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Development of Location Specific Decision Support System (DSS) for Adopting the Best Water Management Strategies to Maximize the Production for Nagarjuna Sagar Right Canal Command Area

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Nagarjuna Sagar Project is built across river Krishna at Nandikonda village of Nalgonda District. The Project is having right main canal namely Jawahar canal having Guntur, Zulakallu, Bellamkonda, Peddanandipadu, Addanki, Eddanapudi, Darsi, Pamidipadu and Ongole branch canals. Conjunctive use is the technique which envisages the use of Groundwater in conjunction with canal water in the Command Area. The productivity is reduced due to irregular operation and maintenance of canals. The decision support system was designed and developed in visual basic 2010. The decision support system was designed and developed for computing crop water demand and domestic water requirement and conjunctive use of water. The DSS analyse data and computed values represented in graphical form. It will display whether the conjunctive quantity of water is sufficient for the cropping pattern chosen or not. If not sufficient, planners can change the cropping pattern so that water requirement is minimised. The maximum surface volume was observed in the year 2008-09 as 6051 MCM, minimum at 2015-16 as 490 MCM and the average surface water volume as 3628 MCM. The average groundwater volume as noticed as 2269.89 MCM and maximum in the year 2008-09 as 3062.21 MCM and minimum in the year 2015-16 as 1825.55 MCM. The crop water requirement for all the seasons was calculated as 4455.32 MCM, Domestic water demand as 155.9 MCM, net surface water availability as 2,229.41 MCM, net groundwater availability as 1384.63 MCM and conjunctive use water as 3,614.04 MCM.

It is concluded that the developed DSS will help the policy makers and planners of water resources for cropping pattern to be followed to save the water in satisfying crop water requirement. The results obtained from the study can be used as a guide for the farmers for selecting the crops and water releases for the main crop.

Keywords: Surface water; groundwater; conjunctive use; canal hydraulics; decision support system.

1. INTRODUCTION

"Nagarjuna Sagar Project is built across river Krishna at Nandikonda village of Nalgonda District. The Project has two main canals namely Lal Bahadur canal on left side and Jawahar right main Canal. The main objective of this Nagarjuna Sagar project is to bring the 9 lakhs hectare of land in to cultivation. The main canals Left as well as right are designed with 11,000 cusecs carrying capacity. About 4.75 lakhs ha area in Guntur and Prakasam Districts is irrigated by Nagarjuna Sagar Jawahar Canal. The Canal is divided into 9 branch canals spread across Guntur and Prakasam districts. The Right main canal feeds Guntur, Zulakallu, Bellarnkonda, Peddanandipadu, Addanki, Eddanapudi, Darsi, Pamidipadu and Ongole branch canals" [1].

"Conjunctive use is the technique which envisages use of groundwater in conjunction with canal water in the command area. This system ensures judicious utilization of groundwater to ensure safe regime of groundwater table so as to eliminate the water logging conditions and to ensure reliable Irrigation facilities in the tail end areas of the command area" [1]. Keeping in view of this, Hydro geological, Hydrological and Geophysical investigations are being conducted to identify the groundwater potential areas in the command area for future planning and for suggesting remedial measures. In addition, the uncertainties of canal releases and dissatisfied farmers seeking more quantity water and timely non supply, have tampered with irrigation structures causing further damage. The productivity is reduced due to irregular operation and maintenance of canals.

1.1Study Area

1.1.1 Nagarjuna Sagar Project Jawahar Command

The command area lies between the latitudes of 15^0 20' to 16^0 41' 24" N and the longitudes of 79^0 18'44" to 80^0 25' 56" E, encompassing Guntur and Prakasam districts in the state of Andhra Pradesh. The geographical command area consists from block 1 to 22 (GA) as shown in Fig. 1.

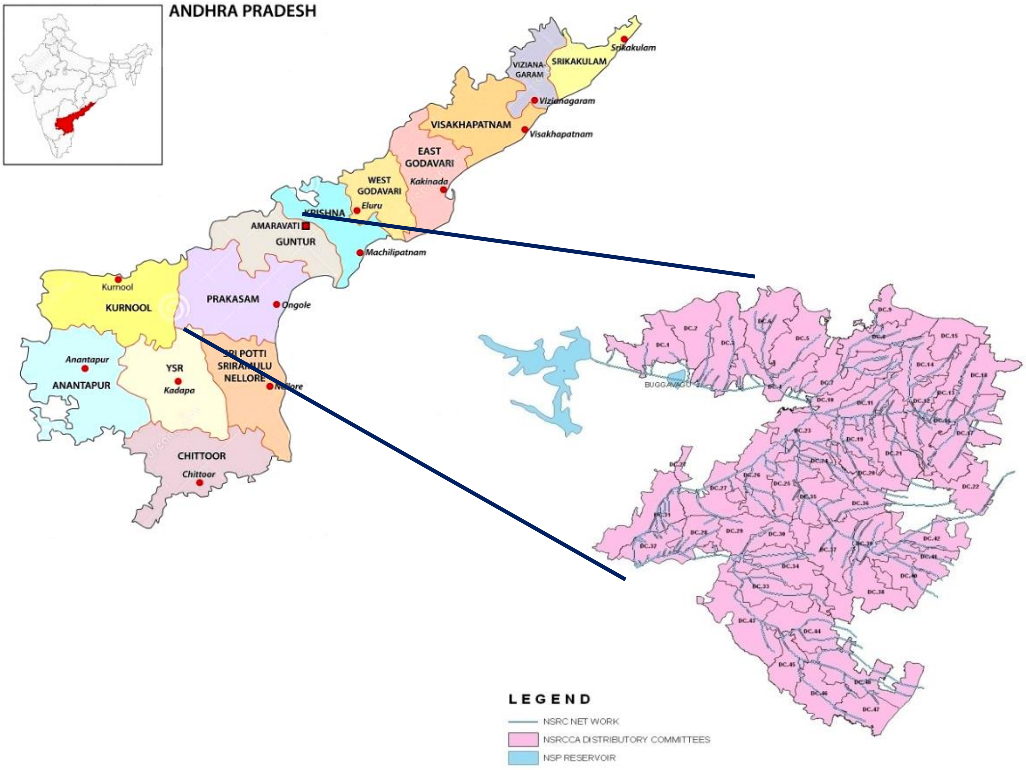


Fig. 1. Location map of study area

1.1.2 Jurisdiction of Nagarjuna Sagar Right canal command

There are two Circles in the jurisdiction of Chief Engineer in the Nagarjuna Sagar Right Canal command as follows.

