agronomy

Review

Advances in Sprinkler Irrigation: A Review in the Context of Precision Irrigation for Crop Production

Junaid Nawaz Chauhdary [1,2,*], Hong Li [1,*], Yue Jiang [1], Xuwei Pan [1], Zawar Hussain [1], Maria Javaid [1] and Muhammad Rizwan [3]

1 Research Center of Fluid Machinery Engineering and Technology, Jiangsu University, Zhenjiang 212013, China; jy261715267@126.com (Y.J.); panxuwei2018@163.com (X.P.); zawar.hussain@bzu.edu.pk (Z.H.); maria_9248@yahoo.com (M.J.)
2 Water Management Research Centre, University of Agriculture, Faisalabad 38000, Pakistan
3 Department of Civil Engineering, Swedish College of Engineering and Technology, Rahim Yar Khan 64200, Pakistan; rizwan514@lzb.ac.cn
* Correspondence: junaid.nawaz@ujs.edu.cn (J.N.C.); hli@ujs.edu.cn (H.L.)

Abstract: The non-judicious use of water at the farm level in traditional irrigation application methods is a present-day concern across the world that can be resolved by enhancing application efficiency through the adoption of advanced irrigation techniques. Sprinkler irrigation is a method that has high application efficiency, which can be further increased when coupled with automation toward precision irrigation. The objectives of this review are to summarize the main aspects of sprinkler and precision irrigation and their development, scope, and future prospects specifically in Asian countries. In this paper, a modified methodology, inspired by PRISMA guidelines, was used to explore the available literature to summarize the existing knowledge in the field. Regarding the technological aspects of the analyzed works, it became evident that sprinkler systems are an efficient method to not only irrigate crops (with 39% water saving) but also for the application of fertilizers with higher efficiency (>35%) and water productivity (>14.1%) compared with gravity irrigation systems. Moreover, this paper highlights the prominent features of precision irrigation for maximizing agricultural productivity. The use of sprinkler irrigation with precision applications using automation with a sensor-based mechanism for field data collection, data transformation, data analysis, and operation of IoT-based automatic solenoid valves can save 20–30% more irrigation water and increase crop yield by 20–27%. An analytical understanding and knowledge of the field were used to draw conclusions that are thought-provoking for scientists, researchers, and other stakeholders.

Keywords: application efficiency; sprinkler types; sprinkler nozzles; irrigation automation; variable rate irrigation

Citation: Chauhdary, J.N.; Li, H.; Jiang, Y.; Pan, X.; Hussain, Z.; Javaid, M.; Rizwan, M. Advances in Sprinkler Irrigation: A Review in the Context of Precision Irrigation for Crop Production. *Agronomy* **2024**, *14*, 47. https://doi.org/10.3390/agronomy14010047

Academic Editor: Maria do Rosário Cameira

Received: 28 November 2023
Revised: 16 December 2023
Accepted: 18 December 2023
Published: 23 December 2023

1. Introduction

The Green Revolution has pushed many countries with agriculture-based economies to introduce reforms, resulting in rapid agricultural growth. The world's agricultural growth can be assessed from the fact that only in China has total grain production reached 117% with a 2% annual increase [1]. The agriculture-based gross domestic product (GDP) is growing at a rate of 9.4% [2] worldwide. There are still opportunities to double agricultural productivity by adopting mechanized practices that enhance crop yields as well as crop intensity [3]. The prime input for agricultural production is water, which is even more important in irrigated agriculture and plays a vital role in food security. Irrigated agriculture represents one-fifth of agricultural land and about half of the production is being cultivated directly from irrigated agriculture, screening its potential for crop production with more diversification and intensification [4]. According to a study [5], 80% of cereal crops and 90% of vegetable crops are being grown under irrigated agriculture; therefore, this sector is being expanded in many countries through the introduction of essential and mechanized irrigation practices. This development of irrigated areas can be assessed from the growth of irrigated land in China (Figure 1) due to it being one of the world's leading agricultural economies [1].

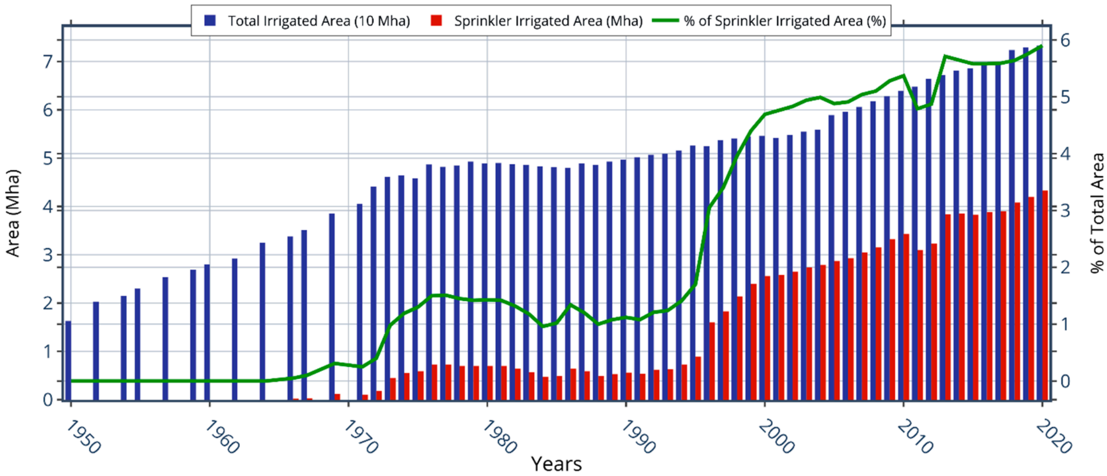

Figure 1. Development of irrigated areas in China (1950–2020) [6,7].

Growth in irrigated land demands more irrigation water and triggers the issue of water security. Being a major consumer, the world's agriculture sector uses more than 70% of available freshwater [8]. The per capita water availability is decreasing all over the world and it has been projected that by 2050, 45 countries will be water scared (<500 m^3/capita/annum) and 87 will be at the margin (<1700 m^3/capita/annum) out of 180 countries [9], indicating increasing pressure on available water resources for the production of food to feed growing populations [10]. The provision of surface water resources to highly irrigated areas and the effective management of available resources are the only methods to sustain development in the agriculture sector to ensure the world's food security with environmental sustainability [5]. This problem can be mitigated from two sides. One side is the enhancement of water availability by building storage infrastructures and the other side is the efficient use of water at the farm level [11–13]. In this respect, several projects in the 1990s were launched throughout the world to introduce water-efficient techniques for improving application efficiencies of traditional irrigation practices [14]. Under traditional irrigation systems, water is applied at constant intervals without considering the crop water requirements and the application efficiencies of these methods are also low as varying amounts of water are applied throughout the field. This uneven irrigation could over-irrigate a portion of the land while the other portion may experience water stress due to less irrigation [15–17]. Sprinkler irrigation is a type of high-efficiency irrigation system that has been used at the farm level since the late 1970s. This technology has proven its capability to save significant amounts of irrigation water with greater uniformity compared with other surface irrigation methods (basin, border, beds, furrow, etc.) [18,19] in addition to improvement in yield and fertilizer management with less leaching effects [20]. The proven facts regarding the benefits of sprinkler irrigation have encouraged farmer communities to use this method as an alternate system to overcome the problem of low application efficiency at the farm level.

This technology has become very popular in Western countries, mainly in the USA and Europe with areas of 3 Mha and 2.5 Mha, respectively, under sprinkler irrigation until the 1970s [21]. Many countries like Australia, Israel, China, etc., have developed and adopted different types of sprinkler irrigation systems and these are very popular in these countries. The adoption rate of sprinkler irrigation has been reported as 4.78% [22]. In China, the government is promoting the sprinkler irrigation system by launching demonstration projects at farmer fields, providing funds to research institutions to carry out research work, and launching subsidies for industries to manufacture sprinkler components at the indigenous level. The effectiveness of these exertions is demonstrated by the fact (Figure 1) that sprinkler irrigation is being adopted by farmers at a high rate and is replacing other irrigation practices at their farms.

The water and fertilizer efficiency of sprinkler irrigation could be further enhanced by introducing advanced interventions like precision irrigation practices within the regular operation of manually operated sprinkler irrigation systems. The precision irrigation system is a combination of an irrigation system coupled with a control system, communication system, and information system for water applications in a precise and automatic way to achieve the highest possible crop water productivity [23,24]. It has been reported that by adopting sprinkler irrigation with precision application tools, maximum economic benefits can be driven [25,26]. To understand the effectiveness and applicability of precision irrigation for absolute water management at the farm level, previous research needs to be reviewed in a meaningful way to identify the research trends and hot spot directions for future research work within the subject field.

The present review paper is an effort to examine the available literature related to sprinkler irrigation and precision irrigation using quantitative analysis in a systematic way. A careful identification of key influential factors affecting the development of sprinkler irrigation toward precision application methods was carried out to draw conclusions and thereby provide a state-of-the-art understanding of the topic to readers. The purpose of this work is to describe the insights of the research topic, understand the ambiguities and research gaps within the scope, and draw consistencies between prior research work and future research directions for researchers.

2. Review Strategy and Exploration of Literature

The spatial and temporal growth of research databases on a massive scale created a momentum toward summarizing research findings in an organized manner, leading to the development of new, systematic approaches to literature review since the start of the 21st century [27–29]. A huge number of scholarly literatures on the use of sprinklers and precision irrigation in the disciplines of agriculture and engineering is available; therefore, systematically productive approaches were taken into account to assess the advanced knowledge on said subjects.

To start the review process, the domain of this paper was divided into two major portions called sub-domains. These included (1) "sprinkler irrigation" and (2) "precision irrigation". Other topics related to "irrigation water management" were taken in the study as a miscellaneous domain. The development in the research volume regarding these domains and published review papers can be seen in Figure 2, presents the volume of literature available only in one database (PubMed). This gradual growth in particular research work demands the summarization of research outcomes of different researchers to set future research directions in the subject field.

The methodology adopted in the present study is inspired by the PRISMA 2020 guidelines [30]. A new strategy was designed by intergrading the PRISMA 2020 guidelines and the review approaches used by other researchers [31–33]. The literature related to each sub-domain was searched according to four approaches, illustrated in Figure 3. These approaches involved searching research papers based on manuscript titles, the keywords, the institution affiliation, and the citations of published articles. To achieve a speedy review, all searches were conducted using online scholar databases including Google Scholar, IEEE Xplore, Wiley, Science Direct, Springer, MDPI, Taylor & Francis, and journal websites. In these huge scholarly libraries, numerous research articles are available related to sprinkler irrigation and precision irrigation; therefore, a sturdy criterion was developed and adopted for the selection of the most influential research findings to eliminate unsuitable search results.

2.1. Inclusion/Exclusion Criteria

A comprehensive criteria to include or exclude literature for review proceedings was adopted. The inclusion criteria included (1) research published in prestigious journals,

(2) research published in English and Chinese language, (3) research findings based on actual field studies, (4) publications having proper citations and available on the internet, (5) publications having relevant data for onward calculations of different quantitative parameters, (6) priority was given to journal publications, and (7) the date of publication was after 2005. Similarly, the exclusion criteria included (1) review articles, (2) research publications with duplicate or similar results, (3) publications containing possible errors in the data, and (4) a publication date older than 2005. The process of obtaining the final search results is illustrated in Figure 4.

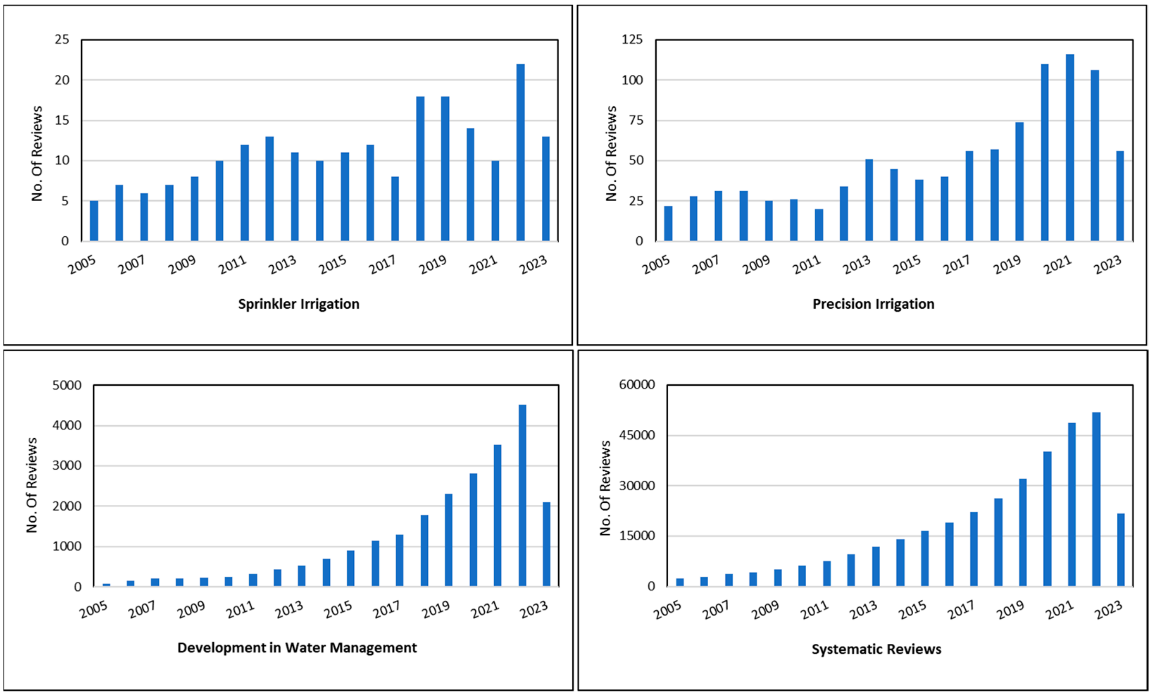

Figure 2. The production of research publications related to specific topics from January 2005 to May 2023.

Figure 3. Illustration of the mechanism through which information on the sub-domains of this paper was summarized and extracted.

2.2. Summary of the Review Process

The information was reviewed from renowned research databases and journal websites. The reviewed publications were dated from 2005 to the present but, of course, preference was given to recent publications. Figure 5 presents a summary of the review process. In Figure 5a, the year-wise number of reviewed papers is presented. It can clearly be seen that the majority of papers were selected between 2012 and the present with a peak in 2022. In Figure 5b, the illustration of major review domains is shown. Most of the papers were reviewed related to sprinkler irrigation followed by precision irrigation. The papers related to all other topics are shown as other papers in Figure 5. In Figure 5c, the application of inclusion/exclusion criteria is given by illustrating the percentage of included papers, which was 85% of the total reviewed papers. The remaining 15% of papers were not included in this study because their results were found to be repeated with similar input conditions.

