Agricultural Intelligent Irrigation Decision Support System Based on Big Data

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Abstract: This article aims to explore the role and potential of agricultural intelligent irrigation DSS in meeting the challenges of traditional agricultural irrigation and promoting the sustainable development of agriculture. By constructing an intelligent irrigation system integrating data collection, processing and analysis, decision support model and user interface, this study has realized accurate control and efficient management of irrigation. The system uses Big data (BD) technology and machine learning algorithm to deeply mine and intelligently analyze multi-source data such as soil moisture, crop growth and weather changes, which provides scientific basis for irrigation decision-making. The research results show that the agricultural intelligent irrigation DSS can improve the accuracy and efficiency of irrigation, promote the transformation and upgrading of agricultural production mode, and inject new vitality into agricultural modernization and sustainable development. The use of the system is also helpful to protect water resources, reduce agricultural non-point source pollution, and promote the improvement of rural environment and the construction of ecological balance.

1. Introduction

Under the background of global climate change and increasingly tight resources, traditional agricultural irrigation methods are facing unprecedented challenges [1]. For a long time, problems such as over-irrigation, waste of water resources and low irrigation efficiency have gradually led to a serious shortage of water resources, and also aggravated environmental problems such as soil salinization and groundwater table decline [2]. With the population growth and increasing food demand, improving the efficiency and sustainability of agricultural production has become an urgent problem [3]. Under the above background, the rise of intelligent irrigation technology has brought revolutionary changes to agricultural irrigation [4-5]. Intelligent irrigation can significantly improve the utilization efficiency of water resources and reduce waste by accurately controlling water quantity and irrigation time; Individualized irrigation is carried out according to crop growth demand and soil conditions. Based on this, it can promote the sustainable development of agriculture.

At present, intelligent irrigation technology has become a research hotspot in the agricultural field, and scholars have made remarkable progress in the research and development of intelligent irrigation system, the optimization of BD processing algorithm and the construction of irrigation decision-making model [6]. In the future, with the continuous development and integration of Internet of Things, artificial intelligence and other technologies, intelligent irrigation systems will be more intelligent and accurate, injecting new vitality into the sustainable development of agricultural production [7].

The purpose of this study is to explore how the intelligent irrigation DSS based on BD can effectively meet the challenges of traditional irrigation and promote the development of agriculture in a more intelligent, accurate and efficient direction. Through in-depth analysis of the advantages, application status and future potential of intelligent irrigation technology, this study expects to provide theoretical support and practical guidance for the transformation and upgrading of agricultural irrigation and promote the sustainable development of agricultural production.

2. Construction and analysis of agricultural intelligent irrigation DSS

2.1. System architecture design

As an important part of modern agricultural science and technology, the architecture design of agricultural intelligent irrigation DSS is very important [8-9]. The overall framework of the system takes data as the core and revolves around key links such as data collection, processing, analysis, decision-making and implementation (see Figure 1).