1.1.2.1 NSJC, O & M circle, Lingamguntla

This Circle is in charge of Operation & Maintenance of Nagarjuna Sagar Jawahar Canal (N.S. Right Canal) from Mile 0/0 to M 85/3+150 (Km 0.000 to Km 137.28) with a designed discharge of 11,000 cusecs covering block Nos. 1 to 10, Part of 11, 11A to 14, Part of 17 to 19 of N.S.J.C., Command Area. The localized ayacut under the control of this Circle covering both the districts of Andhra Pradesh i.e., Guntur and Prakasam.

1.1.2.2 Irrigation circle, Ongole

This Circle is in charge of Operation & Maintenance of Nagarjuna Sagar Jawahar Canal from M 85/3+150 to M 126/0+000 (Km 137.28 to Km 202.79) covering block Nos. 15 to 22 of NSJC Command Area.

2. MATERIALS AND METHODS

2.1 Description of Decision Support System Software

2.1.1 Development of software in visual basic.NET

Visual Basic.NET is a computer programming language developed in Microsoft. VB.NET is an object-oriented programming language. This means that it supports the features of object-oriented programming which include encapsulation, polymorphism, abstraction, and inheritance. Visual Basic .ASP NET runs on the .NET framework, which means that it has full access to the .NET libraries. It is a very productive tool for rapid creation of a wide range of Web, Windows, Office, and Mobile applications that have been built on the .NET framework. The language was designed in such a way that it is easy to understand to both novice and advanced programmers. Since VB.NET relies on the .NET framework, programs written in the language run with much reliability and scalability. With VB.NET, one can create applications that are fully object-oriented, similar to the ones created in other languages like C++, Java, or C#. Programs written in VB.NET can also interoperate well with programs written in Visual C++, Visual C#, and Visual J#. VB.NET treats everything as an object.

2.1.2 Integrated development environment (IDE) For VB.Net

Microsoft provides the following development tools for VB.Net programming

- Visual Studio 2010 (VS)
- Visual Basic 2010 Express (VBE)
- Visual Web Developer

Visual Basic Express and Visual Web Developer Express edition are trimmed down versions of Visual Studio and has the same look and feel. They retain most features of Visual Studio. After the Visual Basic project template was selected and named the file, Visual Studio opens a form. A form is a Windows user interface and creates a "Hello World" application by adding controls to the form, and then the app will be run.

2.2 Description of Decision Support System Software

The decision support system was designed and developed in visual basic. The software was a tool for computing crop water demand and domestic water requirement and conjunctive use of water [2]. Based on the data, the planning of crops as per availability of water under the command area can be suggested. The Developed DSS software contains six main menu buttons namely Data base, Project details, Calculations and Results, Canal hydraulics, Chart/graphs and Help options.

2.2.1 Data base

In the DSS software click on data base button to get the weather data, rainfall data, soil data, crop data, discharge data and groundwater data files which were required for computation of conjunctive use of water.

2.2.2 Weather data

Click on weather data icon, monthly and daily will appear on the screen. Monthly or daily weather data consists the parameters like minimum temperature, maximum temperature, humidity (%), sunshine hours, radiation (MJ/m^2/day), ETO (mm/day). The Reference evapotranspiration can be calculated by using the Penman-Monteith combination method as a new standard for reference evapotranspiration was used and advised on procedures for calculation of the various parameters. By defining the reference crop as a hypothetical crop with an assumed height of 0.12 m having a surface resistance of 70 s m^{-1} and an albedo of 0.23, closely resembling the evaporation of an extension surface of green grass of uniform height, actively growing and adequately watered, the FAO Penman-Monteith method was developed [3].

From the original Penman-Monteith equation and the equations of the aerodynamic and surface resistance, the FAO Penman-Monteith method to estimate ETo is expressed as

$$ET_0 = \frac{0.408\Delta(R_n - G) + \gamma \frac{900}{T+273} U_2(e_s - e_a)}{\Delta + \gamma(1 + 0.34U_2)}$$

Where

ETo Reference evapotranspiration[mmday-1],
Rn Net radiation at the crop surface [MJ m-2 day-1],
G soil heat flux density [MJ m-2 day-1],
T mean daily air temperature at 2 m height [°C],
u_2 wind speed at 2 m height [m s-1],
e_s saturation vapour pressure [kPa],
e_a actual vapour pressure [kPa],
e_s- e_a saturation vapour pressure deficit [kPa],
Δ slope vapour pressure curve [kPa °C-1],
γ Psychrometric constant [kPa °C-1].

The FAO Penman-Monteith equation [4] is used to compute the reference evapotranspiration for different regions.

The weather data of the Nagarjuna Sagar Right Canal Command area and the rainfall data was collected from the Directorate of Economics and Statistics (DES), Vijayawada of Guntur and Prakasam districts mandals under NSP right canal command area from 2000-2018 were input for the software. The crop data was fed according to kharif, rabi and summer seasons. The data in the form of crop duration (days), K_c values and contemplated area of respective crop were fed in the DSS software.