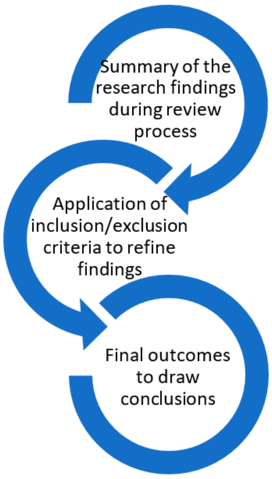

Figure 4. Illustration of the process regarding the improvement in the review summary using inclusion/exclusion criteria.

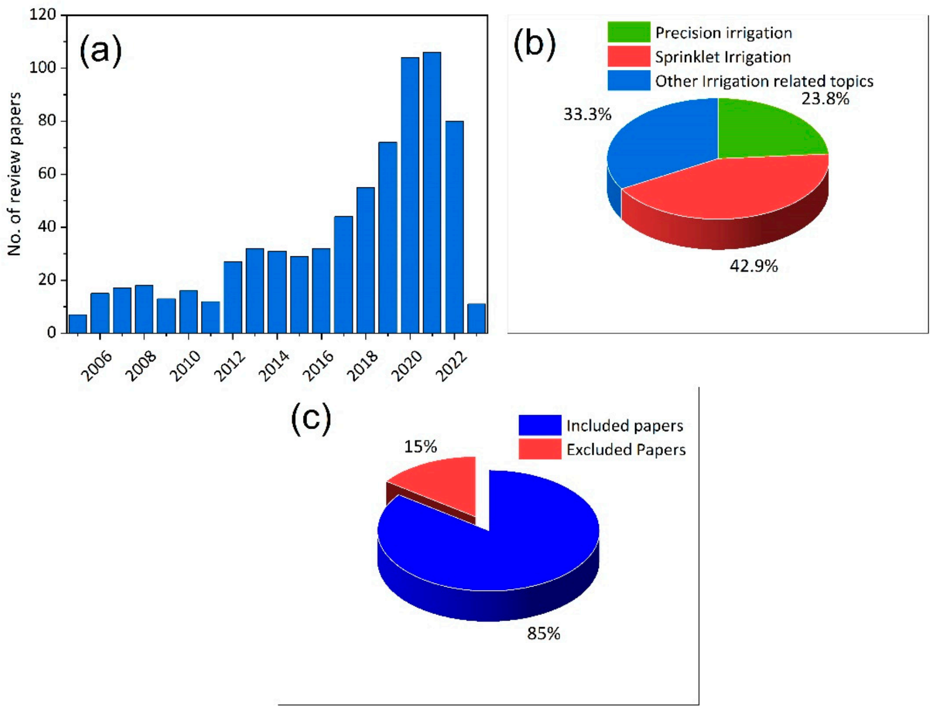

Figure 5. Summary of (**a**) no. of review papers, (**b**) subject-wise reviews, and (**c**) included and excluded papers.

3. Sprinkler Irrigation

Sprinkler irrigation is a type of pressurized irrigation that irrigates crops by spraying water in the form of small droplets like natural rainfall. It has numerous advantages over surface irrigation or even over other pressurized irrigation technologies like drip irrigation as it can not only apply water to a crop but also flush its leaves and regulate canopy temperature to improve the efficiency of the photosynthesis process. Many research studies have been conducted on sprinkler irrigation that proved its viability and adoptability for economically higher crop production [34–37]. These systems have some limitations and disadvantages over other pressurized irrigation systems. These disadvantages include higher capital and operational costs, damage to soft fruit plants, low application efficiency in windy areas, and unsuitability for fields with fine textured soil [38]. Under humid conditions, moisture-related diseases may emerge within the crop canopy due to the presence of excessive moisture after the application of overhead sprinklers [39]. Romero et al. [40] reported the outbreak of fungal-related diseases within crop plants grown under humid and warm conditions. Belo et al. [41] reported management techniques including irrigation time and frequencies to reduce the risks of spreading bacterial-related diseases due to heavy moisture and dirt being splashed into the plant canopy of onion plants. But on the other hand, foliar water application by using an overhead sprinkler is beneficial for plants and good for protecting plants against frost when the temperature is at or below zero °C [42]. Despite these minimal limitations, sprinkler irrigation has marvelous advantages with high water application efficiency in the field [43]. The field application efficiency of different irrigation systems in comparison with different sprinkler types is illustrated in Figure 6.

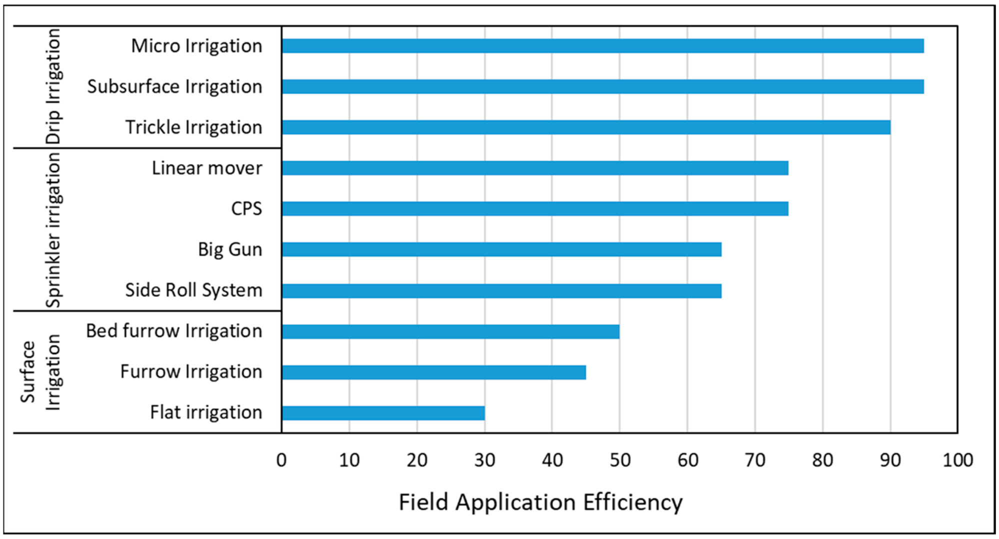

Figure 6. Application efficiencies of different types of sprinkler systems.

3.1. Types of Sprinkler Systems

In the early usage of sprinkler systems, single-point sprinklers were used with moveable positions, and the water was supplied to sprinklers through iron pipes [7]. The iron pipes were susceptible to erosion and heavy when moving sprinklers from one place to another. Iron pipes were replaced with aluminum pipes in the first phase and then with plastic/PVC pipes along with plentiful progress in the design of irrigation systems in the late 1990s [44]. By increasing the understanding of sprinkler systems, moveable machines were developed with sprinkler nozzles that can be transported throughout the field to irrigate entire areas with the same sprinkler setup. This kind of sprinkler system has high application efficiencies and more irrigation coverage with less labor requirements. This form of sprinkler system has many types and is adopted as per field conditions due to specific limitations associated with each type. The features and distribution uniformities (DUs) of different sprinkler systems were obtained from the literature [43,45] and are shown in

Table 1. Generally, Equation (1) is used to calculate the DU of a sprinkler irrigation system. The DU range of each sprinkler type is provided in Table 1. The DU depends on the crop type, field condition, and environmental exposure of a sprinkler system. The maximum DU value belongs to lab experiments and the minimum value belongs to field conditions.

$$Distribution\ uniformity\ (DU) = \frac{Average\ lowest\ quater\ depth\ of\ water\ received}{Average\ depth\ of\ water\ received} \quad (1)$$

Table 1. Features of different types of sprinkler systems [43].

Type of Sprinkler	Description	System Distribution Uniformity
Linear Mover	Use in rectangular fields; less evaporation losses	Up to 70–80%
Center Pivot System	Use mostly in circular and big fields; comparatively good application efficiency; require less pressure than rain guns	Up to 70–80%
Side Roll System	Use mostly in rectangular fields in plain areas; good application efficiency	Up to 60–70%
Big Gun	Use mostly in irregularly fields; suitable for high-intake-rate soils	Up to 55–65%
Hand Move	Use in irregularly shaped hills and rolling terrains; labor-intensive and less efficient	Up to 50–65%

The center pivot system has many advantages over other types; therefore, this type of system has been installed in more than 13% of the area under sprinkler irrigation in China [46]. Researchers are working on a center pivot system to increase its efficiencies via a nozzle configuration corresponding to the particular movement speed [47,48]. Ma et al. studied the uniformity and the application efficacies of a two-span center pivot system and reported a 66.1–68.4% uniformity coefficient [49]. Several other researchers worked on other types of moveable sprinklers and conducted performance tests to determine their suitability and to improve the characteristics of existing systems [50–53]. Hand-mover gravity sprinklers are mostly used in hilly areas where sufficient gravitational head is available to operate sprinklers without irrigation pumps [54].

3.2. Sprinkler Nozzle

Sprinkler nozzles are key components in the whole sprinkler system and their uniform operation determines the efficiency of the system. The study of sprinkler nozzles was limited before the 1970s; however, the topics gradually received attention due to the increasing demand for sprinkler systems. In the late 1970s, work on designing impact sprinklers was started by an industrial group, and a series of sprinkler nozzles were designed with varying diameters (20 mm to 80 mm inner diameter). The Chinese government put a special effort into the development of new sprinkler nozzles by reverse engineering imported sophisticated nozzles and promoting research and development in the same area [50,55]. Currently, researchers and enterprises have been working on the development of new products and refining the hydraulic performance of existing sprinklers with structural improvements. Low-pressure sprinklers are an example of the improvement in the design of existing sprinklers. The research and development (R&D) work by researchers on sprinkler characteristics is presented in Table 2.

3.3. Low-Pressure Sprinklers

The increase in energy demand and its high cost are forcing researchers to introduce new developments in the existing irrigation technologies so that these systems could still be used as a viable source in the new era. Normal sprinkler irrigation is operated at a high pressure of around ($\geq$300 KPa), causing more energy consumption [56]. The low-pressure sprinkler is a new addition to the existing technology, enabling users to operate sprinklers at <200 KPa and subsequently lowering operating costs with different management strategies [56–58]. The key principle of designing a low-pressure sprinkler is to change the internal nozzle structure to reduce the operating pressure without compromising the dispersion uniformity of water droplets.

Table 2. Research work on sprinkler nozzles by researchers.

Researcher	Study	Reference
Li et al.	The optimum structural sizes of the diffusers for different sprinkler nozzles were brought forward using the shortest performance radius R and the affected area angle α to enhance the overall hydraulic performance.	[59]
Wang et al.	Modified the main and secondary nozzle structures of the impact sprinkler (8034D) to improve sprinkler flow rate, radial water distribution, and the uniformity coefficient of combined sprinkler irrigation.	[60]
Tang et al.	The multiple regression models were used to optimize the indices via single and multi-objective optimization on the adjustable parameters for improvement in the design of vertical impact sprinklers.	[61]
Wang et al.	Combined flow simulations in the field with experimental validation to optimize the elevation angle and its position in the impact sprinkler system, which is a major structural parameter to enhance the hydraulic performance of the sprinkler.	[62]
Chen et al.	Evaluated the characteristics of asymmetric and circular-shaped sprinkler nozzles at varying operating conditions and reported the flow rate of both types of sprinklers under the same working conditions.	[63]
Wang et al.	Studied the Nelson R33 nozzle regarding droplet diameter and its velocity using a two-dimensional video disdrometer (2DVD) and found an exponential correlation range between water droplets and the volume-weighted particle size distribution.	[64]
Chen et al.	Studied water droplet characteristics in the rotating sprinkler and reported an increase in the diameter of droplets with an increase in radial distance.	[65]
Liu et al.	Conducted a study on the characteristics of the complete fluidic sprinkler (CFS) system and reported similar results showing that the drop diameter increases with an increase in radial distance and nozzle size.	[66]
Sayyadi et al.	Studied the droplet characteristics of fixed spray plate sprinklers using a low-speed digital photography method and reported an increase in wetted diameter, droplet size, application rate, and droplet velocity with an increase in nozzle size.	[67]
Li et al.	Developed a mathematical model to calculate droplet dynamics and accordingly proposed a method for model input data collection.	[47]
King and Bjorneberg	Evaluated various approaches to characterize the kinetic energy transferred to soil from sprinkler droplets.	[68]
Dwomoh et al.	Reported a 10–25% reduction in the wetted area by increasing wind speed up to 3 m/s	[69]

Li et al. designed a low-pressure rotary sprinkler with different dimensions of scatters and evaluated its performance; the authors reported satisfactory results regarding all selected performance parameters [47]. Other researchers improved the jet dispersion in low-pressure sprinklers by introducing a pair of aerated pipes inside the sprinkler nozzle [70]. The optimal groove numbers were identified during a series of experiments using D3000 range sprinklers after changing their plate structure [71]. Wang et al. [72] derived empirical equations for low-pressure sprinklers for operation under varying operating conditions and design parameters [73]. Ouazaa et al. derived a calculation model for cunnings of water distribution using low-pressure sprinklers [74]. Besides the changes in sprinkler design, researchers improved the field performance of sprinkler irrigation systems by optimizing the pipeline structure to reduce energy loss in order to promote the use of low-pressure sprinklers [75]. Tsaboula et al. studied the effects of different wind speeds on water spray through low-pressure sprinklers [76].

3.4. Sprinkler Irrigation Use for Crop Production

The use of sprinkler irrigation is not only for water saving but also to improve crop yield and reduce crop production costs by limiting crop inputs. Sprinkler irrigation has many advantages over other pressurized irrigation methods (drip irrigation) including rain characteristics and delivery of higher amounts of water during irrigation in time units. Sprinkler irrigation systems can be effective in large areas with less costly installation costs. The regular operation, maintenance, and operational troubleshooting of sprinkler irrigation systems are easier than drip irrigation. The benefits of sprinkler systems over other irrigation systems have been reported by many researchers [77–82]. Sprinkler irrigation can be applied to a variety of crops, soils, and field conditions compared with other systems. These are efficient for keeping crops well flourished and maximizing yield; therefore, about 6% of irrigated area in China has been covered with sprinkler irrigation [7]. Some prolific findings regarding better crop production under sprinkler irrigation are given in Table 3.

Table 3. The benefits of the use of sprinkler irrigation for crop production.

