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Web-based irrigation decision support system with limited inputs for farmers

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ABSTRACT

The increasingly serious water crisis requires all water users to participate in the water saving action. The majority of scattered smallholder farmers are in the disadvantage position of information. It is difficult for them to obtain the guidance of scientific irrigation. In order to satisfy the demands of farmers in North China Plain (NCP), a web-based irrigation decision support system with limited inputs (WIDSSLI) is presented in this paper. WIDSSLI is based on the Brower/Server mode and includes user interfaces (UIs) for farmers and administrators, models, database and a weather data update system (WDUS). FAO-56 dual crop coefficient approach is adopted to simulate the soil water balance of different layers. Without in-field soil moisture monitors, the model is started from the earliest day of these days while crops are sowed or the cropland is irrigated, and soil water depletions of all layers are initialized with 0 at the beginning. Using online weather forecast, future irrigation decision is obtained by the comparison between the field water availability simulated by the system and the lower limit of the soil moisture for irrigation. By which, farmers can obtain the irrigation decision support: when irrigation is needed and how much water is required. Verification results shows that the system initialization method is reasonable, and WIDSSLI can accurately simulate the dynamics of soil water content. WIDSSLI is deployed in the internet, and its mobile version is also developed for ease of use.

1. Introduction

Irrigation has been a priority for agricultural production in arid and semiarid regions due to the great difference between precipitation and crop water requirement. Agricultural water consumption increased dramatically in the past decades to meet the growing food demand and insure the food security. Additionally, because of the urbanization and the improvement of living standard, domestic and industrial water consumption increased and amount of water were allocated to non-agricultural uses. Agriculture water shortage becomes a great issue in terms of limited water resources (Peng, 2011). However, agriculture is still the largest user of water and irrigation water cannot be reduced simply without the risk of food security (Kang et al., 2017). To reduce the wastage of water, energy and labor caused by extensive irrigation, there is an urgent need to improve agricultural water productivity.

Irrigation decision support system (IDSS) can provide scientific and reasonable suggestions for efficient irrigation management (Wang et al., 2017). IDSSs have been extensively studied and developed in the past 20 years in many domains of agriculture water management. Based on a simple water balance model Mateos et al. (2002)) developed a scheme irrigation management information system (SIMIS) to improve irrigation efficiency. Using a bio-decisional model and a spatial database, ADEAUMIS simulation platform can provide real-time water management based on daily timescale, and can even be used under extreme weather conditions (Leenhardt et al., 2004a, b). MIRRG was developed to provide guidance on the design and evaluation of micro-irrigation systems by integrating the optimization model, technical, economic and environmental criterias together (Pedras and Pereira, 2004; Pedras et al., 2009). Due to the fact that IDSSs can only be used in special areas or particular crops, Yang et al (Yang et al., 2017) developed a flexible decision support system for irrigation scheduling (FIS-DSS). CropWat, developed by FAO, is a widely used decision support tool for water management in many countries, yet it is regarded more suitable as a research tool due to the required parameters, operation complexity and system functions (Guo et al., 2016; Song et al., 2016).

The maturity of internet has expanded the function of IDSS and provides potential for farmers to get access to the software. Many web-based IDSSs were therefore developed. Based on collaborating web

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servers and subscription system, Pl@nteInfo was developed to provide real-time user-tailored advice to farmers according to the information from different distribution sources (Jensen et al., 2000). Washington Irrigation Scheduling Expert (WISE) supports cross platform operation and real-time data (e.g. weather data) updating, the producer-oriented design makes it user-friendly and can be used without the guidance from consultants (Leib et al., 2001). As an online decision support system for irrigation, PlanteInfo Irrigation Manager can provide farmers with irrigation advice and explanation in the forms of tables and graphics (Thysen and Detlefsen, 2006) after the irrigation manager inputs required field data and the farmer initiates the system. Based on water balance model and supported by real-time in-field monitoring stations (Wang et al., 2017), WIDSS is a Web-based decision support system for canal irrigation management and can utilize the network resources maximally.

Agriculture water use occupies nearly 62.5% of the total water consumption in China in the past few years (China, 2016), thus, plays a key role in influencing water security. However, not much research focus specifically on the practical application of IDSS, and the knowledge of irrigation water management must be improved. With the impact of rural household contract responsibility system, arable land was divided into small plots. Family-based diversified small-scale operation therefore hindered the investment of modern agricultural equipment. Even the soil moisture sensor, which is required by most IDSSs for the model initialization, can hardly be found in the field. Additionally, information needed by IDSSs, such as soil water content and irrigation amount, cannot be obtained from farmers. Furthermore, little knowledge about software or inaccessible to internet from farmers impose restrictions on the application of IDSSs. What mentioned above motivate the need for developing a simplified and user friendly decision support system.