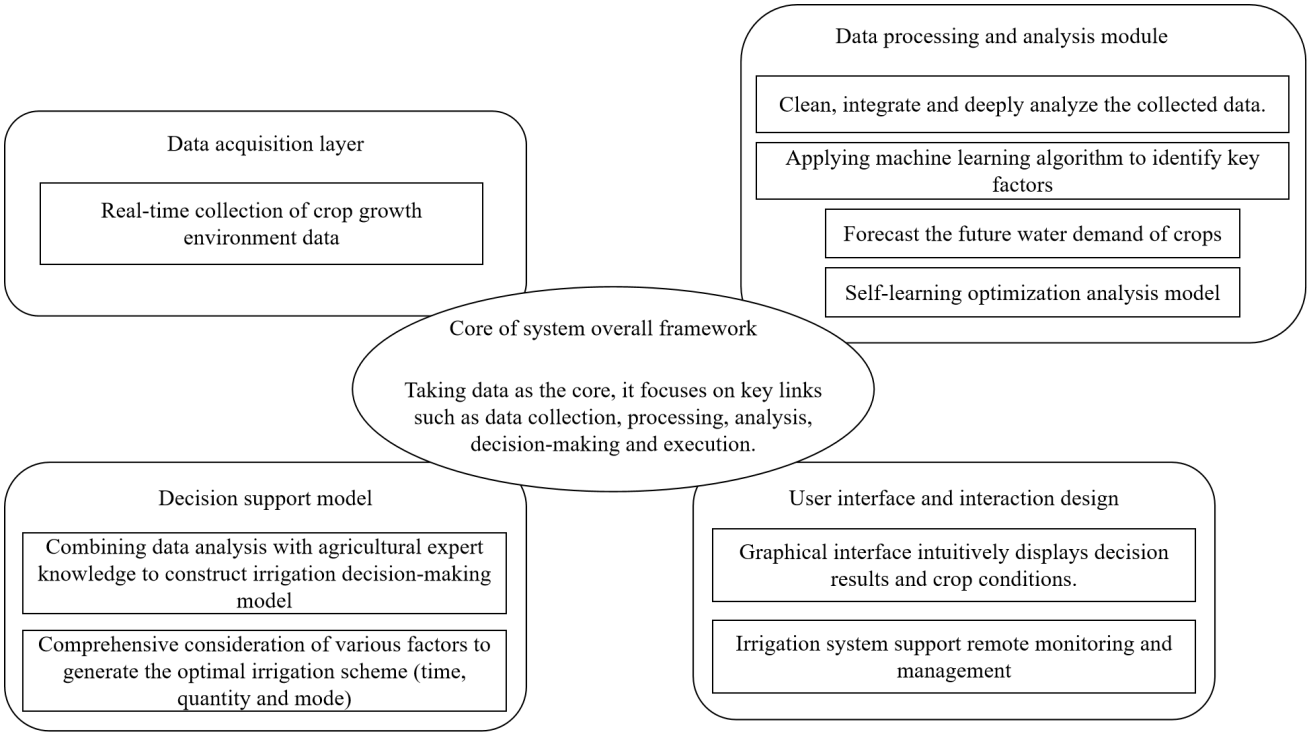

Figure 1 Architecture design of agricultural intelligent irrigation DSS

On the data acquisition level, the system collects multi-dimensional data of crop growth environment in real time through various sensors (such as soil moisture sensors and weather stations) deployed in farmland. These data include soil moisture, temperature, light intensity, rainfall and so on. They are the basis of irrigation decision-making and ensure the accuracy and timeliness of irrigation plan. Next is the data processing and analysis module. This module uses BD processing technology to clean, integrate and deeply analyze the collected massive data. By applying machine learning algorithm, the system can identify the key factors of crop growth, predict the future water demand of crops, and provide scientific basis for irrigation decision-making. The module also has the ability of self-learning, which can continuously optimize the analysis model according to historical data and real-time feedback and improve the accuracy of prediction.

Decision support model is the core of the whole system. Based on the results of data analysis and the knowledge and experience of agricultural experts, it constructs an irrigation decision-making model. The model can comprehensively consider crop species, growth stages, soil conditions, weather conditions and other factors, and automatically generate the optimal irrigation scheme. The scheme includes irrigation time, irrigation amount, irrigation method, etc., to ensure that irrigation not only meets the demand of crop growth, but also avoids waste of water resources. In terms of user interface and interaction design, the system pays attention to ease of use and friendliness. The system uses a graphical interface to visually display the irrigation decision-making results and crop growth conditions. Users can remotely monitor and manage the irrigation system through mobile APP, computer or intelligent terminal equipment, and realize the remote formulation, adjustment and execution of irrigation plan. This greatly improves the convenience and efficiency of irrigation management.