Clicking on discharge icon displays the daily, monthly and yearly data. The yearly data was given to software for average annual surface water availability of the command. The data was collected from Water resources Department, Lingamguntla circle and Ongole circle for a period from 2008 to 2018. The groundwater data icon display as Pre and post monsoon data, Year wise observation wells data, Piezometer data and Groundwater volume data. Ground and surface water together is called the conjunctive use of water. Clicking on the project details icon, it appears Crop Water Requirement, Domestic Water Demand, Surface Water Availability, and Groundwater Availability on window.

Crop Water Requirement was calculated based on the climatic data, crop length and crop co-efficient for different crops. Crop evapotranspiration under standard conditions (ETc)

$$ETc = Kc * ETo$$

Where,

Kc = crop coefficient
ETo = reference evapotranspiration, mm day^{-1}

2.2.3 Surface water availability

The availability of annual discharge of the command from 2008-09 to 2018-19 was given to software as an input data, then computed the average discharge value and deduct the evaporation, seepage and other losses etc., Finally, get the net availability of surface water.

2.2.4 Domestic water demand

Average population and livestock details of the command and their water requirement in litres per day were given to software and calculated the total water requirement for domestic purpose.

2.2.5 Groundwater availability

The availability of annual groundwater of the command from 2008-09 to 2018-19 was given to software as an input data, then computed the average groundwater volume and percentage of not suitable for crop and other purposes was deducted. Finally, the net availability of groundwater was obtained[7].

2.2.6 Calculations and results

In the calculation icon, the parameters crop water requirement, domestic water demand, net surface water availability, groundwater availability and conjunctive use water availability were calculated and displayed [5]. The computed conjunctive use water is to be compared with agricultural and domestic water demand, then results will be displayed as sufficient water is available or insufficient water.

2.2.7 Canal hydraulics

The input data for the canal design is full supply depth (D), bottom width (B), side slope (Z:1), bottom slope (S), Manning's co-efficient (n) and computed the discharge (Q), velocity (V), hydraulic radius (R), area (A), wetted perimeter (P) and critical depth (Yc) [6].

The data required for the software was given as an input data, then results of Decision Support System was described in the result and discussion chapter.

2.3 Crop Water Requirement By Using CROPWAT8.0

The estimation of crop water requirement for different crops under Nagarjuna Sagar Right Canal Command Area was computed by using CROPWAT 8.0 software.

2.3.1 Data required for CROPWAT 8.0 model

CROPWAT 8.0 is a program that uses Penman-Monteith method for calculating reference crop evapotranspiration. The initial data that are needed for the model in order to get the irrigation crop water requirements are summarized as given below

- Climate data
- Rain data
- Crop data
- Soil data
- Cropping pattern

The mean monthly air temperature and humidity, wind speed, sunshine hours and solar radiation of 18 years from 2000-2018 was collected from Agricultural Research Station, Guntur, Lam. The rainfall contributes to a greater or lesser extent in satisfying crop water requirements, depending on the location. The precipitation data required for CROPWAT 8.0 can be daily, decade or monthly rainfall, commonly available from many climatic stations. Monthly rainfall data was collected from the Chief planning office of Guntur and Praksam districts, which is covered by the Nagarjuna Sagar Right Canal Command Area from 1997-2018. [1]

3. RESULTS AND DISCUSSION

3.1 Validation of Developed Decision Support System (Demand and Supply Status of Water Resources)

Decision Support System (DSS) has been developed for the command area of Guntur branch channel which can be easily operated and accessed by anyone and later it was modified with adding some additional features used for any location, command or branch canal [8]. The software consists of data base, Project details, calculations & Result, Canal hydraulics, Charts/graphs and helps shown in Fig.2.

3.1.1 Data base

The data base and weather data was clicked and then loaded the 18 years mean monthly data of the command area from 2000-2018 as shown in Fig. 3. Similarly, monthly mean rainfall data was collected from the Directorate of Economics and Statistics (DES), Vijayawada of Guntur and Prakasam districts mandals under NSP right canal command area from 2000-2018 was loaded. In the same way, yearly discharge data of command area was shown in the Fig. 4, which was collected from Water resources Department, Lingamguntla circle and Ongole circle.

The data base and groundwater is clicked then pre and post monsoon data, year wise observation wells data, piezometer data and ground water volume data will be appeared[10]. The data was obtained from Nagarjuna Sagar Right Canal (Jawahar) Command area Development, State Groundwater Department, Guntur during 2000 to 2018 and presented in Fig.5 and 6.