In this paper, a Web-based irrigation decision support system with limited inputs (WIDSSLI) was developed to support the family diversified irrigation management in North China Plain (NCP). With winter wheat/summer corn rotation system as the target, this decision support system was implemented using the Browser/Server mode. By comparison between soil water balance simulated by the WIDSSLI and the lower irrigation limits of crops at different stages, decision-making supporting information for irrigation can be obtained. By using internet or smartphone, farmers can easily get the support of scientific guidance on when to irrigate and how much water is required.

2. Method

2.1. System structure

The structure of the WIDSSLI is shown in Fig. 1. There are three components deployed on the server side: UI, models and database. Farmers live in any place can get access to the UI of WIDSSLI via web browsers through the internet. UI includes 4 steps (webpages). The first and second step get the information of cropland by the interaction with farmers, thus providing the filter conditions to select the parameters from database for the models. Then the soil-water dynamic is simulated by the soil water balance model, and the results (current soil moisture and irrigation requirement) are shown in the third webpage. The fourth step provides the forecast of the irrigation in the near future. The models are run in the server side and simulation results are sent to the farmer's browser. Because farmers can only provide very limited information, much work must be done by the administrator of WIDSSLI. Parameters setting interface is further provided for the administrator to update the database online. Weather data update system (WDUS) is developed to download weather data from available internet sources everyday automatically.

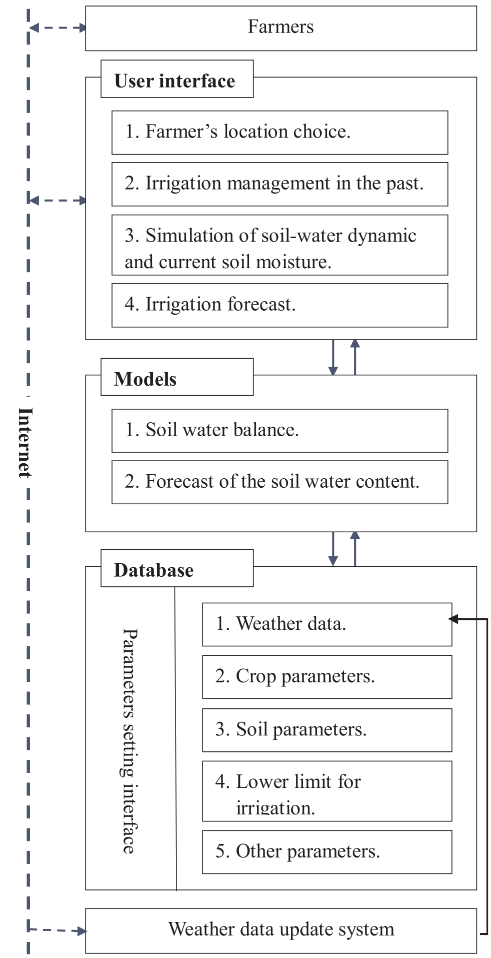

Fig. 1. System structure of WIDSSLI.

2.2. Data requirements

WIDSSLI is designed for irrigation management of winter wheat and summer corn in the NCP (Hebei Province), and five types of data (Fig. 1) required by the system are stored in the database.

2.2.1. Weather data

Maximum, average and minimum air temperature (°C), average wind speed (m/s), relative humidity (%) and precipitation (mm/d) data are required for calculating evapotranspiration (ET) which is taken as water loss in the soil water balance model. To get weather data from as many weather stations as possible, WDUS was developed and installed on the server. There is a table embedded in the system and information of the available weather stations are stored in it in the form of name, longitude, latitude and URL. The weather stations mainly come from weather bureau of Hebei Province, China national ecosystem observation and research network, and NOAA's National Climatic Data Center (NCDC). Weather data of these stations are stored in different formats and units. WDUS downloads the data from URLs at midnight while the server is free. All the data are converted to specific format and reference evapotranspiration (ET_o) is calculated using the method of Hargreaves (Liang et al., 2008) at the same time. The processed data are stored in the database of the weather station.

Since there may be several days' delay in weather data updating in some weather stations, daily average values of these weather data in the past five years are calculated for these weather stations and stored in database respectively. When WIDSSLI is started, the missing data are replaced by these average values.