Collaborative operation and application influence of sprinkler drip irrigation: A systematic progress review

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Abstract: Considering the high-quality requirements related to agricultural crop production, the collaborative operation and application influence of sprinkler drip irrigation is an important issue in precision agriculture. The objective of this review is to give a comprehensive demonstration focusing on the subject of collaborative operation and application influence of sprinkler drip irrigation, by using a set of comparative analysis and literature bibliometric maps, therefore the sprinkler drip irrigation quality considering actual influential factors could be determined and analyzed. This review establishes on a broad spectrum of agricultural drip irrigation performance, throughout its whole procedure of collaborative monitoring, irrigation scheduling, application efficiency, and environmental influence, covering such aspects as soil physicochemical quality, irrigation scheduling, water resource redistribution, crop productivity, tillage management, climate adaptation, and environmental monitoring, etc. This review indicates that, the irrigation efficiency and drip infiltration quality of soil field can be planned precisely and allocated reasonably by sprinkler drip irrigation, which has extraordinary infiltration capability and enables much better performance, than that of other ordinary irrigation approaches in accuracy, stability, regularity, and efficiency. Thereafter, the investigation on the collaborative operation and application influence of sprinkler drip irrigation can be used to ensure the infiltration uniformity of moisture distribution, and then the high-quality requirements of practical irrigation performance can be met, too. This systematic review facilitates the productive soil-moisture-environment management for precision irrigation and agricultural production.

Keywords: sprinkler drip irrigation, collaborative operation, irrigation scheduling, application efficiency, environmental influence, review

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1 Introduction

It is well known that the irrigated agriculture plays a crucial role in global water resource usage. Sprinkler drip irrigation is one of the most accurate and high-efficient agricultural crop production technique in the world. As an essential issue in agricultural irrigation, it is critical for soil tillage and crop cultivation, and has remarkable influence on the high-productive soil irrigation. This approach involves the controlled delivery of water directly to individual crops or plants through a prearranged transmission network constituted by tubes or pipes, which is characterized by an optimal management of various influential elements sourced from soil, environment, schedule and irrigation. Owing to the varied soil infiltration characteristics and external cultivation environment, a systematic review on the collaborative operation and application influence of sprinkler drip irrigation, is imperative to guarantee the high infiltration efficiency and better environmental adaption of soil irrigation performance, and then to facilitate the satisfactory maintenance of crop cultivation. However, a detailed sprinkler drip irrigation investigation from the perspectives of collaborative monitoring, irrigation scheduling, application efficiency, and environmental influence, remains unclear.

2 Development of sprinkler drip irrigation

2.1 The effect of sprinkler drip irrigation for agricultural crop production

As we all know that agriculture is a main user of water resource, since it is accounted for more than 70% of global freshwater withdrawals[1]. On the other hand, water scarcity and soil quality become major constraints to social-economic development in the last few decades, as shown in Figure 1. This figure illustrates that there are a lot of reasons for the worldwide shortage of irrigation water, such as low share of water, poor management of irrigation system, energy breakdown, financial constrains, water level reduction, population explosion, climate change, water resource over-exploitation, water pollution, metropolitan development, poverty area distribution, remote region development, soil desertification, water waste, and outdated hydraulic engineering, etc. Considering these environmental constrains, sprinkler drip irrigation was proposed and investigated for the convenience of infield crop cultivation, due to rapid increase in soil pollution, extreme climate, and expansion of water and crop

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demands. Figure 1 also demonstrates that much of the allocated water resource has been wasted in ordinary irrigation networks frequently used. This water loss sometimes up to 20% of the quota allocated to each agricultural farmer, and increases with the remoteness of irrigation plots. Moreover, the continuous fragmentation of irrigated field aggravates the waste of clean water resource regrettably[2,3]. It is noteworthy to point out that the water scarcity worldwide leads to a remarkable increment of poverty in those undeveloped farms, considering the depletion of groundwater is due mainly to the over exploitation of water resource, so that the research and promotion of sprinkler drip irrigation approach are significant and necessary for modern precision agriculture.

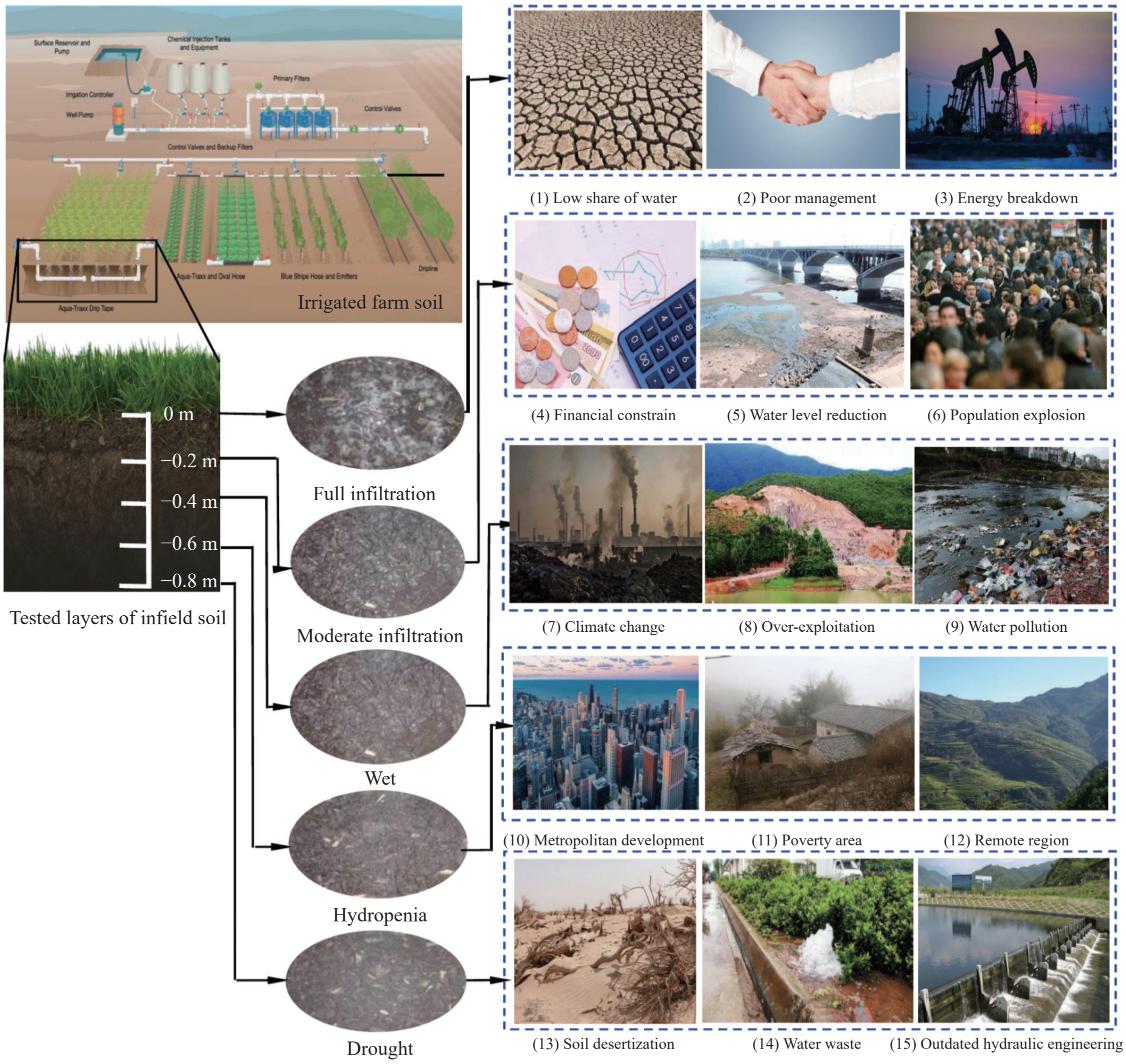


Figure 1 The reasons for shortage of irrigation water[2,3]

Sprinkler drip irrigation effectiveness correlates with such elements as irrigation simulation, drip irrigation performance, irrigation pump optimization, soil irrigation efficiency, integration of water and fertilizer, green house cultivation, turbulence modelling, soil infiltration effect, all these influential factors could be categorized by their functional characteristic, into several key subjects as drip irrigation scheduling, collaborative monitoring, application efficiency, and environmental influence. Using the following influential irrigation factors, including CWSI (Crop water stress index), SDIQ (Sprinkler drip irrigation quality), LSSVM (Least squares support vector machine), FAI (Sensor- Automated Irrigation), DSSAT (Decision support system for agrotechnology transfer), FDR (Frequency Domain Refractometer) and RSAE-ANFIS (Regulated sparse autoencoder-Adaptive neuro- fuzzy inference system), the collaborative operation and application influence of sprinkler drip irrigation should be paid high attention to, and the technological progresses should be promoted into other soil infiltration conditions, which play important roles in hydraulic engineering, soil desertification prevention, environmental resource redistribution, collaborative infiltration monitoring, and irrigation service optimization, as Figures 2 and 3 give the details.

2.2 Typical sprinkler drip irrigation techniques and properties

The working goal of sprinkler drip irrigation techniques is to meet specific requirements of individual crop plants or infield management units, and to minimize adverse environmental impact. It not only conserves water resource for crop production, but also sustains and increases agricultural crop incomes, protects land productivity and irrigation investment, and serves urban and industrial areas, too. Since sprinkler drip irrigation provides efficient tools to regulate the usage of water resource on the cultivated field, it facilitates the water distribution equilibrium and supports a stable state of irrigated water distribution by means of balancing water supply and controlling water allocation, using appropriate water quota system. Because of its highly localized application and scheduling flexibility, sprinkler drip irrigation gains widespread popularity as an efficient and economically viable

Figure 2 Sprinkler drip irrigation system and its correlation with collaborative operation and application influence[3,5]

approach for agricultural crop cultivation, and presents an environment-friendly agricultural condition simultaneously. It could be categorized into such kinds of drip irrigation as subsurface drip irrigation, deficit drip irrigation, alternate drip irrigation, mulched drip irrigation, regulated drip irrigation, and aerated drip irrigation, etc. Table 1 details their respective performance benefits, application characteristics and correlated functions in sequence.