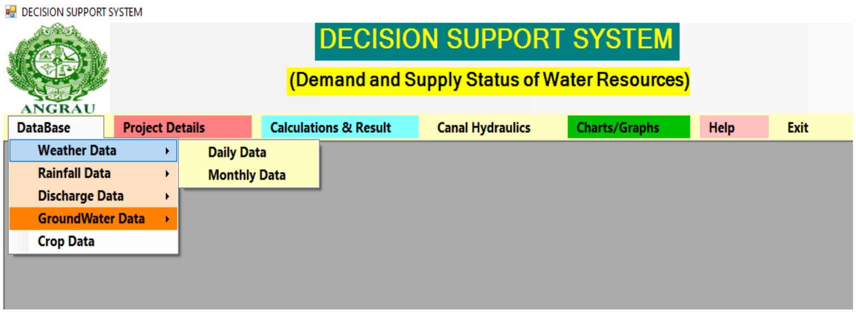
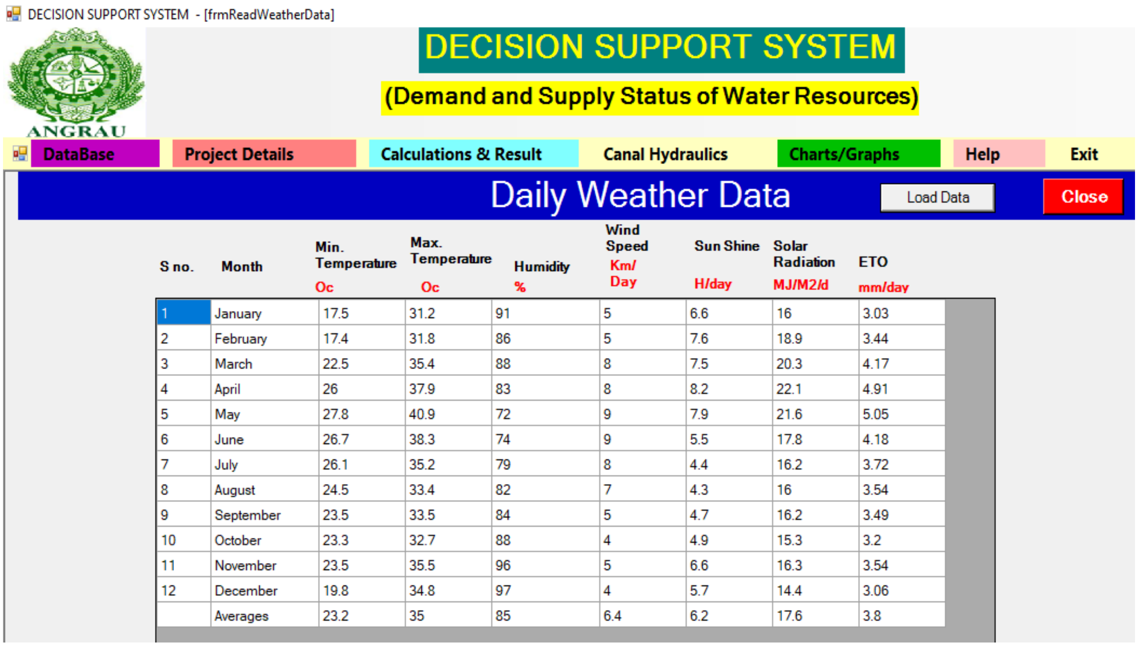


Fig.2. Data base button of DSS software



S no.	Month	Min. Temperature Oc	Max. Temperature Oc	Humidity %	Wind Speed Km/Day	Sun Shine H/day	Solar Radiation MJ/M2/d	ETO mm/day
1	January	17.5	31.2	91	5	6.6	16	3.03
2	February	17.4	31.8	86	5	7.6	18.9	3.44
3	March	22.5	35.4	88	8	7.5	20.3	4.17
4	April	26	37.9	83	8	8.2	22.1	4.91
5	May	27.8	40.9	72	9	7.9	21.6	5.05
6	June	26.7	38.3	74	9	5.5	17.8	4.18
7	July	26.1	35.2	79	8	4.4	16.2	3.72
8	August	24.5	33.4	82	7	4.3	16	3.54
9	September	23.5	33.5	84	5	4.7	16.2	3.49
10	October	23.3	32.7	88	4	4.9	15.3	3.2
11	November	23.5	35.5	96	5	6.6	16.3	3.54
12	December	19.8	34.8	97	4	5.7	14.4	3.06
	Averages	23.2	35	85	6.4	6.2	17.6	3.8

