Greenhouse Irrigation Optimization Decision Support System

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Abstract. Greenhouse irrigation optimization decision support system (GDSS) is developed for the irrigation management of greenhouse crops in the northwest arid area of china. GDSS forecasts on relative yield and aids to develop irrigation schedule in terms of growth periods, comprehensively considered soil, crops and water supply conditions. The system consists of three modules. The database module stores all kinds of data using the Access database. The model module includes optimization models of greenhouse crops under insufficient irrigation based on uncertainty. These models are programmed by lingo, which can be invoked through internal interface. The man-machine dialogue module is designed with the principal of user control, user-friendly, visuality, usability, conciseness and uniformity. The GDSS can provide the decision makers the alternative decision making under uncertainty.

Keywords: Decision support systems, Greenhouse irrigation optimization, Man-machine dialogue, Uncertainty

1 Introduction

In the northwest of China, the available water resources is less than 2200 m^3 per capita, only one quarter of the world average level[1]. The agricultural water consumption accounts for approximately 70% of the total water uses. Improving irrigation management is most likely the best option in most agricultural systems for increasing the efficiency of water using so as to mitigate the shortage of water resources [2]. At present, an effective method to improve management efficiency is applying the modern technology particularly Computer and Database in agricultural irrigation management.

As efficient tools for improving management efficiency, Decision support systems (DSSs) are relatively new disciplines that have emerged from the development of earlier management information systems (MIS) which are data oriented and, for the most part, simply a means of retrieving data from large databases grounded on selected queries. This new discipline focuses on the design and development of DSSs, while at the present time there is a solid conceptual footing and increasing number of applications that demonstrate their importance and efficiency in aiding management

[3]. DSSs involve computer software and hardware, information theory, artificial intelligence, management science, and many other disciplines. DSSs are uesd to solve semi-structured and un-structured problems that cannot normally be expressed in unambiguous formulas [4]. Besides, DSS can effectively improve the decision-making ability of managers, as well as enhance the scientific of decision-making and the degree of information, especially for complicated management systems such as sustainable planning systems of rural area and irrigation management system.

A series of decision support systems for resource management have been developed, regarding the comprehensive planning of socioeconomic development and eco-environment protection, [3,5,6]. With the extensive application of uncertainty methods in optimization management, more and more uncertainty models have been put into above management systems, for example, UREM-IDSS[5] has been developed based on an inexact optimization model to aid decision makers in planning energy management systems. In the field of irrigation, [6] developed an integrated scenario-based multi-criteria decision support system (SMC-DSS) for planning water resources management in the Haihe River Basin. [7] developed the software for water-saving irrigation management and decision support system in the light of the complexity and real-timeliness of water use management in farmland irrigation.

In the northwest arid area of china Greenhouse has been widely applied because of the characters as energy-saving and manageable, hence, study on DSSs for optimal management of greenhouse irrigation is significant to alleviate water scarcity. [8]designed an expert system for mini-watermelon culture management in greenhouse based on the growth model was developed, the system was designed to help agronomists and famers to make strategic and tactical decisions. [9] introduced a decision support system for greenhouse constructed with data warehouse and data mining technology considering most of expert knowledge in agriculture is descriptive and experiential.

In the aspect of greenhouse irrigation optimization, A lot of experiments and research have been carried out, the theories of water consumption efficiency pattern, water use and optimal irrigation schedule of tomato[10], watermelon[11],muskmelon and hot pepper[12]of greenhouse in arid northwest China are pretty mature. However the application of these results is relatively limited because the knowledge is too complex for most of decision makers and a large part of theories are aimed at a given area and specific crops.

The above-mentioned research results indicated applications of DSSs and uncertainty methods in the field of water resource management are significant and commendable. A majority of useful and valuable theories regarding irrigation water management and allocation should be applied more widely. In this paper, consequences in the form of interval would recommended to decision makers as a result of applying uncertainty methods to a crop-water production function-Jensen model. Moreover, a greenhouse irrigation decision support system developed in this study is developed which is a further application of existing associated irrigation theories of water consumption efficiency pattern, water use and optimal irrigation schedule ,and is able to provide alternative decision makings scientifically and comprehensively for decision makers. Through reducing less important variables and keep relative significant variables as well as updating experimental data of representative areas, GDSS is applicable for the northwest arid area of china including where lack measured data.

