DECISION SUPPORT SYSTEM (DSS) FOR IRRIGATION WATER MANAGEMENT IN SUGARCANE PLANTATION

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ABSTRACT

The Decision Support System was designed for supporting irrigation management in sugarcane plantation in Indonesia. Input data for the model are climatic data, soil and crop data as well as infrastructure data related to the sugarcane plantation area. The model is composed of four units. The first unit is a Database Management System (DBMS), it is used for data management of the model. The second unit is a forecasting simulation unit (FORSIM), it is used for predicting climatic data. ETO-model is used in this unit for computation of evapotranspiration. Neural Network Simulation is employed for predicting climatic data. The third unit is a soil water balance unit (SWAT), it is used to simulate water demand of the sugarcane. The fourth unit is a Geographic Information Unit (GIS), it is used for the output presentation of the model in graphic form.
Keywords: Irrigation, management, and sugarcane

INTRODUCTION

The computer simulation models for irrigation management have been attempted by several researchers for determining water allocation and computer-supported technology during the last decade has penetrated into most of agricultural activities. Smith (1992) developed a computer simulation program for planning and management (CROPWAT) that is supported with database CLIMWAT (Smith, 1993). This model can not be used to simulate irrigation scheduling in the daily basis.

The application of microcomputer controlled models to assist in daily operation of irrigation projects in a sugar cane plantation can be very valuable for irrigation/water managers. From above considerations, the idea was born to develop an irrigation decision support system (DSS) for sugarcane plantation, its application to manage the operation of the irrigation network of the Takalar sugar-cane plantation in Indonesia. The set of the program can facilitate the management task of the irrigation system.

The main objective of this research is to develop an interactive software package to assist irrigation manager in scheduling of water in a sugarcane plantation. Using the model, the right time, place and amount of water to be applied can be decided.

MODEL DEVELOPMENT

The core of the Decision Support System (DSS) Model is SWAT and FORSIM models. The SWAT deals with water demand computation and FORSIM deals with forecasting of climatic condition in the next 3 days. The following text describes soil water balance and forecasting simulation.

Development of Soil Water Balance Model (SWAT)

The simplified water balance model that expresses depletion of water depth for SWAT model is given in Equation 1. A soil moisture simulation approach is used in SWAT to estimate water demand in the irrigated parcel. The governing equation for the water balance is expressed below:

$W_i = W_{i-1} + (Pe+Ir+Gr)_i - (Dp+Etact+Evap+Roff)_i$ . . . . (1)

where W_i is soil water content at the day *I,* W_{i-1} is soil water content at the day *i-1, Pe* is rainfall (mm), *Ir* is irrigation (mm), *Gr* is capillary rise (mm), *Dp* is deep percolation (mm), *Etact* is actual evapotranspiration (mm), *Evap* is additional evaporation (mm) and *Roff* is runoff (mm). The soil water content at the beginning of computation, fluxes of the soil water at the top (soil surface), the fluctuation of actual water content of the root zone can be estimated as a function of time by using Equation 1 above. The application depth is determined from the soil moisture deficit for SWAT within 3 days. The supplied water is assumed to reach all allocated fields within the project area.

For the calculation of reference evapotranspiration in the SWAT model, the modified Penman method (FAO) is used, which is based on the procedure guidelines presented by Doorenbos & Pruitt (1977); Dooerenbos et al. (1984). The calculation of Extraterrestrial radiation (*Ra*) and monthly mean maximum sunshine hours (*N*) were carried out according to the method proposed by Igbal (Snyder & Pruitt, 1994). Potential crop evapotranspiration (*Etcrop*) is crop evapotranspiration of a decease free crop grown in a large field under optimum soil water and fertility conditions to achieve the potential production under a given growing environment. The maximum evapotranspiration is calculated as the product of *Eto* and crop coefficient (*Kc*), i.e., *Etcrop= Eto * Kc*. In this model, *Etact* is the sum of the actual evaporation at the soil surface (*Evact*) and the actual plant transpiration (*Tact*), i.e., *Etact = Evact +Tact*. The evapotranspiration rate under an actual soil water condition might be considerably smaller than *Etcrop* if the water available in the root zone is insufficient to fulfil the transpiration demand.