Sr.#	Research Findings	Reference
1	Conducted a modeling study in China to compare the response of wheat, maize, and sunflower grown under sprinkler irrigation compared with flood irrigation on regionals level and reported 16.9%, 8.0%, and 11.4% better yield and 7.9%, 5.0%, and 14.1% better water productivity.	[34]
2	Studied the response of wheat to different water regimes under sprinkler irrigation in north China plain and reported that the highest crop yield, yield parameters, and water productivity were obtained under 0.63% of ETo.	[35]
3	Compared different arrangements of sprinkler and drip irrigation for yield and water productivity of sunflower in the Mediterranean region and revealed that the use of sprinkler irrigation in semi-arid conditions had the highest crop net return compared with the use of partial root drying in drip irrigation.	[36]
4	Compared different irrigation methods for rice sown under transplanted rice (TSR) and direct seeded rice (DSR). The results showed significantly higher water application efficiency and better crop yield under sprinkler irrigation compared with traditional flood irrigation.	[37]
5	Reported 35% water saving and 18% more rice crop under sprinkler irrigation compared with flooded irrigation.	[83]
6	Compared the applications of freshwater and treated wastewater through sprinkler and flood irrigation methods and reported the highest crop water productivity under sprinkler irrigation with fresh water.	[84]
7	Compared efficiencies of micro-sprinklers at different operating pressures and reported 61%, 54%, and 60.7% efficiencies at 2 kg/cm^2, 3 kg/cm^2, and 4 kg/cm^2, respectively, for onion production.	[85]
8	Reported 18.44% water saving under sprinkler irrigation compared with the traditional method of watering carrot crops using furrow irrigation.	[86]
9	Compared field application efficiency (AE) of surface irrigation, sprinkler irrigation, and drip irrigation and reported 60% AE under surface irrigation, 75% AE under sprinkler irrigation, and 95% AE under subsurface drip irrigation.	[87]
10	Recommended sprinkler irrigation in combination with the applications of biochar to increase crop and water productivity of rice in water-stressed regions.	[88]

To obtain better crop response under a sprinkler system, the fertilizer must be applied with water for the highest crop productivity. The overall fertilizer use efficiency has been reported at only 30% [89], which can be improved by its application using sprinkler irrigation systems. The injection of fertilizer via sprinkler irrigation is only possible with the use of injection devices. Different injection devices and application methods have been reported according to specific operating or field conditions [41,90–92].

Irrigation water and fertilizer could be further saved using variable rate technology (VRT), which means specific water application on a particular portion of the field [93]. The first VRT system was introduced in Asia in 2014 [94] followed by continuous research work on modifications of VRT systems. One researcher attuned the variable spray of the sprinkler nozzle by changing the operating pressure, flow rate, and internal structure [95], while another researcher invented the variable spray mechanism of CPS using infrared thermography [96]. A GPS-based operating system was developed by a group of scientists, which can apply fertilizer at variable rates by changing the duty cycle and pivoting the operating speed [54]. In present times, VRT machines are capable of applying water and fertilizers as per the soil conditions and plant needs [97].

3.5. Sprinkler Design for Better Microclimate and Associated Field Losses

Sprinkler systems revolutionized farm irrigation methods with marvelous advantages. The efficiency of these systems is associated with the design of pumping systems, delivery pipes, and sprinkler devices according to the crops, weather, and field conditions [98]. The optimum design and selection of sprinkler components can be helpful in installing a system with economical cost and better performance for crop growing. Several techniques for designing sprinkler systems are available including graphical, analytical, and simulation techniques [99]. Bing et al. introduced the genetic algorithm (GA) technique for the design of an efficient irrigation system based on simulation research work [100]. Other researchers reported the use of binary coding genetic algorithms (BCGAs) for optimum water applications to different crops [101]; general genetic algorithms (GGAs) for irrigation scheduling, rotation, and its distribution [102]; and the use of single parent genetic algorithms (SPGAs) for space–time canal discharge distribution for irrigation rotation [103]. Liu et al. incorporated the weighting method (digital) using the MATLAB (R2013b) toolbox to analyze the distribution pattern of droplet size and identified the variation trends in distribution frequency under changing pressure at varying radial distances from sprinkler nozzles [104]. Based on the single-sprinkler installation approach, a line source sprinkler system with optimized design parameters was established using the analytical approach at Ferdowsi University [105]. These developed techniques are for the design of sprinkler systems for successful field operation with the ability to save significant amounts of irrigation water and create favorable conditions for crops by modifying field microclimate.

Controlling field microclimate is an advantage that is associated with sprinkler irrigation for controlling the factors of high temperature and low humidity [106]. Hot wind drifts can cause an average of 5–10% yield loss that could be up to 20–30% under severe climate conditions. Similar results have also been reported by other researchers regarding abnormal crop growth and the reduction in final biomass [107,108]. Liu et al. conducted long-term scenario studies on sprinkler systems for winter wheat and reported a reduction in ambient crop temperature, low vapor pressure, and less transpiration [109]. The advantage of sprinkler applications also included improvement in photosynthesis and low respiration rates [110,111]. Moreover, the positive impact of water spray on the temperature of the soil's upper layer and the canopy temperature has been proven in other research works [112]. Cai et al. conducted a study on optimizing CPS to regulate field microclimate and reported improvement in the peak splits of temperature difference and photosynthesis rate [113]. Besides these optimistic impacts, there are some undesirable losses associated with sprinkler irrigation in terms of wind drift and evaporation.

A small portion of the discharging water from sprinkler nozzles in the form of thin drops does not reach the crop canopy and evaporates in the air during its transfer, which is called wind drift or evaporation losses in sprinklers [114–116]. The researchers' findings provide evidence that the scale of wind drift depends on wind speed and weather conditions [117,118] and it varies from 3.6 to 7.2% [119]. Colombo et al. reported 3.38% losses of wind drift under the regular operation of CPS [120]. The variation in wind drift was examined by Playan et al. in a number of experiments (52 in 2004 and 39 in 2005) and reported the range of the magnitude of losses as 4.3–14.7 in 2004 and 0.3–8.3% in 2005 [121]. The wind drift losses in cold cum semi-arid climates were reported as 3.3–13.7% [122] and the same for Mediterranean regions as 5.8–36.4% [123]. Yazar revealed the average wind drift losses for various operating conditions and types of systems as 1.7–30.7% [124]. These losses should be controlled otherwise these can cause water and energy loss as well as a reduction in crop yield and poor quality [125], which eventually increases production costs and decreases net income. Mole reported that 30–50% of total wind drift losses are due to direct evaporation from the air and the remaining part is due to the wind drifting [126]. The wind drift losses could be minimized by optimizing the operating pressure, speed of the vehicle, and sprinkler type. It was reported that the 1-Wob sprinkler has better efficiency and causes less drift losses [127]. Sandeghai et al. developed a multiple linear regression model to predict wind drift losses for various weather conditions under varying operating conditions [116]. Using the model, the worker can set the operating conditions as per the weather situation so that the wind drift losses can be minimized. By using the guidelines developed by different researchers [128–130], drift losses can be controlled to improve the application efficiency of sprinkler systems.

4. Precision Irrigation Using Sprinklers

Sprinkler irrigation systems can apply water and fertilizer precisely but manually operated sprinkler systems involve labor for their operation; moreover, it is difficult to apply irrigation as per the real-time crop water requirement, whereas precision irrigation is the latest water-saving technique for maximizing yield and providing water at a desired location based on actual crop water demand [15,131–137]. The potential of water saving with precision irrigation through sprinkler systems has been reported as 30% compared with conventional sprinkler systems [138]. The concept of precision irrigation is based on the temporal and spatial variation in the application rate of irrigation systems based on real-time crop water requirements [25,26]. The entire field or application area is tackled as small parts or zones having the same water requirement at a particular time. Then, irrigation is applied in every zone in the desired quantity using a smart application mechanism attached to an irrigation system. Precision irrigation keeps every part of the field at optimum moisture level for proper plant growth in a uniform way [139], which improves its productivity, yield quality, and water use efficiency [140]. Researchers studied water application via sprinklers using the principles of precision irrigation and reported marvelous results regarding efficient water applications [2,132,141–146]. Precision irrigation involves (1) variable applications of irrigation water in space and time, regulated by the real-time monitoring of irrigation-related parameters in the field using sensors or other tools, (2) analyzing the data to develop irrigation schedules, and (3) feedback and operating mechanisms to control the irrigation machine using GPS to fulfill actual crop water requirements in every section of the field separately. To implement a precision irrigation system, advanced sensing, analyzing (simulating), and control technologies are adopted to achieve its best performance. This understanding of precision irrigation is also expressed as variable rate irrigation.

Typical precision irrigation has been drawn by getting inspiration from the literature [147] and is shown in Figure 7. A precision system includes a mechanism for field data collection, data transformation to the control center/device, data analysis, and calibrated operation of IoT-based automatic solenoid valves to operate the irrigation system. Under precision applications, irrigation is applied frequently for short durations just to maintain the field water balance of a cropping system at every part of the field. Prior to the application of precision irrigation, the actual water requirement is calculated, and the operating time or intensities are designed for the onward operation of sprinkler vehicles. These calculations are referred to as irrigation scheduling.

4.1. Field Parameters Used for Irrigation Scheduling for Precision Irrigation

The monitoring of field conditions is crucial for implementing precision irrigation for food production with minimum water usage. Monitoring of field conditions refers to the data collection regarding irrigation-related parameters that are capable of stating the real-time water balance of the crop system so that the desired water can be applied. Some basic parameters that are related to irrigation scheduling are categorized [17,148] into three classes or groups. Any of these parameters or the sum of some parameters could be adopted to determine irrigation scheduling under precision irrigation. The first group is associated with soil parameters including soil moisture, soil salinity, soil water absorption capacity, soil pH, etc. The second group is associated with plant parameters including leaf area index (LAI), normalized difference vegetation index (NDVI), stomatal conductance, evapotranspiration, leaf turgor pressure, crop water stress index, etc. Plant-related parameters for irrigation scheduling are relatively difficult to monitor but these parameters exhibit the most realistic picture of plant water balance and present the plant growth expected to be affected by droughts and nutrient deficiencies [149]. The third group contained climatic parameters including ambient temperature, humidity, wind speed, solar radiation, precipitation, atmospheric pressure, etc. These climatic parameters are put in the world-renowned "Penman–Monteith evapotranspiration model" for calculating actual evapotranspiration using crop coefficients for the development of irrigation schedules [150].

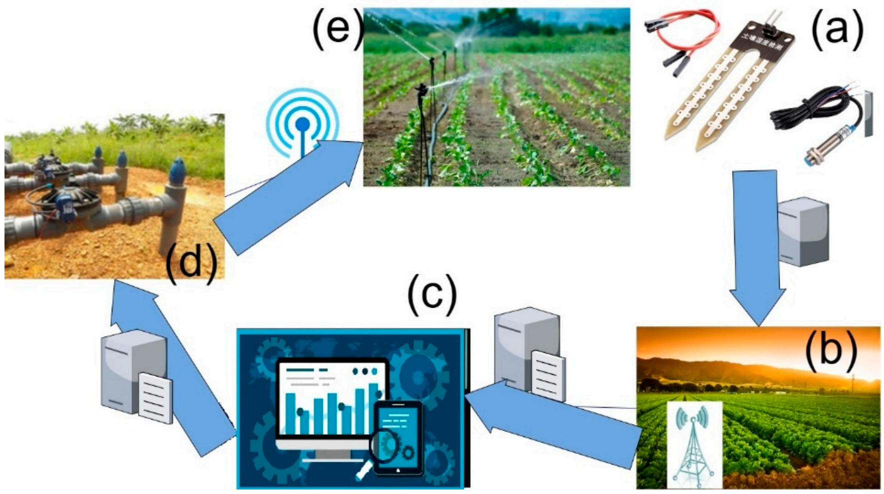

Figure 7. Overview of typical precision irrigation mechanism: (**a**) sensors for data collection from the field; (**b**) data transformation mechanism and transmitters; (**c**) data receiver and data analyzer for data calibration and to generate a command for the irrigation system; (**d**) remotely operated solenoid valves to operate the irrigation system as per commands generated by the data analyzer; and (**e**) the sprinkler irrigation system.

A summary of the literature review regarding the use of different parameters for precision irrigation has been taken from the literature [32] and illustrated in Figure 8 after modifications and improvements. The parameters are shown as per previously defined groups (crop parameters, soil parameters, and climatic parameters).

4.2. Data Collection Regarding Irrigation Scheduling for Precision Irrigation

Precision irrigation requires the accurate measurement of field data related to the above-described parameters to implement its full scope in order to obtain maximum advantages. There are several ways to collect field data including the following:

- Manual monitoring using smart tools;
- Use of sensors (sensors for soil, plant, and climate parameters);
- Use of satellite data;
- Use of UAV for data collection.

4.2.1. Manual Monitoring Using Smart Tools

The accuracy of monitoring field parameters is crucial to implementing precision irrigation in a true sense. The continuous and uninterrupted monitoring of irrigation-related parameters at different points at desired intervals can be conducted manually using smart sensing tools or devices. The biases in data collection by humans have been reported but the data regarding some specific plant or soil-related parameters could still be collected manually by following standard protocols [175]. This method of data collection is convenient and easy to follow but it is very low in efficiency.

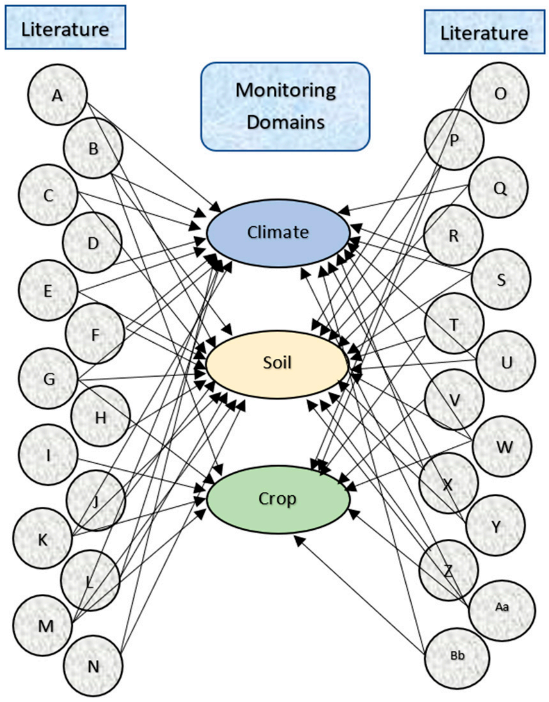

Figure 8. Illustration of the literature showing the domains of monitoring parameters for precision irrigation. A: [151]; B: [152]; C: [153]; D: [154]; E: [155]; F: [156]; G: [150]; H: [157]; I: [149]; J: [158]; K: [159]; L: [160]; M: [161]; N: [162]; O: [163]; P: [164]; Q: [165]; R: [166]; S: [167]; T: [168]; U: [169]; V: [170]; W: [143]; X: [171]; Y: [172]; Z: [173]; Aa: [174]; and Bb: [141].

