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Artificial Intelligence (AI) and Internet of Things (IoT) Enabled Solar Irrigation Systems: A Review

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Modern society is increasingly automating daily tasks, focusing on smart homes, cities, and other structures using artificial intelligence, machine learning, and the Internet of Things for job automation. Automated solar irrigation systems can reduce human labor, financial investment, and time, replacing diesel-powered pumps with renewable energy, making solar energy an ideal replacement for diesel-powered irrigation. This study provides an overview of solar PV-powered water pumping systems in India, discussing components, applications, and economic and environmental aspects, including IoT and AI technology. A solar PV water pump is being developed for irrigating a 0.165 ha banana crop, providing 9.72 m3/day water supply, with government subsidies and farmer contributions. A microprocessor-equipped smart solar irrigation system addresses water management and power consumption concerns for environmentally friendly farming, using an advanced PV water pump and space-saving storage tank.
Keywords: Solar Photovoltaic, Solar irrigation System, Internet of things, Artificial Intelligence.

1. Introduction

Global warming is reducing water availability, necessitating the development of AI or IoT irrigation systems to reduce water wastage. Crop-wise water requirements vary depending on crop type, soil, and climate.

Table-1: An Approximate Crop-wise Water Need

Sr. no	Name of crop	Quantity of water required /ha
1	Rice	1500-2500
2	Wheat	400-500
3	Maize	600-800

4	Sugarcane	2000-2500
5	Cotton	600-800
6	Groundnut	400-500
7	Potato	450-500

In a solar irrigation system, solar energy is used to power irrigation pumps and other devices instead of relying on electricity from the grid or fossil fuel-powered generators. It is relevant to irrigate crops and provide water to cattle, remote communities, and off-grid homes. Solar irrigation systems are sustainable, cost-effective, and environmentally friendly, making them a popular alternative to traditional irrigation methods. It is particularly useful in regions with limited access to electricity or where the cost of running diesel or electric pumps is prohibitive. Additionally, solar irrigation can help farmers increase crop yields and reduce their carbon footprint. To prevent the wastage of water and to make the solar power-based irrigation system more efficient, it is nowadays implemented with AI or IoT technology. The creation and application of computer algorithms and systems that can carry out tasks that ordinarily require human knowledge and judgment constitute AI technology. With the use of this technology, computers may be programmed to study data, draw conclusions based on that learning, and take actions as a result. Machine learning, natural language processing, expert systems, robotic process automation, and other AI technologies are examples. AI aims to develop systems that are capable of performing operations that have historically been performed associated with speech recognition, visual perception, problem solving, and decision-making, all examples of human intelligence. We will be used a simple solar water irrigation system as shown in figure 1.

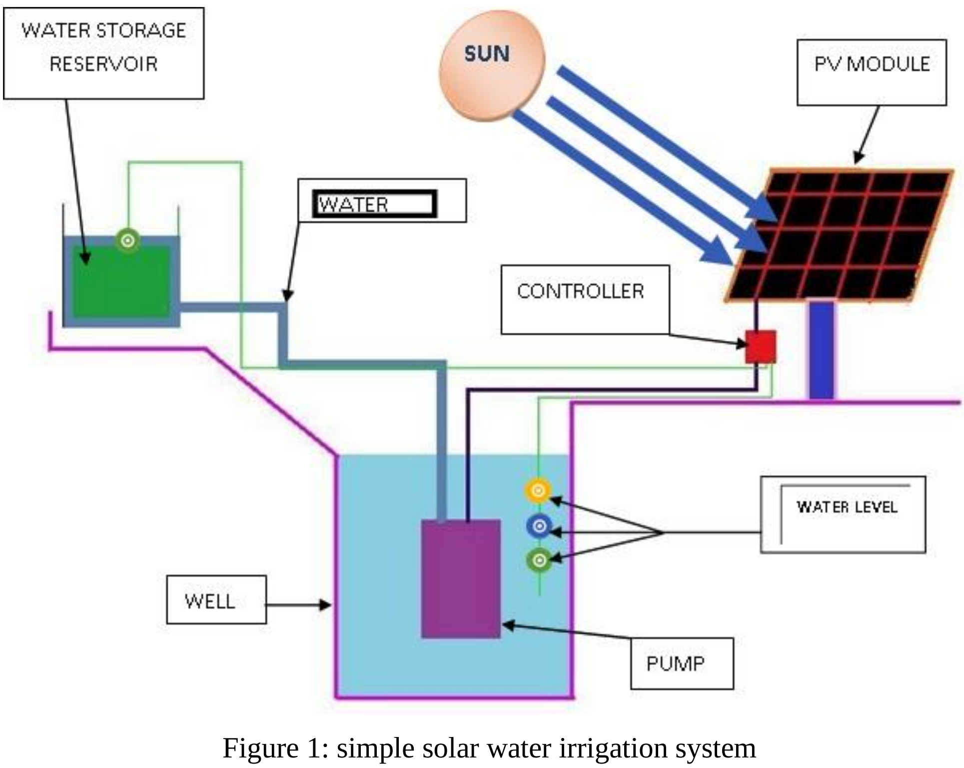

Figure 1: simple solar water irrigation system

2. Classification of Solar Irrigation system based on AI and IoT:

Irrigation systems can be classified based on their integration with water management and artificial intelligence (AI) and the Internet of Things (IoT) into several categories:

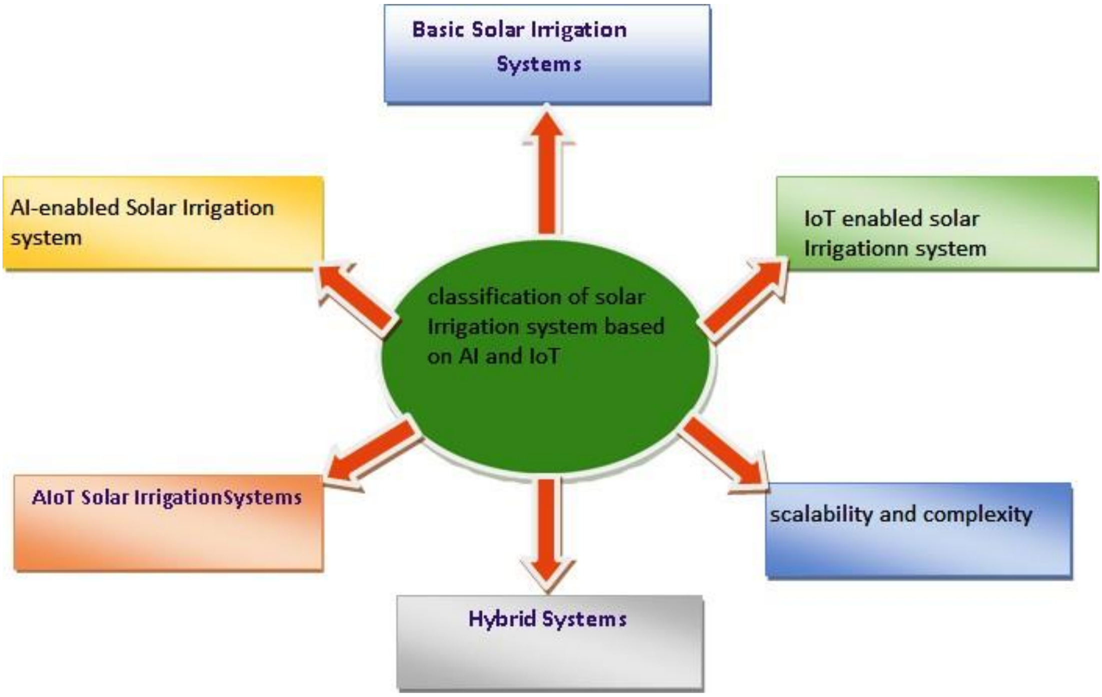

Figure 2: Classification of Irrigation System based on AI and IoT

2.1. Basic Solar Irrigation Systems: Instead of using AI or IoT technology, these devices pump water using just solar power. Usually, they are made up of irrigation infrastructure, solar panels, and solar pumps.

2.2. AI-Enhanced Solar Irrigation Systems: Artificial intelligence algorithms are integrated into these systems to optimize irrigation scheduling, energy management, and performance monitoring. To operate pumps, distribute water, and use energy efficiently, AI algorithms evaluate data from IoT sensors. To maximize system dependability and foresee equipment breakdowns, they could have predictive maintenance features.

2.3. IoT-Enabled Solar Irrigation Systems: These systems monitor and regulate several parts of the irrigation process by using IoT sensors and connections. IoT sensors monitor things like pump function, sun radiation, weather, and soil moisture. Internet- based data transmission from IoT sensors is sent to a centralised platform for analysis and decision-making.

2.4. A I Solar Irrigation Systems: These systems optimize crop management, water distribution, and energy use by combining AI and IoT technology. IoT sensor data is analyzedby AI algorithms to produce forecasts, insights, and real-time system operation optimization. They provide cutting-edge features including autonomous operation, predictive maintenance, and adaptive irrigation scheduling.

2.5. Scalability and Complexity: The scalability and sophistication of their AI and IoT integration may also be used to categories solar irrigation systems. Without complex AI algorithms, small-scale systems may rely on simple IoT sensors for monitoring and control. Extensive monitoring, optimization, and administration may be achieved by large-scale systems combining a network of IoT sensors with sophisticated AI capabilities.