Fig. 3. Mean monthly weather data of command

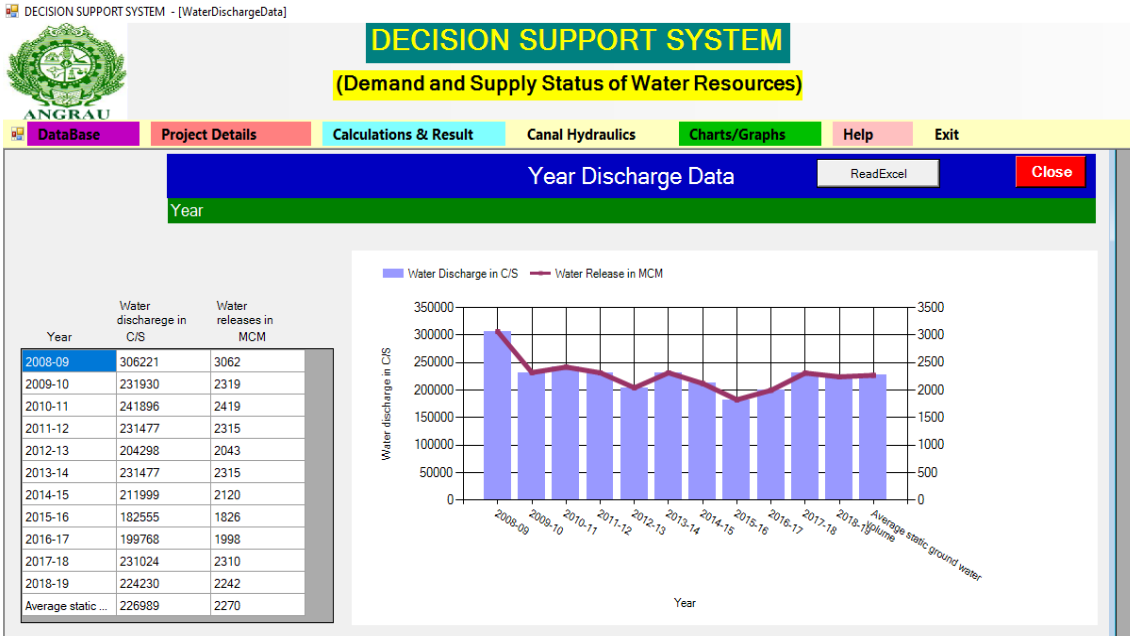


Fig.4. Annual mean discharge at command area during 2008-09 to 2018-19

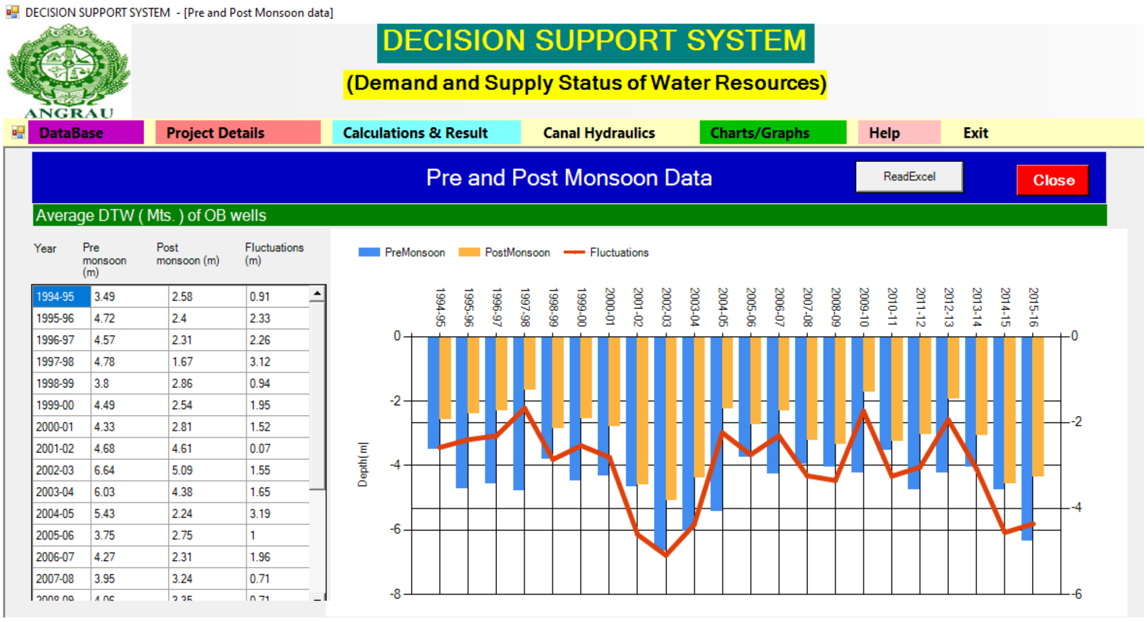


Fig. 5.Pre and Post monsoon data at NSP command area from 1994-95 to 2015-16

The average groundwater volume was noticed as 2269.89 MCM and maximum in the year 2008-09 as 3062.21 MCM and minimum in the year 2015-16 as 1825.55 MCM.

3.1.2 Project details

The window will appear as shown in the Fig. 7 on the screen and data was given as per requirement. In that, four buttons like crop water requirement, surface water availability, domestic water demand and groundwater availability will be displayed.

3.1.3 Crop data requirement

Three seasons namely Kharif, Rabi, Summer seasons and their data was given as an input for the software as shown in Fig. 8 and 9.

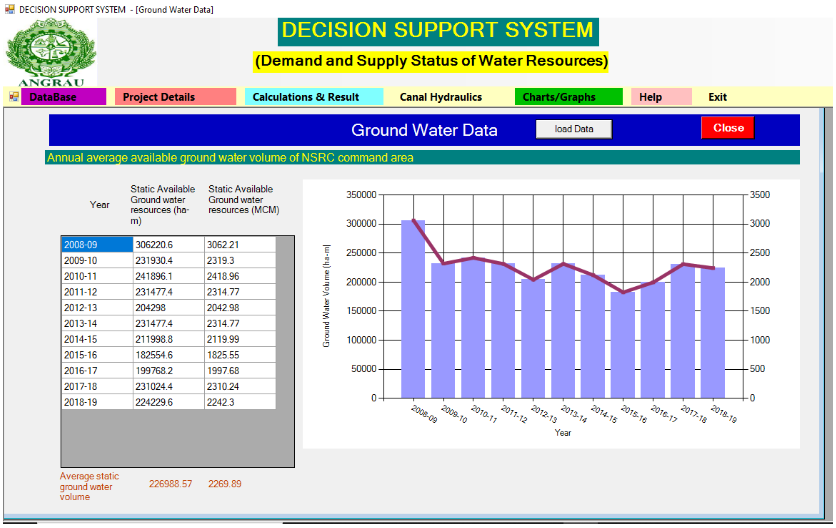


Fig. 6. Average annual groundwater volume at NSP command area from 2008-09 to 2018-19