4.2.2. Use of Sensors

Plant growth is highly dependent on the moisture level in the rhizosphere and frequent monitoring of moisture levels needs to be carried out for accurate irrigation scheduling. Accurate data collection regarding soil moisture on high temporal grounds is the only option for irrigation scheduling in a precise way [169,172,176]. Different kinds of sensors are available in the market and are being used for such purposes. One type is capacitance-based sensors, which are relatively low cost and can measure the moisture level with adequate reliability after efficacious calibration of the sensor with measured field data [177]. A more sophisticated device to monitor soil moisture is TDR (time domain reflectometry), which contains two electrodes. These electrodes are inserted in the soil column up to the desired depth and, afterward, an electric signal is generated from one electrode to another to assess the soil moisture by estimating travel time and soil conductance characteristics. The accuracy of TDR is high, but it is expensive to install in large numbers in open fields for monitoring soil moisture at different field spots. Bitella introduced the methodology to measure soil moisture at different depths at the same time using low-cost dielectric probes [131] while other researchers used IoT-based field monitoring devices for moisture measurements [162]. Huuskonen and Oksanen used drone cameras for remote measurement of soil moisture in upper soil layers [160]. Besides soil parameters, the use of climate parameters for irrigation scheduling has the highest ranking due to their extensive use among all contenders [143,149,162,166,178–180]. Permanent weather stations or weather monitoring devices can be installed in the field to collect real-time climate data. The sensors to monitor plant or soil-related parameters can be installed on the moveable platform of an irrigation system like CPS for real-time monitoring during the irrigation cycle [181]. In addition to the moisture, soil and plant nutrients could also be monitored using soil nutrient detectors connected parallel to moisture sensors [182]. Joly developed a silicon chip for site-specific monitoring of soil nutrients [183].

4.2.3. Application of Remote Sensing for Data Collection

Satellite remote sensing is an excellent and reliable option to collect data on soil and plant-related parameters for irrigation under various environmental conditions throughout the world. The satellites can read ground data using different spectral bands and are capable of differentiating water-stressed crop areas and analyzing crop water needs at high spatial and temporal frequencies [184]. Many commercial satellites like MODIS, Landsat, SPOT, etc., offer crop and soil moisture status at high temporal frequency [185]. Several researchers used open-source satellite data related to crop evapotranspiration, soil moisture, plant water stress, NDVI, etc., for the implementation of precision irrigation using sprinkler irrigation systems [186,187]. Reyes [188] used a satellite-based vegetation index to estimate actual crop water requirements for the design of irrigation scheduling for precise water applications in the field. Ramirez [189] used a GIS-based toolbox to explore satellite data for the assessment of soil moisture to determine crop water requirements. The 10–20% more water saving achieved by using integrated precision cum pressurized irrigation systems has been reported by many researchers who used satellite data for irrigation scheduling of various crops grown under varying field conditions [190,191].

4.2.4. Use of UAV for Data Collection

UAVs (unmanned aerial vehicles) or “drones” are aircraft with no human pilots. The size of a UAV varies from small to large, depending upon the function that it can perform. UAVs are quick, affordable, and reliable alternatives to satellite data if the application area is small (local scale). Depending on the sensors carried by a UAV, various crop- and soil-based parameters for irrigation scheduling could be collected and monitored in real time at high spatial frequency. Various researchers used UAVs for the determination of crop water requirements [192], soil moisture [193], and plant water stress [194] for the implementation of precision irrigation, and satisfactory results were reported.

4.3. Techniques for Data Analysis and Management of Sprinkler Systems for Precision Irrigation

The collected data were analyzed using several sophisticated techniques including modeling tools and multidimensional simulating software (DSSAT(v4.6), MATLAB(R2011b), APSIM (7.1), R(2.4.1.2) etc.) to predict spatially and temporally varied crop water requirements for developing irrigation maps for onward applications of precision irrigation. Mechanized techniques are essential in precision irrigation to manage sprinkler systems for efficient water applications using developed irrigation maps with less energy input and higher crop yield. The mechanized techniques belong to two big categories called open loop technique (OLT) and closed loop technique (CLT). In OLT, irrigation is controlled by a pre-set program designed for a particular field using input data regarding irrigation parameters [195]. The OLT is easier to follow and cheaper in cost; therefore, farmers prefer to adopt these techniques for implementing precision irrigation [196]. Farmers can set operating conditions (pre-timers, speed, and application rate) for any sprinkler system, which can be monitored during the entire operation of the irrigation machine. Many researchers reported the use of OLT by farmers for precision irrigation in their fields [197–199].

The CLT is relatively difficult to implement but is more accurately related to the true spirit of precision irrigation using sprinkler irrigation systems with 20–30% more efficiency [200–202]. Progressive farmers use such techniques at their farms. Many studies have been conducted on the applications, adoptability, and benefits of CLT techniques, and significantly positive responses to these techniques for crop production were reported [203,204]. The controlling mechanism of CLT includes a feedback input mechanism that continuously feeds the field conditions—retrieved from the sensors—to the input controller; then, the operation of irrigation machines is conducted in accordance with this information. The information may relate to climate, soil, or crop parameters [205,206]. Initially, a bigger irrigation program of variable nature is formulated that is implemented accordingly after retrieving information from the sensors at small time intervals [207,208]. However, continuous dynamics in field conditions make the control of irrigation extremely cumbersome under CLT. Also, due to the installation of sensors on irrigation machines and in soil profiles, the capital cost exceeds even unaffordable limits. Also, the use of sensors could mislead operators if they are not calibrated properly, which results in immense implementation struggles for farmers. The simplest illustration of precision irrigation using a center pivot sprinkler system under both controlling mechanisms (OLT and CLT) is shown in Figure 9.

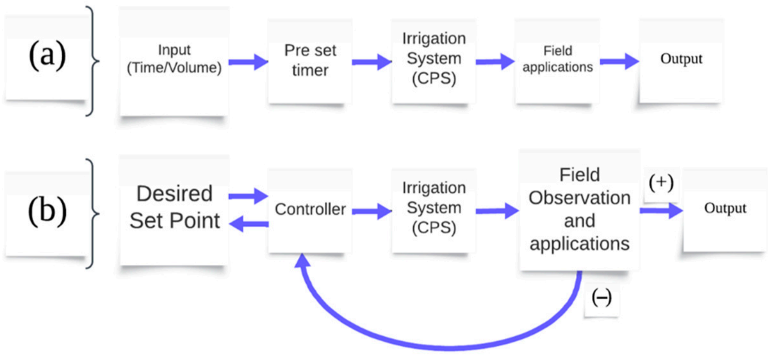

Figure 9. Block diagram of (**a**) open loop technique (OLT) and (**b**) closed loop technique (CLT) under precision irrigation.

4.4. Use of Controlling Devices for Precision Applications of Sprinkler Irrigation

To perform water application using a sprinkler system according to real-time irrigation scheduling, mechanized systems are used to continuously control the operation of the irrigation system to adopt the true spirit of precision irrigation. The operation of the irrigation system is controlled to maintain the desired irrigation level by controlling the application rate or irrigation time [175]. To achieve this, electronic devices called "controllers" have been developed and are available in markets. The selection of controllers is made keeping in view their function, reliability, availability, price, etc. One type of controller is the PID (proportional-integrated derivative) controller. These controllers are widely used due to their simple structure, ease of troubleshooting, and minimum errors but these cannot handle external disturbance and can thus create errors [209]. The second type of controller is an AI (intelligent control for precision irrigation) controller. These controllers use the application of artificial intelligence, which makes these devices capable of providing solutions in a smarter way [210]. These devices with briskly developed algorithms can emulate the process of human decision making; therefore, these devices have been implemented specifically in sprinkler irrigation machines for precise water applications [211,212] in different forms like fuzzy logic, etc. [213]. On the other hand, these kinds of controllers have complex structures, are higher in price, and are difficult to troubleshoot. The third type of controller is the MPC (model predictive-based irrigation) controller, which is widely used in agriculture and other industries [214–218]. By installing MPC controllers instead of classical controllers on sprinkler irrigation machines, many benefits including good efficiency, excellent performance, and optimality can be achieved toward the true spirit of precision [219]. Future research on the development of smart MPC controllers can improve the efficiency of precision irrigation using sprinkler systems in a convenient way with 20–30% more efficiency.

4.5. Use of Precision Irrigation for Crop Production

Precision irrigation has proved its impact in the field of irrigated agronomy. Many researchers worked on the qualitative and quantitative behavior of crops against precision irrigation. Abioye [159] used an MPC controller in sprinkler irrigation for precision applications and reported 30% water saving. The IoT-based precision irrigation system was used for water saving in tomato production and reported 10% water saving with 71%

better uniformity and 27.5% higher yield [220]. Chen [221] recommended the fuzzy neural network with a genetic algorithm (GA) to accomplish precision irrigation for 15–25 better yield and 25% water saving. The same technique was used by Guha [222] to calculate precise amounts of water with reference to greenhouse effects for a significant impact on crop productivity. Perea [223] used a combination of ANN and genetic algorithm (GA) for the prediction of evapotranspiration and crop response under water applications and reported 3–11% better results in terms of system efficiency for crop productivity. Ahmad [224] compared several studies on precision irrigation coupled with sprinkler irrigation and concluded that these technologies have a very positive influence on crop production and in the field of irrigated agronomy.

5. Conclusions and Future Perspectives

This study consulted the major advances in sprinkler systems toward precision applications to save irrigation water and provide an increase in net crop production, maximum irrigation uniformity, and better fertilizer management with minimum leaching losses. A number of research articles from the literature were reviewed as per the designed methodology followed by the application of comprehensive inclusion/exclusion criteria to exclude unnecessary literature from the search results. Regarding the technological aspects of the analyzed works, it became evident that sprinkler systems are an efficient source to not only irrigate crops but also for fertilizer applications in the field with >35% efficiency and >14.1 productivity. This study also revealed the fact that the design of sprinkler irrigation needs to be optimized to avoid associated wind drift losses that are up to 14% of the total application efficiency. Moreover, this study covered prominent features of precision irrigation coupled with sprinkler irrigation technology. The data regarding precision irrigation revealed a dramatic improvement in productivity when automation and sensor-based monitoring were coupled with a control communication and information system to operate the sprinkler system to enhance the yield by 27.5% and save 30% more irrigation water. It is obvious that the cumulative literature and consolidation of results in one place will provide opportunities for students and researchers to develop new ideas for further interventions in the field of precision irrigation and improvements in the design of existing sprinkler systems. Future research should be continued on the smart design and evaluation of sprinkler nozzles with environmental impact assessments and simplified application mechanisms for precision irrigation systems. Research work on these lines will further support the adoption of modern irrigation techniques in large cultivable areas.

Author Contributions: Investigation, original drafting, formal analysis, and visualization, J.N.C.; conceptualization, overall supervision, H.L.; helped in the manuscript drafting, Y.J.; proofing and improvement of the original draft, X.P.; contributed to draft revision, provided support during the literature search, Z.H.; and helped in analysis and acquisition of final conclusions, M.J. and M.R. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Data Availability Statement: Not applicable.

Acknowledgments: The authors are grateful to the administration of Jiangsu University (Zhenjiang, China) and the Chinese Government for providing a working place and research facilities to complete the present study.

Conflicts of Interest: The authors declare no conflicts of interest.

References

1. CSP. *China Statistical Yearbook*; China Statistics Press: Beijing, China, 2018.
2. CSP. *China Rural Statistical Yearbook*; China Statistics Press: Beijing, China, 2019.
3. Wang, J.; Huang, J.; Zhang, L.; Huang, Q.; Rozelle, S. Water Governance and Water Use Efficiency: The Five Principles of WUA Management and Performance in China. *JAWRA J. Am. Water Resour. Assoc.* **2010**, *46*, 665–685. [CrossRef]
4. World Bank. *The World Bank Annual Report 2020*; World Bank: Washington, DC, USA, 2020; ISBN 978-1-4648-1619-2.