The crop water demand must be met by soil moisture in the root zone to achieve the maximum yield. If the water content in the root zone is higher than the critical soil water content, the actual transpiration rate will be equal to the potential transpiration rate. When the readily available water (*RAW*) in the root zone is function can be described as:

$$Dp_i \quad * \frac{(\ sat \quad fc) * (exp(\ _i \quad fc) \quad 1)}{(exp(\ sat \quad fc) \quad 1)} \qquad (2)$$

where Dp_i is deep percolation at the day *i* ($m^3 \cdot m^{-3} \cdot day^{-1}$), is drainage coefficient (dimensionless), *sat* is water content at the saturated condition ($m^3 \cdot m^{-3}$), $_i$ is actual water content at day *i* ($m^3 \cdot m^{-3}$) and *fc* = water content at the field capacity ($m^3 \cdot m^{-3}$). The coefficient expresses the fraction of the water content between saturation and field capacity, which is lost at the end of the first day by the free drainage of the saturated soil. In SWAT model is taken equal to 0.3 for clay soil. The soil water content at saturation (*sat*) is estimated for three different soil types by means of the following equation (Raes &Van Aelst, 1985):

$sat = -0.0001571*TAW+0.4043+\ fc$

for sandy soil (3)

$sat = \ fc + 0.065$

for clay soil (4)

$sat = -0.000754*TAW+0.3259+\ fc$

for loamy soil (5)

where TAW is the total available water ($mm \cdot m^{-1}$) and fc is water content at field capacity ($m^3 \cdot m^{-3}$). When a high intensity rainfall or irrigation occurs, part of a rainfall that is not absorbed on the soil surface is considered as surface runoff. SWAT calculates surface runoff for a rainfall only. It can be obtained by the procedures developed by the U.S. Soil Conservation Service (SCS) in 1972 (Klik 1997). This method was used in SWATRER-model (Dierckx, Belmans & Pauwels, 1986).

Neural Network Algoritm

Neural Network Simulation (NNS) is a knowledge base of the DSS model. It can be defined as a computing system made up processing elements, which process information by their dynamic state response to external input . NNSs are typically organized in layers. Layers are made up of a number of interconnected 'nodes' which contain an activation function. Patterns are presented to the network via the input layers, which communicates to one or more 'hidden layers' where the actual processing is done via a system of weighted 'connection'. The hidden layers where the answer is output. The scheme of the NNS which is used in the DSS-model is presented in the following figure.

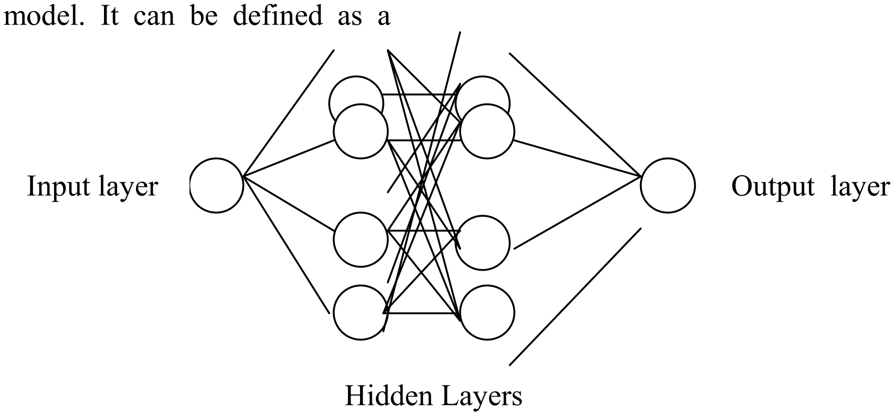


Figure 1. Neural Network Scheme for DSS model.