2.6. Hybrid Systems: AI and IoT technology may be integrated with various power sources or irrigation techniques by some solar irrigation systems. Hybrid irrigation systems are dependable and effective because they integrate solar energy with wind, diesel generators, or grid electricity. AI and IoT technologies optimize energy use and water management, improving the performance and sustainability of hybrid systems.

3. Different Methodology of Solar Irrigation Systems:

3.1. Photovoltaic Technology Based Solar Irrigation Systems: Narale et al. developed a solar-powered water pumping system for watering bananas at Jain Water System Restrictor's PV Ranch in Jalgaon, Maharashtra. The system, designed for a 0.165-hectare banana farm, is cost- effective and efficient compared to diesel-powered motors [1]. Harishankar et al. propose a project model to improve India's irrigation infrastructure, reducing energy consumption and resource waste. The water system uses solar PV to supply sprinkler irrigation pumps, saving water and recovering power. The system can benefit both the government and farmers, making money and solving the country's power problem. Despite a significant capital investment, the long-term benefits outweigh the cost [4]. According to Chandel et al. the absence of power and high fuel prices have an influence on the pumping needs of community water supplies and agriculture. This paper examines the research and applications of solar PV water pumping system technology [7]. Closas et al. suggest using a filtration facility to prevent mineral-rich stream water from causing PV degradation, and LDR sensors and MPPTs to increase output voltage to prevent potential reductions in PV lifetime or efficiency[9]. Nawandar et al. found that diesel-powered syphons are often used in water systems, but the government should promote PV water pumping systems as a sustainable alternative. PV systems are reliable, environmentally friendly, and can be certified with a 60% government subsidy, 10% farmer contribution, and 30% government loan. They use local resources and reduce CO2 levels[17]. Kumar et al. explored the impact of energy shortages and rising fuel costs on irrigation water supply. They found that solar energy can replace diesel-powered pumping systems and conventional electricity. Solar water pumping uses PV technology to convert solar energy into electricity, reducing water consumption and energy usage. This technology contributes to environmental pollution and social and economic development in rural India [20]. Terence et al. proposed a solar-powered pump for efficient, cost-effective, and environmentally friendly crop irrigation. They developed a hybrid approach using search space reduction for optimal PV irrigation system design. They recommend a multi-objective streamlining procedure to balance efficiency and cost, focusing on limiting expenses and increasing energy utilization productivity. [22]. Algeria's Saharan regions face energy issues due to limited power access. A review of the ideal PVWPS plan for water systems in the region found that the optimal plan depends on the number of PV boards and capacity. The study suggests that PVWPS is not cost-effective compared to diesel systems, but could be beneficial for larger water systems

[23]. This study investigates soiling in Zimbabwe, focusing on its impact on solar PV systems' energy consumption. It explores daily and monthly fluctuations, and creates an empirical soiling loss model based on experimental results [25]. Bouzidi et al. found that horticultural practices like water systems harm the climate and use a lot of energy inputs. Non-sustainable petroleum derivatives like power and diesel fuel are used in grain production. Sustainable power innovation can improve energy and natural resources. Grain cultivation produces CO2 emissions, which can be reduced by using sustainable power [28]. Haffaf et al. found that water irrigation systems are crucial for farming and food security. They used HOMER to analyze factors like mechanical, financial, and natural variables. Implementing these systems can reduce CO2 discharges by 10.70% and save petroleum derivatives [33]. Hilarydoss et al. recommend horticulture incorporates a water system for crop growth and food production. Sun-oriented PV syphoning units are recommended for regions with 300-400mm annual precipitation and multiple km from a power source. However, low productivity, high initial cost, and variable radiation may hinder their use[34]. The three operating modes now in use are: full sector control with BPSO, partial sector control with a combination of linear programming, and full sector control without BPSO. The IOP is stable, and the emitter discharge is nearly the generation of water that is commensurate with the reference, which is steady. When compared to other approaches, the SPVDIS controlled by the BPSO methodology performs better [41].