5. Wang, J.; Li, Y.; Huang, J.; Yan, T.; Sun, T. Growing Water Scarcity, Food Security and Government Responses in China. *Glob. Food Secur.* **2017**, *14*, 9–17. [CrossRef]
6. Wang, J.; Zhu, Y.; Sun, T.; Huang, J.; Zhang, L.; Guan, B.; Huang, Q. Forty Years of Irrigation Development and Reform in China. *Aust. J. Agric. Resour. Econ.* **2020**, *64*, 126–149. [CrossRef]
7. Yan, H.; Hui, X.; Li, M.; Xu, Y. Development in Sprinkler Irrigation Technology in China. *Irrig. Drain.* **2020**, *69*, 75–87. [CrossRef]
8. UNESCO World Water Assessment Programme. *The United Nations World Water Development Report 2019: Leaving No One Behind*; United Nations: Paris, France, 2019.
9. Baggio, G.; Qadir, M.; Smakhtin, V. Freshwater Availability Status across Countries for Human and Ecosystem Needs. *Sci. Total Environ.* **2021**, *792*, 148230. [CrossRef]
10. Ning, J. *Main Data of the Seventh National Population Census*; National Bureau of Statistics of China: Beijing, China, 2021.
11. Xie, J. *Addressing China's Water Scarcity: Recommendations for Selected Water Resource Management Issues*; The World Bank: Beijing, China, 2009.
12. Wang, J.; Huang, J.; Yan, T. Impacts of Climate Change on Water and Agricultural Production in Ten Large River Basins in China. *J. Integr. Agric.* **2013**, *12*, 1267–1278. [CrossRef]
13. de Fraiture, C.; Wichelns, D. Satisfying Future Water Demands for Agriculture. *Agric. Water Manag.* **2010**, *97*, 502–511. [CrossRef]
14. Moore, S.M. The Development of Water Markets in China: Progress, Peril, and Prospects. *Water Policy* **2015**, *17*, 253–267. [CrossRef]
15. Semananda, N.P.K.; Ward, J.D.; Myers, B.R. A Semi-Systematic Review of Capillary Irrigation: The Benefits, Limitations, and Opportunities. *Horticulturae* **2018**, *4*, 23. [CrossRef]
16. Vasanthan, V.; Ramasamy, R.; Janarthanan, S.; VasimBabu, M. Implementation of Iot in Smart Irrigation System Using Arduino Processor. *Int. J. Civ. Eng. Technol.* **2017**, *8*, 1304–1314.
17. Lakhiar, I.A.; Jianmin, G.; Syed, T.N.; Chandio, F.A.; Buttar, N.A.; Qureshi, W.A. Monitoring and Control Systems in Agriculture Using Intelligent Sensor Techniques: A Review of the Aeroponic System. *J. Sens.* **2018**, *2018*, 8672769. [CrossRef]
18. Man, J.; Yu, J.; White, P.J.; Gu, S.; Zhang, Y.; Guo, Q.; Shi, Y.; Wang, D. Effects of Supplemental Irrigation with Micro-Sprinkling Hoses on Water Distribution in Soil and Grain Yield of Winter Wheat. *Field Crops Res* **2014**, *161*, 26–37. [CrossRef]
19. Liu, H.-J.; Kang, Y.; Yao, S.-M.; Sun, Z.-Q.; Liu, S.-P.; Wang, Q.-G. Field evaluation on water productivity of winter wheat under sprinkler or surface irrigation in the North China plain. *Irrig. Drain.* **2013**, *62*, 37–49. [CrossRef]
20. Li, J.; Zhang, Z.; Liu, Y.; Yao, C.; Song, W.; Xu, X.; Zhang, M.; Zhou, X.; Gao, Y.; Wang, Z.; et al. Effects of Micro-Sprinkling with Different Irrigation Amount on Grain Yield and Water Use Efficiency of Winter Wheat in the North China Plain. *Agric. Water Manag.* **2019**, *224*, 105736. [CrossRef]
21. Shankar, M.; Neelima, T.; Das, A.; Ramanjaneyulu, A. Sprinkler Irrigation—An asset in water scarce and undulating areas. In *Integrated Soil and Water Resource Management for Livelihood and Environmental Security*; ICAR Research Complex for NEH Region: Shillong, India, 2018.
22. Deen, K.K.; Nanh, M.B.; Alshalak, M.B.; Abdul-Alaziz, A. The Factors Affecting the Adoption of Sprinkler Irrigation Technique for Underground Irrigated Wheat in the First and the Second Agricultural Stability Zone in the Two Provinces of Aleppo and Idleb. *Arab. Univ. J. Agric. Sci.* **2012**, *20*, 45–57. [CrossRef]
23. Stalidzans, E. Application of information technologies in precision apiculture. In Proceedings of the 13th International Conference on Precision Agriculture (ICPA 2012), Indianapolis, IN, USA, 15−18 July 2012.
24. Shibusawa, S. Precision Farming Approaches for Small Scale Farms. *IFAC Proc. Vol.* **2001**, *34*, 22–27. [CrossRef]
25. Cambra, C.; Sendra, S.; Lloret, J.; Lacuesta, R. Smart System for Bicarbonate Control in Irrigation for Hydroponic Precision Farming. *Sensors* **2018**, *18*, 1333. [CrossRef]
26. El Chami, D.; Knox, J.W.; Daccache, A.; Weatherhead, E.K. Assessing the Financial and Environmental Impacts of Precision Irrigation in a Humid Climate. *Hortic. Sci.* **2019**, *46*, 43–52. [CrossRef]
27. Meerpohl, J.J.; Herrle, F.; Antes, G.; von Elm, E. Scientific Value of Systematic Reviews: Survey of Editors of Core Clinical Journals. *PLoS ONE* **2012**, *7*, e35732. [CrossRef]
28. Julian, P.H.; Sally, G. *Cochrane Handbook for Systematic Reviews of Interventions*; Higgins, J.P., Green, S., Eds.; Wiley: London, UK, 2008; ISBN 9780470699515.
29. Chalmers, I.; Hedges, L.V.; Cooper, H. A Brief History of Research Synthesis. *Eval. Health Prof.* **2002**, *25*, 12–37. [CrossRef]
30. Massey, J.H.; Mark Stiles, C.; Epting, J.W.; Shane Powers, R.; Kelly, D.B.; Bowling, T.H.; Leighton Janes, C.; Pennington, D.A. Long-Term Measurements of Agronomic Crop Irrigation Made in the Mississippi Delta Portion of the Lower Mississippi River Valley. *Irrig. Sci.* **2017**, *35*, 297–313. [CrossRef]
31. Zhao, J.; Huang, C.; Huang, H.; Pan, J.; Zeng, L.; Luo, M.; Liang, G.; Yang, W.; Liu, J. Prevalence of Ankylosing Spondylitis in a Chinese Population: A Systematic Review and Meta-Analysis. *Rheumatol. Int.* **2020**, *40*, 859–872. [CrossRef] [PubMed]
32. Abioye, E.A.; Abidin, M.S.Z.; Mahmud, M.S.A.; Buyamin, S.; Ishak, M.H.I.; Rahman, M.K.I.A.; Otuoze, A.O.; Onotu, P.; Ramli, M.S.A. A Review on Monitoring and Advanced Control Strategies for Precision Irrigation. *Comput. Electron. Agric.* **2020**, *173*, 105441. [CrossRef]
33. Vallejo-Gómez, D.; Osorio, M.; Hincapié, C.A. Smart Irrigation Systems in Agriculture: A Systematic Review. *Agronomy* **2023**, *13*, 342. [CrossRef]

34. Xue, J.; Ren, L. Evaluation of Crop Water Productivity under Sprinkler Irrigation Regime Using a Distributed Agro-Hydrological Model in an Irrigation District of China. *Agric. Water Manag.* **2016**, *178*, 350–365. [CrossRef]
35. Liu, H.; Yu, L.; Luo, Y.; Wang, X.; Huang, G. Responses of Winter Wheat (*Triticum aestivum* L.) Evapotranspiration and Yield to Sprinkler Irrigation Regimes. *Agric. Water Manag.* **2011**, *98*, 483–492. [CrossRef]
36. Sezen, S.M.; Yazar, A.; Kapur, B.; Tekin, S. Comparison of Drip and Sprinkler Irrigation Strategies on Sunflower Seed and Oil Yield and Quality under Mediterranean Climatic Conditions. *Agric. Water Manag.* **2011**, *98*, 1153–1161. [CrossRef]
37. Kiani, A.R. Comparison of Rice Direct Seeding and Transplanting Methods under Different Irrigation Methods. *Water Soil* **2022**, *35*, 779–790. [CrossRef]
38. Ravikumar, V. Sprinkler Irrigation Types and Components. In *Sprinkler and Drip Irrigation: Theory and Practice*; Ravikumar, V., Ed.; Springer: Singapore, 2023; pp. 3–23. ISBN 978-981-19-2775-1.
39. Lomas, J. Sprinkler Irrigation and Plant Disease under Semi-arid Climatic Conditions. *EPPO Bull.* **2008**, *21*, 365–370. [CrossRef]
40. Romero, F.; Cazzato, S.; Walder, F.; Vogelgsang, S.; Bender, S.; Van der Heijden, M. Humidity and High Temperature Are Important for Predicting Fungal Disease Outbreaks Worldwide. *New Phytol.* **2021**, *234*, 1553–1556. [CrossRef]
41. Belo, T.R.; du Toit, L.J.; Waters, T.D.; Derie, M.L.; Schacht, B.; LaHue, G.T. Reducing the Risk of Onion Bacterial Diseases through Managing Irrigation Frequency and Final Irrigation Timing. *Agric. Water Manag.* **2023**, *288*, 108476. [CrossRef]
42. Pan, Q.; Lu, Y.; Hu, H.; Hu, Y. Review and Research Prospects on Sprinkler Irrigation Frost Protection for Horticultural Crops. *Sci. Hortic.* **2024**, *326*, 112775. [CrossRef]
43. Howell, T. *Irrigation Efficiency. Encyclopedia of Water Science*; CRC: Boca Raton, FL, USA, 2003.
44. Liu, J.; Zang, C.; Tian, S.; Liu, J.; Yang, H.; Jia, S.; You, L.; Liu, B.; Zhang, M. Water Conservancy Projects in China: Achievements, Challenges and Way Forward. *Glob. Environ. Chang.* **2013**, *23*, 633–643. [CrossRef]
45. Patel, N.H.; Prajapati, C.R. Agricultural Sprinkler for Irrigation System. *Int. J. Eng. Res. Tech. Res.* **2020**, *9*, 162–166. [CrossRef]
46. Yan, H.; Ma, J.; Wang, Z. Design and Field Experiment on Fertilizer Injection Device in Center Pivot Irrigation System. *Trans. Chin. Soc. Agric. Mach.* **2015**, *46*, 100–106. [CrossRef]
47. Li, Y.; Bai, G.; Yan, H. Development and Validation of a Modified Model to Simulate the Sprinkler Water Distribution. *Comput. Electron. Agric.* **2015**, *111*, 38–47. [CrossRef]
48. Yan, H.; Yao, P.; Zhu, Y.; Yu, P. Nozzle Configuration and Software for Center Pivot Irrigation System. *Trans. Chin. Soc. Agric. Mach.* **2011**, *42*, 84–88.
49. Ma, J.; Yan, H.; Wang, C. Effect of End Gun on/off on Variable Rate Fertigation Uniformity and Its Improvement for Center Pivot Irrigation System. *J. Hydraul. Eng.* **2016**, *47*, 1577–1584. [CrossRef]
50. Li, Y.; Chen, W.; Yan, H.; Zhang, Z. Optimization of Structure Parameters for Impulse Water Turbine of Hose Reel Irrigator. *Nongye Jixie Xuebao/Trans. Chin. Soc. Agric. Mach.* **2018**, *49*, 138–144. [CrossRef]
51. Cheng, J.; Tang, Y.; Tang, L. Energy Consumption Analysis of Hydraulic Turbine of JP75 Hose Reel Irrigator. *J. Drain. Irrig. Mach. Eng.* **2016**, *34*, 1008–1012. [CrossRef]
52. Maosheng, G.; Wu, P.; Zhu, D.; Zhang, L.; Xiao, X.; Xu, H. Construction and Application of Mobile Spraying Uniformity Model of Hard Hose Traveler. *Trans. Chin. Soc. Agric. Eng.* **2016**, *32*, 130–137. [CrossRef]
53. Li, Y.; Zhang, Z.; Yan, H.; Gu, T. Hydraulic Performance Analysis and Optimization for Water Turbine of JP75 Hose Reel Irrigation Machine. *Nongye Jixie Xuebao/Trans. Chin. Soc. Agric. Mach.* **2018**, *49*, 100–107. [CrossRef]
54. Zhang, L.; Hui, X.; Chen, J. Effect of Terrain Slope on Water Distribution and Application Uniformity for Sprinkler Irrigation. *Int. J. Agric. Biol. Eng.* **2018**, *11*, 120–125. [CrossRef]
55. Yuan, S.; Zhu, X.; Li, H.; Ren, Z. Effects of Complete Fluidic Sprinkler on Hydraulic Characteristics Based on Some Important Geometrical Parameters. *Trans. Chin. Soc. Agric. Eng.* **2006**, *22*, 113–116.
56. Jiang, Y.; Li, H.; Hua, L.; Zhang, D. Three-Dimensional Flow Breakup Characteristics of a Circular Jet with Different Nozzle Geometries. *Biosyst. Eng.* **2020**, *193*, 216–231. [CrossRef]
57. Jiménez-Bello, M.A.; Royuela, A.; Manzano, J.; Prats, A.G.; Martínez-Alzamora, F. Methodology to Improve Water and Energy Use by Proper Irrigation Scheduling in Pressurised Networks. *Agric. Water Manag.* **2015**, *149*, 91–101. [CrossRef]
58. Tarjuelo, J.M.; Rodriguez-Diaz, J.A.; Abadía, R.; Camacho, E.; Rocamora, C.; Moreno, M.A. Efficient Water and Energy Use in Irrigation Modernization: Lessons from Spanish Case Studies. *Agric. Water Manag.* **2015**, *162*, 67–77. [CrossRef]
59. Li, H.; Xu, M.; Li, Y.; Chen, C. Optimal Design of Rotating Stream Interrupter Diffuser for Sprinklers. *Nongye Jixie Xuebao/Trans. Chin. Soc. Agric. Mach.* **2014**, *45*, 69–74. [CrossRef]
60. Wang, Z.; Hui, X.; Li, Y.; Yan, H. Optimization of Nozzle Structure and Investigation on Hydraulic Performance of Impact Sprinkler. *J. Hydraul. Eng.* **2019**, *50*, 488–496.
61. Tang, P.; Li, H.; Chen, C.; Sun, C. Optimization and Experiment of Adjustable Structural Parameters for Vertical Impact Sprinkler with Working Pressure. *Trans. Chin. Soc. Agric. Eng.* **2016**, *32*, 99–107. [CrossRef]
62. Wang, X.; Li, G.; Guo, C.; Han, W.; Yao, X.; Sun, Y. Optimization of Impact Sprinkler Sub-Nozzle Parameters of Elevation Angle and Position. *Nongye Gongcheng Xuebao/Trans. Chin. Soc. Agric. Eng.* **2015**, *31*, 89–95. [CrossRef]
63. Chen, R.; Li, H.; Wang, J.; Guo, X.; Song, Z. Comparisons of Spray Characteristics between Non-Circular and Circular Nozzles with Rotating Sprinklers. *Appl. Eng. Agric.* **2022**, *38*, 61–75. [CrossRef]
64. Wang, J.; Song, Z.; Chen, R.; Yang, T.; Tian, Z. Experimental Study on Droplet Characteristics of Rotating Sprinklers with Circular Nozzles and Diffuser. *Agriculture* **2022**, *12*, 987. [CrossRef]