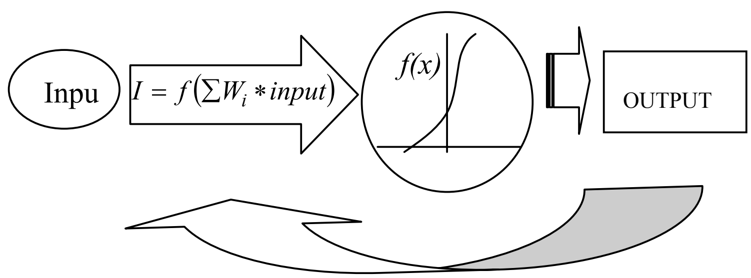
The NNS contains some form of 'learning rule' which modifies the weights of the connections according to the input patterns that is presented with. In the DSS model, the back propagation technique (Kathmann & Rund, 1993; Maddalena, 1996) is employed. The value of the climatic variables (air temperature, humidity, solar radiation, rainfall and wind speed) were collected from the field within the last five days are used as input to train the NNS. All data are normalized into real values between 0.0 and 1.0. This is necessary since every neuron in the hidden and output layers of the back propagation employs a sigmoid function that has the range 0.0 to 1.0.

The Back Propagation Technique (BPT) is a learning rule (Swingler, 1996). This technique is well known for practical use in solving many data mapping problems. It has been proved that 2-layers back propagation can approximate many arbitrary continuous mapping (NIELSEN, 1989). During the training stage, the BPT calculates the differences (errors) between the output and the target samples, and than propagate back these errors from the output layer down to the input layer. The total squared error can be described as:

$$E = \frac{1}{2}\sum_{h}^{M}\sum_{i}^{N}(t_{h_i} - O_{h_i})^2$$

where the index h ranges over the set of input and target pattern pair, i refers i_{th} output neuron, t_{th} is the target pattern for the i_{th} component, O_{th} is the output values of the i_{th} component for pattern h, E_h represents the error on pattern h, and E is the total error of the entire set of the pattern.

The network uses this error information to organize its weights. Thus the training's objective is to minimize the total squared error by modifying the weights. The training rule is called delta rule. The scheme of BPT used in the DSS model are described below.



The Delta Rule

$$W_{new} = W_{old} + \beta EX / |X|$$

Figure 2. The Back Propagation Technique (BPT)

The BPT is a iterative process. it usually takes many cycles before it converges to a solution, if that solution exists. The network topologies, the learning parameters and the initial weights uses are some of the important factors for BPT to find the solution. The weigh which were obtained from the training steps will be used in prediction of climatic data for the model. The prediction follows window moving technique.

Computer Programming

The research was conducted in one year. The first activity is model development and programming step. The second activity is model validation. The software package was written in Object Oriented Programming Delphi. The program works under Windows environment using personal computer that is higher than Pentium 133. The programming was done in the computer Laboratory of Agricultural Technology Hasanuddin University Makassar in the year 1999.

The DSS model is composed of four units. The first unit a Database Management System (DBMS), it used to manage all involved data for the model. A data base program was designed to manage the data in the program. The second unit is a forecasting simulation unit named

FORSIM, it used to simulate expected hydrology and climatic data for the input of SWAT unit. Neural Network Simulation is employed in the FORSIM unit. The third unit is a soil water balance unit (SWAT), it is used to simulate water demand. The fourth unit is a Geographic Information Unit (GIS), it is used for the output presentation. This unit uses Active-X programming in Delphi. The spatial and temporal distribution of water demand can be presented in the screen through GIS technique in this program. The program structure of the DSS is presented in Figure 3.

