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Development of a decision support system for simulation of runoff and available soil moisture at field scale land holdings of watershed

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■ **ABSTRACT :** A decision support system (DSS) is useful in generating alternate decision scenario for management of natural resources in an interactive and holistic way. The developed decision support system on runoff and soil moisture availability as a part of hydrological planning based on SCS curve number method uses the measured information on land use, soil type and rainfall. These conceptual decision and flow logic was formulated to link information through SCS curve number method and has transformed into a computer model using visual basic (VB) programming language. The output format provides daily rainfall and runoff and soil moisture status of the soil continuously for a given period of daily data. The DSS was validated for field scale land holdings of micro-watershed data and proposed for utilization by farmers and technocrats of line departments.

■ **KEY WORDS :** Decision support system, Runoff, Soil conservation service, Watershed, Visual basic

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Rainfall-runoff models that validated at field level are commonly used for computing runoff which as a critical input for hydrological design of structures. The soil conservation service (SCS, 1972) curve number method is a versatile and widely used approach for runoff estimation to a fairly accurate level with relatively more ease to use required data sets (Bhuyan *et al.,* 2003). The soil conservation service (SCS) curve number method was found to be capable of estimating the runoff volume and its peak rate of flow from small field scale land holdings of watershed with a reasonable degree of accuracy, among various models presently available (Amutha and Porechelvan, 2009; Banasika and Woodward, 2010 and Sundar Kumar *et al.,* 2010). The smaller land holding sizes (< 2 ha) in most of the watershed area also support the need for intensive study at field scale. Estimation of daily runoff and available soil moisture were transformed in to computer based decision support system (DSS), which supports many agricultural decision making activities (Pertiwi *et al.,* 1998; Bernard *et al.,* 2003; Miller *et al.,* 2004; Sarangi *et al.,* 2004; Nguyen *et al.,* 2007 and Andre Muga *et al.,* 2008). While developing a DSS, the emphasis on user friendly tools and interfaces would help better to evaluate and to assess the impact of watershed characteristics on runoff volume. In a given situation, the availability of runoff potential or availability of soil moisture for a given soil profile under a specific time frame of the season due to impact of various geo-hydrological factors, would be equally a complex task while transforming into a DSS (Datta, 1995). The applicability of a versatile SCS-CN model to long-term hydrological modeling and efficiency would be maximum with the ratio in the order of 0.01 (Mishra and Singh, 2004). Fixing of the initial abstraction ratio at 0.2 might not be the most appropriate and that it would be interpreted as a regional parameter (Ponce and Hawkins, 1996; Batlas *et al.*, 2007 and Zhi Hua Shi *et al.*, 2009).

METHODOLOGY

The development of DSS was undertaken with a view of its application to the area under agro-climatic condition of the North eastern dry zone, Northern dry zone and North eastern transition zone of Karnataka during the year 2013. The general empirical form of SCS-CN follows the procedure of selection of land use and its cover of a particular area was subjected to verification and modification to suite prevailing agronomic conditions (Sahu *et al.*, 2012). In the process of selection of land use, land cover, treatment or practice and hydrologic condition or crop canopy was based on best management practices adopted and formulated jointly by university and line departments. The suitable snapshots of crop spacing, growth stages and canopy development were also introduced to enhance practical selection of crops under the prevailing agro-climatic conditions. The selection of land use and cover were mainly classified as agriculture, horticulture and forest type. Further, agriculture and horticulture subdivided into different individual category of these crops which are grown in agro climatic conditions. The density of crop or canopy was expressed in terms of percentage of the total growth as a improved means of data inputs.

The selection of hydrologic soil groups (A, B, C and D) of SCS method were made more expressive towards revealing actual situation soil original than in SCS-CN method. Here, the soils were classified on the basis of their textural classes. The new criteria of selection of soil category would be among 12 classes and linked to original four hydrological group's *viz*., group A, B, C and D to get better interpretation. The appropriate snapshots of typical textural classification found to be enhancing user friendliness.

The relationship between initial abstractions and potential maximum retention (Vandersypen *et al*., 1972) was adopted for prevailing agro-climatic conditions. For black soil region with AMC-I, I_a was taken as 0.3S and whereas, for black soil region with AMC-II and AMC-III, I_a was taken 0.1S.