65. Chen, R.; Li, H.; Wang, J.; Guo, X. Effects of Pressure and Nozzle Size on the Spray Characteristics of Low-Pressure Rotating Sprinklers. *Water* **2020**, *12*, 2904. [CrossRef]
66. Liu, J.; Liu, X.; Zhu, X.; Yuan, S. Droplet Characterisation of a Complete Fluidic Sprinkler with Different Nozzle Dimensions. *Biosyst. Eng.* **2016**, *148*, 90–100. [CrossRef]
67. Sayyadi, H.; Nazemi, A.H.; Sadraddini, A.A.; Delirhasannia, R. Characterising Droplets and Precipitation Profiles of a Fixed Spray-Plate Sprinkler. *Biosyst. Eng.* **2014**, *119*, 13–24. [CrossRef]
68. King, B.; Bjorneberg, D. Characterizing Droplet Kinetic Energy Applied by Moving Spray-Plate Center-Pivot Irrigation Sprinklers. *Trans. ASABE* **2010**, *53*, 137–145. [CrossRef]
69. Dwomoh, F.; Shouqi, Y.; Hong, L. Field Performance Characteristics of Fluidic Sprinkler. *Appl. Eng. Agric.* **2013**, *29*, 529–536. [CrossRef]
70. Xiang, Q.; Xu, Z.; Chen, C.; Li, H. Experiment on Aeration Water Jet Applied to Low Pressure Impact Sprinkler Irrigation. *Trans. Chin. Soc. Agric. Eng.* **2016**, *32*, 54–58. [CrossRef]
71. Zhang, Y.; Zhang, L.; Zhu, D.; Hui, X. Simulation of Water Distribution and Calculation on Water Application Uniformity for Sprinkler Irrigation on Sloping Land Based on Ballistic Theory. *Trans. Chin. Soc. Agric. Eng.* **2016**, *32*, 59–66. [CrossRef]
72. Wang, X.; Liu, J.; Zhang, Q. Water–Pesticide Integrated Micro-Sprinkler Design and Influence of Key Structural Parameters on Performance. *Agriculture* **2022**, *12*, 1532. [CrossRef]
73. Negeed, E.-S.R.; Hidaka, S.; Kohno, M.; Takata, Y. Experimental and Analytical Investigation of Liquid Sheet Breakup Characteristics. *Int. J. Heat Fluid Flow* **2011**, *32*, 95–106. [CrossRef]
74. Ouazaa, S.; Burguete, J.; Paniagua, M.P.; Salvador, R.; Zapata, N. Simulating Water Distribution Patterns for Fixed Spray Plate Sprinkler Using the Ballistic Theory. *Span. J. Agric. Res.* **2014**, *12*, 850. [CrossRef]
75. Tu, Q.; Li, H.; Wang, X.; Cai, B.; Zhuang, J.; Wang, L. Optimization of Small-Scale Sprinkler Irrigation Systems for Different Indicators. *Nongye Gongcheng Xuebao/Trans. Chin. Soc. Agric. Eng.* **2013**, *29*, 83–89. [CrossRef]
76. Tsaboula, A.; Papadakis, E.-N.; Vryzas, Z.; Kotopoulou, A.; Kintzikoglou, K.; Papadopoulou-Mourkidou, E. Environmental and Human Risk Hierarchy of Pesticides: A Prioritization Method, Based on Monitoring, Hazard Assessment and Environmental Fate. *Environ. Int.* **2016**, *91*, 78–93. [CrossRef] [PubMed]
77. Hedley, C.B.; Bradbury, S.; Watson, E.; Dalrymple, H.; Wright, J. Farm-Scale Trials of Variable Rate Irrigation to Assess the Benefits of Modifying Existing Sprinkler Systems for Precision Application. *Int. J. Agric. Manag.* **2011**, *1*, 51–55.
78. Brennan, D. Factors Affecting the Economic Benefits of Sprinkler Uniformity and Their Implications for Irrigation Water Use. *Irrig. Sci.* **2008**, *26*, 109–119. [CrossRef]
79. Fan, Y.; Wang, Q.; Zhou, Q.; Duan, F.; Wang, Z.; Chen, Z. Main Problems in Technological Development of Sprinkler Irrigation in China and Corresponding Countermeasures. *J. Drain. Irrig. Mach. Eng.* **2015**, *33*, 450–455. [CrossRef]
80. Wijetunga, S.; Imthiyas, A.W.M.; Karunaratne, W.K.P.; Sirisena, A.H.H.T. Comparison of Water Use by Mango Nursery Plants under Sprinkler and Manual Irrigation—A Case Study at Seed and Planting Material Production Farm in Polonnaruwa. In Proceedings of the International Symposium on Agriculture and Environment 2020, Surakarta, Indonesia, 25–27 August 2020.
81. Kumar, R.; Naresh, R.K.; Bhatt, R.; Chandra, M.S.; Kumar, D.; Alamri, S.; Siddiqui, M.H.; Alfagham, A.T.; Kalaji, H.M. Tillage Crop Establishment and Irrigation Methods Improve the Productivity of Wheat (*Triticum Aestivum*): Water Use Studies, and the Biological Properties and Fertility Status of Soil. *Agronomy* **2023**, *13*, 1839. [CrossRef]
82. Wenzel, J.L.; Conrad, C.; Piernicke, T.; Spengler, D.; Pöhlitz, J. Assessing the Impact of Different Irrigation Levels on Starch Potato Production. *Agronomy* **2022**, *12*, 2685. [CrossRef]
83. Kahlown, M.A.; Raoof, A.; Zubair, M.; Kemper, W.D. Water Use Efficiency and Economic Feasibility of Growing Rice and Wheat with Sprinkler Irrigation in the Indus Basin of Pakistan. *Agric. Water Manag.* **2007**, *87*, 292–298. [CrossRef]
84. Cao, C.; Zhang, P.; Ma, Z.-P.; Ma, Z.-B.; Wang, J.; Tang, Y.; Chen, H. Coupling Sprinkler Freshwater Irrigation with Vegetable Species Selection as A Sustainable Approach for Agricultural Production in Farmlands with A History of 50-Year Wastewater Irrigation. *J. Hazard. Mater.* **2021**, *414*, 125576. [CrossRef]
85. Maina, M.; Zubair, L. Design and evaluation of micro-sprinkler irrigation system using onion for sustainable dryland agriculture. *Niger. J. Eng. Sci. Technol. Res.* **2022**, *8*, 1–13.
86. Seidazimova, D.; Aitbayev, T.; Hufnagel, L.; Kampitova, G.; Sultanuly Rakhymzhanov, B.; Askarkyzy, D. Prospects for Using Sprinkler Irrigation for Carrots (*Daucus carota* L.) in the Foothills of South-East Kazakhstan. *Biosci. Biotechnol. Res. Asia* **2016**, *13*, 653. [CrossRef]
87. Romana, T.; Singh, B.; Kaur, J. Comparative Evaluation of Efficiency of Surface Irrigation and Micro Irrigation in Cereals: A Review. *Pharma Innov. J.* **2022**, *11*, 1427–1430.
88. Nunes, J.M.; Martín-Franco, C.; Peña, D.; Terron, J.; Gil, L.A.; Rodríguez, D.; Albarrán, Á.; Pineiro, A. Combined Use of Biochar and Sprinkler Irrigation May Enhance Rice Productivity in Water-Stressed Regions. *Ann. Agric. Sci.* **2023**, *68*, 48–59. [CrossRef]
89. Tang, H.; Wang, J.; Xu, C.; Zhou, W.; Wang, J.; Wang, X. Research Progress Analysis on Key Technology of Chemical Fertilizer Reduction and Efficiency Increase. *Nongye Jixie Xuebao Trans. Chin. Soc. Agric. Mach.* **2019**, *50*, 1–19.
90. Zhang, M.; Zhao, W.; Li, J.; Li, Y. Fertigation Uniformity and Evaporation Drift Losses of Center Pivot Irrigation System. *Paiguan Jixie Gongcheng Xuebao/J. Drain. Irrig. Mach. Eng.* **2018**, *36*, 1125–1130. [CrossRef]
91. Cai, D.; Zhou, L.; Gu, T.; Yan, H. Yield and Nitrogen Utilization of Winter Wheat under Different Nitrogen Application Frequencies with Sprinkler Irrigation System. *Nongye Jixie Xuebao/Trans. Chin. Soc. Agric. Mach.* **2018**, *49*, 278–286. [CrossRef]

92. Li, J. Increasing Crop Productivity in an Eco-Friendly Manner by Improving Sprinkler and Micro-Irrigation Design and Management: A Review of 20 Years' research at the IWHR, China. *Irrig. Drain.* **2017**, *67*, 97–112. [CrossRef]
93. Evans, R.; King, B. Site-Specific Sprinkler Irrigation in a Water Limited Future. In Proceedings of the 5th National Decennial Irrigation Conference Proceedings, Phoenix, AZ, USA, 5–8 December 2010; Volume 55.
94. Zhao, W.; Li, J.; Yang, R.; Li, Y. Field Evaluation of Water Distribution Characteristics of Variable Rate Center Pivot Irrigation System. *Nongye Gongcheng Xuebao/Trans. Chin. Soc. Agric. Eng.* **2014**, *30*, 53–62. [CrossRef]
95. Hu, Z.F. *Research and Experiment of Self-Propelled Variable Irrigation System Based on Infrared Thermography*; China Agricultural University: Beijing, China, 2014.
96. Han, W.; Yao, X.; Zhu, B.; Zhang, C.; Zhou, X.; Wu, P. Test and Evaluation on Variable-Rate Irrigation Sprinkler. *Nongye Jixie Xuebao/Trans. Chin. Soc. Agric. Mach.* **2013**, *44*, 112+121–126. [CrossRef]
97. Li, J. Crop Yield and Water Productivity Responses in Management Zones for Variable-Rate Irrigation Based on Available Soil Water Holding Capacity. *Trans. ASABE (Am. Soc. Agric. Biol. Eng.)* **2017**, *60*, 1659–1667. [CrossRef]
98. Martin, D.L.; Kincaid, D.C.; Lyle, W.M. Chapter 16. Design and Operation of Sprinkler Systems. In *Design and Operation of Farm Irrigation Systems*, 2nd ed.; American Society of Agricultural and Biological Engineers: St. Joseph, MI, USA, 2007; pp. 557–631.
99. Tu, Q.; Wang, X.; Li, H. *Optimization of Sprinkler Irrigation Machine Based on Genetic Algorithms*; American Society of Agricultural and Biological Engineers: St. Joseph, MI, USA, 2012; Volume 7.
100. Zhang, B.; Yuan, S.; Zhang, J.; Li, H. Study of Corn Optimization Irrigation Model by Genetic Algorithms. In Proceedings of the First IFIP TC 12 International Conference on Computer and Computing Technologies in Agriculture (CCTA 2007), Wuyishan, China, 18–20 August 2007; Volume 258, pp. 121–132.
101. Jiang, Y.; Xu, X.; Huang, Q.; Huo, Z.; Huang, G. Optimizing Regional Irrigation Water Use by Integrating a Two-Level Optimization Model and an Agro-Hydrological Model. *Agric. Water Manag.* **2016**, *178*, 76–88. [CrossRef]
102. Bai, D.; Wang, X. Optimum Design for Tapered Diameter Pipeline with Multiple Outlets Based on Genetic Algorithm. *Trans. Chin. Soc. Agric. Eng.* **2005**, *21*, 42–45.
103. Gao, W.; Yu, Z. Optimization Model of Rotation Irrigation Channel Distribution with GA and FS. In Proceedings of the 2011 2nd International Conference on Artificial Intelligence, Management Science and Electronic Commerce (AIMSEC), Dengfeng, China, 8–10 August 2011; pp. 1305–1308. [CrossRef]
104. Liu, J.; Liu, W.; Bao, Y.; Zhang, Q.; Liu, X. Drop Size Distribution Experiments of Gas-Liquid Two Phases Fluidic Sprinkler. *Paiguan Jixie Gongcheng Xuebao/J. Drain. Irrig. Mach. Eng.* **2017**, *35*, 731–736. [CrossRef]
105. Naderianfar, M.; Faryabi, A.; Dehghan, H. Estimation of Wind Drift and Evaporation Losses in Sprinkler Irrigation of Urban Green Spaces. *Prog. Agric. Eng. Sci.* **2018**, *14*, 77–96. [CrossRef]
106. Cavero, J.; Medina, E.T.; Puig, M.; Martínez-Cob, A. Sprinkler Irrigation Changes Maize Canopy Microclimate and Crop Water Status, Transpiration, and Temperature. *Agron. J.* **2009**, *101*, 854–864. [CrossRef]
107. Wang, S.; Zheng, H.; Liu, S.; Miao, Y.; Li, J. Numerical Study on the Stomatal Responses to Dry-Hot Wind Episodes and Its Effects on Land-Atmosphere Interactions. *PLoS ONE* **2016**, *11*, e0162852. [CrossRef]
108. Bennell, M.R.; Cleugh, H.; Leys, J.; Hein, D. The Effect of Hot Dry Wind on the Pod Set of Faba Bean (Vicia Faba) Cv. Fiord: A Preliminary Wind Tunnel Study. *Aust. J. Exp. Agric.* **2007**, *47*, 1468–1475. [CrossRef]
109. Liu, H.-J.; Kang, Y. Effect of Sprinkler Irrigation on Microclimate in the Winter Wheat Field in the North China Plain. *Agric. Water Manag.* **2006**, *84*, 3–19. [CrossRef]
110. Li, P.; Ren, L. Assessing the Feasibility of Sprinkler Irrigation Schemes at the Regional Scale Using a Distributed Agro-Hydrological Model. *J. Hydrol.* **2022**, *610*, 127917. [CrossRef]
111. Mu, Q.; Cai, H.; Sun, S.; Wen, S.; Xu, J.; Dong, M.; Saddique, Q. The Physiological Response of Winter Wheat under Short-Term Drought Conditions and the Sensitivity of Different Indices to Soil Water Changes. *Agric. Water Manag.* **2021**, *243*, 106475. [CrossRef]
112. Liu, H.-J.; Kang, Y. Regulating Field Microclimate Using Sprinkler Misting under Hot-Dry Windy Conditions. *Biosyst. Eng.* **2006**, *95*, 349–358. [CrossRef]
113. Cai, D.; Shoukat, M.R.; Zheng, Y.; Tan, H.; Meng, F.; Yan, H. Optimizing Center Pivot Irrigation to Regulate Field Microclimate and Wheat Physiology under Dry-Hot Wind Conditions in the North China Plain. *Water* **2022**, *14*, 708. [CrossRef]
114. Al-Ghobari, H.M.; El-Marazky, M.S.; Dewidar, A.Z.; Mattar, M.A. Prediction of Wind Drift and Evaporation Losses from Sprinkler Irrigation Using Neural Network and Multiple Regression Techniques. *Agric. Water Manag.* **2018**, *195*, 211–221. [CrossRef]
115. Stambouli, T.; Martínez-Cob, A.; Faci, J.M.; Howell, T.; Zapata, N. Sprinkler Evaporation Losses in Alfalfa during Solid-Set Sprinkler Irrigation in Semiarid Areas. *Irrig. Sci.* **2013**, *31*, 1075–1089. [CrossRef]
116. Sadeghi, S.-H.; Peters, T.; Shafii, B.; Amini, M.Z.; Stöckle, C. Continuous Variation of Wind Drift and Evaporation Losses under a Linear Move Irrigation System. *Agric. Water Manag.* **2017**, *182*, 39–54. [CrossRef]
117. Sanchez, I.; Faci, J.M.; Zapata, N. The Effects of Pressure, Nozzle Diameter and Meteorological Conditions on the Performance of Agricultural Impact Sprinklers. *Agric. Water Manag.* **2011**, *102*, 13–24. [CrossRef]
118. Faria, L.C.; Colombo, A.; Oliveira, H.F.E.; Prado, G. do Simulação Da Uniformidade Da Irrigação de Sistemas Convencionais de Aspersão Operando Sob Diferentes Condições de Vento. *Eng. Agrícola* **2009**, *29*, 19–27. [CrossRef]
119. Beskow, S.; Faria, L.C.; Colombo, A.; Moura, D.C.M. Modelagem Das Perdas de Água Por Evaporação e Arraste Em Aspersores de Média Pressão. *Rev. Bras. De Eng. Agrícola E Ambient.* **2011**, *15*, 221–228. [CrossRef]