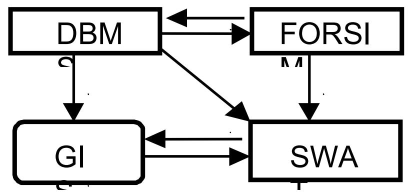


Figure 3. Schematic presentation of the DSS model

RESULT AND DISCUSSION

Description of the program

The software package RTI-DSS is composed of 4 main menu. The first main menu is FILE, it deals with database management system. The second main menu is SIMULATION, it deals with forecasting simulation (using Neural Network Algorithm), evapotranspiration simulation and water balance simulation. The third main menu is OUTPUT, this main menu deals with output presentation of DSS model. The fourth main menu is HELP, this main menu deals with logo presentation and providing on line help for the DSS model.

The output menu employs a Geographic Information System (GIS), it is used to assist the system in visualizing input output data in spatial and temporal form. This menu can view spatial and temporal map of irrigation decision, moisture content, soil and cropping pattern.

Application

Figure 4. presents the result of water demand simulation in each command area (parcel) on 20.08.1999 at Takalar Sugarcane Plantation, South Sulawesi, Indonesia. From this simulation result, it is clear that the maximum water demand was found to be 86.71 mm. for the parcel 6.

The program can be used continuously to simulate irrigation water demand (decision planning) during the growing season. For each interval of 3 days, irrigation manager shall get the measured or estimated climatic data of the last day. Based on this climatic data or predicted data, the DSS could execute the decision planning for each tertiary command in the project within a short-term period in the next 3 days.

Validation

Prediction of rainfall data

Validity of estimated climatic data is a critical aspect in the overall irrigation management. The purpose of an irrigation planning is to distribute water to the fields in accordance with maximum crop production. Figure 5 shows the comparison between measured and simulated rainfall using Neural Network in the DSS model.

The correlation of rainfall between simulated (by Neural Network, FORSIM) and measured rainfall is satisfactory as shown in Figure 5. The mean rainfall for simulated data is about 1.81 and 2.96 mm · day^{-1} for measured data. The correlation coefficient and mean square error are 0.83 and 9.23, respectively. From the measured and simulated rainfall data, it is noted that the occurrence of measured and predicted data often occurred on different days, which is somewhat expected, since the prediction of specific rainfall is difficult. However, trends, peak and day to day variation in daily rainfall were quite similar between measured and predicted values.

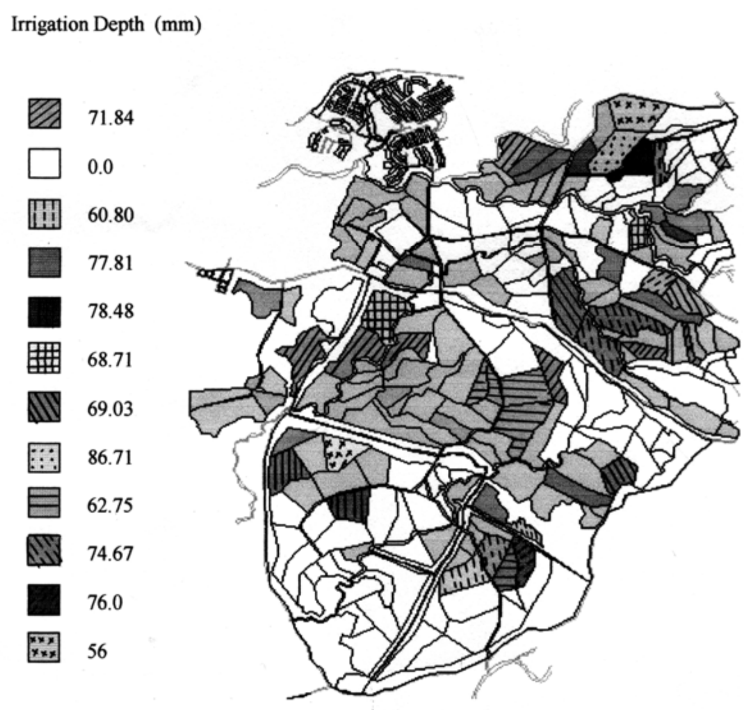


Figure 4. Decision of water demand (mm) on 20.08.1999 at the Takalar Sugar Cane Plantation (output from the DSS software package).