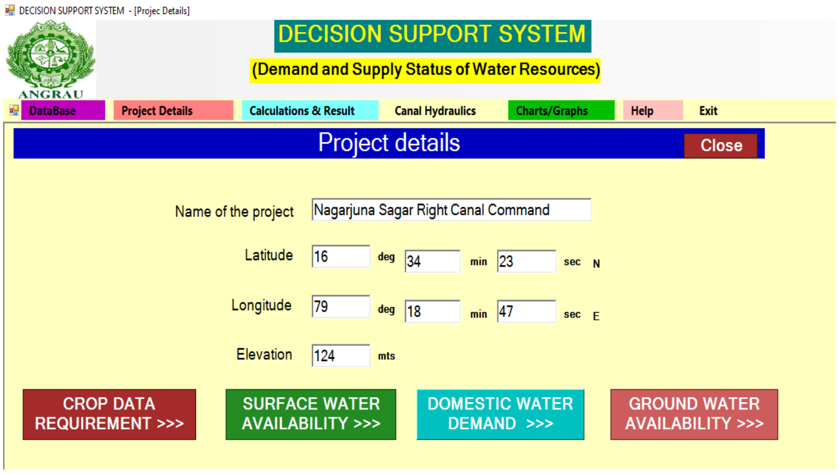


Fig. 7.Project details of Decision Support System

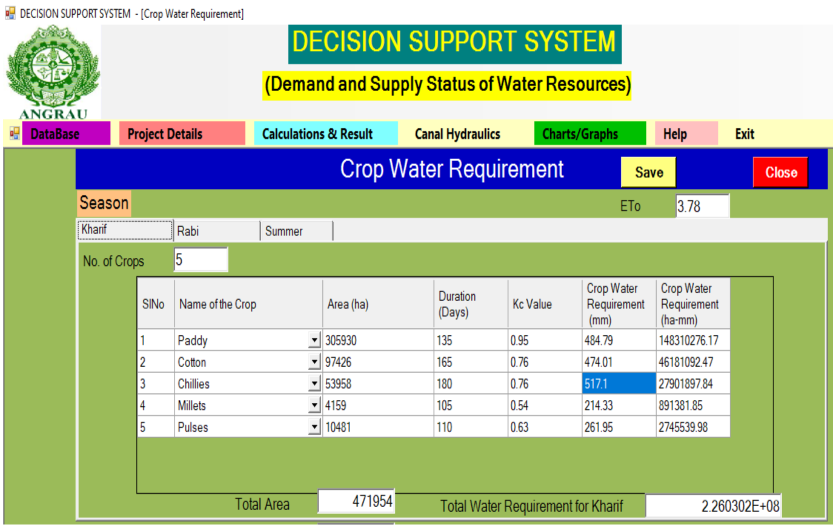


Fig. 8. Crop water requirement of the NSP command area during kharif season

Paddy, cotton, chillies, millets and pulses were present in the command area as major crops[11]. The agricultural water requirement for kharif season was 2,260.30 MCM, and rabi season was 2,195.01 MCM and there is no much varieties of crops grown in summer season. Finally, the agricultural water demand for all seasons was obtained as 4,455.32 MCM

3.1.4 Surface water availability

Available surface water is calculated from the annual average discharge data and evaporation losses and seepage losses etc. as 38.55% recommended by the CWC, Government of India [9] as shown in Fig.10. Then finally, net available surface water volume was 2,229.41 MCM.

3.1.5 Domestic Water Demand

The livestock details of the command area were obtained from the Chief Planning Office of the respective districts [12]. The domestic water demand was analysed as shown in Fig. 11 and obtained the domestic water demand of command area as 155.9 MCM.

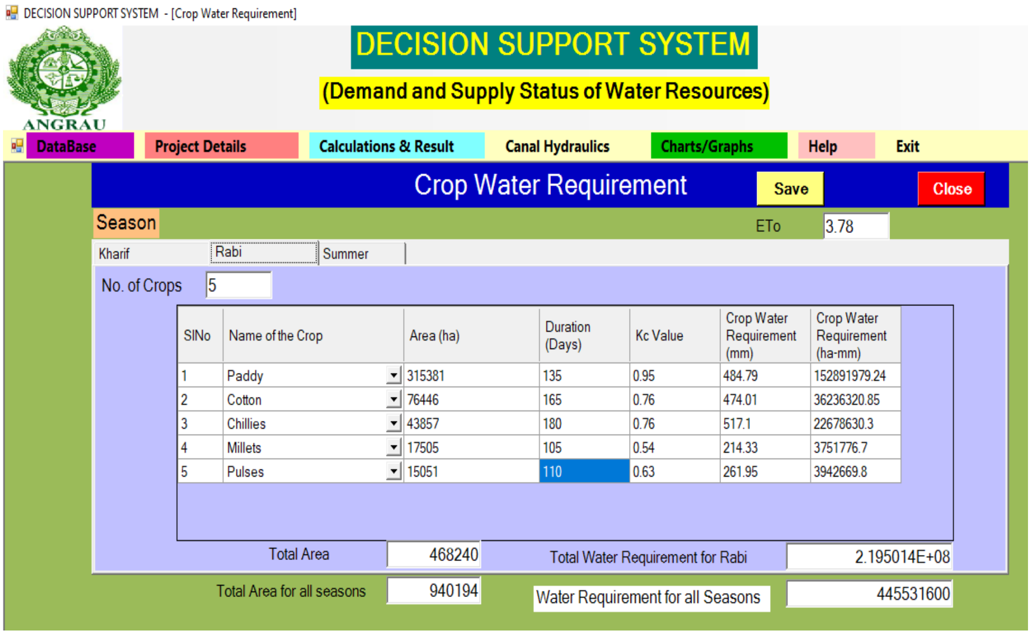


Fig. 9. Crop water requirement of the NSP command area during rabi season

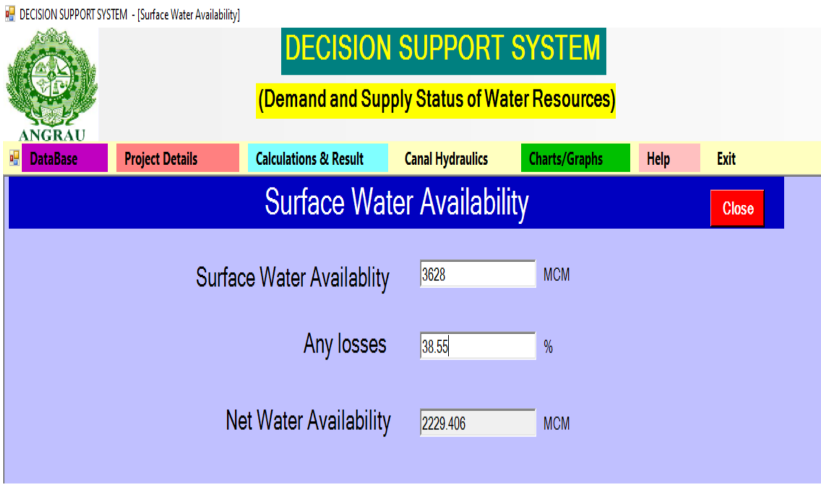


Fig. 10. Calibration of surface water availability of command area

3.1.6 Groundwater availability

The data was obtained from the State Groundwater Department, Vijayawada [13]. Finally, net availability of groundwater was calibrated as 1,384.663 MCM as shown in Fig. 12.

