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A flexible decision support system for irrigation scheduling in an irrigation district in China

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ABSTRACT

Decision support systems for agricultural irrigation scheduling are generally designed and developed for specific agricultural regions or irrigation districts. Flexible irrigation scheduling decision support tools which are applicable to various irrigation districts are desired for sound agricultural irrigation planning and management. This study attempts to develop a flexible irrigation scheduling decision support system (FIS-DSS) which could be easily customized and adapted to different irrigation districts and cases, and thus repeated software development is not needed. The developed FIS-DSS includes a user interface, a knowledge base, and an inference engine. As the core module of the FIS-DSS, the inference engine uses specific computer programs to maneuver the knowledge base, and the knowledge base was used to store and provide data, knowledge, information and rules for the inference engine. As the core of the FIS-DSS, a fuzzy interval programming model with multiple objectives and constrains was developed with advantages in data processing, model flexibility, alternative solving algorithm and friendly result display. The system users can obtain suitable water allocation schemes for each crop on a temporal and spatial fashion by modifying the model inputs and scenarios through the software interface. A case study was introduced to demonstrate the functions and operations of the FIS-DSS, and useful information has been generated to provide a practical guidance for agricultural water allocation and utilization.

1. Introduction

In the past two decades, water supply shortage has become a growing concern and serious issue for many provinces in China associated with their fast socio-economic development (Zhi et al., 2016). For feeding explosively growing population on earth, the demand for domestic water uses and food production has increased dramatically, which raised the major conflicts between the competing water users (Oad et al., 2009). Agricultural irrigation is one of the major water users in many countries across the world and is now facing intense competition with other major water users, such as industrial sectors. In agriculture irrigation systems, it is important to improve the processes for the rational use of water resources, and to achieve high productivity per unit water use (Maia et al., 2012). Although China has a large agricultural population and a long history of agricultural production, its water use planning for irrigation districts is based on experiences through using the crop areas and estimated unit irrigation quota to calculate the total irrigation amount. In the past, the scientific decision support tools with the integration of multiple techniques and economic framework have been widely used for providing scientific and reasonable decisions for managers in different fields (Karamouz et al., 2014). However, it is very limited in China in developing and using such decision support tools for agricultural irrigation scheduling and planning. The lack of such decision support systems (DSSs) has caused many difficulties for local managers in seeking effective water use planning and management alternatives (Huang et al., 2009).

The use of DSSs for agricultural applications is plagued with high complexities due to the interactions among various system processes and factors such as meteorological conditions, types of pastures, poultry, and crop, and soil conditions (Tanure et al., 2013). For example, the major factors that affect the growth of wheat include environmental factors (such as climate variability, soil type and water condition, N- and P-content in soil, and fertilizer application) and biological factors (such as variety phenology, planting time, frost risk, and weed infestation) (Woodruff, 1992). To deal with these complexities, professional DSSs have developed the optimization models as their core modules to generate optimal

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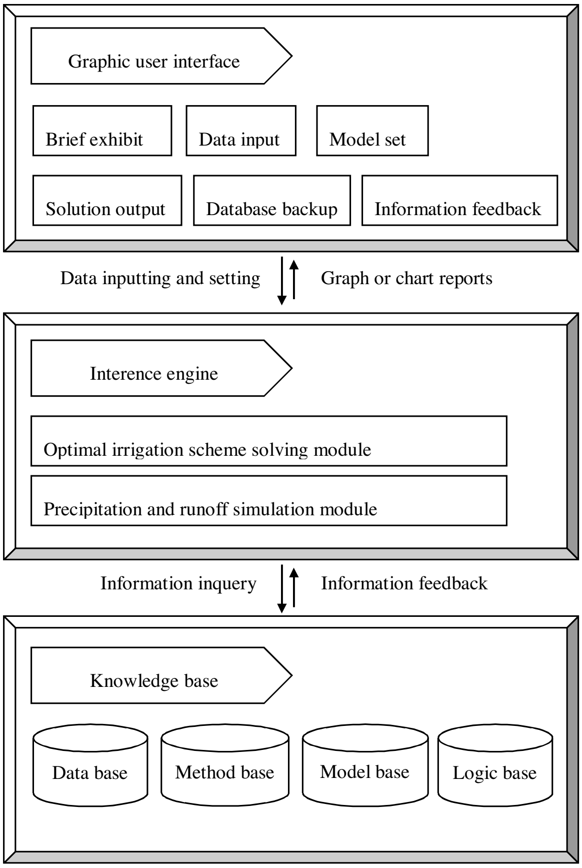