3.2. Source of Renewable Energy Technology Based Solar Irrigation System: Satya et al. propose off-grid systems using sunlight for renewable energy generation, automating resource management and using a solar-powered water pump. This system allows users to irrigate from anywhere, safeguarding government-granted free power, and automating the agricultural sector, making it cost-effective and efficient [2]. Dhanne et al. explored the use of programmed watering, robotization, soil dampness sensors, and an environmentally friendly power age for irrigation. This cost-effective method reduces energy consumption, protects assets, and eliminates labor. It also promotes local energy production and reduces environmental pollution. [3]. Kirtana et al. highlight the use of IoT technology for remote management, monitoring, and control of distributed solar energy resources. They propose three operating modes for farmers, including the fuzzy logic method, which can be expanded to accommodate farm sizes and sustain operations without human intervention[12]. Waleed et al.'s study explores the potential of renewable energy-powered desalination and improved irrigation water use efficiency to safeguard global water supplies. The research highlights the interconnectedness between irrigation and decarbonized desalination industries, which could significantly improve global water supply. The study also emphasizes the importance of limitless electricity in desalination, supporting the United States' goals for sustainable water improvement [14]. Adamsab et al. suggest that recent advancements in renewable energy technologies are driving the evolution of agricultural practices. A photovoltaic (PV) water irrigation system is an ideal solution for crop irrigation, consisting of AC/DC water pumps and solar panel arrays. The system uses sunlight- based cells to produce DC momentum, which is then converted to AC ebb and flow using DC- AC inverter siphons. Farmers can remotely start their engines using mobile devices, and the system receives sufficient power from the sun for sustainability. This smart irrigation system offers control, supportability, and water reserve funds, allowing farmers to plant and harvest crops on time and with less labor [27]. Ramli et al. have developed a portable solar water pump (SPWP) for an IoT-enabled smart irrigation system. The system uses a Node MCU microcontroller with a Wi-Fi interface, temperature, humidity, and soil moisture sensors. The pump can be controlled remotely using cellphones and uses renewable energy. The system tested six different nozzle types and was found to be lightweight due to two solar panels. However, its flexibility reduces weight and makes it easy to move around the deployment site. The study did not provide specific ambient temperature and humidity values [39].

3.3. Internet of Things Based Solar Irrigation system: India's agriculture relies heavily on horticulture, making a robust water system crucial. A study presents an IoT-based system that adjusts irrigation based on demand, allowing users to monitor the system's status using an Android mobile phone. The system displays soil pH, temperature, and moisture content on an LCD. It addresses range issues and reduces messaging costs, allowing remote monitoring and control. The pH sensor allows for remote water control, and the system is solar-powered, consuming less electricity[8]. Al-Ali et al. studied that the right size solar energy cells have been placed and the required amount of solar energy has been determined. The device can be operated in one of three primary modes by farmers [13]. Laksiri et al. developed a weather-based, low- cost smart irrigation system using a trickle water system framework. Future modifications include incorporating cloud density in cloud photos, improving HMM for hourly states, and enhancing the LPU system for energy efficiency and solar power deployment, making it suitable for remote areas with limited grid access [15]. Sudharshan et al. highlight the urgent need for water management in countries with limited water resources, leading to increased research on reducing irrigation water use. They discuss the use of wireless nodes and technologies, challenges, and best practices for sensor-based irrigation systems, affecting agriculture and promoting water conservation [16]. Peng et al. explore the use of IoT in agriculture, specifically "smart farming," to monitor plants remotely and improve productivity. They classify these methods into three groups: IoT-based rural monitoring, programmed water system, and plant disease monitoring. IoT technologies are used in various aspects of agriculture, including pest monitoring, irrigation, and farms. The study emphasizes the need for further research on security, food supply, and circulation [18]. Alhejji et al. studied water pumping systems for plant growth and development. Water supply systems have evolved over time, with advances in the 1980s and 2021. The evapo-happening (ET) method separates water from clammy soil, allowing plants to grow their root zones. A cloud- and IoT-based water system system collects and stores water system data, allowing for informed decision-making [30]. Sumathi et al. examine sun-based photovoltaic system execution expectations using man-made intelligence and MPPT methods for sun-oriented controlled water systems. IoT is used to monitor fields for moisture, bugs, and pests, ensuring food quality. MPPT is used in PV systems with regulators, resulting in better results, fewer fluctuations, and no overshoot. Camera images are sent to the cloud for capacity and irrigation monitoring [32]. Kashyap et al. suggest that farming requires accurate water systems to meet the growing demand for food and water. They propose an IoT-based irrigation system that can predict soil moisture content and precipitation depth, thereby saving more water and enhancing harvests with fewer resources [35]. Obaideen et al. suggest that countries are implementing technology to enhance agriculture sustainability, particularly in irrigation systems. This can help achieve the UN's Sustainable Development Goals. Recommendations include thorough research to identify inefficiencies, R&D for long-term efficacy, and addressing management and security issues. A robust communication infrastructure is crucial for efficient operation, reducing errors and challenges. Despite potential increased costs, strong security systems can reduce online threats and improve overall efficiency [40]. Rahim et al. propose a portable solar water pump for an IoT-enabled smart irrigation system. The pump uses an integrated algorithm to collect temperature, humidity, and moisture data from sensors. Farmers can control the pump using a smartphone interface. The pump can be operated using the Blynk mobile app, monitoring the environment. The project aims to create an automated irrigation system with minimal physical labor. [43].