The original SCS-CN method was used to predict the runoff potential.

$$Q = \frac{(P - I_a)^2}{P - I_a + S}$$

where,

Q = Runoff depth (mm),

P = Precipitation (mm),

Ia = Initial abstraction (mm) and

S = Potential maximum retention (mm)

The runoff (Q) depth thus generated also provides data on cumulative infiltration (F) on each event of rainfall. Hence, the cumulative infiltration could be obtained as

$$F = P - Ia - Q$$

where

F = Cumulative infiltration.

The infiltration quantity (F) expressed in mm was compared with available moisture holding capacity (AMHC) for each soil class to get moisture availability.

The developed decision support system for hydrological planning incorporates the established information on land use, soil type and rainfall. The itenery was transformed into computer based software using visual studio (Fig. A). The decision support system (DSS) which generates runoff (mm) and soil moisture availability (mm/m) in field scale area uses interactive controls and algorithms of visual basic programming language. The nested "If . . . Then . . . Else" logical decisions were extensively used as an interpretive algorithm for the generation of alternative options using the input data and information (Sarangi *et al.*, 2004). The DSS runs on a platform of Windows 95™, or above and its interface are user-friendly. It is best viewed at a screen resolution of 1024 × 768 pixels. The graphic user interface (GUI) of the DSS is a combination of pop-up windows, pull-down menus and button controls.

The developed decision support system (Hydrological planner) consists of five tabs form named as 'Welcome', Land use',' Soil type', 'Rainfall data' and 'Results'. All the tabs in the VB forms are linked in a visual studio 2010 environment.

The developed DSS was validated for field scale rainfall-rainfall data pertaining to a micro watershed (16° 48' and 16° 52' North latitude and 75° 49' to 75° 53' East longitude) which located in Bijapur taluk and district (Premanand, 2002). The soils of the test watershed were clayey and crop during *Kharif* was bajra which occupied

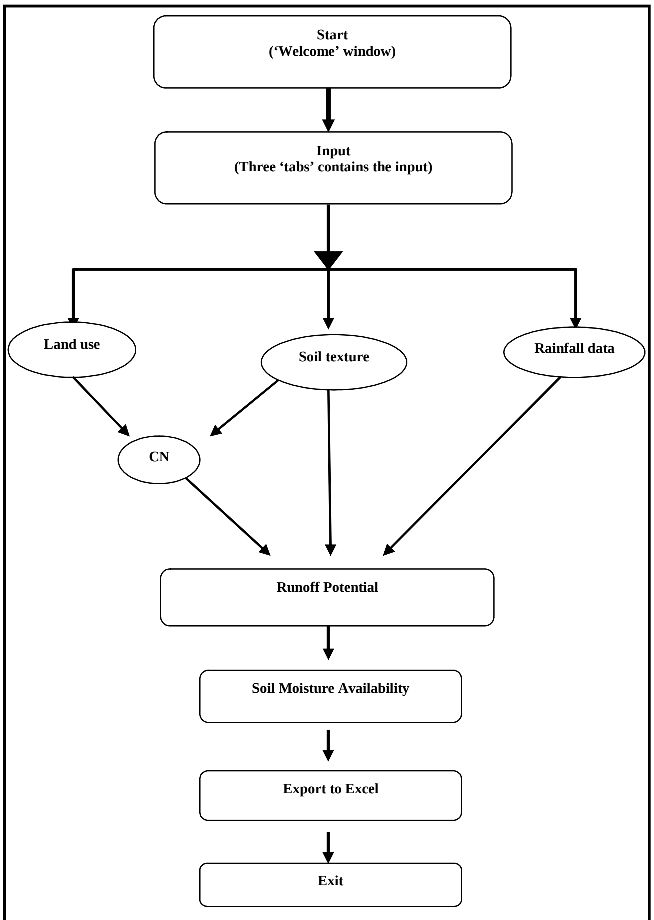

Fig. A : Flow chart of the DSS displaying the flow control architecture

major area.

■ RESULTS AND DISCUSSION

The development of decision support system was envisaged to estimate runoff (mm) and available moisture status (mm/m) of land holding at field scale through computerized software namely hydrological planner was developed. The software was redesigned itself to cover the crops that are grown in Northern dry zone, North eastern dry zone and North eastern transition zones of Karnataka and prevailing soil type that come across (Anonymous, 2009). However, user with similar situations could use elsewhere as the case may can use alike.

The conceptual decision and flow logic was formulated to link this information through the VB programming language. The decision support was developed with graphical user interface (GUI) capability. This provides the user vital interactive environment to select, enter input and to get output information regarding land use, soil type and rainfall data.