As water demand increases greatly in agricultural irrigation, there is an urgent need to meet critical requirements of water balance for sprinkler drip irrigation. Water conservation through sprinkler drip irrigation alleviates a large part of burden on water resource. Notably, some current adaptive measures in irrigated agriculture include fallowing land, shifting cropping patterns, increasing groundwater pumping, expanding reservoir storage capacity, and increasing production of risk-averse crops[2]. It is important to realize water-saving sprinkler drip irrigation to ensure the sustainable usage of water and feed the enormous population[3], more extensive efforts have been made to survey the amount and distribution of irrigation water withdrawals[4]. Based on this development tendency, Table 2 gives typical problems and solving strategies for precision drip irrigation and drainage networks. Is is shown that the whole problems of sprinkler drip irrigation network range across irrigation materials, environmental and drainage aspects, structure and construction, and management strategy, which brought about such resultant consequences as drainage system development, environmental system optimization, design quality improvement, supervision and execution, operation and maintenance, irrigation procedure monitoring, proper drainage equipment and machinery provision, and drainage structure familiarization. According to the comprehensive investigations on sprinkler drip irrigation effectiveness, the causes and reasons of irrigation problems could be summarized as: removing financial limitations, allocating sufficient funds with comprehensive plans, application of synthetic filters, identification of waste water and sewage, developing environmental standards, accuracy of design parameters, punishment and rewards of irrigation rules, and selection of suitable drainage system and employ skilled experts. Therefore distinctive executive and research strategies were proposed here, by considering various irrigation effect criteria: appropriate use of local materials, reuse impacts of drainage waste water, qualitative and quantitative monitoring of executive activities, selection of material and structures, appropriate measurement approaches, developing institutions and strategies, environmental monitoring of groundwater, surface water and soil infiltration, and obligating network monitoring by moisture infiltration sensors, etc. All these measures help to optimize the sprinkler drip irrigation networks[5], for instance, soil water storage,

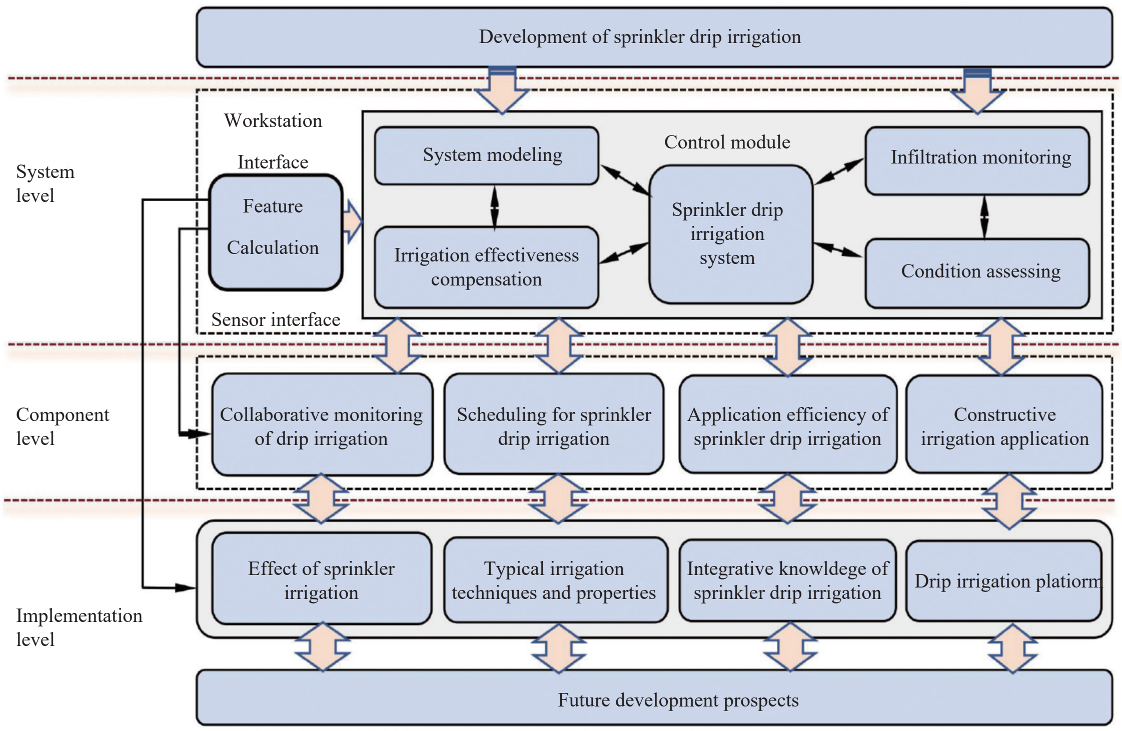


Figure 3 The operational levels and integrative control in the hierarchical architecture of sprinkler drip irrigation[4,5]

Table 1 Typical sprinkler drip irrigation techniques and their performance properties

Techniques	Benefits	Applications & functions	Network layout	Ref.
Subsurface sprinkler drip irrigation	Reduction of irrigation costs.	Injection of nutrients, pesticides, and other chemicals to modify water and soil conditions.		[1,3,5]
Deficit sprinkler drip irrigation	Diversity of sprinkler drip irrigation, Water resources be used more efficiently and sustainably.	High crop cultivation rate, high efficient cultivation performance, with reduced soil-moisture integrity.		[2,4-6]
Alternate sprinkler drip irrigation	Balances plant height, stem diameter, leaf area and dry matter, and yield of crops.	Limits the depth of water infiltration, but helps to irrigation control and optimization.		[3,8,10]
Mulched sprinkler drip irrigation	Effective water-saving fertigation for dry land regions.	Improves water\mulch infiltration without additional crop cultivation costs.		[11-13,16]
Regulated sprinkler drip irrigation	Promotes drip infiltration and water distribution.	Deal with the lack of efficient mulch film recovery, residual plastic film fragments accumulating.		[7,9,15]
Aerated sprinkler drip irrigation	Mitigates rhizosphere hypoxia caused by wetting front	Transfers water-air two-phase flow to crop root through sprinkler drip irrigation system.		[14,17,18]

groundwater circulation, moisture distribution, and water infiltration are all necessary to promote irrigation efficiency and regulate moisture infiltration. It is necessary to determine the technical requirements for sprinkler irrigation management:

Table 2 Typical problems and solving strategies for optimizing irrigation and drainage networks

Key problems	Resultant consequence	Causes and reasons	Solving approaches	Ref.
Irrigation materials	Developing drainage systems	Removing financial limitations	Appropriate use of local materials	[3,6,8]
	Environmental system	Allocating sufficient funds	Reuse impacts of drainage waste water	[4,7]
Environmental and drainage aspects	Improvement of design quality	Application of synthetic filters	Qualitative & monitoring of executive activities	[9,10]
	Improvement of supervision and execution	Identification of waste water and sewage	Selection of appropriate material and structures	[11,12,14]
Structure and construction	Improvement of operation and maintenance	Developing environmental standards	Selection of appropriate measurement approaches	[16,17,20]
	Monitoring of irrigation systems	Accuracy of design parameters	Developing institutions and strategies for monitoring	[22-24]
Management strategy	Provision of proper drainage equipment and machinery	Punishment and rewards of irrigation rules	Monitoring of groundwater, surface water and soil infiltration	[26,29,30]
	Familiarization of drainage structure	Selection of suitable drainage system and employ skilled experts	Network monitoring by moisture infiltration sensors	[32,33,35]

(1) Balancing the input and output of sprinkler drip irrigation performance: This requires the effective approach focuses on the irrigation techniques and integrative management, and the complete operational cycle ranged from schedule planning, irrigation design and equipment installation, for the convenience of irrigation operation and productivity maintenance.

(2) The standardization of sprinkler drip irrigation performance: It is obvious that the information coordination between different intelligent decision-making networks for sprinkler drip irrigation needs to be improved. The balance between the input and output of sprinkler drip irrigation performance should be maintained, considering individual decision-making need for flexible irrigation requirements, which call for accurate control of irrigation implementation.

(3) The focus on irrigation technique development: There is ample evidence that advanced intelligent control is a prerequisite for most sprinkler drip irrigation projects. The research of irrigation control is extremely important and necessary for sprinkler drip irrigation experiences throughout the world.

2.3 Integrative knowledge of sprinkler drip irrigation

Based on the above-mentioned introduction of sprinkler drip irrigation, the integrative knowledge of key subjects discussed in this review could be demonstrated as:

Collaborative monitoring is an important subject of precision irrigation research, and it has been frequently used to evaluate irrigation parametric changes, and/or water infiltration progress toward meeting a prearranged irrigation effectiveness, which consists an integral part of adaptive operation project based on the notion of irrigation efficiency, effective water resource management, and appropriate infiltration efficiency. The speed and influence of water infiltration, denoted as the distributive process of water entering soil surface and passing through different soil layers, should be deliberately observed and controlled.

Intelligent scheduling of sprinkler drip irrigation presents a complete set of configuration design knowledge to solve irrigation planning problem in precision agriculture. By using dynamic programming and inference knowledge, it could be used to select suitable irrigation scheme, which minimizes unexpected environmental changes and maximizes water productivity. The intelligent scheduling for drip irrigation greatly improves the understanding of complicated interactions in the irrigated agriculture, and enhances accurate decision making under uncertain soil\water conditional interference.

The environmental influence of sprinkler drip irrigation consists of conditional knowledge and domain superiority, most of them give clear indications of the crop's response to the irrigated agriculture and water distribution environment, that will facilitate the reliable construction of sprinkler drip irrigation framework in return. Based on this environmental influence investigation, sprinkler drip irrigation could be promoted to build up a more environmental friendly tool to protect the irrigated soil from water resource over-exploitation and waste pollution.

3 Collaborative monitoring of sprinkler drip irrigation

3.1 Importance and necessity of sprinkler drip irrigation monitoring

To accurate understanding the importance and necessity of sprinkler drip irrigation monitoring, two fundamental problems need to be clarified in advance: (1) the irrigation parameters should be monitored accurately and determined robustly to establish an effective drip irrigation system, and (2) the influence of drip irrigation monitoring should be analysed to accelerate the convergence velocity and accuracy of irrigation scheduling process. Therefore, the concept of collaborative monitoring is proposed based on the unique integration of sprinkler drip irrigation and surrounding working environment, and is employed for the effectiveness improvement of drip irrigation performance. This collaborative monitoring process first uses the sensor network to extract the drip infiltration properties of infield soil, subsequently, the monitoring platform provides high-efficiency tools to observe the moisture infiltration effect, for the mechanism investigation and performance promotion of drip irrigation.

3.2 Constructive application of sprinkler drip irrigation monitoring

It is obvious that the collaborative monitoring of sprinkler drip irrigation system plays important role for the sustainable irrigated agriculture, this process focuses on the collection of irrigated field data, including on-the-spot status of soil, plants, and weather information. Here, the operational strategy of drip irrigation is to supply appropriate amount of water and to evacuate excess water through a set of high-efficient irrigation and drainage system. However, traditional irrigation monitoring concentrates on soil-moisture distribution, characterized by less capacity than the peak demand, irregular delivery rates, and low irrigation uniformity. With respect to the first problem, the major reason for the low efficiency of sprinkler drip irrigation, is nonuniform moisture distribution due to lack of precise monitoring system for water delivery[6-8]. Secondly, as the flow measurements at key delivery points are highly needed to evaluate irrigation water distribution[9], the reliable soil-infiltration monitoring and instantaneous coordinated operation are imperative for preventing any unscheduled use of water[10]; Moreover, the collaborative monitoring of sprinkler drip irrigation is also necessary to compare the estimated irrigation demands with actual water supplies, for the purpose of maintaining the highly efficient water supply in every practical irrigation conditions. Based on this prerequisite, in a field experiment with the use of Frequency Domain Refractometer (FDR) sensor-Automated Irrigation (FAI), an intelligent logical structure could be established for the sensor-automated irrigation monitoring, provided a high-efficient drip infiltration monitoring platform composed of moisture sensor, irrigation workstation, and soil-moisture interaction monitoring module, etc[11,12]. It investigates the potential application of irrigation monitoring, based on the previously determined threshold values of volumetric substrate water content to improve crop cultivation. Specifically, it collaborative monitors the water and fertilizer delivery in a coir substrate hydroponics system using FAI. It could also be observed that FAI techniques reduce drainage from hydroponic system for large-scale hydroponic farms, which results to the efficient, environmentally sustainable employment of water and fertilizer. From this model it could be seen that the soil moisture monitoring sensor sends the real-time soil signal to a micro-controller, via ADC (Analog-to-digital converter) and LCD (Liquid Crystal Display) displaying the readings of moisture content. From the collaborative monitoring unit these information signals are collected and transmitted to the solenoid wall where sprinkler drip irrigation process is carried out. As an embedded system, the collaborative monitoring system closely monitors the micro climatic parameter of irrigated field for the cultivation of crops or specific plant species. It observes plant cultivation over whole crop growth season, and eliminates the difficulties involved in irrigation monitoring system by reducing human intervention to the best possible extent. These two exampled approaches employed in sprinkler drip irrigation condition were known by their highly efficient collaborative monitoring in actual agricultural practices. Based on these preparation it could be learned that when the raw data of soil moisture infiltration is measured, the collected data set sourced from irrigation rate, moisture ratio, and infiltration speed, be processed in the module of data sensor located on the measurement level, before their predictive computation, including data processing and infiltration extraction, which corresponds to the calculative operations such as data filtering, statistical analysis, and regulated classification separately on the calculation level. When the moisture infiltration is observed, the processed data of sprinkler drip irrigation efficiency could be transmitted for real-time parameter coordination, so that the monitored results stored in the database could be employed freely for the irrigation effectiveness calibration.