3.4. Artificial Intelligence Technology Based Solar Irrigation System: Indians heavily rely on farming for their livelihoods, contributing significantly to the nation's economy. This study aims to develop a low-cost intelligent irrigation technology suitable for greenhouses and farms. The system uses NN to detect and process information, communicating with the IU and sensor information to the SIU [26]. Kassanuk et al. highlight the growing importance of efficiency and food grain yield in the farming industry due to population growth and environmental impacts. They explore the use of AI and IoT in agrarian design, highlighting the potential of simulated intelligence and IoT in digitalization and mechanization. However, security concerns arise due to the information-driven nature of these technologies. As they become more robust and affordable, they will likely be widely used in agriculture [29]. Blessy et al. utilized IoT, artificial intelligence, and AI in creating a smart water pumping system framework. The article discusses the components, testing methods, and requirements of this advanced system, while also discussing potential future directions [31]. Al-Qammaz et al.'s research explores a water system framework using LoRaWAN and ChirpStack for information handling, stockpiling, and introduction. Weather condition estimation is used to determine the best water system methodology. Effect Sprinklers and Smoothes out for shallots and red chilies improve crop development and yield [36]. The technological implementation of the smart irrigation system is described in Khalifeh et al.'s (2021) publication, which also focuses on the weather forecasting process, which makes use of the Wind Driven Optimisation - Least Square Support Vector Machine (WDO-LS-SVM) algorithm. The findings obtained demonstrate superior performance in comparison to the LS-SVM, confirming the efficacy of combining the WDO and the LS- SVM.

3.5. Micro Irrigation Technology Based Solar Irrigation System : Kumar et al. suggest that small water collecting ponds in India's dry land agriculture can sustain productivity by providing supplemental irrigation. A solar-powered pumping system and gravity-fed microirrigation system can conserve energy and reduce climate change [6]. The study by Caldera et al. highlights the importance of efficient water use in Oman's agrarian business. They developed an intelligent irrigation system using solar energy and Oman falaj (hydro), focusing on waste reduction and better use of water. The system uses Arduino controllers, sensors, and IoT applications to monitor temperature, moisture, and soil dampness, enabling farmers to calculate water requirements more effectively [19]. García et al. discovered that over 20% of agricultural land is wasted due to water scarcity. They developed an irrigation system with a solenoid valve, three sensors, and fuzzy logic to address this issue. The system eliminates human labor and automatically assesses soil conditions, reducing water pumping. The Arduino microcontroller made the design more adaptable, allowing for easy sensor addition. This system could be expanded to fit farm sizes [21].

3.6. Advance Technology Based Solar Irrigation System: India's economy heavily relies on horticulture, using 60% of its land. An effective irrigation system is needed to increase crop output. The proposed framework uses IoT and AI algorithms to create smart water systems. It uses a solar-powered sensor hub and Zigbee technology to distribute data, making it both practical and intelligent India's economy heavily relies on horticulture, using 60% of its land. An effective irrigation system is needed to increase crop output. The proposed framework uses IoT and AI algorithms to create smart water systems. It uses a solar-powered sensor hub and Zigbee technology to distribute data, making it both practical and intelligent [11]. Shinde et al. explore solar irrigation systems, a sustainable and eco-friendly method for water supply systems. They highlight the potential of this technology to reduce flooding and increase crop water usage, while also supporting economic development and reducing matrix power usage, making it a simple and environmentally friendly solution [5]. Wazed et al. developed an affordable solar-powered automatic irrigation system that integrates with existing water infrastructure. The system is portable, efficient, and can be used for scheduled or manual irrigation. The system's Bluetooth- enabled Android application is expected to enhance its functionality [10]. Ghasemi et al.'s research reveals that global freshwater availability is insufficient for clean agricultural production. A water request estimate model using the BP brain network achieved an R value of 0.98963, indicating its potential for use in stable climate settings and in southern China's rugged fields. [24]. Rejekiningrum et al. studied the SIPTS plan using syphon execution, water system framework execution, syphon working strain, and release relationship bend. They found that a syphon running 7.59 hours daily could water 2,333 m2 and 3,630 m2, respectively, for shallot and bean stew plants [37]. Kisi and colleagues recommended that wetting pattern sizes be defined systems in order to properly design and operate surfaces and subsurface irrigation with drip systems. The general result recommend for applying a novel method to determine drip irrigation system’s wetting front dimensions. Future research may evaluate the developed methods using more experimental data, allowing for the development of more general conclusions [38]. Ramli et al. explore the use of sensing technologies like Wireless Sensor Network (WSN) for sustainable agriculture, focusing on the Sustainable Development Goals (SDGs). They highlight the need for efficient planning and management of security issues in intelligent irrigation systems, despite the already effective and efficient costs associated with continuous automation and technological advancement [42].

