing season. However, given the quality of the water used in this field and the occurrence of reduced water availability (particularly at the end of the silage maize growing season in summer), an increase in soil salinity is not unexpected. Furthermore, due to the simultaneous cultivation of multiple crops in this field and the need to supply water requirements for all crops in the rotation pattern, irrigation management in the silage maize field was optimized in consultation with the farmer to appropriately manage available water resources. Based on the defined scenario, a certain degree of forced deficit irrigation was applied in the field, which also contributed to the increase in soil salinity. The comparison of salinity estimated by the decision support system with measured values, particularly at the end of the growing season, indicated a decrease in the system's accuracy in estimating this parameter.

Further investigations revealed that due to the reduction in extractable water from the available water resources of this field, water quality was affected at the end of the planting season in summer, whereas the system had performed irrigation scheduling and soil salinity simulation based on the initial input values. This finding underscores the necessity of updating the information on available water quality within the decision support system at critical intervals, preferably on a seasonal basis, in order to enhance the system's accuracy in estimating the saturated extract salinity.

A comparison of the net irrigation requirement for silage maize estimated by the HooshAb system with the results obtained from the water requirement system (NIAZAB) is presented in

Figure 4. Furthermore, a comparison of the applied water volume and crop yield in the treatment and control fields is shown in Figure 5, and the water productivity values for these two fields are presented in Figure 6.

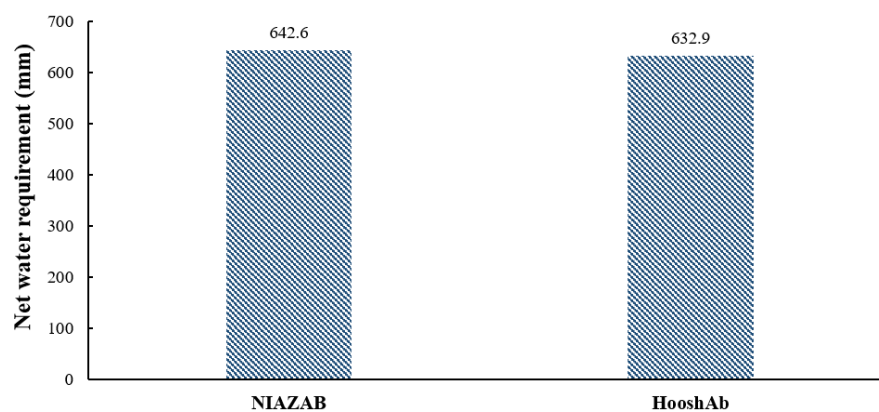


Figure 4 - Comparison of net irrigation requirement for silage maize estimated by two decision support systems: HooshAb and NIAZAB

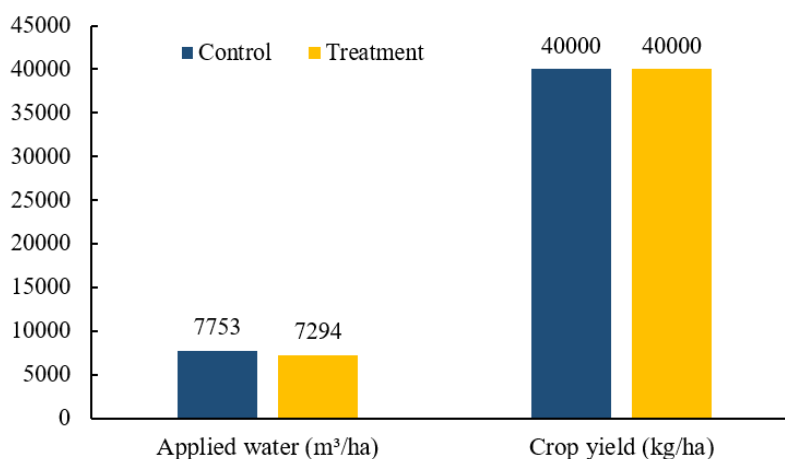


Figure 5 - Comparison of applied water volume and silage maize yield under treatment and control conditions