The aim of this study is to build a common uncertainty based irrigation optimization model for greenhouse crops on the basis of existing associated irrigation theories, use the actual greenhouse irrigation experiment data and corresponding analysis results as references, and develop a greenhouse irrigation decision support system to provide alternative irrigation schedules for decision makers through comprehensive scenario analysis and an user-friendly graphical user interface (GUI).

2 System design

Greenhouse irrigation optimization decision support system (GDSS) is developed for the irrigation management of greenhouse crops in the northwest arid area of china. GDSS forecasts relative yield and aids to develop irrigation schedule in terms of growth periods, comprehensively considered soil, crops and water supply conditions. The system contains meteorological data outside the greenhouse and all kinds of experimental data inside the greenhouse in Shaiynghe River Basin from 2008 to 2011.GDSS is based on the interval optimization model of greenhouse crop under insufficient irrigation, which Fig out relative yield interval and water consumption interval of each growth period, and recommend an optimal irrigation procedure according to the soil and crop parameter and water supply conditions input by the users. Furthermore, scenario analysis of a series of information include the relative yield, water consumption and irrigation schedule according to the experimental data and User's input will presented thus to provides decision makers a clear comparison between all the circumstances so as to aid decision making efficiently. Fig1 demonstrates the system architecture.

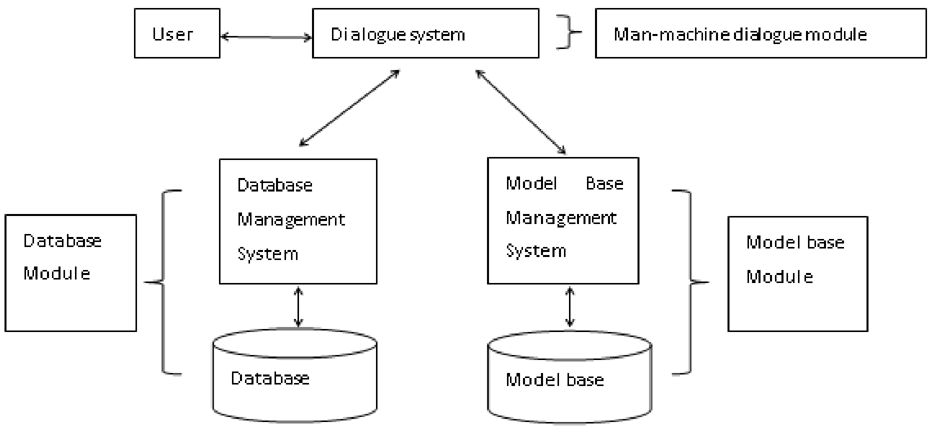

Fig. 1. System architecture

3 Database module

The database module is responsible for the retrieval, updating and visualization of the information required, and is composed of a database and a database management system. The database is designed and implemented to represent all the relevant data, while the data management system comprises the software required to create, access and update the database [13].

All these data can be divided into two classes, one is static data from Shiyanghe River Basin, which is stored in Access database, and exit in the form of data table of data set. Consequently, database operations can be performed even disconnecting from the database. We use ReportViewer control to display chart, line graph and histogram in graphic user interface. Another data class is dynamic data consist of user input and calculated results. Data structure is showed as Fig2.

