Computers and Electronics in Agriculture xxx (xxxx) xxx–xxx

Contents lists available at ScienceDirect

Computers and Electronics in Agriculture

journal homepage: www.elsevier.com/locate/compag

Original papers

Web-based decision support system for canal irrigation management

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ARTICLE INFO

Keywords:
Web-based decision support system
Irrigation water management
Irrigation forecast

ABSTRACT

Irrigation plays an important role in agricultural production. In this paper, a Web-based irrigation decision support system (WIDSS) is designed for canal irrigation management in large irrigated districts. WIDSS has many functions including data acquisition and detection, real-time irrigation forecast, dynamic water allocation decision and irrigation information management. It uses technical methods to reduce the need for users' specialized knowledge and can also take users' managerial experience into account. As the system is developed by the Browser/Server model, it is possible to make full use of the Internet resources and to facilitate users at any place with access to the Internet. Two years' application in the Zhanghe Irrigation System (Central China) indicates that the proposed WIDSS can achieve promising performance for canal irrigation.

1. Introduction

China is facing severe water scarcity while the demand keeps increasing and distribution of water resources is spatially and seasonally uneven. Although the total fresh water volume in China is large in absolute value, ranking sixth in the world, the per capita water resource is only 25% of the world average. In the past 10 years (2006–2015), the Chinese average total water consumption was 601.4 billion m^3, 62.5% of which is agricultural water consumption ("China Statistical Yearbook-2015," 2015). Therefore, conserving water in agriculture is important for both water and food security for China.

With urbanization and enhanced living standards, the amount of water used for domestic and industrial purposes has also increased (Peng, 2011). Increasing the efficiency of water use in irrigation practice is important for ensuring the sustainable development of agriculture. However, the lack of practical methods of irrigation management results in substantial waste of irrigation water and labour. Surface irrigation using canals is the main method of water application in paddy rice irrigation systems in Southern China. Owing to the constraints of canal water delivery capacity, irrigation often has to be rotated, and it usually takes several days to complete one round in a large irrigation system. Uncertainty of rainfall and difficulty of monitoring overall field water availability complicate the irrigation practice. Unexpected rainfall and underestimated actual field water availability will lead to the wastage of labour, water, and energy.

An irrigation decision support system is a platform developed for irrigation water management. It can improve irrigation efficiency and reduce labour inputs in daily irrigation management with a few added engineering services. Furthermore, adopting the latest technology in agricultural practice is also meaningful. The influence of rainfall uncertainty on irrigation decisions can be improved with the help of weather forecast information (Gowing and Ejieji, 2001). Daily reference evapotranspiration (ET_0) prediction using the public weather forecast information can be adopted for real-time water allocation and irrigation management (Cai et al., 2007, 2009; Luo et al., 2014). Weather forecast information can be produced by many public websites. In China, Weather China (www.weather.com.cn) can provide weather forecast data including weather type, wind scale, and maximum and minimum air temperatures. These data are provided daily for many cities in China for up to 15 days ahead, which is sufficient for a real-time irrigation scheduling trial. The decision to initiate irrigation should consider knowledge of true field water availability (soil moisture and ponding water) in the whole area. The practice of utilizing sensors and their networks is a positive step for agriculture (Abbasi et al., 2014). Distributed in-field sensor-based irrigation systems offer a potential solution to support site-specific irrigation management that allows producers to maximize their productivity while saving water (Kim et al., 2008; Kim and Evans, 2009). However, the integration of distributed in-field sensors, software design, data interface, and communication can be challenging.

Many irrigation decision support systems have been developed with different emphases in the past 20 years. Scheme irrigation management information system (SIMIS) was developed in 1993 to assist managers in their daily tasks (Mateos et al., 2002). Pl@nteInfo® was developed on the Internet to provide personalised advice to farmers and advisers in real time based on information across platforms (Jensen et al., 2000).

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https://doi.org/10.1016/j.compag.2017.11.018
Received 2 September 2017; Received in revised form 10 November 2017; Accepted 12 November 2017
0168-1699/

Table 1
Project data requirement description.

	Items	Data acquisition approach					Refresh rate		
		Local managers	Experiments	Field survey	Sensors	Internet	Hourly	Daily	Yearly[a]
1. Meteorological data	1.1 Weather station data	√						√	
	1.2 Weather forecast data					√		√	
2. Engineering information	2.1 In-field monitoring station locations and codes			√					√
	2.2 Canal length & default rotational irrigation group	√							√
	2.3 Canal net irrigation area & conveyance losses	√		√					√
3. Crop and soil characteristics	3.1 Crop distribution details	√		√					√
	3.2 Crop water demand calendar & crop coefficient	√	√						√
	3.3 Soil distribution and corresponding infiltration data	√	√	√					√
4. Real-time data	4.1 In-field monitoring data				√		√	√	

[a] The data only need a yearly check. Updates will only be needed in cases with construction activity or a change in farmers' cultivation techniques.