3.1.7 Canal hydraulics

In this, as per the given input data computed the discharge, velocity of flow, critical depth as shown in Fig.13. The input data parameters like full supply depth (D) 3.871 m, bottom width (B) 2.62 m, side slope (Z:1) 2:1,bottom slope (S) 0.00008333 and Manning's co-efficient (n) 0.0255 of main canal hydraulic particulars were given to the software. The computed discharge (Q) was 111.58 m^3/sec, velocity (V) 0.85 m/s, hydraulic radius (R) 3.02 m, area (A) 131.44 m^2, wetted perimeter (P) 43.52 m and critical depth (Yc) was obtained as 10.83 m by the model.

3.1.8 Charts/graphs

The graphs dialogue box and for different seasons of the crops were shown in Fig. 14.

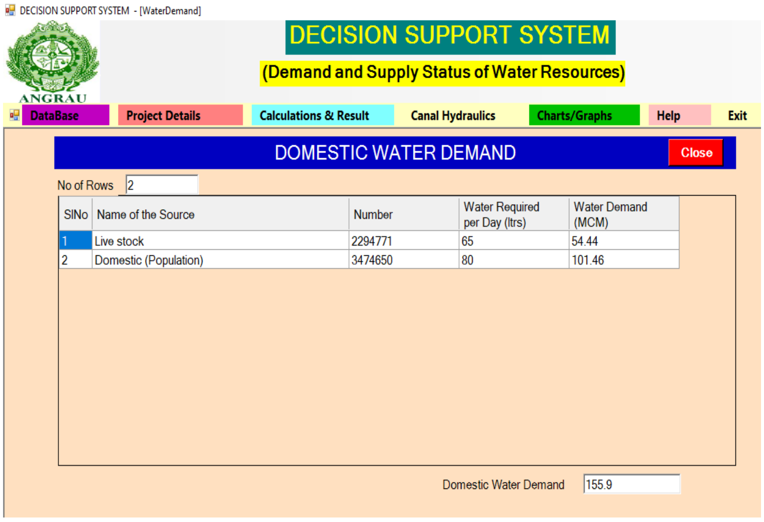


Fig. 11. Calibration of Domestic water demand

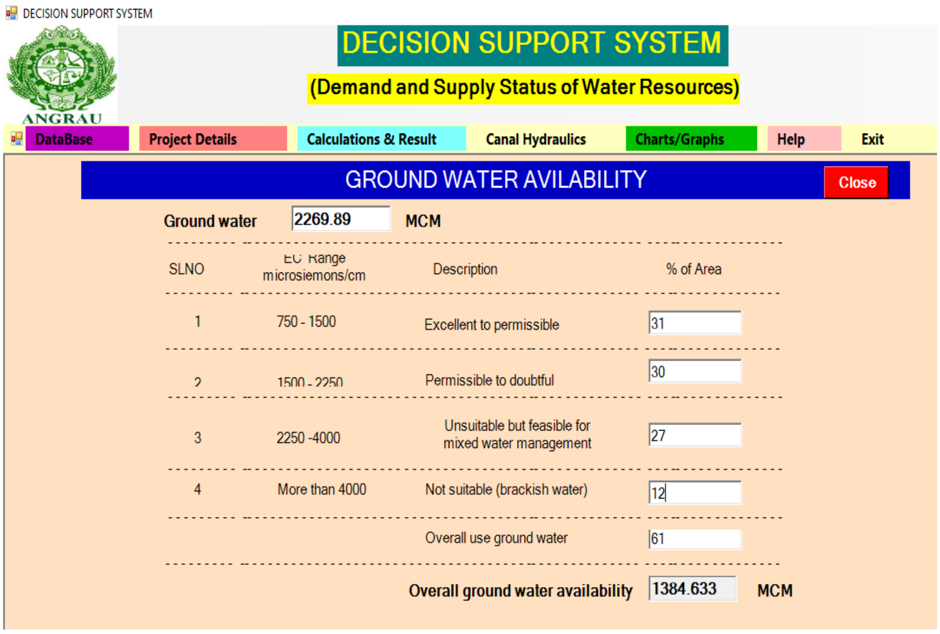


Fig. 12. Calibration of net groundwater availability of the command

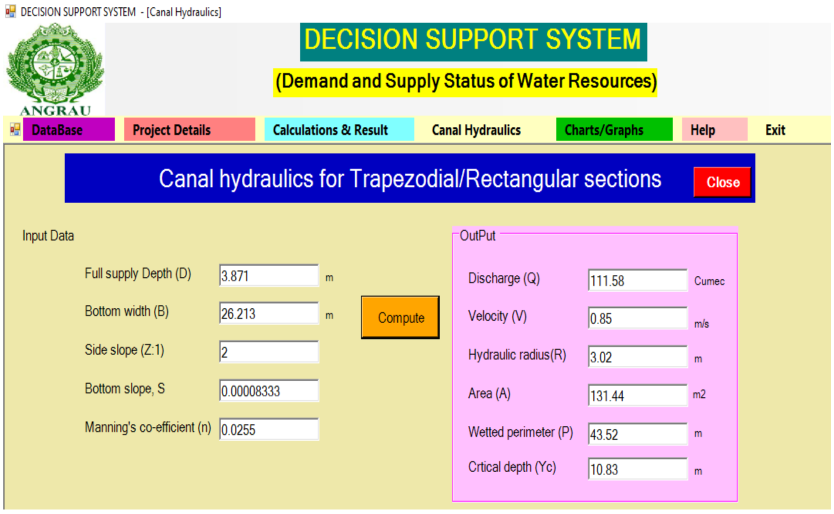


Fig. 13. Computation of discharge of canal

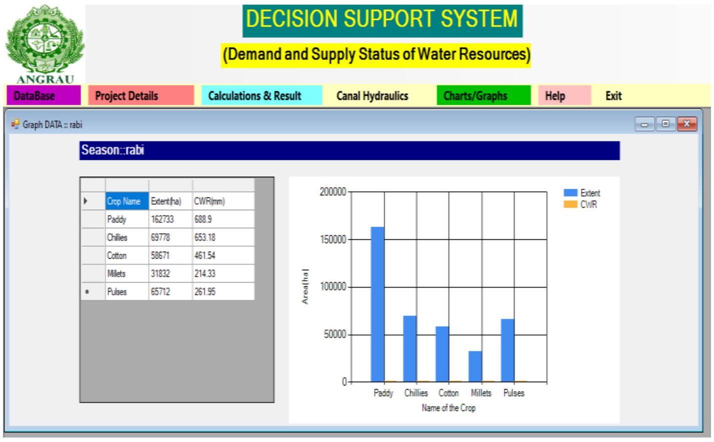


Fig. 14. Crops in Kharif season

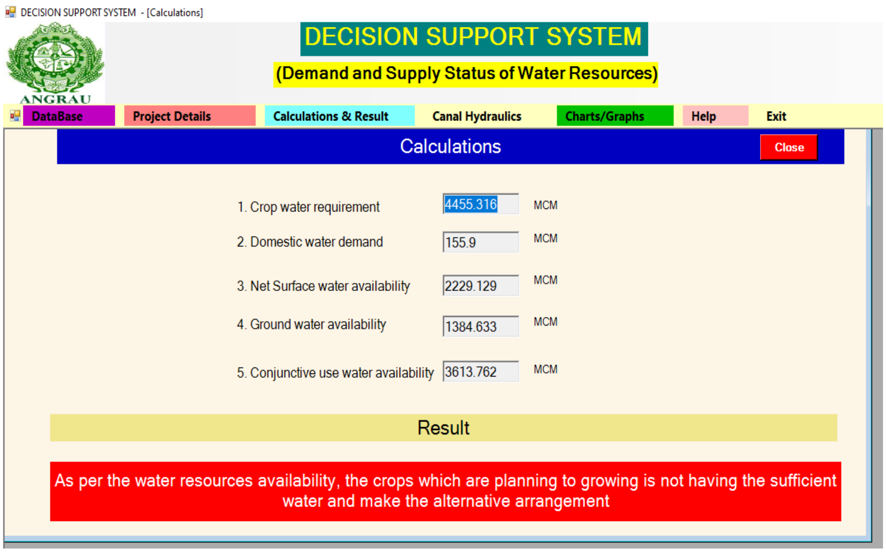


Fig.15. Calculations & result window of DSS

3.1.9 Calculations and Result

The crop water requirement for all the seasons was calculated as 4455.316 MCM, Domestic water demand as 155.9 MCM, net surface water availability as 2,229.406 MCM, net groundwater availability[14] as 1384.633 MCM and conjunctive use water as 3,614.039 MCM. The agricultural water demand and domestic water demand is more than the conjunctive use water. Hence, the availability of the water is not sufficient to raise the crops of their contemplated area. Finally, to reduce the cropped area or grow the less water requirement crops and shown in Fig. 15.

3.2 Crop Water Requirement by Using CROPWAT8.0

The crop water demand was calculated with CROPWAT8.0 in the Prakasam district of NSRC command area was 1,412 MCM and 3,044 MCM in Guntur district respectively. Overall crop water demand for both districts of NSRC command area for different soils and different crops was 4,456 MCM. Conjunctive use water of the command area was computed as 3,614 MCM after excluding all the losses.

