RATIONAL USE OF WATER RESOURCES, EFFECTIVENESS OF IRRIGATION TECHNOLOGIES ADAPTED TO CLIMATE CHANGE CONDITIONS

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Abstract: This article explores the critical need for innovative irrigation technologies in the face of climate change impacts on agriculture and water resources. With changing precipitation patterns and increasing water scarcity, the rational use of water resources becomes imperative. The review focuses on the effectiveness of various irrigation technologies, particularly precision irrigation, in adapting to evolving climatic conditions. Findings reveal that precision irrigation methods, including drip and micro-sprinkler systems, offer significant benefits by conserving water and enhancing system resilience. These technologies deliver water directly to plant roots, reducing evaporation and runoff. Additionally, integrating soil moisture sensors and weather data optimizes irrigation scheduling, further enhancing efficiency. Moreover, the article underscores the importance of sustainable water management practices to combat water scarcity, such as drip irrigation, rainwater harvesting, and smart irrigation systems. These approaches not only conserve water but also reduce energy consumption and greenhouse gas emissions associated with agriculture.

Key words: irrigation technologies, climate change, adaptation to climate change, water resources management, rational use, sustainable agriculture, irrigation methods, efficiency.

Introduction: Climate change is altering precipitation patterns and intensifying water scarcity in many regions, placing increased pressure on agriculture and water resources. In response, innovative irrigation technologies are being developed and implemented to optimize water use efficiency and resilience in irrigation systems [1-4]. This article reviews the current state of these technologies and their efficacy in adapting to changing climatic conditions [5-7]. In 1900, the world's irrigated area increased from 40 million hectares to more than 260 million hectares. This growth rate is about 1% per year, mainly due to the increase in food demand and population growth. Today, 40% of the world's food comes from irrigated land and 18% from cultivated land. This shows the importance of food consumption and arable land. The demand for water for irrigation will increase by 13.6% until 2025. This growth rate is high, and its main reason may be the increase in population and irrigation in agricultural areas. Water consumption is related to the requirements of plants and industry. Fresh water plays a major role in the cultivation of food. Fresh water accounts for 8-15% of water use. Only 55% of water is used by crops. This shows the low efficiency of water and how more than half of the crop production is used for irrigation [8-9].

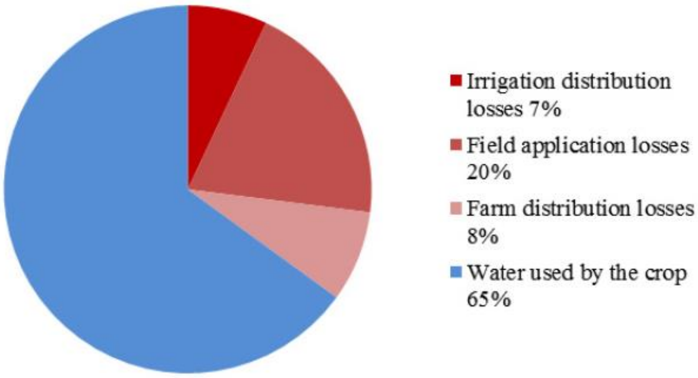

Fig 1 Water losses in agriculture

Despite the benefits of irrigation, water scarcity remains a pressing global issue. It's estimated that by 2025, around 60% of the global population could be affected by water scarcity. This means that while irrigation has enabled human habitation in arid regions, the increasing demand for water due to population growth and other factors poses significant challenges to water availability [9-10]. The sustainability of irrigation practices is crucial in addressing water scarcity concerns. Overuse and mismanagement of water resources for irrigation can lead to depletion of aquifers, salinization of soils, and ecological imbalances. Sustainable irrigation practices, such as drip irrigation and water-efficient crop varieties, are essential to ensure the long-term availability of water for agriculture and human consumption [11-13]. Given the projected increase in water scarcity, there is a growing need for holistic water management strategies that balance the needs of agriculture, industry, and urban populations. This includes investing in water infrastructure, promoting water conservation practices, and exploring innovative technologies for water reuse and desalination [14-16].