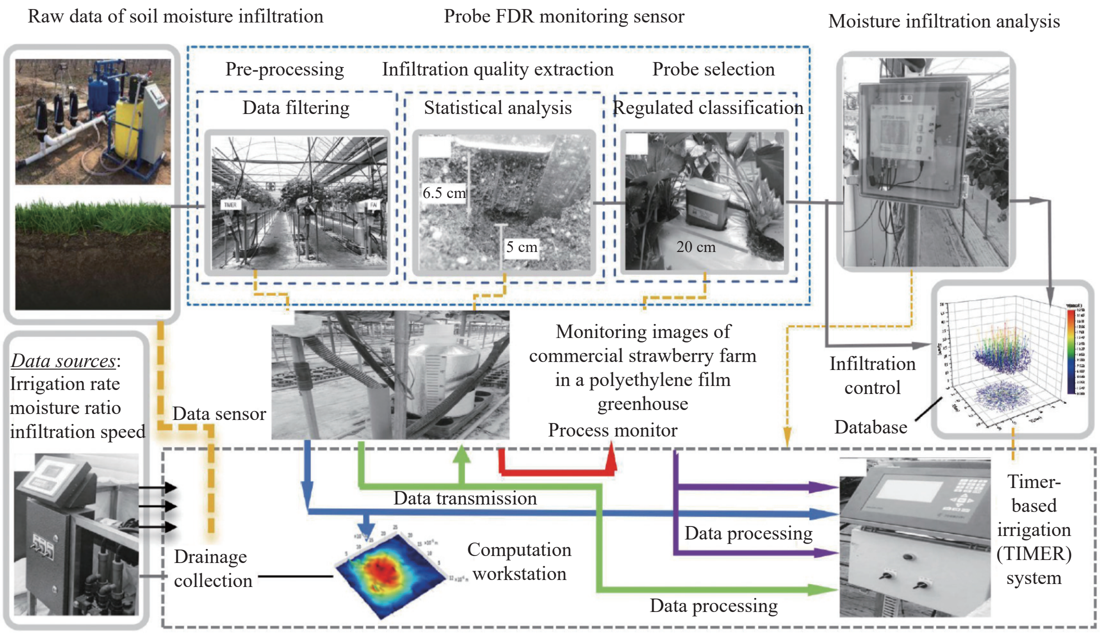


Figure 4 Flowchart of sensor-automated irrigation monitoring[11,12]

Using the sprinkler drip irrigation monitoring flowchart demonstrated in Figures 4 and 5, recent investigation reveals that the irrigation practices negatively contributed to the rise of shallow groundwater. For the long-term sustainability of agricultural soils, it is recommended to replace the current monitoring procedure with an adequate and more efficient technological flowchart such as textile envelopes to prevent sand clogging in the subsurface sprinkler drip irrigation system. The adoption of monitoring measures leading to higher efficiency in the use of water and energy is strongly demanded. Based on this idea this figure demonstrates different monitoring procedures for sprinkler drip irrigation in typical scenarios[13,14]. The comparison of the selected solutions in these proposed scenarios showed that operational cost savings between 65% and 76% could be guaranteed.

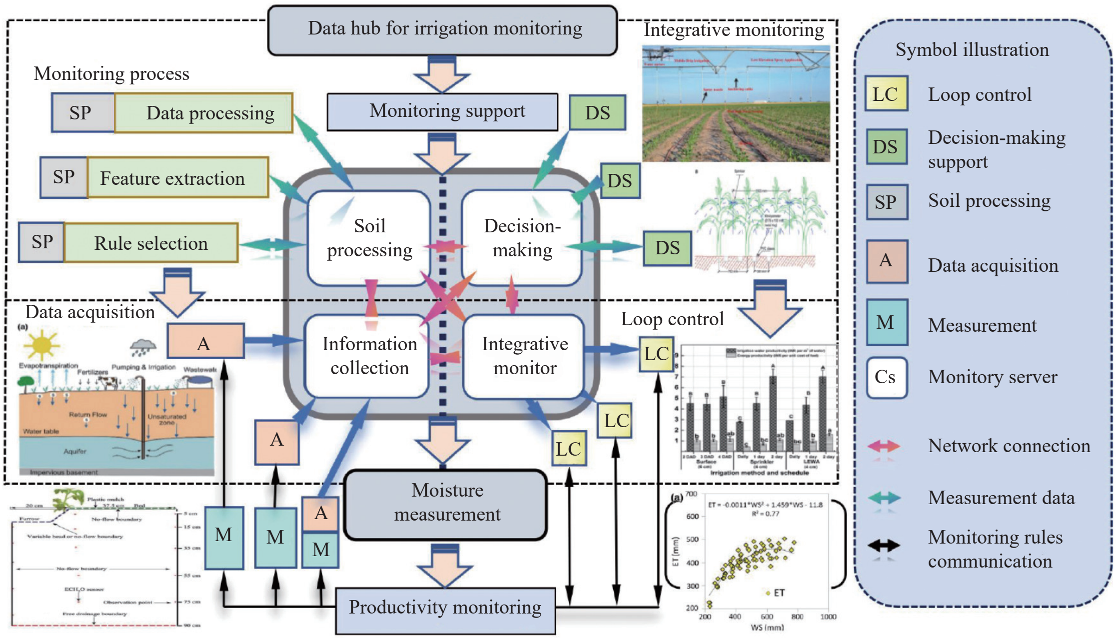


Figure 5 Logical architecture and computational data flow of drip irrigation monitoring system

Liang et al.[49,53,59] demonstrates the logical architecture for integrative irrigation monitoring, which provides a highly efficient data processing platform for the monitoring system composed of data sensors, database, computation workstations, and process monitoring modules. The data hub of sprinkler irrigation effectiveness measurement provides a monitored data set for irrigation effect. Therefore, the soil processing, decision-making, information collection, and integrative monitoring can be implemented freely. It is also noteworthy to point out that several key elements of soil moisture measurements such as loop control, decision-making support, data processing, data acquisition, and information communication between the measurement sensors and prediction modules are all interconnected to each other. Based on the computational data flow of collaborative monitoring system, where the data hub of moisture infiltration quality indexes located on the measurement level, then the data processing operations such as data processing, decision-making, information collection, and integrative control, could be implemented freely. Such key elements of soil moisture measurement as loop control, decision-making support, data processing, data acquisition, and communication server oriented for the measurement sensors and prediction modules, are all interconnected to each other through data channel. This unique monitoring flowchart ensures the high computational accuracy and flexible environmental adaption for collaborative monitoring in practice.

On the other side, Table 3 demonstrates the technological characteristics and application range of the collaborative monitoring of irrigation system, in which typical technology items, reference source, technological advantage and disadvantage, applicable conditions, reasons and objectives, are all demonstrated in sequence. For instance, this table shows that GPRS (General Packet Radio Service module), a novel telecommunication system provides very fast internet connections for mobile phones, could be used for the collaborative monitoring of reliable soil and environmental moisture data transmission. Xbee-Pro, also named as Digi XBee-PRO Zigbee RF (Radio Frequency) module, provides the cost-effective wireless connectivity and high-speed interface for irrigation electronic control devices, simultaneously it optimizes data integration with embedded micro-controllers for the collaborative irrigation monitoring. Similar technology items include the wireless sensor networks (WSNs), map variability, computerized environmental control, crop evapotranspiration-guidelines, embedded system for automatic irrigation, monitoring of aeroponic greenhouse, sensor placement, decision-maker and heuristic algorithms, and site-specific irrigation management, etc. Since the soil-moisture distribution model quantifies the working performance of water delivery accurately, this model was promoted in different sprinkler drip irrigation cases, such as improving the monitoring accuracy[15], updating the working status of irrigation system[16], determining the influential factors of irrigation deviation[17], and observing soil infiltration[18]. Instructed by the intelligent monitoring management, Nagarajan et al. tried to use the wireless sensor network (WSN) system to automate the state monitoring and parametric measurement for irrigation infiltration efficiency[19]. In this test, the humidity, temperature and pH (hydrogen ion concentration) sensors provide accurate monitoring feedback to control the water-soil environment as derivative collaborative indexes, such as moisture distribution efficiency, soil moisture pressure or tension, and moisture uniformity, be regarded as highly important.

Table 3 Typical sprinkler drip irrigation techniques and their performance properties

Items	Ref.	Advantage	Disadvantage	Applicable condition	Reasons and objectives
Wireless sensor networks (WSNs)	[20, 21, 31]	High speed, far distance	Error of signal transmission	Soil infiltration monitoring	Solar cells constitute serious additional cost for farmers
GPRS (General Packet Radio Service) module	[22, 23]	Low error, high accuracy	External weather interference	Drip irrigation effectiveness control	Water delivery system planning
Digi XBee-PRO Zigbee modules	[24, 25, 31, 32]	Mobile control in far distance	High cost	Irrigation scheduling optimization	Estimating water balance in arid regions
Map variability	[26, 29, 33]	Good adaptation	Geographic information dependency	Large-scale irrigation scheduling	Economic assessment of water harvesting
Computerized Environmental Control	[27, 28]	High technological flexibility	Climate change dependency	On-the-spot irrigation performance verification	Resolving resource conflicts generated by irrigated agriculture
Crop evapotranspiration-guidelines	[39]	Better environmental adaptation	Low accuracy	Crop cultivation monitoring	Site-specific management of fixed irrigation system
Embedded system for automatic irrigation	[34, 35, 40]	High flexibility	Far distance transmission	Intelligent drip irrigation control	Artificial neural network based modelling of spatial distribution of phosphorus
Monitoring of aeroponic greenhouse	[36-38]	Low cost and high productive	Complex scheduling	Greenhouse crop cultivation monitoring	Nonlinear evaporation and evapotranspiration modelling
Sensor placement	[41]	Adaptation to extreme environment	Low flexibility	Large-scale field soil monitoring	Conjunctive use of surface and ground water resources
Decision-maker and heuristic algorithms	[42-44]	Precise decision-making	Large storage for data calculation	Irrigation parametric selection	Hydrological impact of a high-density reservoir network
Site-specific irrigation management	[45-47]	Better terrain adaptability	Mobile dependency	Sprinkler drip irrigation scheduling	Soil moisture sensors are used to determine the water needs of agricultural lands

3.3 Contributions of collaborative monitoring of sprinkler drip irrigation

According to the review of previous irrigation studies, two critical aspects of collaborative monitoring for sprinkler drip irrigation are crop growth and yield prediction[3,17,42]; and appropriate monitoring pertaining to drip irrigation, which include the scale mapping of irrigation areas and the quantification of irrigation effectiveness[19,24,41]. The collaborative monitoring of sprinkler drip irrigation covers many subjects ranged from irrigation equipment, irrigation application, to irrigation control. Its major contributions could be summarized as follows:

(1) The published investigations proposed various novel collaborative monitoring approaches, improved actual irrigation monitoring effectiveness greatly, and quantified their inherent variation principles accurately as well; (2) Using different collaborative monitoring approaches to ensure the working reliability of drip irrigation system, they analyzed the correlative influences of operational factors, on the cultivation qualities or the growth properties of objective crops; (3) Various collaborative monitoring schemes have been designed to calibrate the effect mechanism of sprinkler drip irrigation, they provided insightful discussions on the infield infiltration variability and accurate moisture diffusivity; (4) All these irrigation studies presented feasible suggestions regarding collaborative monitoring and evaluation mechanism, in the interests of remarkable promotion of soil moisture uniformity and drip irrigation quality.