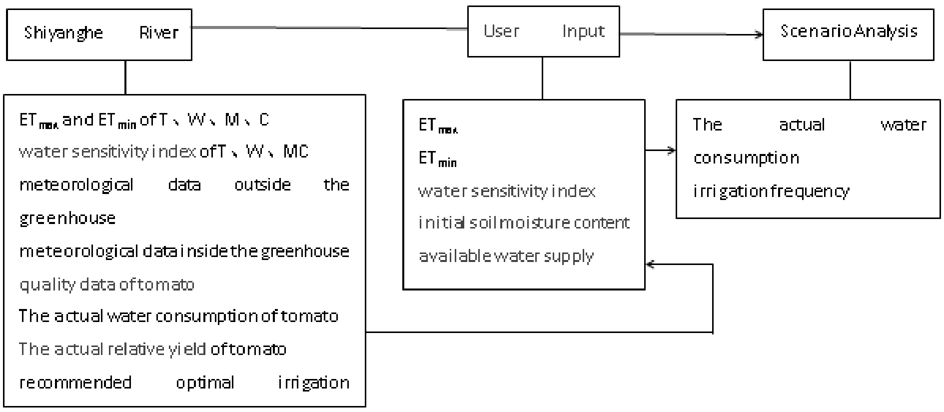

Fig.2.data structure

4 Model module

4.1 Overview of model

The optimization model of greenhouse crop under insufficient irrigation(OMGII) is based on the crop-water production function-Jensen model, which is structure logical and has been widely used in arid area in China [14]. With the consideration of uncertainty exit in formulating the insufficient irrigation schedule of greenhouse crops, the maximal evapotranspiration(ET_{max})and minimum evapotranspiration(ET_{min}) are set as interval value, therefore, the consequences of this model are interval number, which provides users with a reference range. The final model is as follows:

Object function:

$$\max f^{\pm} = \frac{Y^{\pm}}{Y_{\max}^{\pm}} = \prod_{i=0}^{n}\left(\frac{ET_i^{\pm}}{ET_{\max i}^{\pm}}\right)^{\lambda_i} \tag{1}$$

The object of OMGII is to maximum the relative yield. Where Y is actual yield, Ymax is the yield under sufficient irrigation, n is growth stages, a stage variable, ETi is the actual water consumption of each growth stage, mm, ETmaxi is the maximal water consumption, mm, λi is water sensitivity index,

Constraint condition：

$$W_i = 1000\gamma H_i\left(\theta_i - \theta_{\min}\right) \tag{2}$$

Where Wi is the effective water available for crop at stage i, a state variable, mm, Hi is the depth of design root zone, mm, θi is average soil water content, g/g, θ0 is the initial soil moisture content θmin is the lower limit of soil water content, g/g, γ is the soil dry density, g/cm3.

$$ET_i^{\pm} = W_i - W_{i+1} + m_i^{\pm} + P_i + G_i \tag{3}$$

Equation (3) is a state transition equation indicating water balance process, where P_i is the effective precipitation, mm, G_i is irrigation quota, mm, m_i is irrigation water amount, decision variable, mm.

$$Q_{i+1}^{\pm} = Q_i^{\pm} - m_i^{\pm} \tag{4}$$

Equation (4) is a state transition equation indicating water distribution process, where Q_i is increment of ground water, mm.

$$m_i^{\pm} \le Q_i \tag{5}$$

Equation (5) is an irrigation quota upper limit equation.

$$ET_{\min i}^{\pm} \le ET_i^{\pm} \le ET_{\max i}^{\pm} \tag{6}$$

Equation (6) indicates the bound of actual water consumption.

$$\theta_{\min} \le \theta_i \le \theta_f \tag{7}$$

Equation (7) indicates the bound of average soil water content.

$$m_i^{\pm} \ge 0, \forall i \tag{8}$$

Equation (8) is the variable nonnegative constraint.

4.2 Model linkage

Above model is programmed by lingo, which supports programming in the form of dynamic linking library. On the basis of different number of growth period, two lingo programs are written. After sufficient case tests, by changing the file input output function to @pointer(n) and corresponding address defined in C#, it is able to transmit data from shared memory directly.