Methods: Research for this article involved a comprehensive review of literature on irrigation technologies and their applications in mitigating climate change impacts. Studies focusing on precision irrigation, drip irrigation, and other advanced techniques were analyzed to evaluate their effectiveness under varying climate scenarios.

Result and their discussion: The findings reveal that precision irrigation technologies, such as drip and micro-sprinkler systems, are highly effective in conserving water and adapting to climate variability. These systems apply water directly to the root zone of crops, minimizing evaporation and runoff. They can be coupled with soil moisture sensors and weather data to optimize irrigation scheduling based on real-time conditions. Additionally, adoption of low-pressure systems reduces energy consumption, making them economically and environmentally beneficial.

Climate-friendly irrigation technologies are essential to address water scarcity and reduce the environmental impact of agriculture. These technologies focus on optimizing water use efficiency, minimizing energy consumption, and reducing greenhouse gas emissions associated with irrigation practices. Modern water-saving technologies were studied and their effective analysis was studied.

Drip Irrigation - Technology Overview: Drip irrigation delivers water directly to the root zone of plants through a network of tubes and emitters, minimizing water loss due to evaporation and runoff. Climate Benefits: Drip irrigation can significantly improve water use efficiency, often reducing water consumption by 30-50% compared to conventional surface irrigation methods. This helps conserve water resources, particularly in water-scarce regions. Environmental Impact: By reducing water usage, drip irrigation helps lower energy requirements for pumping water, thereby reducing carbon emissions associated with energy use in agriculture.

Sprinkler Irrigation - Technology Overview: Sprinkler irrigation systems distribute water over the crops in the form of small droplets, simulating natural rainfall. Climate Benefits: Sprinkler systems can also improve water use efficiency and reduce water wastage compared to flood irrigation. They are suitable for a wide range of crops and can be automated for efficient water management. **Environmental Impact -** While sprinkler irrigation can be more water-efficient than flood irrigation, it may still have energy requirements for pumping water. However, advancements in energy-efficient sprinkler systems can help minimize this impact.

Smart Irrigation Systems - Technology Overview: Smart irrigation systems use sensors, weather data, and automated controls to optimize irrigation schedules based on real-time conditions and plant water needs. Climate Benefits: By adjusting irrigation based on weather forecasts, soil moisture levels, and crop requirements, smart irrigation systems can reduce water wastage and energy consumption. Environmental Impact: Smart irrigation technologies contribute to resource conservation by preventing overwatering and reducing reliance on fossil fuels for water pumping.

Subsurface Irrigation - Technology Overview: Subsurface irrigation delivers water directly to the root zone below the soil surface, minimizing evaporation losses and reducing weed growth. Climate Benefits: Subsurface irrigation can significantly improve water use efficiency and reduce water evaporation compared to surface irrigation methods. Environmental Impact: By minimizing soil surface wetting, subsurface irrigation can also help reduce soil erosion and nutrient runoff, contributing to improved soil health and water quality.

Rainwater Harvesting - Technology Overview: Rainwater harvesting systems collect and store rainwater for later use in irrigation, reducing reliance on freshwater sources. Climate Benefits: Rainwater harvesting reduces demand on groundwater and surface water supplies, particularly during dry seasons or droughts. Environmental Impact: By capturing rainwater, this technology helps conserve natural water resources and can be integrated with other irrigation technologies to enhance overall water management.

Climate-friendly irrigation technologies play a crucial role in sustainable agriculture by improving water use efficiency, reducing energy consumption, and minimizing environmental impacts associated with irrigation practices. Integrating these technologies into agricultural systems can contribute to climate resilience, resource conservation, and overall environmental sustainability. Ongoing research and innovation in this field are essential to further advance the adoption and effectiveness of climate-friendly irrigation technologies globally.