Decision Support System computed the agricultural water demand for all the crops was 4455.32 MCM, domestic water demand was 155.9 MCM and conjunctive use water after deducting the all losses was obtained as 3,614.039 MCM. Finally, it could be seen that there is no much difference was observed by using this software [16]. With this model, the cropping pattern can be changed to change water demand can be changed and run the model to suit the conjunctive use quantity and water demand quantity same. The present study can be applied for minor canal to major head command areas also. The cropping pattern can be selected based on the net profit and use of less water crops. Thus the developed DSS can be clubbed with the output of any other optimization models that the conjunctive use be better possible.This usage of DSS could also be applied to a single crop where measurements can be made and a comparison can be made between the results of the field measurements and DSS.

4. CONCLUSIONS

The decision support system was designed and developed in visual basic. The DSS analyse data and computed values represented in graphical form. The maximum surface volume was observed in the year 2008-09 as 6051 MCM, minimum at 2015-16 as 490 MCM and the average surface water volume as 3628 MCM. Available surface water was obtained from the annual average discharge data. Then net available surface water volume was 2,229.41 MCM. The average groundwater volume as noticed as 2269.89 MCM and maximum in the year 2008-09 as3062.21 MCM and minimum in the year 2015-16 as 1825.55 MCM. Paddy, cotton, chillies, millets and pulses were grown under the command area as a major crop. The agricultural water requirement for kharif season was 2,260.30 MCM, and rabi season was 2,195.01 MCM. Finally, the agricultural water demand for all seasons was obtained as 4,455.32 MCM. The agricultural water demand and domestic water demand is more than the conjunctive use water[15].

Hence, the availability of the water is not sufficient to raise the crops of their contemplated area. The developed model can be linked with Flowpro, CROPWAT 8.0 and any other DSS conjunctive use planning of cropping pattern optimization programme modelling. The results obtained from the study can be used as a guide by farmers for selecting the amount and frequency of canal releases for the main crop.

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