5 Man-machine dialogue module

5.1 System flow

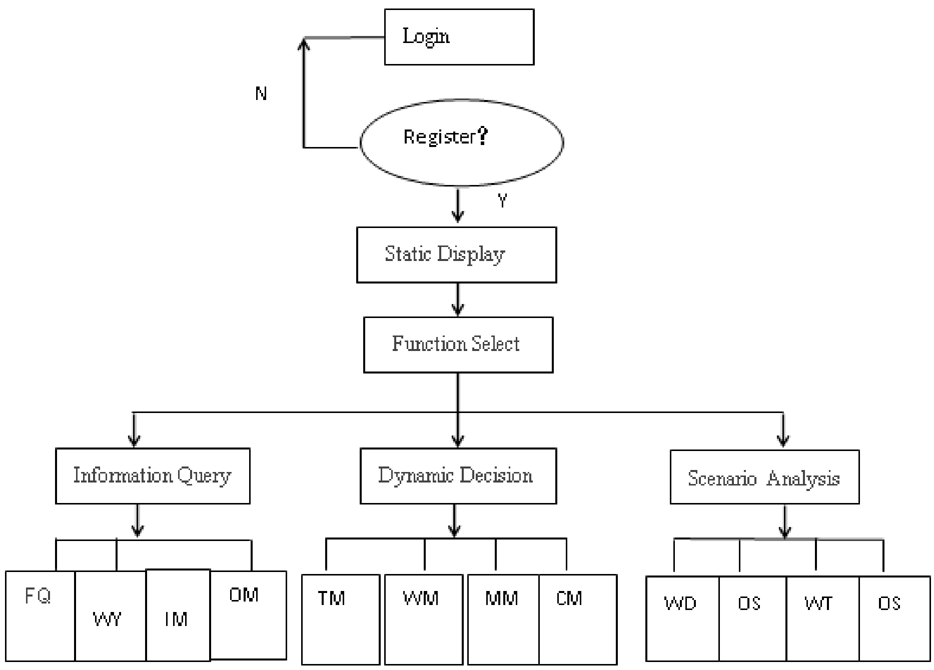

Fig.3. System flow

5.2 GUI and functions

By double-clicking the icon of the GDSS, the user can enter the system's login interface (Fig 4). After register an ID and check username and password, the user can enter Static display interface (Fig 5). Technical route, system function, framework, system flow, model can be displayed by clicking on buttons in the left side of static display interface.

Fig.4.login interface

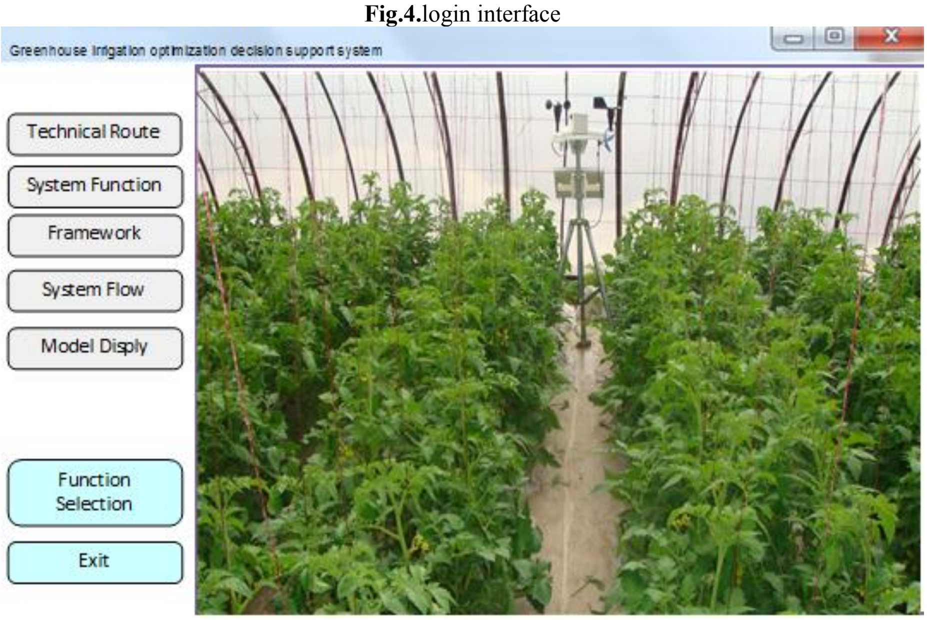

Fig.5. static display interface

Users can access a function selection interface (Fig 6 by clicking on Function Selection button, this interface consists of three buttons corresponding three important functions of GDSS.

