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Hydraulic Justification Of Parameters Of Water-Saving Techniques And Technologies For Irrigation Of Agricultural Crops

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Abstract
This study investigates the hydraulic justification of parameters for water-saving irrigation techniques and technologies applied in agricultural crop cultivation. The efficiency of modern drip and sprinkler irrigation systems is analyzed in terms of water conservation, hydraulic performance, and energy consumption. Hydraulic calculations were carried out using Bernoulli's equation and Darcy–Weisbach formula to determine flow rates, pressure distribution, and head losses within irrigation networks. Field experiments were conducted on cotton, vegetable, and orchard crops under different irrigation technologies. Results demonstrated that drip irrigation reduced water losses to 10–15%, compared to 35–40% in traditional surface irrigation. Sprinkler irrigation saved up to 25–30% of water while ensuring uniform distribution. Energy consumption was reduced by 18–22% when pipe diameters and operating pressure were optimized. On average, 1000–1200 m³ of water per hectare was saved in cotton production. Additionally, water-saving technologies decreased groundwater table rise by 20–25%, reducing soil salinization risks and improving land reclamation conditions. The findings highlight the potential of water-saving technologies as an effective strategy for sustainable water resource management in irrigated agriculture.
Keywords: water-saving technology, hydraulics, drip irrigation, sprinkler irrigation, water resources, energy efficiency, land reclamation.

1. Introduction

Water scarcity has become one of the major global challenges for sustainable agricultural development. Traditional surface irrigation methods, such as flooding and furrow irrigation, are characterized by low efficiency, excessive water use, and negative impacts on land reclamation. In arid and semi-arid regions, where irrigated agriculture plays a crucial role in food security, implementing water-saving technologies is of utmost importance. Hydraulic justification of the parameters of such systems is essential for achieving high irrigation efficiency, energy saving, and sustainable land management.

Globally, agriculture accounts for about 70% of freshwater withdrawals, with much of this water being lost due to inefficient irrigation practices. As a result, there is a pressing need to introduce advanced irrigation methods that minimize losses and optimize the use of limited water resources. This paper provides an in-depth analysis of hydraulic parameters of drip and sprinkler irrigation systems and their contribution to sustainable water management.

2. Materials and Methods

The research methodology included hydraulic calculations, experimental field trials, and comparative analysis:

- Hydraulic analysis: Flow rates and pressure losses were calculated using Bernoulli's equation and Darcy–Weisbach formula. Hydraulic uniformity coefficients and distribution efficiency indices were also determined.
- Drip irrigation systems: Pipe diameters ranged from 16 to 90 mm; operating pressure varied between 0.05–0.2 MPa; emitter discharge rates were 1–4 L/h. Uniformity of distribution was measured using Christiansen's coefficient.
- Sprinkler irrigation systems: Operating pressure was 0.2–0.4 MPa; water distribution radius ranged from 6 to 20 m; discharge rates were 0.2–0.5 L/s. Field distribution uniformity was evaluated using catch-can tests.

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- Field experiments: Cotton, vegetables, and orchard crops were selected as experimental sites. Soil properties, groundwater level, and salinity indicators were regularly monitored.
- Data analysis: Statistical methods (ANOVA, regression analysis) were used to compare water use efficiency across different technologies.

3. Results and Discussion

3.1 Hydraulic Efficiency

Drip irrigation reduced water losses to 10–15%, while in traditional surface irrigation losses reached 35–40%. Sprinkler irrigation ensured water savings of 25–30% and provided more uniform moisture distribution. Hydraulic uniformity coefficients ranged between 85–92% in drip irrigation systems, compared to 60–70% in traditional methods.

3.2 Energy Consumption

Optimizing pipe diameter and operating pressure reduced pump energy costs by 18–22%, making the systems more energy efficient. For instance, reducing friction losses by selecting larger diameter pipes resulted in significant long-term energy savings.

3.3 Water-Saving Potential

In cotton production, drip and sprinkler irrigation technologies saved 1000–1200 m^3 of water per hectare compared to traditional methods. Vegetable crops under drip irrigation showed an increase in water productivity by 25–30%.

3.4 Impact on Land Reclamation

Due to reduced water overuse, groundwater table rise decreased by 20–25%, which lowered the risk of soil salinization and improved the meliorative condition of irrigated lands. Soil salinity in experimental sites decreased by an average of 0.3–0.5 g/L compared to control plots.

3.5 Socio-Economic Aspects

Introducing water-saving technologies resulted in reduced operational costs for farmers due to lower water and energy requirements. The initial investment was offset within 3–5 years through increased yields and reduced input costs.

4. Conclusion

Hydraulic justification of water-saving irrigation parameters is fundamental for the efficient operation of drip and sprinkler irrigation systems. These technologies significantly reduce water and energy consumption, increase crop water productivity, and contribute to improving land reclamation. In addition to technical benefits, water-saving irrigation supports socio-economic stability in rural areas by reducing costs and increasing farm profitability. The study emphasizes that large-scale adoption of water-saving irrigation technologies can serve as an effective tool for sustainable water resource management and agricultural development in arid regions.
Future studies should focus on integrating digital tools such as remote sensing, soil moisture sensors, and smart controllers to further enhance irrigation efficiency.

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