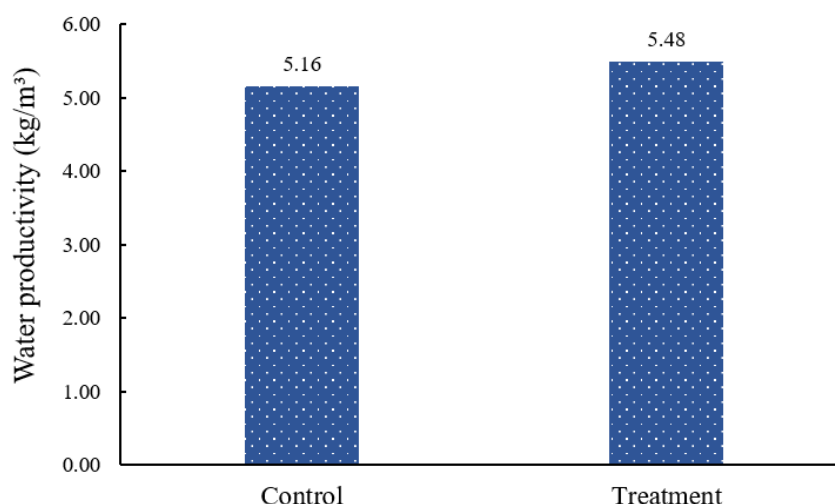


Figure 6 - Comparison of irrigation water productivity for silage maize under treatment and control conditions

The results of the comparison of the net irrigation requirement estimated by the decision support system and the NIAZAB system for silage maize are presented in Figure 4. As observed in this figure, the volume of applied water in the treatment field was approximately 6% lower than that in the control field. Meanwhile, the silage maize yield in both pilot fields was nearly identical, amounting to approximately 40 (t/ha) (Figure 5). As previously mentioned, various factors caused stress in the silage maize field, mostly related to insufficient water availability and the simultaneous cultivation of multiple crops. Nevertheless, overall, the use of the HooshAb decision support system resulted in a 6.3% increase in irrigation water productivity for silage maize cultivation (Figure 6).

4. Discussion

The present study evaluated the performance of the HooshAb intelligent irrigation management decision support system (DSS) in optimizing water consumption and enhancing water productivity in a silage maize field under the arid climatic conditions of Qom Province. The findings demonstrated that the DSS reduced applied water volume by approximately 6% compared to traditional farmer management, while maintaining similar yield levels (≈ 40 t/ha), resulting in a 6.3% increase in irrigation water productivity. These results are consistent with previous studies that have reported water savings and improved water use efficiency through the implementation of intelligent irrigation systems.

Compared to conventional methods, the HooshAb system showed reliable performance in estimating net irrigation requirements, with strong agreement with the reference NIAZAB system. This aligns with the findings of Polinova et al. (2019), who used the SWAP model for irrigation optimization under water scarcity; however, unlike their model, the HooshAb system was capable of accounting for yield reduction risks caused by phenological water stress. Moreover, the real-time scheduling capability of HooshAb parallels that of the fuzzy logic-based wireless system developed by Touati et al. (2013), which used soil moisture, air temperature, and radiation to determine irrigation duration. While the system of Touati et al.

was effective, the HooshAb system offers the added advantage of integrating multi-source data (soil, crop, weather, and water quality) within a user-friendly interface.

The soil moisture simulation accuracy of HooshAb, with an R^2 of 0.76 between simulated and measured values, is comparable to other DSS tools reported in the literature. For instance, Gong et al. (2022) achieved high water-saving efficiency (94.74%) using LSTM-based data fusion and LoRa networks, but their system was tested in landscape watering rather than in a production-scale agricultural field. Similarly, the satellite-based low-cost DSS proposed by Bazaluk et al. (2022) increased water productivity from 4.09% to 9.8% across different crops, with a payback period as short as 3–12 months for corn. Although HooshAb demonstrated a more modest water productivity increase (6.3%), it operated under real-world constraints such as multi-crop water allocation and forced deficit irrigation, which likely moderated its observed efficiency.

Regarding soil salinity, the HooshAb system initially provided reasonable estimates of saturated extract salinity; however, its accuracy declined toward the end of the growing season when water availability decreased and water quality deteriorated. This sensitivity to input data quality is a common limitation among DSS. Carucci et al. (2023) also emphasized the importance of continuous data updating in their PlaSoMan system, which integrated both plant water status and soil moisture monitoring. Likewise, Ercan Oğuztürk et al. (2025) highlighted that real-time monitoring of air and soil moisture allowed their AI-supported system to adapt instantly to seasonal variations, preventing soil salinization. Our findings reinforce the necessity of seasonal or even real-time updates of irrigation water quality data within the HooshAb system to maintain prediction accuracy, especially under conditions of declining groundwater quality.