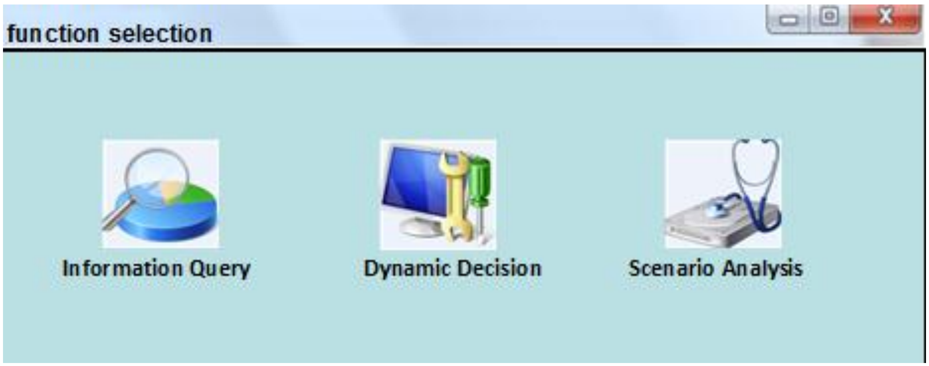

Fig.6.function selection interface

(1)Information Query

With the selection of Information Query, there entrance an information query interface (Fig 7), there are four parts as showed in Fig7, each of them includes two areas. The left area provides user Listbox for select time or district and checkbox for multiple selection of correlation parameters, as well as buttons for select display format of data on the report area on the right side. In addition, the report area on the right side has export capabilities for export useful data.

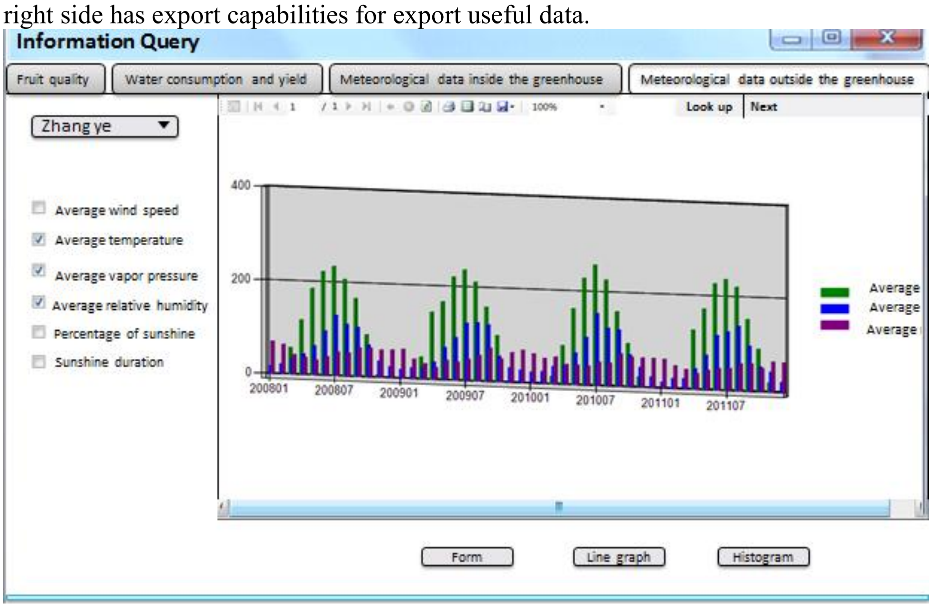

Fig.7. information query interface

(2) Dynamic Decision

The dynamic decision interface is able to help formulating optimizing irrigation schedule of four crops as Fig 8 showed after above dynamic linking. For each crop, the upper input region comprises input parameters that would affect the result to a different extent. An initial value (from the experimental data)is assigned to each input parameter for users who is short of measured data, while users might as well modify the input with their owe data. An optimizing irrigation schedule and a predicted relative yield are output in the output region below by clicking on the obtain solution button after all input parameters get a value conformed to the specification.

Moreover, a Save button on the bottom panel is for users to save a set of input parameters and optimizing solution under a certain condition of crops, soil and water supply. The saved parameters and solution can be viewed in the Scenario Analysis interface.