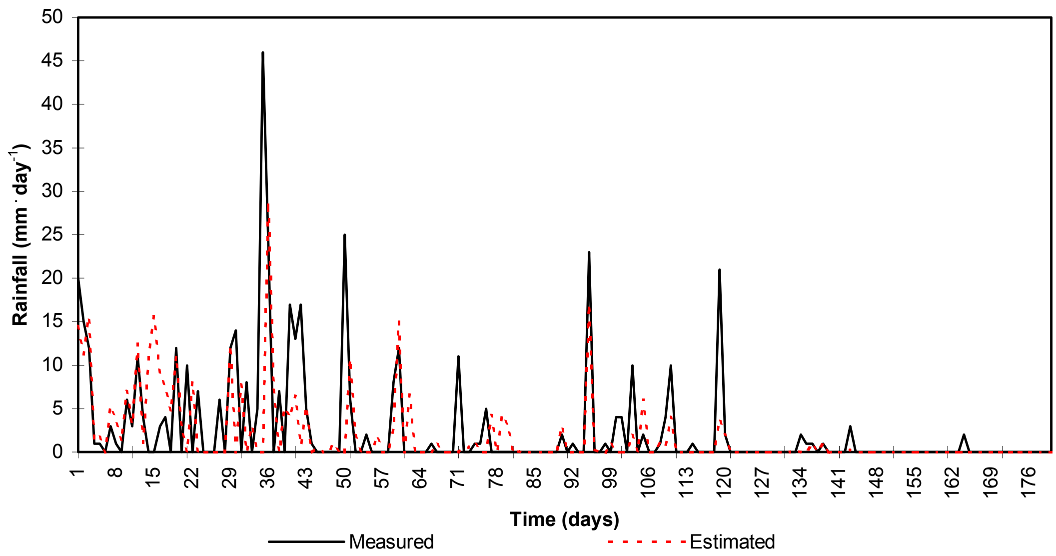


Figure 5. Simulated (by FORSIM-model) and measured rainfall

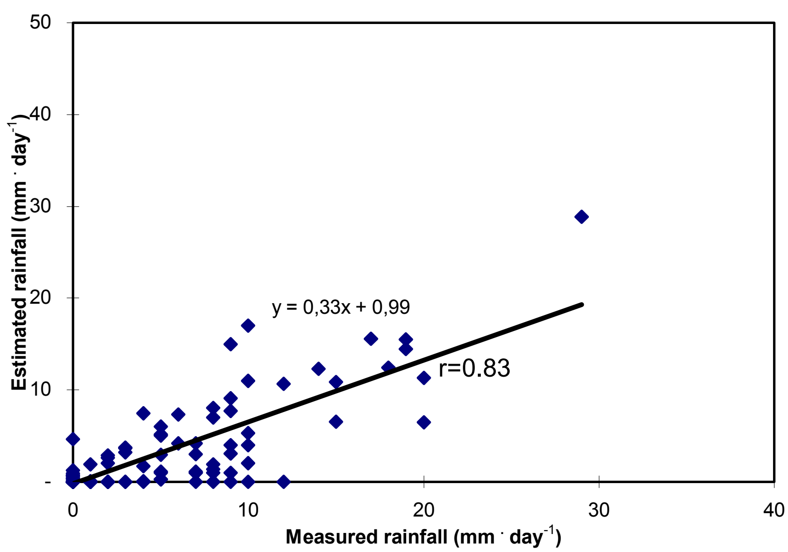


Figure 6. Correlation of rainfall (simulated by FORSIM and measured data) during the whole growing season

From the measured and simulated moisture content data (Figure 7), it is noted that the occurrence of measured and predicted data often occurred on the same days, which is somewhat expected, since the prediction of moisture content is easy. Trends, peak and day to day variation in daily moisture content were quite similar between measured and predicted values.