4 Intelligent scheduling for sprinkler drip irrigation

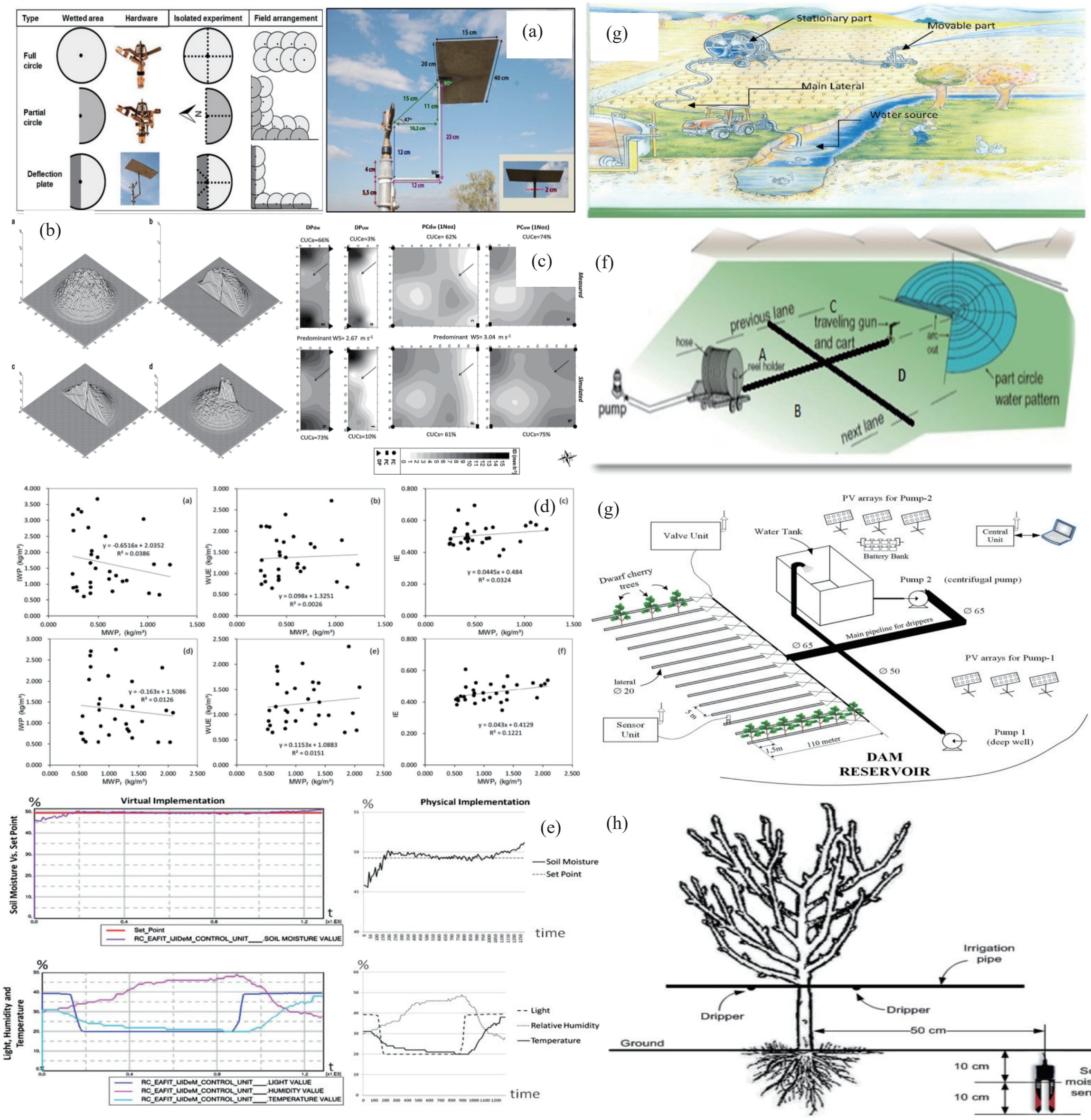
4.1 Importance and necessity of sprinkler drip irrigation scheduling

With the constrained water supplies in current agricultural production, farmers need appropriate scheduling strategies to arrange water resource allocation in advance, and to control irrigation processes efficiently during crop growing season. The irrigation scheduling is regarded as a promising research domain that aims at predicting and achieving optimal water supply for agricultural crop productivity, based on the collection and analysis of crop/plant response to moisture infiltration, especially when soil water content being maintained close to field capacity. So that the intelligent scheduling of sprinkler drip irrigation is important for water balance in soil field, it provides theoretical basis to rationally manage the circulation efficiency of groundwater. Here, two questions are addressed: What is the constructive impact of intelligent scheduling on irrigation quality, crop productivity, and uptake of soil infiltration efficiency? and what are the impacts of intelligent scheduling measures on reducing error in crop productivity estimation?

4.2 Constructive application of sprinkler drip irrigation scheduling

As water allocation optimization enhances the crop productivity and profitability of water-limited irrigation system[48,49], the intelligent scheduling for sprinkler drip irrigation provides efficient tools to regulate the influence of soil, weather on crop yield[50]. To answer the first question, Liu et al.[51] used the GEPIC (GIS based executive process/interactive control) scheduling model to assess the yield and productivity of wheat. Gallardo et al.[52] used a VegSyst simulation to calculate water requirements simultaneously. Liang et al.[53] proposed a novel RSAE-ANFIS (Regulated Sparse Autoencoder - Adaptive Network-based Fuzzy Inference System) prediction system, to give a set of high-efficient decision-making tools for the intelligent scheduling of sprinkler drip irrigation, which including the Labview program designed for RSAE-ANFIS scheduling, MATLAB fuzzy controller design interface, membership function used for ANFIS prediction, data simulation of infiltration, and fuzzy logic rules for decision-making. In his proposed irrigation scheduling network, RSAE is an excellent autoencoder that can be used for calculating the optimal irrigation parameters from raw data. It is highly valued by incorporating irrigation feature extraction and process quantification into a general-purpose fuzzy scheduling system. After the logic network of RSAE has been established, an intelligent scheduling system, based on the working principle of adaptive network-based fuzzy inference system (ANFIS), could be developed to determine the irrigation effectiveness indexes. RSAE identifies the mathematical properties of environmental parameters and ANFIS possesses an excellent capability of adaptive scheduling for water infiltration efficiency, which are characterized by their mutual influence and fuzzy correlations. Because the probabilistic density of sprinkler drip infiltration data monitored by the RSAE can help NPSO to obtain higher accuracy in calculating the drip irrigation quality indexes, RSAE-NPSO possesses much better operating advancements than any alternative ones, which finally proves its robust scheduling quality of the drip infiltration. Besides, Todorovic et al.[54] used different scheduling models ranged from solar radiation and carbon assimilation to water-based models, to accurately simulate the sunflower growth stage. An applied water-driven scheduling model called AquaCrop[55], was reported to be suitable for assessing crop productivity response to water resource storage, it requires fewer mathematical inputs compared to alternative models, such as DSSAT (decision support system for agrotechnology transfer) and APSIM (applied simulation technology)[56-58], etc.

According to this principle an adaptive scheduling test of precision irrigation was carried out, to achieve accurate planning and comprehensive arrangement of sprinkler drip irrigation performance in various test conditions[59]. This approach monitors the probability density of water droplet infiltration, flow speed variance, and error variance tendency of fuzzy scheduling, so that the irrigation infiltration and high-efficient water utilization could be facilitated, which offer convenience to manage the irrigated field equipped with multiple center pivot networks[60]. Figure 6 pictures the constructive influence of sprinkler drip irrigation scheduling, it could be observed that the field-boundary sprinklers should be designed by fully considering its field arrangement and the shape of deflecting plate, thus the accurate three-dimensional simulation of water distribution pattern could be facilitated. Based on these preparations, the contour maps of water distribution for the simulated sprinklers can be obtained. Moreover, the scatter plots of marginal crop productivity and traditional water use efficiency can be determined, thereafter a comprehensive overview of precision irrigation system, and the installation position of moisture sensors in soil field could be made. All these arrangements makes the constructive influence and regulated production of sprinkler drip irrigation scheduling possible[61].



(a) Evaluated field-boundary sprinklers and the shape of the deflecting plate[60]; (b) Three-dimensional simulation of water distribution pattern[61]; (c) Contour maps of the water distribution pattern[61]; (d) Scatter plots of marginal crop productivity and traditional water use efficiency evaluation indexes[62]; (e) Virtual vs. physical implementation[60]; (f) Overview of the area with the installed precision irrigation system, and installation position of the moisture sensor in soil field[30,61]; (g) Hose- reel sprinkler system and its layout diagram[62]; (h) Overview of the area with the installed precision irrigation system, and installation position of the moisture sensor in soil field[31,62]

Figure 6 The constructive influence and regulated production of sprinkler drip irrigation scheduling

4.3 Contributions of sprinkler drip irrigation scheduling

As the working mechanism of intelligent scheduling offers effective tools for investigating the drip infiltration characteristics, the infiltration quality stands for the moisture space distribution effectively. This subject describes the dynamic scheduling of drip infiltration according to actual irrigation environments, it not only demonstrates the close correlation among different scheduling-making tasks in a robust form but also integrates the useful sprinkler drip infiltration characteristics under the uncertain crop production conditions. According to the above-mentioned analysis, the following contributions of intelligent scheduling for sprinkler drip irrigation could be identified:

(1) Optimal water resource allocation: towards the connected, autonomous, decentralized scheduling support for actual drip irrigation operations;

(2) Dynamic water-resource allocation coordination: towards adaptability and better real-time scheduling capabilities in complex irrigation processes;

(3) Data-oriented irrigation scheduling architecture: towards big data analysis and distributed intelligent decision-making network throughout whole irrigation scheduling operation;

(4) Process-centric scheduling approach for sprinkler drip irrigation process: towards the integrative management effectiveness and irrigation data interoperability;

(5) Web-oriented irrigation scheduling principles: towards irrigation service orientation and secure information communication between different sprinkler drip irrigation system, and ensuring optimal coordination of them for appropriate consumption of deep water percolation into soil field.

This section concentrates on appropriate irrigation scheduling performance, all these mentioned studies contributed greatly to the deployment of sprinkler drip irrigation. Most scheduling approaches only focus on the pure computation and prediction of objective irrigation performance, for the purpose of quantifying the crop growth characteristics and environmental influences, without the detailed considerations about their instantaneous adaption to the environmental change and the integrated irrigation scheduling regrettably. Therefore, some difficult problems concerning accurate irrigation scheduling and its resultant resource-arrangement mechanism remain unstudied and unsolved. Since a highly efficient scheduling performance of sprinkler drip irrigation, improves the efficiency of irrigation management, the quantitative evaluation of inherent scheduling among all participant factors of sprinkler drip irrigation, for instance, soil water content, surface runoff and drainage, infield infiltration rate, groundwater circulation efficiency, and moisture penetration, needs to be developed and promoted.