120. Colombo, A.; Faria, L.C.; da Silva, J.J.; Sant'Ana, J.A.d.V.; Beskow, S.; Nörenberg, B.G. Modelagem Das Perdas de Água Por Evaporação e Arraste de Sprays de Placa Oscilante. *Rev. Bras. Eng. Agrícola Ambient.* **2015**, *19*, 719–726. [CrossRef]
121. Playán, E.; Salvador, R.; Faci, J.M.; Zapata, N.; Martínez-Cob, A.; Sánchez, I. Day and Night Wind Drift and Evaporation Losses in Sprinkler Solid-Sets and Moving Laterals. *Agric. Water Manag.* **2005**, *76*, 139–159. [CrossRef]
122. Ortíz, J.N.; Tarjuelo, J.M.; de Juan, J.A. Characterisation of Evaporation and Drift Losses with Centre Pivots. *Agric. Water Manag.* **2009**, *96*, 1541–1546. [CrossRef]
123. Faria, L.C.; Beskow, S.; Colombo, A.; Nörenberg, B.G.; Rettore Neto, O.; Simões, M.C. Influence of the Wind on Water Application Uniformity of a Mechanical Lateral Move Irrigation Equipment Using Rotating Plate Sprinklers. *Ciênc. Rural* **2015**, *46*, 83–88. [CrossRef]
124. Yazar, A. Evaporation and Drift Losses from Sprinkler Irrigation Systems under Various Operating Conditions. *Agric. Water Manag.* **1984**, *8*, 439–449. [CrossRef]
125. Luz, P.B.; Heermann, D. A Statistical Approach to Estimating Runoff in Center Pivot Irrigation with Crust Conditions. *Agric. Water Manag.* **2005**, *72*, 33–46. [CrossRef]
126. Molle, B.; Tomas, S.; Hendawi, M.; Granier, J. Evaporation and Wind Drift Losses during Sprinkler Irrigation Influenced by Droplet Size Distribution. *Irrig. Drain.* **2012**, *61*, 240–250. [CrossRef]
127. Baifus Manke, E.; Nörenberg, B.G.; Faria, L.C.; Tarjuelo, J.M.; Colombo, A.; Chagas Neta, M.C.C.; Parfitt, J.M.B. Wind Drift and Evaporation Losses of a Mechanical Lateral-Move Irrigation System: Oscillating Plate versus Fixed Spray Plate Sprinklers. *Agric. Water Manag.* **2019**, *225*, 105759. [CrossRef]
128. Sarwar, A.; Peters, R.T.; Shafeeque, M.; Mohamed, A.; Arshad, A.; Ullah, I.; Saddique, N.; Muzammil, M.; Aslam, R.A. Accurate Measurement of Wind Drift and Evaporation Losses Could Improve Water Application Efficiency of Sprinkler Irrigation Systems—A Comparison of Measuring Techniques. *Agric. Water Manag.* **2021**, *258*, 107209. [CrossRef]
129. King, B.A.; Dungan, R.S.; Bjorneberg, D.L. Evaluation of Center Pivot Sprinkler Wind Drift and Evaporation Loss. In Proceedings of the 2012 ASABE Annual International Meeting, Dallas, TX, USA, 29 July–1 August 2012; American Society of Agricultural and Biological Engineers: St. Joseph, MI, USA, 2012.
130. Mohamed, A.Z.; Peters, R.; Sarwar, A.; Molaei, B.; Mcmoran, D. Impact of the Intermittency Movement of Center Pivots on Irrigation Uniformity. *Water* **2021**, *13*, 1167. [CrossRef]
131. Bitella, G.; Rossi, R.; Bochicchio, R.; Perniola, M.; Amato, M. A Novel Low-Cost Open-Hardware Platform for Monitoring Soil Water Content and Multiple Soil-Air-Vegetation Parameters. *Sensors* **2014**, *14*, 19639–19659. [CrossRef] [PubMed]
132. Capraro, F.; Tosetti, S.; Rossomando, F.; Mut, V.; Vita Serman, F. Web-Based System for the Remote Monitoring and Management of Precision Irrigation: A Case Study in an Arid Region of Argentina. *Sensors* **2018**, *18*, 3847. [CrossRef] [PubMed]
133. Elijah, O.; Abd Rahman, T.; Orikumhi, I.; Leow, C.Y.; Hindia, M. An Overview of Internet of Things (IoT) and Data Analytics in Agriculture: Benefits and Challenges. *IEEE Internet Things J.* **2018**, *5*, 3758–3773. [CrossRef]
134. Kamilaris, A.; Kartakoullis, A.; Prenafeta-Boldú, F.X. A Review on the Practice of Big Data Analysis in Agriculture. *Comput. Electron. Agric.* **2017**, *143*, 23–37. [CrossRef]
135. Talavera, J.M.; Tobón, L.E.; Gómez, J.A.; Culman, M.A.; Aranda, J.M.; Parra, D.T.; Quiroz, L.A.; Hoyos, A.; Garreta, L.E. Review of IoT Applications in Agro-Industrial and Environmental Fields. *Comput. Electron. Agric.* **2017**, *142*, 283–297. [CrossRef]
136. Wolfert, S.; Ge, L.; Verdouw, C.; Bogaardt, M.-J. Big Data in Smart Farming—A Review. *Agric Syst* **2017**, *153*, 69–80. [CrossRef]
137. Elshaikh, A.E.; Jiao, X.; Yang, S. Performance Evaluation of Irrigation Projects: Theories, Methods, and Techniques. *Agric. Water Manag.* **2018**, *203*, 87–96. [CrossRef]
138. Hedley, C.B.; Yule, I.J. A Method for Spatial Prediction of Daily Soil Water Status for Precise Irrigation Scheduling. *Agric. Water Manag.* **2009**, *96*, 1737–1745. [CrossRef]
139. Daccache, A.; Knox, J.W.; Weatherhead, E.K.; Daneshkhah, A.; Hess, T.M. Implementing Precision Irrigation in a Humid Climate—Recent Experiences and on-Going Challenges. *Agric. Water Manag.* **2015**, *147*, 135–143. [CrossRef]
140. Smith, R.J.; Baillie, J.; McCarthy, A.C.; Raine, S.R.; Baillie, C.P. *Review of Precision Irrigation Technologies and Their Application*; University of Southern Queensland: Toowoomba, Australia, 2010.
141. Castañeda-Miranda, A.; Castaño-Meneses, V.M. Internet of Things for Smart Farming and Frost Intelligent Control in Greenhouses. *Comput. Electron. Agric.* **2020**, *176*, 105614. [CrossRef]
142. Chen, Y.-A.; Hsieh, W.-H.; Ko, Y.-S.; Huang, N.-F. An Ensemble Learning Model for Agricultural Irrigation Prediction. In Proceedings of the 2021 International Conference on Information Networking (ICOIN), Jeju, Republic of Korea, 13–16 January 2021; pp. 311–316.
143. Keswani, B.; Mohapatra, A.G.; Mohanty, A.; Khanna, A.; Rodrigues, J.J.P.C.; Gupta, D.; de Albuquerque, V.H.C. Adapting Weather Conditions Based IoT Enabled Smart Irrigation Technique in Precision Agriculture Mechanisms. *Neural Comput. Appl.* **2019**, *31*, 277–292. [CrossRef]
144. Torres, A.B.B.; da Rocha, A.R.; Coelho da Silva, T.L.; de Souza, J.N.; Gondim, R.S. Multilevel Data Fusion for the Internet of Things in Smart Agriculture. *Comput. Electron. Agric.* **2020**, *171*, 105309. [CrossRef]
145. Kashyap, P.K.; Kumar, S.; Jaiswal, A.; Prasad, M.; Gandomi, A.H. Towards Precision Agriculture: IoT-Enabled Intelligent Irrigation Systems Using Deep Learning Neural Network. *IEEE Sens. J.* **2021**, *21*, 17479–17491. [CrossRef]
146. Chang, C.-L.; Lin, K.-M. Smart Agricultural Machine with a Computer Vision-Based Weeding and Variable-Rate Irrigation Scheme. *Robotics* **2018**, *7*, 38. [CrossRef]

147. Ćulibrk, D.; Vukobratovic, D.; Minic, V.; Alonso Fernandez, M.; Alvarez Osuna, J.; Crnojevic, V. *Sensing Technologies for Precision Irrigation*; Springer: New York, NY, USA, 2014; ISBN 978-1-4614-8328-1.
148. Fernández, J. Plant-Based Methods for Irrigation Scheduling of Woody Crops. *Horticulturae* **2017**, *3*, 35. [CrossRef]
149. Bauer, J.; Aschenbruck, N. Design and Implementation of an Agricultural Monitoring System for Smart Farming. In Proceedings of the 2018 IoT Vertical and Topical Summit on Agriculture, Tuscany, Italy, 8–9 May 2018; pp. 1–6.
150. Abd Rahman, M.K.I.; Zainal Abidin, M.S.; Mahmud, M.S.A.; Buyamin, S.; Ishak, M.H.I.; Emmanuel, A.A. Advancement of a Smart Fibrous Capillary Irrigation Management System with an Internet of Things Integration. *Bull. Electr. Eng. Inform.* **2019**, *8*, 1402–1410. [CrossRef]
151. Saha, H.N.; Chakraborty, S.; Roy, R. Integration of RFID and Sensors in Agriculture Using IOT. In *AI, Edge and IoT-Based Smart Agriculture*; Elsevier: Amsterdam, The Netherlands, 2022; pp. 361–372.
152. Shahzadi, R.; Ferzund, J.; Tausif, M.; Asif, M. Internet of Things Based Expert System for Smart Agriculture. *Int. J. Adv. Comput. Sci. Appl.* **2016**, *7*, 341–350. [CrossRef]
153. Villarrubia, G.; Paz, J.F.D.; Iglesia, D.H.D.L.; Bajo, J. Combining Multi-Agent Systems and Wireless Sensor Networks for Monitoring Crop Irrigation. *Sensors* **2017**, *17*, 1775. [CrossRef]
154. Goap, A.; Sharma, D.; Shukla, A.K.; Rama Krishna, C. An IoT Based Smart Irrigation Management System Using Machine Learning and Open Source Technologies. *Comput. Electron. Agric.* **2018**, *155*, 41–49. [CrossRef]
155. Newlin Rajkumar, M.; Abinaya, S.; Kumar, V. Intelligent Irrigation System—An IOT Based Approach. In Proceedings of the International Conference on Innovations in Green Energy and Healthcare Technologies (IGEHT), Coimbatore, India, 16–18 March 2017.
156. Liao, R.; Zhang, S.; Zhang, X.; Wang, M.; Wu, H.; Zhangzhong, L. Development of Smart Irrigation Systems Based on Real-Time Soil Moisture Data in a Greenhouse: Proof of Concept. *Agric. Water Manag.* **2021**, *245*, 106632. [CrossRef]
157. Jia, X.; Huang, Y.; Wang, Y.; Sun, D. Research on Water and Fertilizer Irrigation System of Tea Plantation. *Int. J. Distrib. Sens. Netw.* **2019**, *15*, 155014771984018. [CrossRef]
158. Huuskonen, J.; Oksanen, T. Soil Sampling with Drones and Augmented Reality in Precision Agriculture. *Comput. Electron. Agric.* **2018**, *154*, 25–35. [CrossRef]
159. Abioye, E.A.; Abidin, M.S.Z.; Aman, M.N.; Mahmud, M.S.A.; Buyamin, S. A Model Predictive Controller for Precision Irrigation Using Discrete Lagurre Networks. *Comput. Electron Agric.* **2021**, *181*, 105953. [CrossRef]
160. Nalliah, V.; Ranjan, R. Evaluation of a Capillary-Irrigation System for Better Yield and Quality of Hot Pepper (*Capsicum annuum*). *Appl. Eng. Agric.* **2010**, *26*, 807–816. [CrossRef]
161. Harun, A.N.; Mohamed, N.; Ahmad, R.; Abdul Rahim, A.; Ani, N. Improved Internet of Things (IoT) Monitoring System for Growth Optimization of *Brassica chinensis*. *Comput. Electron. Agric.* **2019**, *164*, 104836. [CrossRef]
162. Mohanraj, I.; Ashokumar, K.; Naren, J. Field Monitoring and Automation Using IOT in Agriculture Domain. *Procedia Comput. Sci.* **2016**, *93*, 931–939. [CrossRef]
163. Aleotti, J.; Amoretti, M.; Nicoli, A.; Caselli, S. A Smart Precision-Agriculture Platform for Linear Irrigation Systems. In Proceedings of the 26th International Conference on Software, Telecommunications and Computer Networks (SoftCOM), Split, Croatia, 13–15 September 2018.
164. Uddin, M.A.; Mansour, A.; Le Jeune, D.; Aggoune, E.H.M. Agriculture Internet of Things: AG-IoT. In Proceedings of the 2017 27th International Telecommunication Networks and Applications Conference (ITNAC), Melbourne, Australia, 22–24 November 2017; pp. 1–6.
165. Harun, A.N.; Kassim, M.; Mat, I.; Ramli, S. Precision Irrigation Using Wireless Sensor Network. In Proceedings of the International Conference on Smart Sensors and Application (ICSSA), Kuala Lumpur, Malaysia, 26–28 July 2015.
166. Viani, F.; Bertolli, M.; Salucci, M.; Polo, A. Low-Cost Wireless Monitoring and Decision Support for Water Saving in Agriculture. *IEEE Sens. J.* **2017**, *17*, 4299–4309. [CrossRef]
167. Agale, R.R.; Gaikwad, D.P. Automated Irrigation and Crop Security System in Agriculture Using Internet of Things. In Proceedings of the 2017 International Conference on Computing, Communication, Control and Automation (ICCUBEA), Pune, India, 17–18 August 2017; pp. 1–5.
168. Wheeler, W.D.; Chappell, M.; van Iersel, M.; Thomas, P. Implementation of Soil Moisture Sensor Based Automated Irrigation in Woody Ornamental Production. *J. Environ. Hortic.* **2020**, *38*, 1–7. [CrossRef]
169. Kothawade, S.N.; Furkhan, S.M.; Raoof, A.; Mhaske, K.S. Efficient Water Management for Greenland Using Soil Moisture Sensor. In Proceedings of the 2016 IEEE 1st International Conference on Power Electronics, Intelligent Control and Energy Systems (ICPEICES), New Delhi, India, 4–6 July 2016; pp. 1–4.
170. Lozoya, C.; Mendoza, C.; Aguilar, A.; Román, A.; Castelló, R. Sensor-Based Model Driven Control Strategy for Precision Irrigation. *J. Sens.* **2016**, *2016*, 9784071. [CrossRef]
171. Lozoya, C.; Eyzaguirre, E.; Espinoza, J.; Montes-Fonseca, S.L.; Rosas-Perez, G. Spectral Vegetation Index Sensor Evaluation for Greenhouse Precision Agriculture. In Proceedings of the 2019 IEEE Sensors, Montreal, QC, Canada, 27–30 October 2019; pp. 1–4.
172. Kumar, A.; Surendra, A.; Mohan, H.; Valliappan, K.M.; Kirthika, N. Internet of Things Based Smart Irrigation Using Regression Algorithm. In Proceedings of the 2017 International Conference on Intelligent Computing, Instrumentation and Control Technologies (ICICICT), Kannur, India, 6–7 July 2017; pp. 1652–1657.