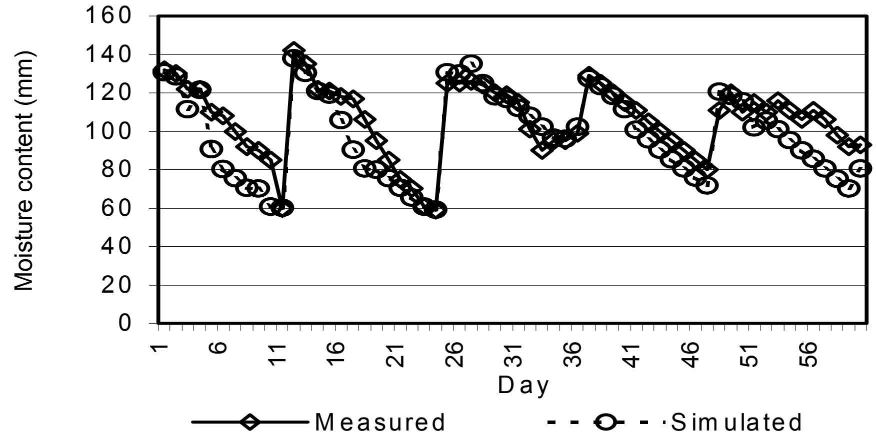


Figure 7. Simulated (by FORSIM-model) and field measurement

The correlation of moisture content between simulated (by Neural Network, FORSIM) and measured moisture content is satisfactory. Mean of moisture content for simulated data is 98.23 and for measured data is105.74 mm. The correlation coefficient and mean square error are 0.89 and 160.8 mm, respectively.

CONCLUSION

- The Decision Support System Model (DSS) was applied successfully in managing irrigation system in a sugarcane plantation.
- The model assists the operation of irrigation water delivery in irrigation network. It is structured in four integrated units:
  - Database Management System (DBMS),
  - Forecasting simulation (FORSIM-model),
  - Soil Water Balance Simulation (SWAT-models),
  - Geographic Information System (GIS).
- The software packages of DSS-model were developed as an interactive software packages.
- This software can contribute in helping irrigation water manager during the growing season in a sugarcane plantation..

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REFERENCES

Dierckx, J., C. Belmans & P. Pauwels, 1986. SWATRER, a computer package for modelling the field water balance. Lab. of Soil and Water Eng. KUL, Belgium.

Doorenbos, J & W.O. Pruitt, 1977. Crop water requirements. Irrigation and Drainage Paper 24 (revised). FAO. Rome, Italy, 144 pp.

Doorenbos, J., W.O. Pruitt, A. Aboukhaled, J. Damagnes, N.G. Dastane, C. Van Den Berg, P.E. Rijtema, O.M. Ashford, M. Prere & Field staffs, 1984. Guide lines for predicting water requirement .Irrigation and Drainage Paper 24 (revised). FAO. Rome, Italy, 114 p.

Kathman, Ruud M, 1993. Neural Networks for the mass appraisal of real estate. Computers Environment and Urban Systems 17. pp. 373-384

Klik, A., 1997. Internal note on ''Entwicklung und Anwendung von Modellen zur Simulation der Wasserosion''. LKWW. Univ. für Bodenkultur Wien. Austria.

Maddalena DJ, 1996. Application of artificial neural networks in quantitative structure activity relationships. Exp. Opin. Ter. Potens 6. pp. 239-251.

Raes, d & p. Van aelst, 1985. The field parameters of the BUDGET model. Internal note, Inst. for Land and Water Management, Katholieke Universiteit Belgium.

Snyder, r.l & w.o. Pruitt, 1994. ETO, user's guide and program documentation. Dept. of Land, Air and Water Res., California, USA.

Smith, M, 1992. CROPWAT, A computer program for irrigation planning and management. FAO Irrig. and Drainage paper no: 24 . Rome, Italy.

Smith, M, 1993. CLIMWAT for CROPWAT. FAO Irrig. and Drainage paper no: 49 . Rome, Italy.

Swingler, K, 1996. Applying neural networks. A practical guide. Pub. Academic Press. NY.