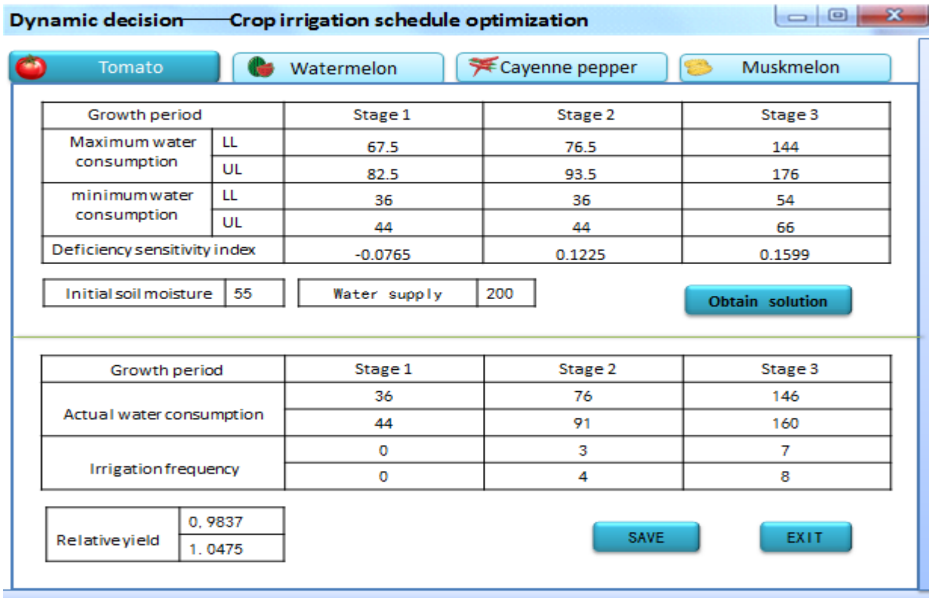

Fig.8. dynamic decision interface

(3)Scenario Analysis

Scenario analysis interface is the most important part to assist decision making with a tab control including four tab pages showed in Fig 9 to 12 Buttons on the left is corresponding to four crops. Water consumption and deficiency sensitivity index (WD) section (Fig9) contains interval value of maximal and minimal crop water consumption data and deficiency sensitivity index of each growth period acquired from experiment data, which is a reference for users who is short of measured data.

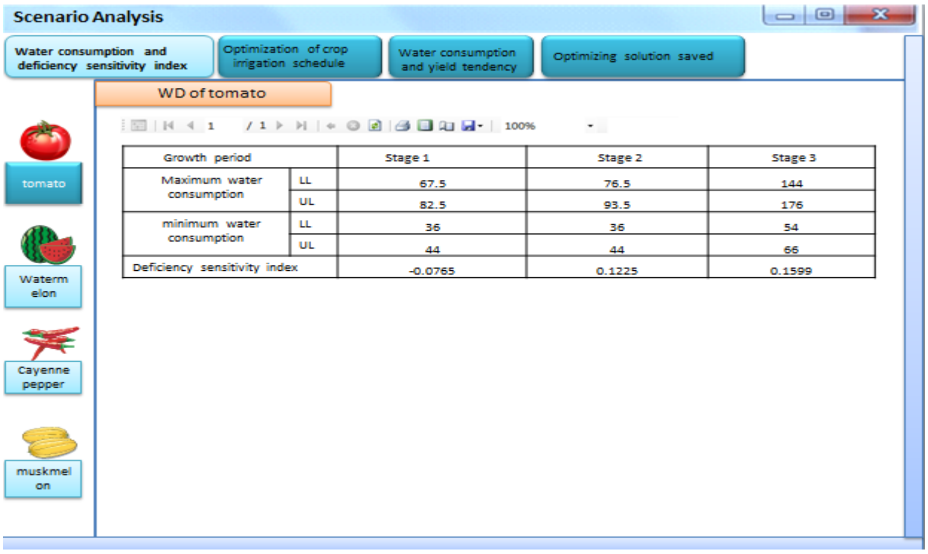

Fig.9. WD section

Optimization of crop irrigation schedule (OS) (Fig 10)and water consumption and yield tendency (WT) section (Fig 11) consist of optimizing solutions calculated from the reference data. Three ReportViewers have been added to both of them, the upper one is used to display chart of optimizing irrational schedule and optimizing relative yield, while the lower two is for display line graph and histogram. In OR section, the lower report will display the range of actual water consumption at a certain water supply condition by choosing water supply and clicking show chart button, and the variation range of actual water consumption with the increase of water supply at a certain growth period will be revealed after choosing a growth period and clicking above button in the WT section.