173. Chieochan, O.; Saokaew, A.; Boonchieng, E. Internet of Things (IOT) for Smart Solar Energy: A Case Study of the Smart Farm at Maejo University. In Proceedings of the 2017 International Conference on Control, Automation and Information Sciences (ICCAIS), Chiang Mai, Thailand, 31 October–1 November 2017; pp. 262–267.
174. Prasad, A.N.; Mamun, K.A.; Islam, F.R.; Haqva, H. Smart Water Quality Monitoring System. In Proceedings of the 2015 2nd Asia-Pacific World Congress on Computer Science and Engineering (APWC on CSE), Nadi, Fiji, 2–4 December 2015; pp. 1–6.
175. Anjum, M.N.; Cheema, M.J.M.; Hussain, F.; Wu, R.-S. Precision Irrigation. In *Precision Agriculture*; Elsevier: Amsterdam, The Netherlands, 2023; pp. 85–101.
176. Divya, Y. Smart Water Monitoring System Using Cloud Service. *Int. J. Trend Sci. Res. Dev.* **2019**, *3*, 406–408. [CrossRef]
177. Shigeta, R.; Kawahara, Y.; Goud, G.D.; Naik, B.B. Capacitive-Touch-Based Soil Monitoring Device with Exchangeable Sensor Probe. In Proceedings of the 2018 IEEE Sensors, New Delhi, India, 28–31 October 2018; pp. 1–4.
178. Difallah, W.; Benahmed, K.; Bounaama, F.; Belkacem, D.; Saidi, A. Intelligent Irrigation Management System. *Int. J. Adv. Comput. Sci. Appl.* **2018**, *9*, 429–433. [CrossRef]
179. Hamouda, Y.E.M. Smart Irrigation Decision Support Based on Fuzzy Logic Using Wireless Sensor Network. In Proceedings of the 2017 International Conference on Promising Electronic Technologies (ICPET), Deir El-Balah, Palestine, 16–17 October 2017; pp. 109–113.
180. Islam, M.; Al-Momin, M.; Tauhid, A.; Hossain, M.; Sarker, S. IoT Based Smart Irrigation Monitoring & Controlling System in Agriculture. *Int. J. Recent Technol. Eng. (IJRTE)* **2020**, *8*, 2436–2440. [CrossRef]
181. Bogue, R. Sensors Key to Advances in Precision Agriculture. *Sens. Rev.* **2017**, *37*, 1–6. [CrossRef]
182. Zhang, X.; Zhang, J.; Li, L.; Zhang, Y.; Yang, G. Monitoring Citrus Soil Moisture and Nutrients Using an IoT Based System. *Sensors* **2017**, *17*, 447. [CrossRef] [PubMed]
183. Joly, M.; Mazenq, L.; Marlet, M.; Temple-Boyer, P.; Durieu, C.; Launay, J. Multimodal Probe Based on ISFET Electrochemical Microsensors for In-Situ Monitoring of Soil Nutrients in Agriculture. *Proc. West Mark Ed. Assoc. Conf.* **2017**, *1*, 420. [CrossRef]
184. Karthikeyan, L.; Chawla, I.; Mishra, A.K. A Review of Remote Sensing Applications in Agriculture for Food Security: Crop Growth and Yield, Irrigation, and Crop Losses. *J. Hydrol.* **2020**, *586*, 124905. [CrossRef]
185. Bwambale, E.; Naangmenyele, Z.; Iradukunda, P.; Agboka, K.M.; Houessou-Dossou, E.A.Y.; Akansake, D.A.; Bisa, M.E.; Hamadou, A.-A.H.; Hakizayezu, J.; Onofua, O.E.; et al. Towards Precision Irrigation Management: A Review of GIS, Remote Sensing and Emerging Technologies. *Cogent Eng.* **2022**, *9*, 2100573. [CrossRef]
186. Elnashar, A.; Abbas, M.; Sobhy, H.; Shahba, M. Crop Water Requirements and Suitability Assessment in Arid Environments: A New Approach. *Agronomy* **2021**, *11*, 260. [CrossRef]
187. Tessema Roba, N.; Kebede Kassa, A.; Yadeta Geleta, D. Modeling Climate Change Impacts on Crop Water Demand, Middle Awash River Basin, Case Study of Berehet Woreda. *Water Pract. Technol.* **2021**, *16*, 864–885. [CrossRef]
188. Reyes-González, A.; Kjaersgaard, J.; Trooien, T.; Hay, C.; Ahiablame, L. Estimation of Crop Evapotranspiration Using Satellite Remote Sensing-Based Vegetation Index. *Adv. Meteorol.* **2018**, *2018*, 4525021. [CrossRef]
189. Ramírez-Cuesta, J.; Mirás-Avalos, J.; Rubio-Asensio, J.; Intrigliolo, D. A Novel ArcGIS Toolbox for Estimating Crop Water Demands by Integrating the Dual Crop Coefficient Approach with Multi-Satellite Imagery. *Water* **2018**, *11*, 38. [CrossRef]
190. Fares, A.; Awal, R.; Fares, S.; Johnson, A.B.; Valenzuela, H. Irrigation Water Requirements for Seed Corn and Coffee under Potential Climate Change Scenarios. *J. Water Clim. Chang.* **2016**, *7*, 39–51. [CrossRef]
191. Garrido-Rubio, J.; Calera Belmonte, A.; Fraile Enguita, L.; Arellano Alcázar, I.; Belmonte Mancebo, M.; Campos Rodríguez, I.; Bravo Rubio, R. Remote Sensing-Based Soil Water Balance for Irrigation Water Accounting at the Spanish Iberian Peninsula. *Proc. Int. Assoc. Hydrol. Sci.* **2018**, *380*, 29–35. [CrossRef]
192. Mokhtari, A.; Ahmadi, A.; Daccache, A.; Drechsler, K. Actual Evapotranspiration from UAV Images: A Multi-Sensor Data Fusion Approach. *Remote Sens.* **2021**, *13*, 2315. [CrossRef]
193. Zeyliger, A.M.; Muzalevskiy, K.V.; Zinchenko, E.V.; Ermolaeva, O.S. Field Test of the Surface Soil Moisture Mapping Using Sentinel-1 Radar Data. *Sci. Total Environ.* **2022**, *807*, 151121. [CrossRef] [PubMed]
194. Ortega-Farias, S.; Esteban-Condori, W.; Riveros-Burgos, C.; Fuentes-Peñailillo, F.; Bardeen, M. Evaluation of a Two-Source Patch Model to Estimate Vineyard Energy Balance Using High-Resolution Thermal Images Acquired by an Unmanned Aerial Vehicle (UAV). *Agric. For. Meteorol.* **2021**, *304*, 108433. [CrossRef]
195. Bwambale, E.; Abagale, F.K.; Anornu, G.K. Smart Irrigation Monitoring and Control Strategies for Improving Water Use Efficiency in Precision Agriculture: A Review. *Agric. Water Manag.* **2022**, *260*, 107324. [CrossRef]
196. Crous, C.J.; Samways, M.J.; Pryke, J.S. Grasshopper Assemblage Response to Surface Rockiness in Afro-Montane Grasslands. *Insect Conserv. Divers.* **2014**, *7*, 185–194. [CrossRef]
197. Montesano, F.F.; van Iersel, M.W.; Parente, A. Timer versus Moisture Sensor-Based Irrigation Control of Soilless Lettuce: Effects on Yield, Quality and Water Use Efficiency. *Hortic. Sci.* **2016**, *43*, 67–75. [CrossRef]
198. Sudarmaji, A.; Sahirman, S.; Saparso; Ramadhani, Y. Time Based Automatic System of Drip and Sprinkler Irrigation for Horticulture Cultivation on Coastal Area. *IOP Conf. Ser. Earth Environ. Sci.* **2019**, *250*, 012074. [CrossRef]
199. Krishnan, R.S.; Julie, E.G.; Robinson, Y.H.; Raja, S.; Kumar, R.; Thong, P.H.; Son, L.H. Fuzzy Logic Based Smart Irrigation System Using Internet of Things. *J. Clean. Prod.* **2020**, *252*, 119902. [CrossRef]
200. O'Shaughnessy, S.; Urrego Pereira, Y.; Evett, S.; Colaizzi, P.; Howell, T. Assessing Application Uniformity of a Variable Rate Irrigation System in a Windy Location. *Appl. Eng. Agric.* **2013**, *29*, 497–510. [CrossRef]

201. Takács, S.; Bíró, T.; Helyes, L.; Pék, Z. Variable Rate Precision Irrigation Technology for Deficit Irrigation of Processing Tomato. *Irrig. Drain.* **2018**, *68*, 234–244. [CrossRef]
202. Yari, A.; Madramootoo, C.; Woods, S.; Adamchuk, V. Performance Evaluation of Constant Versus Variable Rate Irrigation: Variable Rate Irrigation. *Irrig. Drain.* **2017**, *66*, 501–509. [CrossRef]
203. Yari, A.; Madramootoo, C.; Woods, S.; Adamchuk, V.; Huang, H.-H. Assessment of Field Spatial and Temporal Variabilities to Delineate Site-Specific Management Zones for Variable-Rate Irrigation. *J. Irrig. Drain. Eng.* **2017**, *143*, 04017037. [CrossRef]
204. Szabó, A.; Tamás, J.; Kövesdi, Á.; Nagy, A. Evaluation of New Pivoting Linear-move Precision Irrigation Machine. *Irrig. Drain.* **2023**, *72*, 922–933. [CrossRef]
205. Deng, X.; Dou, Y.; Hu, D. Robust Closed-Loop Control of Vegetable Production in Plant Factory. *Comput. Electron. Agric.* **2018**, *155*, 244–250. [CrossRef]
206. Adeyemi, O.; Grove, I.; Peets, S.; Norton, T. Advanced Monitoring and Management Systems for Improving Sustainability in Precision Irrigation. *Sustainability* **2017**, *9*, 353. [CrossRef]
207. Klein, L.J.; Hamann, H.F.; Hinds, N.; Guha, S.; Sanchez, L.; Sams, B.; Dokoozlian, N. Closed Loop Controlled Precision Irrigation Sensor Network. *IEEE Internet Things J.* **2018**, *5*, 4580–4588. [CrossRef]
208. Patil, P.; Desai, B.L. Intelligent Irrigation Control System by Employing Wireless Sensor Networks. *Int. J. Comput. Appl.* **2013**, *79*, 33–40. [CrossRef]
209. Gauri, M.; Kulkarni, N.R. Design and optimization of pid controller using genetic algorithm. *Int. J. Res. Eng. Technol.* **2013**, *2*, 926–930. [CrossRef]
210. Fuentes, S.; Tongson, E. Advances and Requirements for Machine Learning and Artificial Intelligence Applications in Viticulture. *Wine Vitic. J.* **2018**, *33*, 47–52.
211. Dimitriadis, S.; Goumopoulos, C. Applying Machine Learning to Extract New Knowledge in Precision Agriculture Applications. In Proceedings of the 2008 Panhellenic Conference on Informatics, Samos Island, Greece, 28–30 August 2008; pp. 100–104.
212. Goldstein, A.; Fink, L.; Meitin, A.; Bohadana, S.; Lutenberg, O.; Ravid, G. Applying Machine Learning on Sensor Data for Irrigation Recommendations: Revealing the Agronomist's Tacit Knowledge. *Precis. Agric.* **2018**, *19*, 421–444. [CrossRef]
213. Singh, S.N.; Jha, R.; Nandwana, M.K. Optimal Design of Solar Powered Fuzzy Control Irrigation System for Cultivation of Green Vegetable Plants in Rural India. In Proceedings of the 2012 1st International Conference on Recent Advances in Information Technology (RAIT), Dhanbad, India, 15–18 March 2012; pp. 877–882.
214. Wong, W.; Chee, E.; Li, J.; Wang, X. Recurrent Neural Network-Based Model Predictive Control for Continuous Pharmaceutical Manufacturing. *Mathematics* **2018**, *6*, 242. [CrossRef]
215. Lee, J.B.; Gondhalekar, R.; Dassau, E.; Doyle, F.J. Shaping the MPC Cost Function for Superior Automated Glucose Control. *IFAC-PapersOnLine* **2016**, *49*, 779–784. [CrossRef]
216. Bosschaerts, W.; Van Renterghem, T.; Hasan, O.A.; Limam, K. Development of a Model Based Predictive Control System for Heating Buildings. *Energy Procedia* **2017**, *112*, 519–528. [CrossRef]
217. MacDermott, A.; Shi, Q.; Merabti, M.; Kifiyat, K. Considering an Elastic Scaling Model for Cloud Security. In Proceedings of the 2013 IEEE Third International Conference on Information Science and Technology (ICIST), Yangzhou, China, 23–25 March 2013; pp. 150–155.
218. Ding, Y.; Wang, L.; Li, Y.; Li, D. Model Predictive Control and Its Application in Agriculture: A Review. *Comput. Electron. Agric.* **2018**, *151*, 104–117. [CrossRef]
219. Morato, M.M.; Normey-Rico, J.E.; Sename, O. Model Predictive Control Design for Linear Parameter Varying Systems: A Survey. *Annu. Rev. Control* **2020**, *49*, 64–80. [CrossRef]
220. Seyar, M.H.; Ahamed, T. Development of an IoT-Based Precision Irrigation System for Tomato Production from Indoor Seedling Germination to Outdoor Field Production. *Appl. Sci.* **2023**, *13*, 5556. [CrossRef]
221. Chen, P.; An, J.; Shu, S.; Cheng, R.; Nie, J.; Jiang, T.; Wang, Z.L. Super-Durable, Low-Wear, and High-Performance Fur-Brush Triboelectric Nanogenerator for Wind and Water Energy Harvesting for Smart Agriculture. *Adv. Energy Mater.* **2021**, *11*, 2003066. [CrossRef]
222. Guha, A.; Samanta, D.; Banerjee, A.; Agarwal, D. A Deep Learning Model for Information Loss Prevention From Multi-Page Digital Documents. *IEEE Access* **2021**, *9*, 80451–80465. [CrossRef]
223. González Perea, R.; Camacho Poyato, E.; Montesinos, P.; Rodríguez Díaz, J.A. Optimisation of Water Demand Forecasting by Artificial Intelligence with Short Data Sets. *Biosyst. Eng.* **2019**, *177*, 59–66. [CrossRef]
224. Ahmed, Z.; Gui, D.; Murtaza, G.; Yunfei, L.; Ali, S. An Overview of Smart Irrigation Management for Improving Water Productivity under Climate Change in Drylands. *Agronomy* **2023**, *13*, 2113. [CrossRef]