The forced deficit irrigation applied in the treatment field, due to concurrent cultivation of multiple crops and reduced water availability, inevitably contributed to increased soil salinity. This observation is consistent with Masseroni et al. (2018), who reported that although their automated rice irrigation system did not significantly reduce water use or increase yield, it eliminated mechanical failures and reduced labor time. In our case, despite the salinity increase, the HooshAb system successfully minimized yield loss, highlighting its robustness under suboptimal conditions.

In comparison with Shahrokhnia et al. (2015), who achieved 46–56% water savings and 54–110% increases in water productivity in orange orchards using various scheduling tools, the relative improvements observed in our study (6% water saving, 6.3% productivity increase) are more modest. This discrepancy can be attributed to differences in crop type (perennial orchards vs. annual silage maize), irrigation system design, baseline farmer efficiency, and the fact that our control field was managed by a knowledgeable farmer with relatively efficient traditional practices, leaving less room for dramatic improvement.

Nevertheless, the HooshAb system proved to be a practical and locally adapted DSS that can support farmers and policymakers in arid regions. Its success depends critically on the accuracy and timeliness of input data, as noted by Navarro-Hellin et al. (2016) and Gutiérrez et al. (2013), both of whom emphasized that real-time sensor data and user interaction are key to

achieving high efficiency. The payback period and economic viability of HooshAb were not explicitly calculated in this study; however, based on the framework of Abdelhamid et al. (2025), who reported a 5.6-year payback period for a solar-powered smart rooftop system, it is plausible that HooshAb would be economically attractive for Iranian farmers, especially in regions facing severe water scarcity. This preliminary assessment provides initial evidence of the HooshAb system's performance under the conditions of this pilot study. Further evaluation across additional growing seasons and locations is recommended to support more definitive decision-making.

5. Conclusions

In the present study, the efficiency of the HooshAb intelligent irrigation management decision support system was evaluated for optimizing water consumption and enhancing water productivity. The results showed that the system performed well in estimating the net crop water requirement, demonstrating good agreement with the values calculated by the NIAZAB system. Furthermore, monitoring of the soil moisture pattern during the growing season and at various intervals after irrigation commencement indicated that the decision support system predicted soil moisture with appropriate accuracy and minimized moisture stress, even under conditions of reduced water availability and forced deficit irrigation. Regarding soil salinity estimation, continuous monitoring of the saturated extract salinity revealed that the system was largely dependent on the accuracy of the irrigation water salinity input data, and that updating water quality information during the growing season had a significant impact on the accuracy of soil salinity trend estimation. In the present study, the failure to update water quality information, particularly at the end of the growing season in summer, led to a decrease in the system's accuracy in simulating the saturated extract salinity. Thus, overall, given the high sensitivity of the system to input data—including irrigation system design information, physical and chemical properties of the field soil, as well as the quality of available water resources during the growing season—emphasis must be placed on the accuracy of input data measurement. In general, the success of the system largely depends on the accuracy of the user, and interaction with the user as well as monitoring of the irrigation schedule during the growing season are essential. In conclusion, the HooshAb decision support system demonstrated promising performance in reducing water consumption and improving water productivity under the conditions of this pilot study. The findings provide valuable initial evidence for the system's effectiveness, while also highlighting the importance of regular data updates and user training to enhance salinity prediction accuracy. Future research is encouraged to build upon these results by integrating real-time water quality sensors, expanding the system to additional crops and regions, and conducting economic analyses to support broader adoption.

Author Contributions

S.S. conceived and designed the study, performed the experiments, analyzed the data, and wrote the manuscript. M.M.N. assisted in field measurements and data collection. B.Y. contributed to

software development and data interpretation. All authors reviewed and approved the final manuscript.

Data Availability Statement

Data are available from the authors upon request.

Ethical Considerations

The authors avoided data fabrication, falsification, and plagiarism, and any form of misconduct.

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Conflict of Interest

The authors declare no conflict of interest.

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