5 Application efficiency of sprinkler drip irrigation

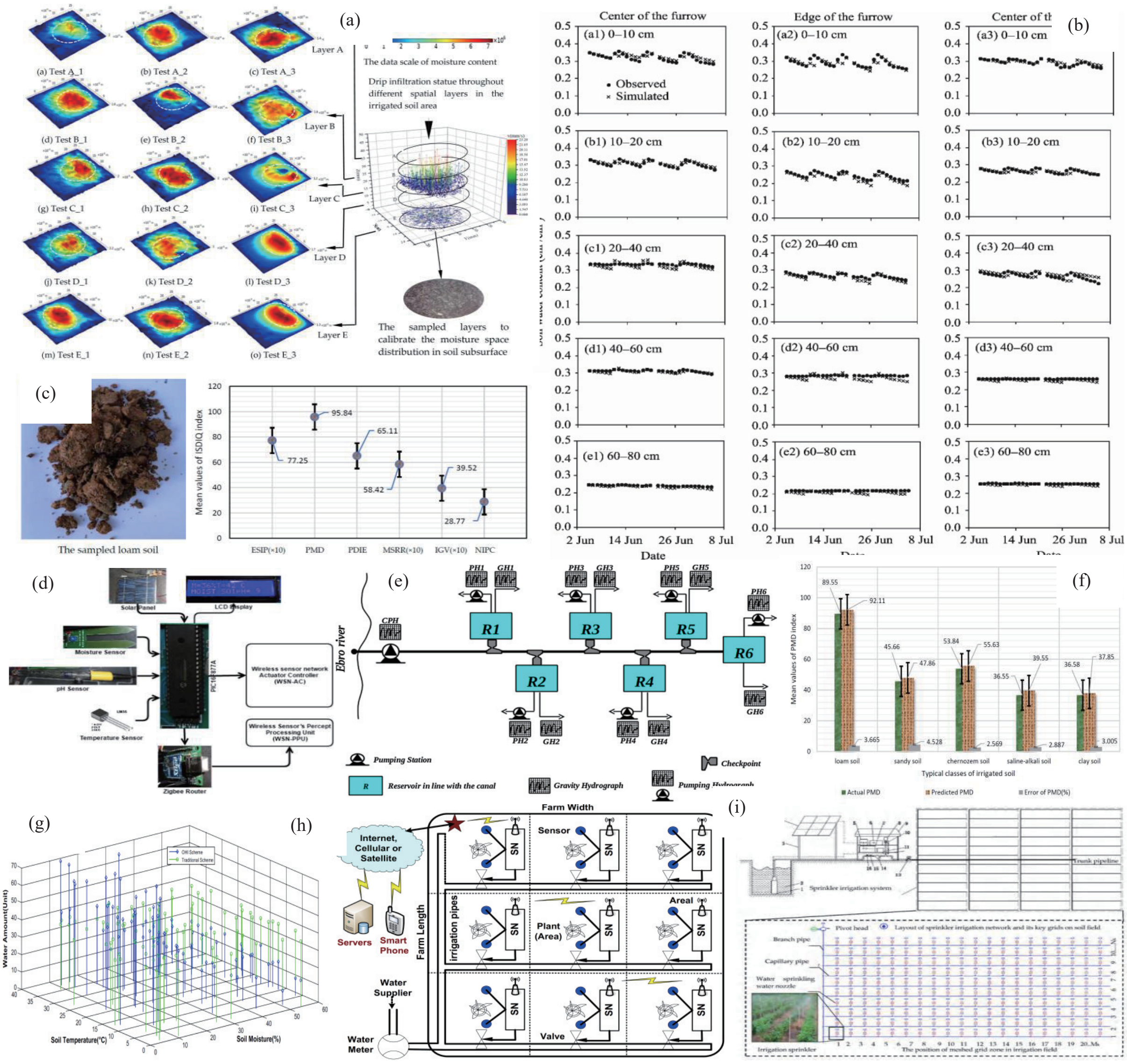
5.1 Importance of drip irrigation application efficiency

As sprinkler drip irrigation deserves high significance in the agricultural crop production domain, its representative application efficiency, including the working properties and inherent superiority, should be demonstrated clearly, in the interest of better understanding and improved employment of irrigation system in various test conditions. The application efficiency of sprinkler drip irrigation introduces overall control of irrigation system, according to the growth information and other bio-information of objective plants, by monitoring, sensing, transferring, diagnosing, and managing moisture dynamics in soil fields. For instance, the techniques of deficit irrigation (DI) and partial root-zone drying (PRD) are the most commonly-used approaches, that ensure effective water use and infiltration efficiency of drip irrigation performance in different moisture diffusivity conditions. By using these novel approaches the crops and plants receive less water amount than those in traditional irrigation cases[62]. Here, the partial root-zone drying approach, modified from the deficit irrigation approach, was proposed to create alternate wet-dry regions in two halves of the root system[63]. Since the aim of deficit irrigation is to control reproductive and vegetative growth and to improve WUE (water usage effectiveness) and crop quality, Sayyed-Hassan et al.[64] investigated the impacts of traditional deficit irrigation and partial root-zone drying on the water-use efficiency of corn cultivation. The sustained precise deficit irrigation supplies water amount below the evapotranspiration (ET) demands throughout the whole cropping season. Therefore, the irrigated plant is exposed to gradual water stress in various time period, which changes the root distribution patterns in different cases, depending on the adaptation of crop plants to the water-limited irrigation conditions[65]. As the presence of compacted soil layer impedes the deep growth and appropriate distribution of plant root system, the root elongation rate and crop yield during sprinkler drip irrigation would be reduced in return[66]. As a result, understanding the root growth adaptation dynamics of cultivars to prolonged water stress, can help in the reasonable allocation of water resources for maximizing profit returns. Thus, a satisfactory performance of precise deficit irrigation could be ensured.

5.2 Verification and assessment of drip irrigation application efficiency

Figure 7 describes the application efficiency calibration of sprinkler drip irrigation system, from this figure we can learn how the environmental condition plays important roles in actual crop production. When the data illustration of drip infiltration considering the moisture space distribution is provided, a complete set of performance comparison could be realized between the observed and simulated soil water contents. For instance, considering typical soil specimen and its correspondingly drip irrigation quality, the control unit of precision irrigation system could be designed and optimized, therefore the optimally heterogeneous irrigation architecture and water amount are demonstrated[67-72]. Furthermore, the tested sprinkler irrigation system and spatial layout of pipeline network should be improved, for the convenience of investigating its application efficiency.

It is necessary to compare the estimated irrigation demands with actual water supplies, to promote the decision making accuracy in sprinkler drip irrigation[72,73]. To maintain appropriate water supply according to local resource demand, accurate measurement and instantaneous control of moisture distributions are essential to solve existing problems of irrigation water efficiency and application availability. Based on this idea, Akbariyeh et al.[68] and Sayari et al.[73] and Biplab et al.[74] assessed the influences of annual water balance conditions, relative proportions of deep drainage, and stability of soil water seepage on crop cultivation, which use the comprehensive analysis of land suitability to optimize the drip irrigation performance. To cope with the complexity of water resource management and irrigation planning[75], Mérida et al. [76] coupled the irrigation procedures with solar energy employment in a smart irrigation management system. Other promotions of irrigation application efficiency also base upon the implementation of energy use optimization[77], irrigation network sector[78], critical point control[79], and improved management of pumping stations[79]. Furthermore, Surjeet et al.[80] also found potential energy savings of 36% for representative water user associations, as the influence of



(a) Data illustration of drip infiltration considering the moisture space distribution[59]; (b) Comparison of observed and simulated soil water content values[61]; (c) The loam soil specimen and its corresponding SDIQ index values[59,83]; (d) The overall controller unit of precision irrigation system[20]; (e) Scheme of the XSIC irrigation system[63]; (f) Comparison between the actual and predicted PMD values[83,84]; (g)-(h) The optimally heterogeneous irrigation architecture and water amount[96]; (i) The tested sprinkler irrigation system and spatial layout of pipeline network[94]

Figure 7 The application efficiency calibration of sprinkler drip irrigation system

soil water redistribution and circulation efficiency of groundwater could be monitored and concentrated on.

5.3 Contributions of drip irrigation application efficiency

The following benefits of characterizing the application of sprinkler drip irrigation have been justified and could be expected:

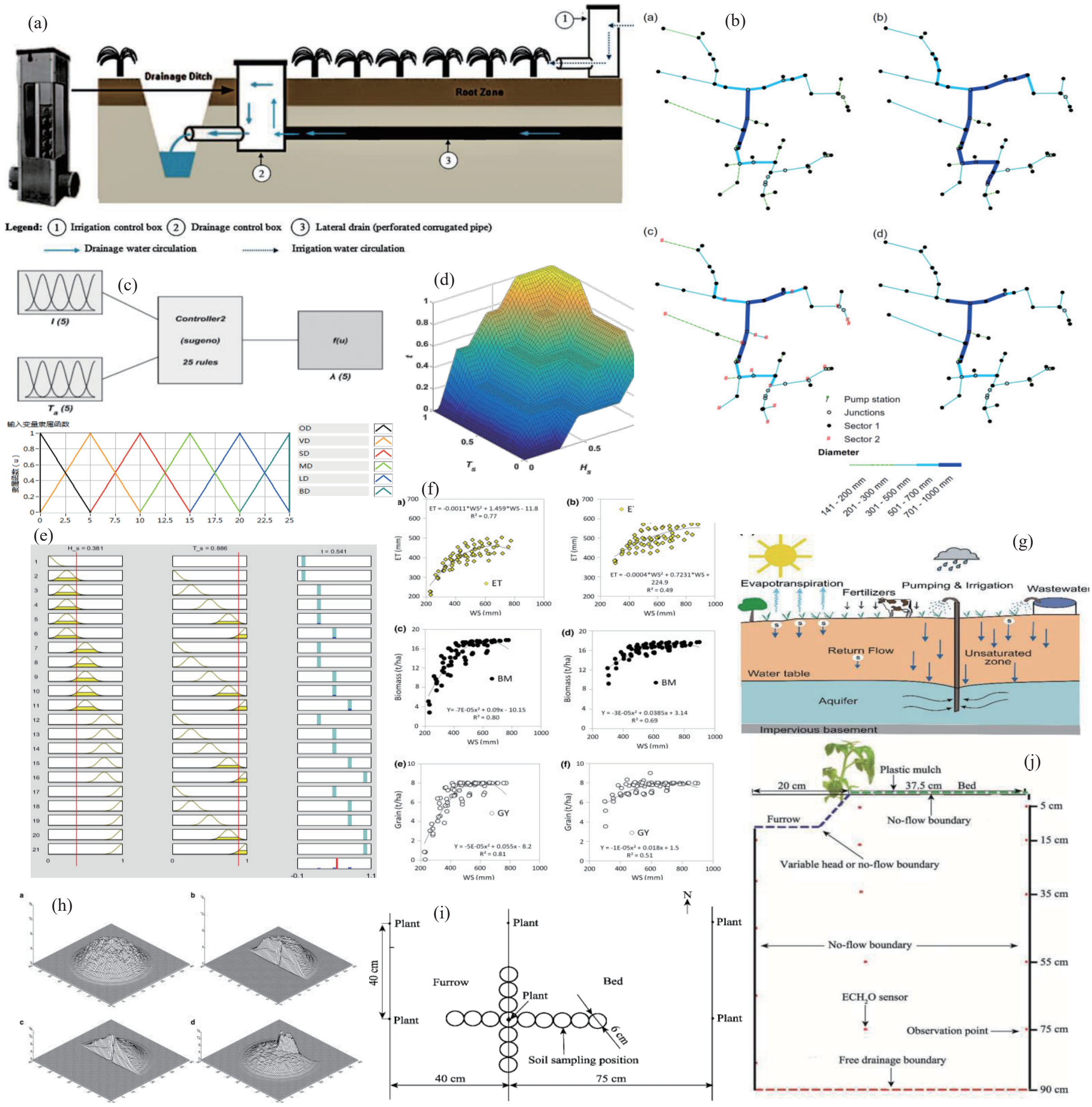
(1) Better irrigation application: Advanced design approaches and optimization tools for drip irrigation equipment enable the application development for optimal collaboration of sprinkler drip irrigation; (2) Appropriate resource supply: Environmental resources transmitted to the supply chain of sprinkler drip irrigation, enable a constant synchronization between accurate irrigation operation and application adaptation to conditional changes; (3) Improved irrigation implementation: Using optimal application objectives as elements of irrigation system, allows the instantaneous coordination of application factors related to agricultural crop production. Therefore it is necessary to illustrate the application efficiency of sprinkler drip irrigation for different agricultural crop production demands; (4) Environmental maintenance and resource recycling: The optimized irrigation effect caused from new environment-oriented irrigation management, allows the best operations of sprinkler drip irrigation.