However, it is more suitable as an information management system, as the decision support model needs further development. WISE was created as a tool based on daily water balance that users can operate without professional aid and can also apply their own expertise (Leib et al., 2001). It introduced a feasible framework to develop this type of model further. AQUAMAN used the FAO-56 guidelines and the APSIM peanut model to assist with irrigation management for peanuts and showed good performance in improving irrigation water use efficiency (Keating et al., 2003; Chauhan et al., 2013). Thysen and Detlefsen (2006) developed an entirely Web-based system in terms of input of farm and field data, automatic supply of weather data, and advice consulting. The system had 322 active users in 2004 and 490 in 2005. Fernandez and Trolinger (2007) fully discussed the structure of a Web-based decision system and offered a simple online system for crop managers. Flores et al. (2010) developed a dynamic decision support system (DDSS) called INNOVA RIEGO based on the formulation and integration of three components: a dynamic-relational data base, an administrator model, and a graphical user interface. It was applied in an orange orchard and assisted the decision-making process effectively. A risk-based online decision support system for the operation and management of agricultural water was developed to support the preliminary step of irrigation water decision-making, aiming at evaluating the water delivery performance of irrigation canals (Hong et al., 2015). Different systems have diverse emphases for the given objectives and physical conditions. Constant research on the irrigation decision support system makes the structure more explicit and the function more diverse. However, researches seldom consider using the platform to integrate automatic data acquisition, complicated computing process encapsulation, and input and output (IO) graphical display. Managers only need to follow an operation process, perform confirmations, and make decisions. A more intellectualized decision support system should reduce the workload of the user and simplify comprehension for operation.

The different systems listed above contain both online systems and stand-alone PC programmes. As the Internet technology advances, it is important to provide up-to-date website building technologies and excavate useful information for a more scientific and user-friendly irrigation decision system. This paper presents a Web-based decision support system for canal irrigation management (WIDSS). The WIDSS model is based on water balance approach for both lowland paddy and upland crops. Considering a basic database for different crops' water demands in the whole growth stages and irrigation system engineering information, the WIDSS can make efficient decisions for water allocation with the help of real-time, in-field moisture detection and weather forecast. This system uses technical methods to reduce requirements of a user's specialized knowledge and can also take a user's managerial experience into account. As the system is developed by the Browser/Server model, it is possible to make full use of the Internet resources and to facilitate users at any place with access to the Internet. Two years' application in the Zhanghe Irrigation System (Central China) indicates that the proposed WIDSS can achieve promising performance for surface irrigation.

2. System design

The WIDSS is based on a stand-alone PC programme, available since 2003 (Cai et al., 2003). The early version was developed in VisualBasical6.0, which must be installed on the computer. The Internet version (WIDSS) has experienced several modifications and upgrades, mainly focusing on aspects of the inputs and developing platform. Input data updates automatically from in-field monitoring stations, the database of the meteorological station, and the public weather forecast website. This makes the operation easier and more intelligible. A Web-based version provides in-field data displayed with geographic information, makes upgrades more convenient, and allows users to easily access the system at any place with Internet access.

2.1. Data requirement

The project data are organized into four main categories related to meteorological data, engineering information, crop and soil characteristics, and real-time data (see Table 1).

Weather station data can be divided into historical data and recent data. Meteorological data from the past 30 years can been obtained from irrigation experiment station located in the catchment, and are used for model parameter calibration and validation. Recent data can be acquired from the administration's server. Weather forecast data come from Weather China (www.weather.com.cn). This public weather forecast data can be obtained automatically through a regular expression match using the PHP language in the server.

Engineering information data will not change frequently, which contains in-field monitoring station locations and codes, canal length, default rotational irrigation group, canal net irrigation area and conveyance losses. It comes from detailed design reports and operating experience of canals and monitoring stations. Crop and soil characteristics data depend on field investigation and experiments. A great deal of preliminary work (field investigation and experiment, material collection) is required before the software development.

These data are stored in the system in advance or will be obtained by the server automatically to reduce the workload of users and simplify use. The basic data that do not change frequently, such as engineering information data, crop and soil characteristics data, and