2.2. Application of BD in irrigation decision-making

The use of BD in agricultural intelligent irrigation DSS is reflected in data collection and processing, and also in its deep participation in irrigation decision-making [10]. Through the comprehensive analysis of historical irrigation data, crop growth data and meteorological data, the system can reveal the complex relationship between crop growth and irrigation. This provides a more accurate basis for irrigation decision. The use of BD technology makes irrigation decision-making no longer rely on empirical judgment, but based on data-driven scientific decision-making. It improves the precision and efficiency of irrigation, and plays a certain role in promoting the sustainable development of agricultural production.

2.3. Case study

In order to verify the actual effect of agricultural intelligent irrigation DSS, this article selects a representative area as a case study. The climate in this area is changeable, the crops are rich and the irrigation demand is complex, so it is an ideal place to test the system performance. Before the implementation of the system, irrigation in this area mainly relied on manual experience, which led to low irrigation efficiency and serious waste of water resources. After the implementation of the system, with the support of intelligent irrigation decision, the irrigation plan is more scientific and reasonable, and the irrigation efficiency is significantly improved (see Table 1).

Table 1 Comparison of Irrigation Efficiency Before and After the Implementation of the Agricultural Intelligent Irrigation DSS

Indicator	Before Implementation (Manual Irrigation)	After Implementation (Intelligent Irrigation)	Improvement Rate
Irrigation Efficiency (%)	45	75	+30%
Average Irrigation Water Volume (m^3/mu)	800	550	-31.25%
Over-Irrigation Rate (%)	25	5	-20%
Under-Irrigation Rate (%)	15	3	-12%
Water Resource Utilization Rate (%)	55	80	+25%
Crop Yield (jin/mu)	500	600	+20%
Crop Quality Improvement Rate (%)	-	15	+15%
Production Cost Reduction Rate (%)	-	10	-10%
Farmer's Income Increase Rate (%)	-	18	+18%
Labor Input Reduction Rate (%)	-	30	-30%
Agricultural Production Efficiency Improvement Rate (%)	-	25	+25%

By comparing the irrigation efficiency before and after the implementation of the system, it can be found that the intelligent irrigation system can accurately irrigate according to the actual water demand of crops, avoiding over-irrigation and insufficient irrigation, and improving the utilization efficiency of water resources. The system can also adjust the irrigation plan in time according to the weather change, which reduces the irrigation waste caused by natural factors such as rainfall. In terms of social and economic benefits, the use of intelligent irrigation system has significantly improved the yield and quality of crops, reduced production costs and increased farmers' income. In addition, the intelligent management of the system reduces manpower input and improves agricultural production efficiency. These have laid a solid foundation for agricultural modernization and sustainable development.

3. Social impact and policy suggestions

3.1. Changes in agricultural production

The wide use of agricultural intelligent irrigation DSS is quietly changing the face of traditional agricultural production. This technological innovation has greatly improved the accuracy and efficiency of irrigation and promoted the transformation and upgrading of agricultural production mode. Farmers changed from relying on traditional experience and intuition to making irrigation plans based on scientific data, which reduced the waste of water resources and significantly improved the yield and quality of crops. The use of intelligent irrigation system makes agricultural production more standardized, refined and intelligent, and lays a solid foundation for the realization of agricultural modernization. This reform has also stimulated farmers' desire for new technology and knowledge, and promoted the popularization and popularization of agricultural science and technology. It has injected new vitality into the sustainable innovation and development of agricultural production.

3.2. Rural development and environmental protection

Agricultural intelligent irrigation DSS has a far-reaching impact on rural development and environmental protection: (1) The popularization of intelligent irrigation technology has improved agricultural production efficiency, increased farmers' income and injected new impetus into rural economic development. By adopting intelligent irrigation system, farmers have reduced production costs and improved the market competitiveness of agricultural products, thus promoting the prosperity and development of rural economy. (2) The intelligent irrigation system effectively reduces the waste and pollution of water resources by accurately controlling the irrigation amount. This is of great significance for protecting water resources and maintaining ecological balance. Intelligent irrigation can also reduce the use of chemical fertilizers and pesticides and reduce agricultural non-point source pollution. This has made positive contributions to the improvement of rural environment and sustainable development.