It is summarized that this section describes new ideas and inspires readers on how irrigation efficiency can be enhanced, to generate the improved achievement of sprinkler drip irrigation for agricultural developments, and to facilitate water saving for imminent water resource shortages. This systematic investigation of high-efficient application mechanism and integrated collaboration of irrigation techniques, which ensures effective irrigation performance, need to be developed further.

6 Environmental influence of sprinkler drip irrigation

6.1 Importance of environmental influence investigation of sprinkler drip irrigation

Figure 8 presents the application efficiency and environmental influence of sprinkler drip irrigation, it could be learned that based on the field-boundary sprinklers and the shape of deflecting plate, the network design of sprinkler drip irrigation could be



(a) Evaluated field-boundary sprinklers and the shape of the deflecting plate[61]; (b) Network design according to the original network and three representative scenarios[14]; (c)-(e) The RSAE-ANFIS prediction system proposed to give high-efficient decision-making tools for the scheduling of sprinkler drip irrigation[59]; (f) The relationship between evapotranspiration and water supply[60,61]; (g) Main direct and indirect impacts of precision irrigation on groundwater quality[62]; (h) Effects on water and energy productivity under different approaches and irrigation schedules[63]; (i) Schematic diagram of planting pattern and soil core sampling[64]; (j) Schematic and boundary conditions of flow domain[65]

Figure 8 The application efficiency and environmental influence of sprinkler drip irrigation

differentiated from original network and representative scenarios. In order to determine the drip irrigation quality, Oren et al.[79] and Hale et al.[81] provided the high-efficient decision-making tools for drip irrigation performance. Considering the correlation between evapotranspiration and water supply, the main direct and indirect impacts of precision irrigation on groundwater quality and energy productivity could be identified easily. Through appropriate irrigation scheduling, the planting pattern and soil core sampling could be facilitated thereafter, especially when the boundary conditions of irrigation flow is focused.

6.2 Constructive environmental influence assessment of sprinkler drip irrigation

As water scarcity is one of the main barriers to sustainable irrigation performance, wastewater has usually been used for agricultural irrigation purposes, particularly in water-scarce areas. It greatly reduces the need for chemical fertilizers, results to net cost savings. According to the intrinsic vulnerability of groundwater, the DRASTIC-based approach, as DRASTIC denotes the depth to water, net recharge, aquifer media, soil media, topography, impact of the vadose zone and hydraulic conductivity, was employed to establish a GIS (geographic information system)-based groundwater assessment model. This assessment model, namely the DRSIN model, contains several key influential parameters such as the groundwater depth, net recharge, soil type, and the impact of vadose zone and nitrogen, etc[82]. The proposed Optimally Heterogeneous Irrigation (OHI) system was evaluated using the event-driven simulation, which has been compared with other commonly-used fuzzy logic approaches for the quantification of environmental influence. Furthermore, the estimated soil moisture and temperature are input parameters, and the water amount are output parameters, for the fuzzy logic controller, which could be defined as fuzzy assessment scheme. The water amount is computed using the fuzzy assessment scheme according to the predefined fuzzy rules. Inspired by this model, Liang et al.[83,84] predicted drip irrigation effectiveness based on the moisture infiltration characteristics by using an improved ANFIS system; therefore an efficient influence evaluation covering the water-use efficiency, transpiration consumption, saturated hydraulic conductivity, and water balance condition, could be realized[85].

6.3 Contributions of environmental influence investigation of sprinkler drip irrigation

This section overviews mutual influence between environmental conditions and sprinkler drip irrigation. Actual experimental results and operational procedures indicated that the increasingly remarkable improvements in irrigation effects and cultivation qualities could be achieved, by introducing the following issues in the interests of understanding the complicated relationship between environmental influential factors and sprinkler drip irrigation: Firstly, the influence of adaptation measures, such as irrigation water quotas, proportional water allocation to irrigation, water-use efficiency, and irrigation water demand, should be fully considered about. Secondly, the impacts of environmental conditions on agricultural crop production and changes in water affordability should be focused on. Thirdly, more research needed to be carried out to analyze the uncertainty in environmental influence related to irrigation scheduling[86]. In parallel with physical development of sprinkler drip irrigation networks, the quality control and performance improvement of irrigation effectiveness would be considered about, which impacts on the circulation efficiency of groundwater, soil moisture pressure, and soil infiltration uniformity.

7 Future development prospects

7.1 Literature bibliometric investigation of sprinkler drip irrigation

Through using big data techniques, all the above-mentioned subjects of sprinkler drip irrigation, including their historical developments and integrated application, found to be improved rapidly[87-90]. Figure 9 presents a literature bibliometric map showing its most focused topics, activeness degree, citation frequency, and topological correlations, referenced from the papers published from 2000 to 2023. Here the software of VOS viewer is used to create a comprehensive bibliometric visualization, which extracted from 1860 published papers, and interconnected by co-authorship, citation, bibliographic coupling, or co-citation links.

In this VOS visualization, specific knowledge points or focused items are denoted by circles, such as crop yield, irrigation quality, water supply, moisture concentration, soil infiltration, etc. Each circle is sized by the occurrence frequency and focused level of certain knowledge points or research items: Large circle represents a lot of published literature investigating the research item which it stands for. The higher the occurrence frequency of a research item, the larger diameter the circle is. Furthermore, VOS viewer groups these research terms into different circle clusters by colors: Red cluster locates at the upper area of bibliographic visualization and concerns the collaborative monitoring of sprinkler drip irrigation; Purple cluster locates at the upper left area and focuses on irrigation scheduling; Green cluster locates at the lower left area and aims at environmental influence; Blue and yellow clusters locates at the right area and emphasize on infiltration efficiency and irrigation service respectively. Lines between these circles stand for the logical links between two knowledge items. Based on this topological arrangement, distance between two circled groups indicates the logical relatedness and mutual influence between them. For instance, a strong correlation between irrigation scheduling and environmental influence could be verified by their close linear distance. Therefore, effective irrigation scheduling reduces the amount of water consumption in comparison with ordinary water allocation approaches, demonstrating extraordinary adaptation of sprinkler drip irrigation to different complex soil conditions. This bibliometric visualization exhibits generic properties of sprinkler drip irrigation that worthy of investigation and discussion, their development tendencies could be illustrated and highlighted simultaneously.

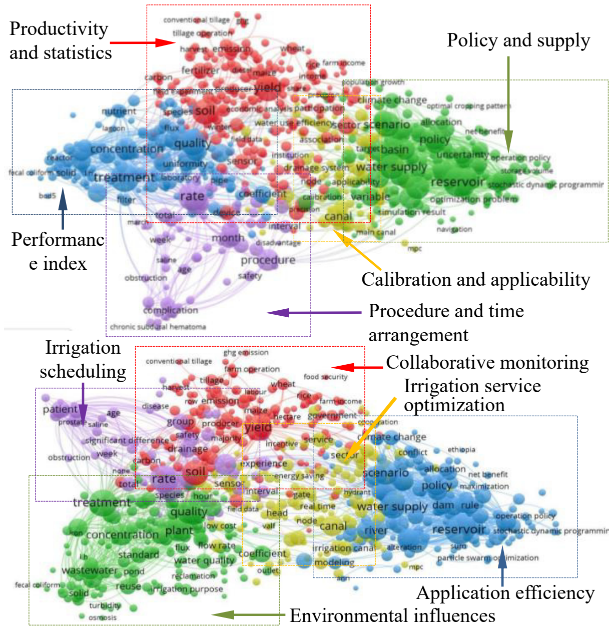


Figure 9 Literature bibliometric map concerning the most-relevant keywords in sprinkler drip irrigation during 2000-2023.

7.2 Endeavored directions of sprinkler drip irrigation

7.2.1 Collaborative monitoring of irrigation system

The developments of irrigation capabilities in water infiltration, water resource distribution, and irrigation strategy management entails the collaborative monitoring of sprinkler drip irrigation system, which capable of monitoring irrigation duration, cultivation qualities and irrigation effectiveness with high accuracy and strong robustness[91,92]. The collaborative monitoring of irrigation system is found to be a major research domain emphasizes on the component cooperation and irrigation procedure, time arrangement and effectiveness calibration, system applicability and performance index, crop productivity and process statistics, agricultural development policy and water/fertilizer resource supply, and the collaborative planning of irrigation schedules, etc[93,94]. As the adaptive improvements in irrigation system and the cooperative controls of operational performance in different meteorological conditions could be realized by optimizing irrigation processes, this topic deserves considerable attention in near future.

7.2.2 Intelligent scheduling for sprinkler drip irrigation

Irrigation scheduling was studied to promote irrigation effectiveness. This subject uses effective mathematical algorithms to determine the parametric coefficients and performance limitations, design irrigation networks and working capabilities, and plan resource supplies and conditional scenarios as well. Therefore, it is important to plan irrigation processes and select optimal combination of irrigation parameters, such as the moisture distribution efficiency and soil\water uniformity. Since intelligent scheduling enhances the understanding of induced irrigation principles and keeps close control of resultant infiltration performance, many high-efficient intelligent reasoning algorithms and decision-making system have already been utilized, contributing to accurate prediction and effective monitoring of irrigation effectiveness[59]. As irrigation scheduling is frequently used to predict irrigation efficiency and to confirm the operational capability of irrigation system, its outcomes show that the processed data of intelligent schedule algorithms are meaningful and correlative. Since typical scheduling models show shift-invariant calculation characteristics and determine irrigation quality precisely, the superiority of sprinkler drip irrigation can be verified clearly, and its instantaneous working supervision and mechanism optimization could be facilitated remarkably.

7.2.3 Application efficiency of sprinkler drip irrigation

The application efficiency of sprinkler drip irrigation helps to develop the predictive insights into crop cultivation environment, such as soil treatment and infiltration quality, water supply and scenario implementation, energy pumping and service environment, crop yields and planting efficiency, and irrigation productivity and statistical analysis as well. Application efficiency should be observed to ensure more powerful irrigation capability and higher schedule accuracy, especially in complicated geographical conditions[60]. As this subject sheds new light on irrigation efficiency to achieve the desired soil environment and cultivation effectiveness, more attempts on application efficiency should be prioritized to guarantee the stable drip irrigation results.

7.2.4 Environmental influence of sprinkler drip irrigation

Since sprinkler drip irrigation is quintessential, there is a great need to quantify its environmental influence, which is capable of regulating water requirements and coordinating irrigation parameters, to demonstrate the growth principle of crop plants and control the developing mechanism of water infiltration. Furthermore, several recently-proposed environmental topics such as waste components and water pollution, irrigation productivity and crop yields, ecosystem protection and climate conditions, should be highly concentrated on[95]. Irrigation influence evaluation entails the viability of irrigation techniques to increase agricultural productivity and upgrade operation efficiency, which need to be assessed to enhance its constructive applicability and ensure the widespread usage of sprinkler drip irrigation.

7.3 The comprehensive influence of sprinkler drip irrigation

It could be learned that the comprehensive influence of sprinkler drip irrigation, ranged from the well-known irrigation performance, to the accurate evaluative indexes such as the relative proportion of deep drainage and tail water, infield spatial infiltration variability, and the consumption of deep percolation[96].