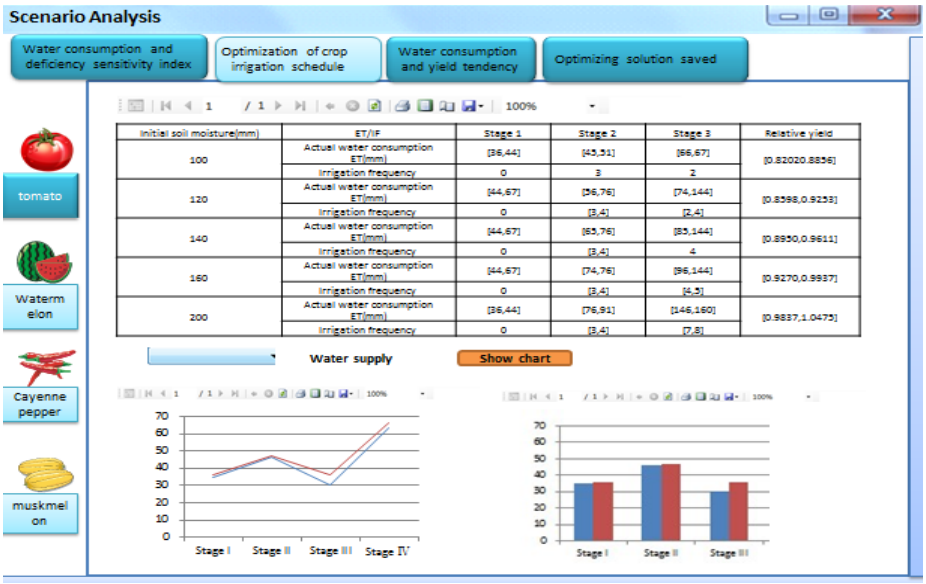

Fig.10.OR section

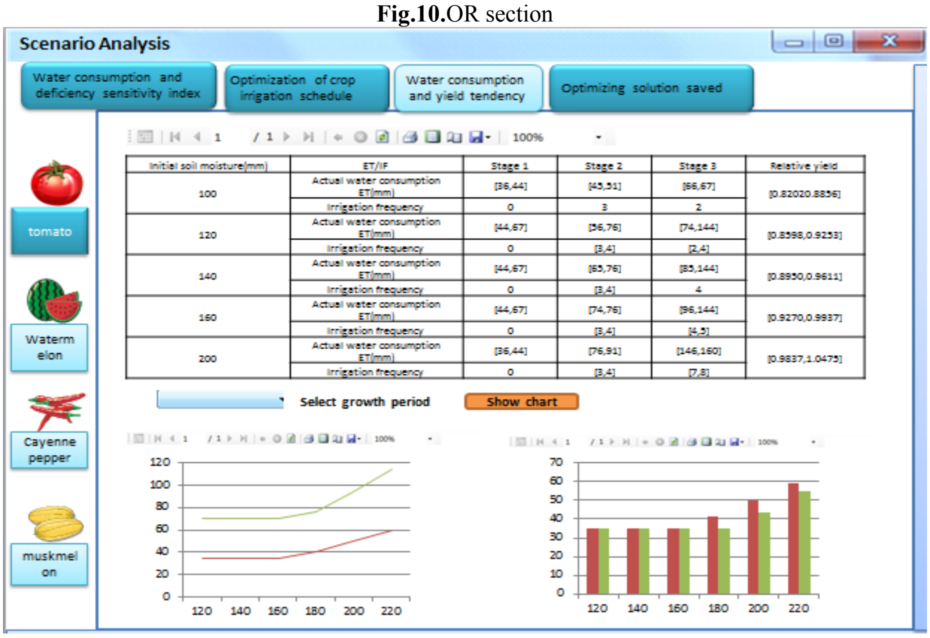

Fig.11. WT section

The last section (Fig12) is for user to check the data that user saved before in the dynamic decision interface. User can contrast all the saved optimizing solution and delete useless data, thereby, GDSS helps decision maker to make a wise decision.