3.3. Policy suggestions and support measures

In order to promote the wide application and sustainable development of agricultural intelligent irrigation DSS, this article holds that the government should issue a series of policy suggestions and support measures (see Table 2).

Table 2 Detailed list of government policy suggestions and support measures

Policy Recommendation Category	Specific Support Measures	Implementation Goals	Expected Outcomes
Financial Support	Establish special financial subsidy policies	Reduce costs for farmers and enterprises	Increase the enthusiasm for applying intelligent irrigation systems
	Provide research and development funding subsidies to enterprises	Promote technological innovation and upgrading	Enhance system performance and applicability
Tax Incentives	Implement tax reductions and exemptions for intelligent irrigation-related enterprises	Alleviate corporate tax burdens	Encourage enterprises to invest more resources in technological research and development
Technical Training	Establish a multi-level and multi-form training system	Improve farmers' operational skills	Enhance farmers' acceptance of intelligent irrigation technology

	Organize expert on-site guidance and demonstrations	Solve practical application problems	Accelerate technology adoption and popularization
Demonstration & Promotion	Establish demonstration fields in typical regions	Showcase technological effects and advantages	Inspire neighboring farmers to adopt similar technologies
	Host exhibitions showcasing intelligent irrigation technology achievements	Expand technological influence	Increase public awareness and trust in the technology
Information Sharing	Build an agricultural BD and intelligent irrigation information platform	Provide precise decision-making data support	Improve the scientific and accurate nature of irrigation decisions
	Promote the establishment of data openness and sharing mechanisms	Facilitate cross-domain data integration and application	Expand the application scenarios of intelligent irrigation technology
Industry-Academy-Research Collaboration	Encourage collaboration between universities, research institutions, and enterprises	Accelerate the transformation and industrialization of technological achievements	Form an innovative ecosystem integrating industry, academia, research, and application
	Establish joint research and development centers or laboratories	Strengthen technological research and innovation capabilities	Enhance the core competitiveness of intelligent irrigation technology
Standards & Regulations	Formulate technical standards and norms for intelligent irrigation	Ensure system compatibility and interoperability	Ensure the stability and reliability of technological applications
Financial Assistance	Provide financial services such as low-interest loans and venture capital	Reduce financial pressures on farmers and enterprises	Promote the widespread use of intelligent irrigation systems
Promotion & Publicity	Utilize various media channels for extensive promotion	Increase public awareness of intelligent irrigation technology	Create a favorable social environment supporting intelligent irrigation
	Organize lectures and seminars on intelligent irrigation technology	Deepen public understanding and recognition of the technology	Enhance societal confidence and expectations in intelligent irrigation technology

4. Conclusions

Through systematic and in-depth research, this article reveals the important role of agricultural intelligent irrigation DSS in improving irrigation efficiency, promoting agricultural production reform, promoting rural development and environmental protection. The research summary shows that intelligent irrigation technology can significantly improve the accuracy and efficiency of irrigation, reduce the waste of water resources and improve the yield and quality of crops through accurate data collection, processing and analysis and scientific decision support model. The use of this technology has promoted the transformation and upgrading of agricultural production mode, enhanced farmers' acceptance and application ability of science and technology, and laid a solid

foundation for the development of agricultural modernization.

Intelligent irrigation system is of great significance for protecting water resources, reducing agricultural non-point source pollution and improving rural environment. It is found that the guidance and support of government policies are very important for the popularization and use of intelligent irrigation technology, and it is necessary to further improve the relevant policy system to provide a strong guarantee for the sustainable development of technology. With the continuous progress of science and technology and the continuous support of policies, the future agricultural intelligent irrigation DSS will play a more important role in promoting the modernization of agricultural production, rural development and environmental protection, and contribute more to the sustainable development of agriculture.

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