Fig. 1. The FIS-DSS – A flexible DSS for irrigation scheduling. The arrows show the direction of information flow.

irrigation water allocation schemes for practical applications. For example, Pedras and Pereira (2009), Pedras et al. (2009) developed a decision support system (DSS) for the design and evaluation of micro-irrigation systems and the developed DSS was applied to a citrus orchard of Algarve (Portugal). Leenhardt et al. (2004a,b) presented a simulation platform ADEAUMIS for improving agricultural water uses and management in years under extreme climatic and hydrological conditions and it was successfully applied to south-western France in 1998 and 2000. This ADEAUMIS included a bio-decisional model and a large data base composed of irrigated area, weather data and agricultural practices. Nain and Singh (2016) developed a DSS which was used in the hilly regions of Indian to obtain appropriate decisions on selection of cultivar, sowing time, irrigation, fertilization and harvesting of crops. One difficulty in developing optimization models for DSSs is the high computational requirement from solving large-scale optimization problems (Galelli et al., 2010). Recently, with the rapid development of computer, numerically intensive approaches to nonlinear modeling have become feasible to solve large-scale optimization problems (Young, 1998). For example, Monte Carlo simulation is such a manner through a low-order, computationally efficient model identified from the original large model for computationally intensive applications (Castelletti et al., 2012). In general, simplifying the optimization model is an alternative method to avoid complexity caused by computational requirements.

DSS tools have also been used for agricultural applications in the past. Generally, previous DSSs for irrigation scheduling were developed for specific areas and/or particular crops. The optimization models, as the core module of the designed DSSs, were usually formulated with three characteristics, which might bring constraints and limitations of the developed DSS to other real-world application cases. Firstly, specific objectives or goals were usually designed and formulated for the study cases, which are commonly designated as the economic returns, such as maximizing the crop production, maximizing the value added under water resources constraints, and maximizing the total system benefit under limited water resource availability for irrigation to different areas (Tanure et al., 2013; Guo et al., 2014; Gu et al., 2013; Li et al., 2014a). Since these objectives (goals) were pre-designed and fixed into the system and could not be modified, this could make the models themselves unsuitable to other applications.

Secondly, the DSSs were generally developed for specific application cases and areas. For example, an agricultural DSS that was developed by Ritaban et al. (2014) was applied to Tasmania area in Australia, and this DSS includes a variety of specific environmental data, such as meteorological factors and available water capacities. An agricultural water and nonpoint sources pollution manage-

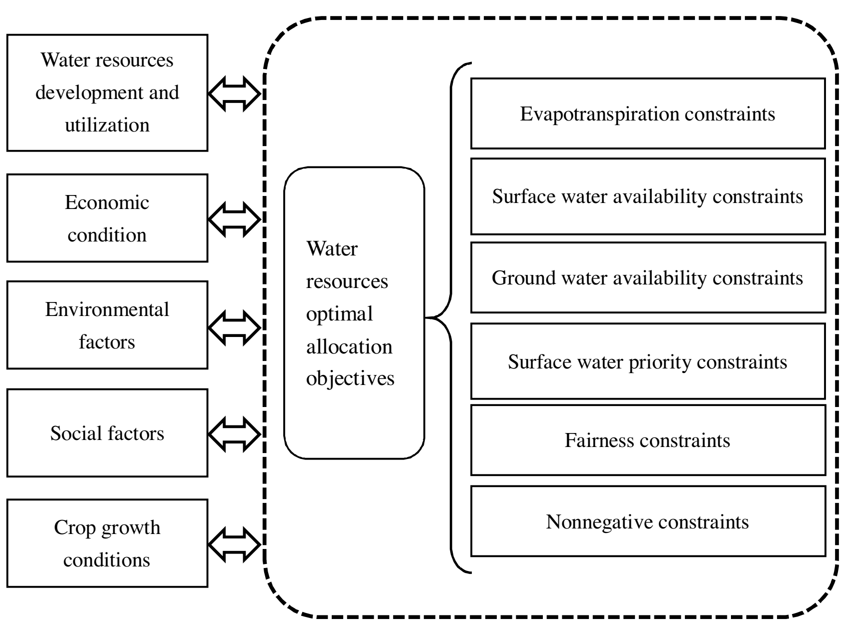

Fig. 2. Modeling framework.