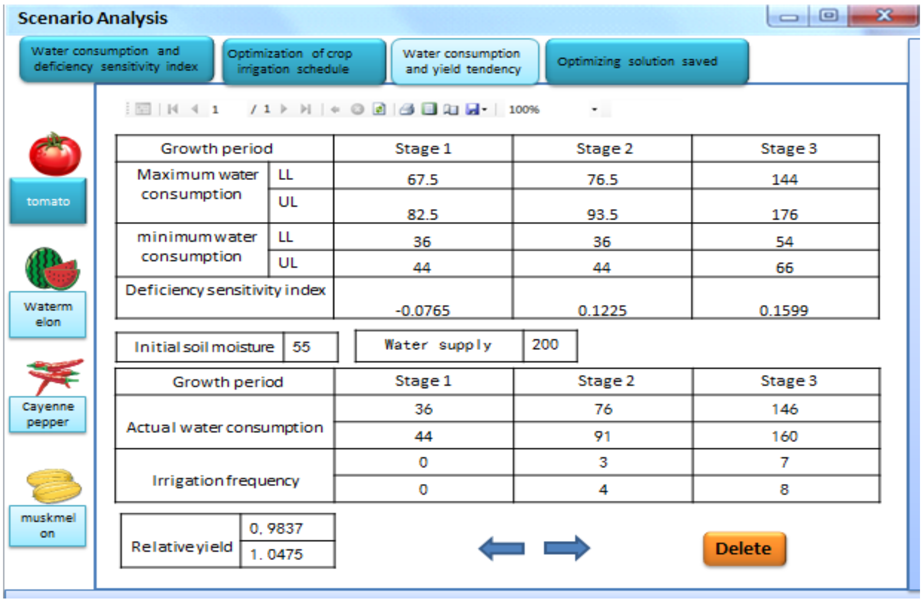

Fig.12. OS section

6 Result Analysis and Discussions

Generally, the developed GDSS could be used to support greenhouse irrigation management in the northwest arid area of china. Through incorporating advanced database system, optimization technique, uncertainty method and User-friendly graphic user interface, a series of practical and scientific irrigation schedule under various circumstances could be recommended. The basic fruit quality, water consumption and yield, and meteorological data, compiled in the database system were collected from many greenhouse experiments in Shiyanghe River Basin. These first-hand data reflected the actual relation between irrigation schedule and fruit parameters and provided valuable references to districts lack of measured data. A dynamic decision function is developed for obtaining a recommended solution presented in the form of interval through a dynamic linking with lingo program of OMGII. The input parameters should be assigned according to the local actual data. In the last stage of the whole decision, users enter scenarios analysis interface, compare all the alternative solutions intuitively.

In future research, more valuable data such as experiment results from other district should be added into the database to provide more references. Moreover, the irrigation optimization model under uncertainty should consider more uncertainty factors besides water consumption thereby obtaining more precise solution.

7 Conclusion

Greenhouse irrigation optimization decision support system (GDSS) is developed in this study for the irrigation management of greenhouse crops in the northwest arid area of china. GDSS forecasts relative yield and aids to develop irrigation schedule in terms of growth periods, comprehensively considered soil, crops and water supply conditions. The system contains meteorological data outside the greenhouse and all kinds of experimental data inside the greenhouse in Shiyanghe River Basin from 2008 to 2011.GDSS is based on the interval optimization model of greenhouse crop under insufficient irrigation, which Fig out relative yield and water consumption of each growth period, and recommend an optimal irrigation procedure according to the soil and crop parameter and water supply conditions input by the user. Furthermore, scenario analysis of a series of information include the relative yield, water consumption and irrigation schedule obtained from the experimental data and user's input will presented to the user and thus aid decision making.

GDSS is a further application of existing associated irrigation theories of water consumption efficiency pattern, water use and optimal irrigation schedule ,and is able to provide alternative irrigation schedules for decision makers through above comprehensive scenario analysis and user-friendly graphical user interface (GUI). GDSS is convenient for users even those who are lack of computer programming or system modeling knowledge. Thus, users can concentrate on developing and comparing alternative irrigation schedule.

Acknowledgment

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