(1) Most sprinkler drip irrigation approaches possess unique capabilities for plant cultivation, it is necessary to understand their importance in prompting the cultivation productivity of agricultural crops and improving soil physicochemical quality. For example, agricultural sustainability, crop consumption, utilization of water resources, environmental impact, and social/economic development are significant factors frequently affected by sprinkler drip irrigation. The working interactions or mutual impact among water resources, crop growth, moisture distribution, and irrigation schedule should be detailed to picture irrigation progress in these discussed domains.

(2) A constructive investigation of collaborative monitoring of irrigation system is imperative to the highly efficient control and mass production of applicable irrigation system, providing a set of instructive data and applicable references for its health management and effective operation. Taking advantage of collaborative irrigation monitoring, this review drafts a general picture about its current and future status in high-efficiency monitoring coordination and dynamic cooperation; thus, the optimized settings and well-balanced collaborative irrigation monitoring could be anticipated.

(3) The intelligent scheduling for sprinkler drip irrigation was clearly explained, including the theoretical probabilistic calculations and numerical inference models most suitable to illustrate the integrated mechanism verification and combined schedule principles. As a result, more novel computational decision-making algorithms and effective schedule modelling could be used to provide the constructive demonstrations and heuristic descriptions for practical irrigation results. Better-adaptive scheduling approaches should be prepared to obtain higher irrigation performance in the future.

(4) To promote crop productivity and irrigation efficiency, a deliberate integration of application efficiency in sprinkler drip irrigation can be extremely important to obtain better soil infiltration effects. When the correspondingly effect of sprinkler drip irrigation is investigated thoroughly, a detailed comprehension and comparative analysis of application mechanism and soil-water interaction could be realized. Otherwise, undesirable consequences would be obtained.

(5) This paper explains the environmental influence of sprinkler drip irrigation, together with its specific influence analysis and comparative irrigation mechanism, greatly helps to obtain a clear demonstration of environmental influence mechanism with higher reliability and better stability. Actual influenced results of sprinkler drip irrigation indicate that, a series of remarkable improvements in working coordination and significant promotions of irrigation efficiency could be achieved; Moreover, the theoretical analysis and result comparison between drip irrigation process and crop productivity establish useful basis for irrigation improvement and efficiency promotion.

8 Conclusions

In this paper, a comprehensive review of sprinkler drip irrigation is made, emphasizing on its latest research developments and integrated coordination in collaborative monitoring, irrigation scheduling, application efficiency, and environmental influence, for improving the moisture space distribution and water infiltration efficiency in the irrigated soil field, simultaneously guiding the performance optimization of agricultural crop production. It observes sprinkler drip irrigation effectiveness and focuses on its influential factors—collaborative operation, application influence, effectiveness improvement, intelligent monitoring, integrated controlling, and automated equipment—are discussed from theoretical and technical perspectives. This review is merited by the following theoretical superiority and technological contributions: It realizes accurate description of sprinkler drip irrigation development for modern precision agriculture; Based on the comparison of relevant drip irrigation approaches with actual measurement data, it is found that sprinkler drip irrigation deserves high expectations for its working efficiency, productivity management and stable quality, clearly facilitating the effectiveness and reliability of agricultural crop production; The quality verification of sprinkler drip irrigation is implemented to assess the its extraordinary performance, prominent universality, and operational reliability, from different innovative perspectives. Therefore, the irrigation efficiency and infiltration quality of soil field can be planned precisely, which supports a remarkable improvement of agricultural crop production under complex working conditions eventually.

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[References]

[1] Odegard I Y R, Van der. The future of food Scenarios and the effect on natural resource use in agriculture in 2050. Eco. Econ., 2014; 97: 51–59.

[2] Wu G, Li L, Ahmad S. A dynamic model for vulnerability assessment of regional water resources in arid areas, a case study of Bayingolin, China. Water Resour. Manag., 2013; 27(8): 3085–3101.

[3] Salah E B, Foued C. Irrigation problem in Ziban oases (Algeria): causes and consequences. Environ. Dev. Sustain, 2018; 5: 1–14.

[4] Shen Y, Li S, Chen Y, Estimation of regional irrigation water requirement and water supply risk in the arid region of Northwestern China 1989-2010. Agric. Water Manag, 2013; 128: 55–64.

[5] Nader A, Reza B, Mohammad M. Strategic planning for remediation and optimization of irrigation and drainage networks: a case study for Iran. Agric. Sci. Proc., 2015; 4: 211–221.

[6] Panahi M, Khosravi K, Ahmad S, Panahi S, Lee C W. Cumulative infiltration and infiltration rate prediction using optimized deep learning algorithms, A study in Western Iran. J. Hydrol., 2021; 35: 100825.

[7] Luo Y, Zhang J. M, Zhou Z, Shen Z J, Chong L, Victor C. Investigation and prediction of water infiltration process in cracked soils based on a full-scale model test. Geoderma. 2021; 400: 115111.

[8] Pahlavan-Rad M M R, Dahmardeh K, Hadizadeh M. Prediction of soil water infiltration using multiple linear regression and random forest in a dry flood plain, eastern Iran. CATENA, 2020; 194: 104715.

[9] Anni A H, Cohen S. Sensitivity of urban flood simulations to storm water infrastructure and soil infiltration. J. Hydrol. . 2020; 588: 125028.

[10] Stuurop J C, Sjoerd E A, Helen K F. The influence of soil texture and environmental conditions on frozen soil infiltration, A numerical investigation. Cold Reg. Sci. Technol., 2022; 194: 103456.

[11] Choi K, Choi E, Kim S, Lee Y. Improving water and fertilizer use efficiency during the production of strawberry in coir substrate hydroponics using a FDR sensor-automated irrigation system. Hortic. Environ. Biotechnol., 2016; 57(5): 431–439.

[12] Nam W, Hong E, Choi J. Assessment of water delivery efficiency in irrigation canals using performance indicators. Irrig. Sci., 2016; 34: 129–143.

[13] Zied H, Salem B. Subsurface drainage system performance, soil salinization risk, and shallow groundwater dynamic under irrigation practice in an arid land. Arab. J. Sci. Eng., 2019; 44: 467–477.

[14] Fernández G, Montesinos P, Camacho P, Rodríguez D. Optimal design of pressurized irrigation networks to minimize the operational cost under different management scenarios. Water Res. Manag. 2017; 31: 1995–2010.

[15] Sivagami A, Hareeshvare U, Maheshwar S, Venkatachalapathy V S K. Automated irrigation system for greenhouse monitoring. J. Inst. Eng. India Ser. A., 2018; 99(2): 183–191.

[16] Clemmens A J, Molden D J. Water uses and productivity of irrigation systems. Irrig. Sci. 2007; 25: 247–261.

[17] Pereira L S, Cordery I, Iacovides I. Improved indicators of water use performance and productivity for sustainable water conservation and saving. Agric. Water Manag., 2012; 108: 39–51.

[18] Shakir A. S, Khan N. M, Qureshi M M. Canal water management, case study of upper Chenab canal in Pakistan. Irrig. Drain. 2010; 59: 76–91.

[19] Molden D, Burton M, Bos M G. Performance assessment, irrigation service delivery and poverty reduction, benefits of improved system management. Irrig. Drain. 2007; 56: 307–320.

[20] Nagarajan G, Minu R. Wireless Soil Monitoring Sensor for Sprinkler Irrigation Automation System. Wireless Pers. Commun. 2018; 98: 1835–1851.

[21] Paek J, Hicks J, Coe S, Govindan R. Image-based environmental monitoring sensor application using an embedded wireless sensor network. Sensors, 2014; 14: 15981–16002.

[22] Podimata M V, Yannopoulos P C. Evolution of game theory application in irrigation systems. Agric. Sci. Proc. 2015; 4: 271–281.

[23] Ravishanker A, Pandian R. Embedded system based sensor failure detection and industrial environment control over wireless network. Int. J. Eng. Res., 2014; 3: 716–715.

[24] Yang S, Zhang Y. Wireless measurement and control system for environmental parameters in greenhouse. Proc. Measuring Technol., 2010; 2: 1099–1102.

[25] Gutlirrez J, Villa M, Nieto G, Parta G. Automated irrigation system using a wireless sensor network and GPRS module. IEEE Trans. Instrum. Meas., 2013; 63: 166–176.

[26] Machiwal D, Gupta A, Jha M. K. Analysis of trend in temperature and rainfall time series of an Indian arid region, comparative evaluation of salient techniques. Theor. Al. Climatol., 2019; 136(1/2): 301–320.

[27] Kim Y, Evans R G. Software design for wireless sensor based site-specific irrigation. Comput. Electron. Agric., 2009; 66(2): 159–165.

[28] Vrugt J A, Hopmans J W, Šimunek J. Calibration of a two-dimensional root water uptake model. Soil Sci. Soc. Am. J., 2001; 65(4): 1027–1037.

[29] Yercan M, Atis E, Salali H E. Assessing irrigation performance in the Gediz River Basin of Turkey, water user associations versus cooperatives. Irrig. Sci., 2009; 27: 263–270.

[30] Lin C P. Frequency domain versus travel time analyzes of TDR wave forms for soil moisture measurements. Soil Sci. Soc. Amer. J. 2003; 67: 720–729.

[31] Dursun M, Ozden S. Application of solar powered automatic water pumping in Turkey. Int. J. Comput. Electr. Eng., 2012; 4(2): 161–164.

[32] Domingo P F, Lazaro G L, Wieser A, Martin G E. Sensor placement determination for range-difference positioning using evolutionary multi-objective optimization. Expert Syst. Al. 2016; 47: 95–105.

[33] Vellidis G, Tucker M, Perry C, Reckford D, Butts C, Henry H. A soil moisture sensor based variable rate irrigation scheduling system. Prec. Agric., 2013; 13: 713–720.

[34] Feng G, Ouyang Y, Adeli A, Read J, Jenkins J. Rainfall deficit and irrigation demand for major row crops in the Blackland Prairie of Mississippi. Soil Sci. Soc Am. J., 2018; 82(2): 423–435.

[35] Siew C, Tanyimboh T T. Penalty-free feasibility boundary convergent multi-objective evolutionary algorithm for the optimization of moisture distribution systems. Water Resour. Manag., 2012; 26: 4485–4507.

[36] Swamy D, Rajesh G, Pooja M. Micro controller based precise sprinkler drip irrigation system. Int. J. Emerg. Sci. Eng., 2013; 1: 2319–6378.

[37] Tasumi M, Allen R. G, Trezza R, Wright J L. Satellite-based energy balance to assess within-population variance of crop coefficient curves. J. Irrig. Drain. Eng., 2005; 131(1): 94–109.

[38] Pisciotta A, Cusimano G, Favara R. Groundwater nitrate risk assessment using intrinsic vulnerability approaches, a comparative study of environmental impact by intensive farming in the Mediterranean region of Sicily, Italy. J. Geochem. Explor., 2015; 156: 89–100.

[39] Milind P K, Bhaskar P C. Microcontroller based adaptive irrigation system using WSN for variety crops and development of insect avoidance system for better yield. Int. J. Res. Eng. Technol., 2014; 3: 308–312.

[40] Safavi H R, Enteshari S. Conjunctive use of surface and ground water resources using the ant system optimization. Agric. Water Manag., 2016; 173: 23–34.

[41] Hendrawan Y, Murase H. Neural-intelligent water drops algorithm to select relevant textural features for developing irrigation system using machine vision. Comput. Electron. Agric. 2011; 77(2): 214–228.