4. Role of Artificial Intelligence (AI) in Solar Irrigation System:

Artificial Intelligence (AI) plays a crucial role in optimizing performance, efficiency, and sustainability of solar irrigation systems in several ways:

4.1. Energy Optimization: AI systems can predict solar energy generation trends, optimize solar panel performance, and maximize energy capture and utilization for irrigation pumps and other components using past data and weather forecasts.

4.2. Dynamic Pump Control: Artificial intelligence algorithms use data from Internet of Things sensors to dynamically adjust pump settings, ensuring water demand, energy efficiency, and waste reduction.

4.3. Irrigation Scheduling: AI-powered irrigation scheduling algorithms optimize crop yields by considering crop development phases, environmental data, and water availability, ensuring optimal water usage and resource conservation.

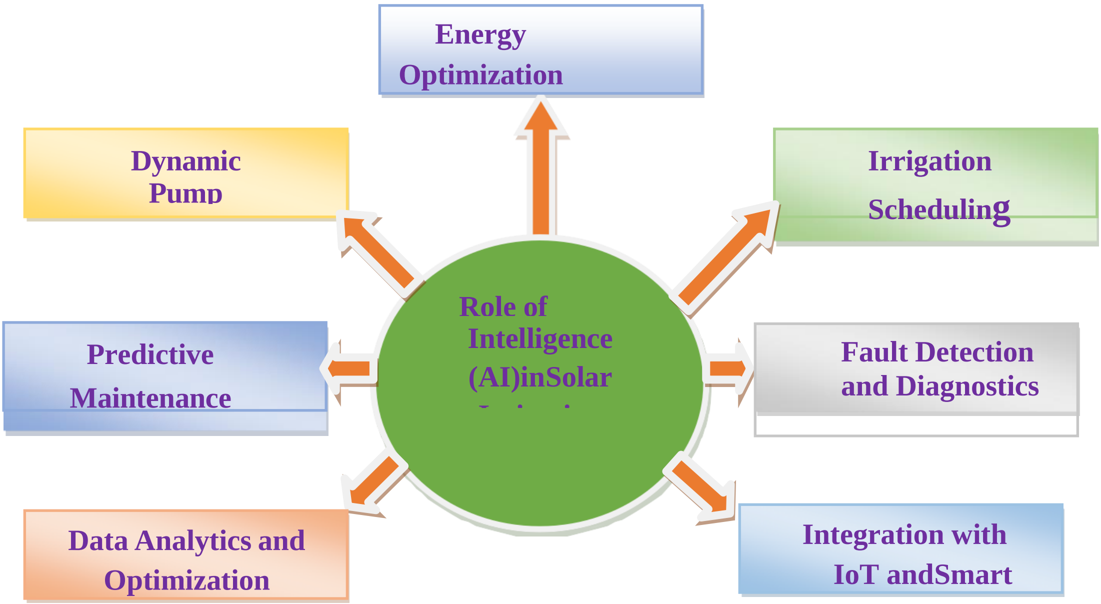

Figure 3: Role of Artificial Intelligence (AI) in Solar Irrigation System

4.4. Predictive Maintenance: AI algorithms can predict solar irrigation system equipment failures and repair needs, enabling proactive interventions like preventive repairs or component replacements to avoid costly downtime.

4.5. Fault Detection and Diagnostics: AI-based fault detection systems scan sensor data for abnormalities in solar panels, electricity generation, or pumps, enabling quick troubleshooting and immediate remedial steps to maintain system efficiency.

4.6. Data Analytics and Optimization: AI techniques, including data analytics and machine learning, analyze vast data from solar irrigation systems to identify trends, optimize design, and enhance performance and resource utilization.

5. Integration with IoT and Smart Agriculture:

AI and IoT sensors can be integrated to create data-driven ecosystems, enhancing resource optimization, crop management, and farm production through seamless data interchange and interoperability.