Precision irrigation technologies offer numerous advantages over traditional methods, especially in water-scarce regions. By delivering water precisely where and when it's needed, these systems minimize water waste and promote healthy crop growth. Furthermore, they contribute to increased crop yields and improved soil health by reducing salinization and waterlogging. However, the widespread adoption of these technologies requires investment in infrastructure and capacity building among farmers.

In conclusion, the rational use of water resources in agriculture necessitates the adoption of innovative irrigation technologies that are adaptive to climate change conditions. Precision irrigation systems emerge as promising solutions, offering increased efficiency, reduced water consumption, and enhanced resilience to climate variability. Policymakers and stakeholders should prioritize the promotion and adoption of these technologies to ensure sustainable water management and food security in a changing climate. While irrigation has played a crucial role in supporting economies and communities in arid and semiarid regions, the looming challenge of water scarcity underscores the importance of sustainable water management practices to ensure the continued viability of agriculture and human habitation in these areas.

Adaptation of irrigation technologies to soil conditions is crucial to optimize water use efficiency, increase crop productivity, and minimize environmental impact. Different irrigation methods work differently depending on soil type, texture, structure and water holding capacity. Let's see how different irrigation technologies are suitable for different soil conditions. Drip Irrigation, irrigation is highly versatile and can be used effectively in various soil types, including sandy, loamy, and clay soils. Advantages: Ideal for soils with lower water-holding capacity as it delivers water directly to the root zone, reducing water loss through evaporation and surface runoff. Considerations: Requires careful filtration and maintenance to prevent clogging, especially in soils with higher sediment content. Sprinkler Irrigation, Suitable Soil Types: Sprinkler systems work well in most soil types, provided they are not overly sandy (which can lead to water loss due to fast infiltration) or heavily compacted clay soils (which may experience runoff). Advantages: Suitable for irrigating large areas and can be used in soils with moderate to good water-holding capacity. Wind can affect uniformity of water distribution, and evaporation losses can be significant in hot, dry climates. Typically used in soils with moderate to good water-holding capacity, such as loamy soils. Advantages: Simple and inexpensive method, suitable for flat landscapes. Considerations: Not ideal for sandy soils (due to excessive infiltration and potential leaching of nutrients) or heavy clay soils (prone to runoff and soil erosion). Subsurface Irrigation, Best suited for soils with good capillary action, such as loamy or sandy loam soils. Minimizes water loss due to evaporation and reduces weed growth. Requires careful management to prevent soil saturation and root zone issues, particularly in heavier clay soils. Center Pivot Irrigation, Suitable Soil Types: Works well in flat or gently sloping terrains with moderately textured soils. Efficient for large-scale farming and adaptable to various soil types. Not suitable for very uneven terrains or soils prone to waterlogging. Mulching, Suitable Soil Types: Mulching can be beneficial for any soil type. Helps conserve soil moisture, reduces evaporation, and improves soil structure and fertility. Mulching is a supplemental practice that complements other irrigation methods and is not a standalone irrigation technology.

Conclusion: This article underscores the critical role of advanced irrigation technologies in mitigating the impacts of climate change on agriculture and water resources. By embracing these innovations, farmers can optimize water use efficiency while building resilience against the uncertainties of a warming world. Climate-smart irrigation technologies play a critical role in sustainable agriculture by improving water use efficiency, reducing energy consumption, and minimizing environmental impacts associated with irrigation practices. Integrating these technologies into agricultural systems can contribute to climate resilience, resource conservation and overall environmental sustainability. Ongoing research and innovation in this area is essential to further improve the implementation and efficiency of climate-friendly irrigation technologies on a global scale. The suitability of irrigation technologies to specific soil conditions depends on factors such as soil texture, structure, slope, and water retention capacity. Understanding these factors helps in selecting the most appropriate irrigation method to maximize water use efficiency and promote sustainable agriculture practices.

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