[42] Zhang J, Zhang X, Shan Y. Numerical simulation on soil water infiltration

for spring wheat under ridge furrow irrigation. J. Arid Land Resour. Environ., 2014; 28(6): 165–170.
[43] Yahyaoui I, Tadeo F, Segatto M. Energy and water management for drip-irrigation of tomatoes in a semi-arid district. Agric. Water Manag., 2017; 183: 4–15.
[44] Annor F, van G, Liebe J, Zaag P, Tilmant A, Odai S. Delineation of small reservoirs using radar imagery in a semi-arid environment, a case study in the upper east region of Ghana. Phys. Chem. Earth., 2009; 34: 309–315.
[45] Antonino A, Hammecker C, Montenegro S, Netto A, Angulo R, Lira C. Subirrigation of land bordering small reservoirs in the semi-arid region in the Northeast of Brazil, monitoring and water balance. Agric. Water Manag., 2005; 73: 131–147.
[46] Dechmi F, Playán E, Faci J, Tejero M. Analysis of an irrigation district in northeastern Spain. I, characterisation and water use assessment. Agric. Water Manag., 2003; 61: 75–92.
[47] Playán E, Zapata N, Faci J M, Tolosa D, Lacueva J L, Pelegrín J, Salvador R, Sánchez I, Lafita A. Assessing sprinkler irrigation uniformity using a ballistic simulation model. Agric. Water Manag., 2006; 84: 86–100.
[48] Prima S D, Stewart R D, Castellini M, Bagarello V, Lassabatere L. Estimating the macroscopic capillary length from Beerkan infiltration experiments and its impact on saturated soil hydraulic conductivity predictions. J. Hydrol. . 2020; 589: 125159.
[49] Liu X C, Liang Z W, Wen G L, Yuan X F. Waterjet machining and research developments: a review. Int. J. Adv. Manuf. Technol., 2018; 102(5): 1257–1335.
[50] Klocke N L, Currie R S, Tomsicek D J. Grain sorghum yield response to precise deficit irrigation. Trans. ASABE, 2012; 55(3): 947–955.
[51] Liu J, Wiberg D, Zehnder A, Yang H. Modeling the role of irrigation in winter wheat yield, crop crop productivity, and production in China. Irrig. Sci., 2007; 26(1): 21–33.
[52] Gallardo M, Thompson R. B, Gimenez C, Padilla F M, Stockle C O. Prototype decision support system based on the VegSyst simulation model to calculate crop N and water requirements for tomato under plastic cover. Irrig. Sci., 2014; 32(3): 237–253.
[53] Liang Z W, Liao S P, Wen Y H, Liu X C. Working parameter optimization of strengthen waterjet grinding with the orthogonal- experiment-design-based ANFIS. J. Intell. Manuf., 2019; 30(2): 833–854.
[54] Todorovic M, Albrizio R, Zivotic L. Assessment of AquaCrop, CropSyst, and WOFOST models in the simulation of sunflower growth under different water regimes. Agron. J. 2009; 101: 509–521.
[55] Steduto P, Hsiao T C, Raes D, Fereres E. AquaCrop-The FAO crop model to simulate yield response to water. I. Concept and underlying principle. Agron. J., 2009; 101(3): 426–437.
[56] Keating B A, Carberry P S, Hammer G L, Probert M E, Smith C J. An overview of APSIM, a model designed for farming systems simulation. Eur. J. Agron., 2003; 18(3-4): 267–288.
[57] Létourneau G, Caron J, Anderson L, Cormier J. Matric potential-based irrigation management of field- grown strawberry, Effects on yield and water use efficiency Agric. Water Manag., 2015; 161: 102–113.
[58] Susan A O, Manuel A A, Steven R E. Using an integrated crop water stress index for irrigation scheduling of two corn hybrids in a semi-arid region. Irrig. Sci., 2017; 35: 451–467.
[59] Liang Z, Liu X, Wen G, Xiao J. Effectiveness prediction of abrasive jetting stream of accelerator tank using NSAE-ANFIS. Proc. IMechE. Part B, J. Eng. Manuf., 2020; 234(13): 1615–1639.
[60] Cao X C, Shu R, Guo X P, Wang W G. Scarce water resources and priority irrigation schemes from agronomic crops. Mitig Adapt Strateg Glob Change, 2019; 24: 399–417.
[61] Ouaza S, Burguete J, Zapata N. Solid-set sprinklers irrigation of field boundaries: experiments and modeling. Irrig Sci., 2016; 34: 85–103.
[62] Sadras V O. Does partial root-zone drying improve irrigation crop productivity in the field? A meta-analysis. Irrig. Sci., 2009; 27: 183–190.
[63] Sepaskhah A R, Ahmadi S H. A review on partial root-zone drying irrigation. Int. J. Plant Prod., 2010; 4: 241–258.
[64] Sayyed H, Rohollah F, Payam N. Comparison of traditional and modern precise deficit irrigation techniques in corn cultivation using treated municipal Waste water. Int. J. Recycl. Org. Waste Agric., 2017; 6: 47–55.
[65] Geerts S, Raes D. Review, precise deficit irrigation as an on-farm strategy to maximize crop crop productivity in dry areas. Agric. Water Manag. 2009; 96: 1275–1284.
[66] Hodgkinson L, Dodd I C, Binley A, Ashton R W, White R P, Watts C W, Whalley W R. Root growth in field-grown winter wheat, some effects of soil conditions, season and genotype. Eur. J. Agron. 2017; 91: 74–83.
[67] Qi W, Zhang Z, Wang C, Huang M. Prediction of infiltration behaviors and evaluation of irrigation efficiency in clay loam soil under Moistube® irrigation. Agric. Water Manag. 2021; 248: 106756.
[68] Akbariyeh S, Pena C, Wang T, Mohebbi A, Li Y. Prediction of nitrate accumulation and leaching beneath groundwater irrigated corn fields in the Upper Platte basin under a future climate scenario. Sci. Total Environ. 2019; 685: 514–526.
[69] Fu Q, Hou R, Li T, Li Y, Liu D, Li M. A new infiltration model for simulating soil water movement in canal irrigation under laboratory conditions. Agric. Water Manag. 2019; 213: 433–444.
[70] Khasraei A, Zare H, Mehdi A, Albajic J M. Determining the accuracy of different water infiltration models in lands under wheat and bean cultivation. J. Hydrol., 2021; 603: 127122.
[71] Nie W, Li Y, Zhang F, Ma X. Optimal discharge for closed-end border irrigation under soil infiltration variability. Agric. Water Manag., 2019; 221: 58–65.
[72] Jie F, Fei L, Li S, Hao K, Liu L, Zhu H. Prediction model for irrigation return flow considering lag effect for arid areas. Agric. Water Manag., 2021; 256: 107119.
[73] Sayari M, Zounemat K. Irrigation water infiltration modeling using machine learning. Comput. Electron. Agr., 2021; 180: 105921.
[74] Biplab M, Gour D, Sujan S. Land suitability assessment for potential surface irrigation of river catchment for irrigation development in Kansai watershed, Purulia, West Bengal, India. Sustain. Water Resour. Manag., 2018; 4: 699–714.
[75] Sengupta S, Bhattacharyy K. a, Mandal J, Bhattacharya P, Halder S, Pari A. Deficit irrigation and organic amendments can reduce dietary arsenic risk from rice, Introducing machine learning-based prediction models from field data. Agr. Eco. Environ., 2021; 319: 107516.
[76] Hamilton G J, Akbar G, Raine S, Mchugh A. Deep blade loosening and two-dimensional infiltration theory make furrow irrigation predictable, simpler and more efficient. Agric. Water Manag. 2020; 239: 106241.
[77] Mondaca-Duarte F D, Mourik S V, Balendonck J, Voogt W, Henten J. Irrigation, crop stress and drainage reduction under uncertainty: A scenario study. Agric. Water Manag., 2020; 230: 1059900.
[78] Sun M, Gao X, Zhang Y, Song X. A new solution of high- efficiency rainwater irrigation mode for water management in apple plantation, Design and application. Agric. Water Manag., 2022; 259: 107243.
[79] Oren O, Yechieli Y, Bohlke J. K, Dody A. Contamination of groundwater under cultivated fields in an arid environment, central Arava Valley, Israel. J. Hydrol., 2004; 290: 312–328.
[80] Surjeet S, Ghosh N. C, Suman G, Gopal K, Sumant K, Preeti B. Index-based assessment of suitability of water quality for irrigation purpose under Indian conditions. Environ. Monit. Assess. 2018; 190: 29.
[81] Hale L, Curtis D, Azeem M, Montgomery J, Crowley D E, McGiffen M E. Influence of compost and biochar on soil biological properties under turfgrass supplied deficit irrigation. Appl. Soil Eco., 2021; 168: 104134.
[82] Chari M M, Poozan M T, Afrasia P. Modelling soil water infiltration variability using scaling. Biosyst. Eng., 2020; 196: 56–66.
[83] Liang Z W, Tan S, Liao S P, Liu X C. Component parameter optimization of strengthen waterjet grinding slurry with the orthogonal-experiment-design-based ANFIS, Int. J. Adv. Manuf. Technol., 2016; 90(1-4): 1–25.
[84] Liang Z W, Liu X C, Zou T, Xiao J R. Adaptive prediction of water droplet infiltration effectiveness of sprinkler irrigation using RSAE-ANFIS. Water, 2021; 13(1): 791.
[85] Liang Z W, Shan S Y, Liu X C, Wen Y H. Fuzzy prediction of AWJ turbulence characteristics by using multi-phase flow models. Eng. Appl. Comp. Fluid, 2017; 11(1): 225–257.
[86] Yang X, Wang G, Chen Y, Sui P, Pacenka S. Reduced groundwater use and increased grain production by optimized irrigation scheduling in winter wheat–summer maize double cropping system—A 16-year field study in North China Plain. Field Crops Res., 2022; 275: 108364.
[87] Lena B P, Bondesan L, Pinheiro A, Ortiz B V, Morata G T, Kumar H. Determination of irrigation scheduling thresholds based on HYDRUS-1D simulations of field capacity for multi-layered agronomic soils in Alabama, USA. Agric. Water Manag., 2022; 259: 107234.
[88] Wang J, Long H, Huang Y, Wang X, Liu W. Effects of different irrigation management parameters on cumulative water supply under negative pressure irrigation. Agric. Water Manag., 2019; 224: 105743.
[89] Li M, Sui R, Meng Y, Yan H. A real-time fuzzy decision support system for alfalfa irrigation. Comput. Electron. Agr., 2019; 163: 104870.

[90] Yu Q, Kang S, Hu S, Zhang L, Zhang X. Modeling soil water-salt dynamics and crop response under severely saline condition using WAVES, Searching for a target irrigation for saline water irrigation. Agric. Water Manag., 2021; 256: 107100.

[91] Mairech H, López B L, Moriondo M, Dibari C, Testi L. Sustainability of olive growing in the Mediterranean area under future climate scenarios, Exploring the effects of intensification and deficit irrigation. Eur. J. Agron., 2021; 129: 126319.

[92] Thorp K R, Thompson A L, Bronson K F, Clothier B E, Dierickx W, Oster J. Irrigation rate and timing effects on Arizona cotton yield, water productivity, and fiber quality. Agric. Water Manag., 2020; 234: 106146.

[93] Yalin D, Schwartz A, Tarchitzky J, Shenker M. Soil oxygen and water dynamics underlying hypoxic conditions in root-zone of avocado irrigated with treated wastewater in clay soil. Soil Till. Res., 2021; 212: 105039.

[94] Liang Z W, Liu X C, Xiao J R, Liu C H. Review of conceptual and systematic progress of precision irrigation. Int J Agric & Biol Eng, 2021; 14(4): 20–31.

[95] Liang Z, Zou T, Zhang Y, Xiao J, Liu X. Sprinkler Drip Infifiltration Quality Prediction for Moisture Space Distribution Using RSAE-NPSO. Agriculture, 2022; 12: 691.

[96] Yousef E, Chris P. Optimally heterogeneous irrigation for precision agriculture using wireless sensor networks. Arab. J. Sci. Eng., 2019; 44: 3183–3195.