6. Role of Internet of Things (IoT) in Solar Irrigation System:

Through remote monitoring, data collecting, and component management made possible by the IoT, solar irrigation systems are enhanced in terms of sustainability, dependability, and efficiency. The following is how IoT benefits solar irrigation systems:

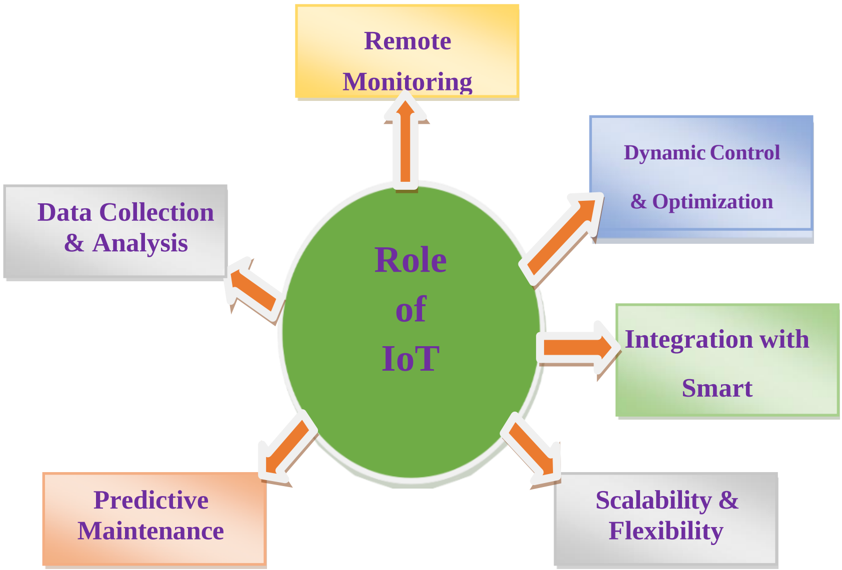

Figure 4: Role of IoT In Solar Irrigation System

6.1. Remote Monitoring: IoT sensors in irrigation systems, pumps, and solar panels monitor variables like energy output, water flow rates, soil moisture content, and equipment condition, enabling proactive management and prompt interventions.

6.2. Data Collection and Analysis: IoT sensors collect data on crop water requirements, equipment performance, energy usage trends, and environmental factors, enabling farmers to make informed decisions and optimize system performance.

6.3. Dynamic Control and Optimization: IoT-enabled solar irrigation systems use real-time data to adjust watering schedules, energy management, and pump settings, enhancing agricultural output, water efficiency, and reducing energy usage and environmental impact.

6.4. Predictive Maintenance: IoT sensors enable real-time monitoring of equipment performance and health parameters, enabling predictive maintenance algorithms to identify patterns, anticipate malfunctions, and extend component lifespan.

6.5. Integration with Smart Agriculture: Solar irrigation systems with Internet of Things connectivity can be integrated with smart agricultural technology for improved resource optimization, crop management, and overall farm production.

6.6. Scalability and Flexibility: IoT solutions offer flexibility and scalability for various agricultural environments, crop types, and irrigation needs, enabling easy deployment, expansion, and customization of solar irrigation systems.

Table 2: A small summery of few authors based on methodology/ method

Author (Year)	**Prob / Objective**	**Methodology/method**	**Discussion**
Narale etal. (2013)	To Design and develop efficientsolar water pumping system	The PV array is positioned in true south direction to utilized maximum sunlight due to the local declination which depends on thelocation and changes withthe times.	When compared to diesel- powered engines, the suggested photovoltaic systems are more cost- effective and suited

			for long- term investments.
hanneet al. (2014)	Automatic supply of waterto fields to save electrical energyfrom thegrid.	The sun light is converted into DC current by solar panel which is stored in battery to operate the pump in night time. One end of a relay is connected to battery and the other end to the DC pump. The water is stored in a watertankfrom DC pump. The text message via mobile phone as [@.ONX] is send by user to check water level in the tank and condition of the moisture in the field.	The suggested method would significantly close the energy consumption and demand gap while conserving resources and minimising resource waste.
Kumar etal. (2015)	Applications of Smal water harvesting ponds using micro- irrigation	Through the use of a gravity-fed micro- tube irrigation system, water isredirected to the plant from a higher elevation using a solar pumping unit as part of the micro-irrigation process. Little-scale water gathering ponds can supply water to the microirrigation system, which can run at low pressure.	In order to overcome the drawbacks of the drip irrigation method and boost water output, small property owners were given access to an affordable and effectivesolar-powered micro-irrigationsystem.
Gupta etal. (2016)	Controlling of irrigation by the development of automatic and android based irrigation system	The proposed system consists of temperature sensor, moisture sensor and pH sensor to explore the field conditions.	Comparing the suggested solution to other automation systems, it was more affordable and effective. The design is compact, sturdy, low-cost, low-power, andincredibly adaptable.
Closas etal. (2017)	An affordable and environmentally friendly electricity option for farmers whoare off the grid	An motor, a submersible, surface, or floating pump, and solar PV panels make up the majority of off-grid PV groundwater pumps.	While solar-powered pumps are more expensive initially (at retail) than diesel pumps, they are more reliable over time and have reduced operating and maintenance expenses. .
Wazed etal. (2017)	Development of solar energ y operated effective drip irrigation systemfor small scale rural farm	Though more environmentally friendly than other renewable energy sources, multijunction photovoltaic panels are themost efficient type of PV panels.	The most efficient PV systemsare multijunction ones with CdTe modules.
ekonnen et al. (2018)	To creation of an autonomous intelligent irrigation systemthat uses real-time informationfrom wirelesssensor networksto plan an irrigation	With sensors buried in the crop roots and around the test-bed, a wireless network tracks temperature, humidity, sun radiation, soil moisture, and fertiliser levels. Using the Zig-Bee protocol, anAccess Point (AP) controls the wireless sensor data transmission and collection..	Additionally, an attempt will be made to comprehend how severe weather affects food production. In an effort to provide a more sustainable way to satisfy the anticipated spike in demand, this all-encompassing strategy will investigate the relationship between crop production for a number of important crops and water and energyresources.
Al-Ali etal. (2019)	To creating an Internet of Things (IoT) solar energy system for intelligent irrigation	A control method based on fuzzy logic is employed by the smart irrigation system.	It was successful to design an IoT-based renewable energy system for intelligent agricultural irrigation. The necessary amount of solar energy has been determined, and the appropriate size solar energy cells have been placed.
obtaker etal. (2020)	In order to attain energy- environmental sustainability,	This study aims to assess the energy consumption patterns and environmental analyses of two irrigation systems (SFI and SPI) used in barley production. To	As a result, barley farming will have a less negative environmental impact.

	photovoltaic (PV) systems should be simulated as a potential clean energy source.	replace electricity and fuel with renewable energy, solar technologies aresimulated using TRNSYS software. Next, to evaluate the environmental harm caused by various scenarios, LCA and CExD analysis are employed.	
halifehet al. (2021)	Application of AI,Low RaWAN and cloud computing technology for irrigation systemand weathe rforecasting	An irrigation system receives this data via a LoRaWAN communication link,which is used to transmit it to a remote centre that collects, processes, and evaluates the data before determining how much water is needed for irrigation.	The outcomes demonstrate an enhanced level of performancein comparison to the LS-SVM, confirming the efficacy of combining the WDO and the LS-SVM.
Ramli etal. (2022)	The integrationof IoT technology with smart irrigation systems enables the automation of water pumping operations withless effort andcost.	The solar-powered, portable, and environmentally friendly water pump is operated by the Blynk smartphone application, which also serves as a surround-monitoring tool.	One of the things that will likely be improved in oursystem in the near future is theuse of long-range communication technologies.

7. Challenges:

Implementing solar irrigation systems integrated with AI and the IoT faces several challenges and barriers: Cost: AI and IoT technology in solar irrigation systems may be costly for smallholder farmers or communities with limited funding, including upfront costs for AI software, sensors, and infrastructure changes. Complexity: Integrating AI and IoT technologies into solar irrigation systems requires expertise in hardware engineering, software development, data analytics, and agricultural research, despite potential challenges in performance optimization and compatibility. Data Quality and Reliability: The accuracy of AI algorithms in solar irrigation systems is influenced by the quality, precision, and dependability of data from Internet of Things sensors.Energy Efficiency: AI processing's computational demands may increase energy consumption, especially in off-grid or resource-constrained areas, making it challenging to balance AI energy usage with energy savings. Scalability: Scalability issues may arise when integrating AI-enabled solar irrigation systems into larger agricultural fields, necessitating standardized procedures and modular design techniques for seamless operation across diverse settings and management techniques.Data Privacy and Security: IoT devices transfer sensitive data, raising security and privacy concerns. Unauthorised access to irrigation system data can lead to breaches, cyberattacks, or system manipulation.User Acceptance and Capacity Building: Farmers' ignorance and mistrust of AI and IoT technologies hinder their efficient use. It's crucial to provide instruction, training, and capacity-building programs for AI- enabled solar irrigation systems.Regulatory and Policy Frameworks: Regulatory frameworks impact AI and IoT irrigation systems, necessitating compliance with laws and guidelines for legal and ethical application in agriculture.

8. Conclusions:

A study found solar PV water pumps are suitable for irrigating a banana crop, providing 9.72 m3/day water supply, being eco-friendly, less expensive, and reducing water waste. Modern solar irrigation pumps, powered by renewable energy, can prevent global warming due to electricity scarcity and rising fossil fuel costs, but are not widely used in rural areas. Governments are developing PV-powered water pumps to improve efficiency, with subsidies and loans, but only 10% user/farmer contribution. Solar pumps integrate temperature, moisture, and pH sensors. A smart solar irrigation system, equipped with a microprocessor, monitors water and electricity usage in sub-Saharan African nations, promoting sustainable agriculture and reducing space consumption.

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