The information regarding crop details like recommended crop spacing, cropping period and crop duration and sample crop images can be displayed in the same window so that user appended with more realistic information (Fig. 1). The information regarding soils was shown with image along with per cent of sand, silt and clay that it contains so that user can easily identify what types of soil that he come across and land holding being considered (Fig. 2). Rainfall is the basic input data in predicting the runoff and soil moisture availability status. The antecedent moisture condition (AMC) class would be decided based on 5 days antecedent rainfall. Hence, data on rainfall events are to be entered by selecting the

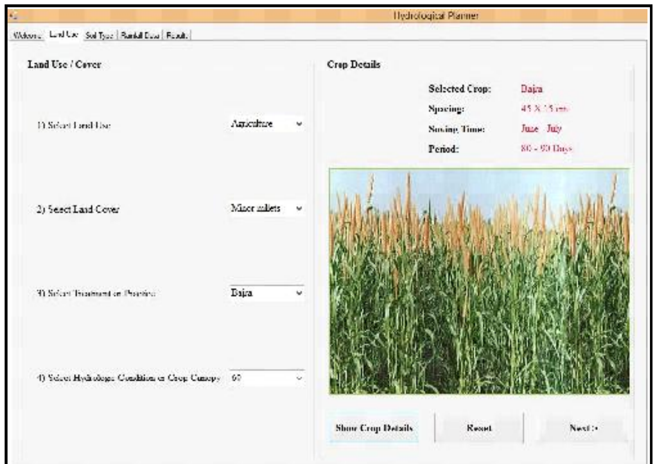

Fig. 1 : The DSS frame displaying the selected land use pattern of micro watershed

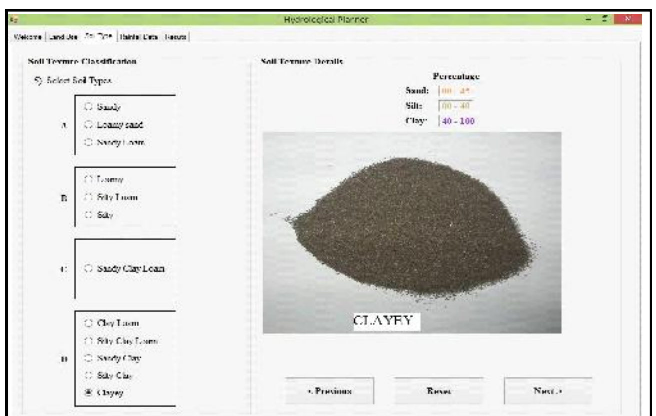

Fig. 2 : The DSS frame displaying the selected soil type of micro watershed

corresponding year and month followed by day of the rainfall in the corresponding boxes provided on the window (Fig. 3). The user can work for the rainfall data from the year of 1990 to till date.

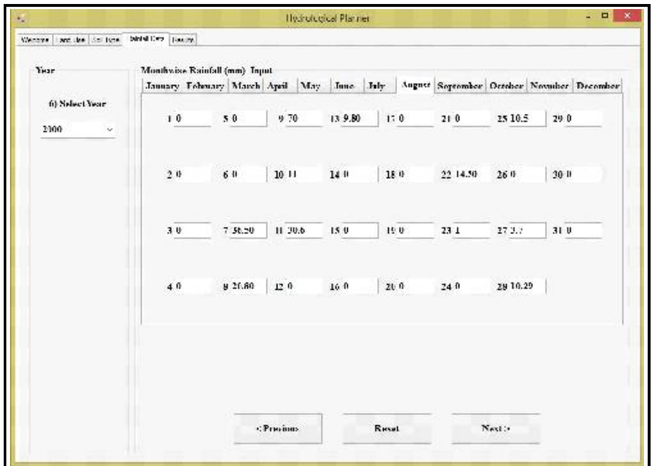

Fig. 3 : The DSS frame displaying the rainfall data of micro watershed

Results window consists of different parameters *viz.*, rainfall data, 5 days antecedent rainfall, AMC class, CN, potential maximum retention (S) and initial abstraction. These are essential factors in the calculation of runoff potential and moisture availability status. Hence, the results have been presented in spreadsheet form so as to get detailed information on each of the parameters that are essential for the calculation. This window also displays the appropriate interpolated curve number for each corresponding land use and soil type. The available moisture holding capacity in each corresponding soil would be compared with the cumulative infiltration (F) value by the software to get the status of the soil moisture

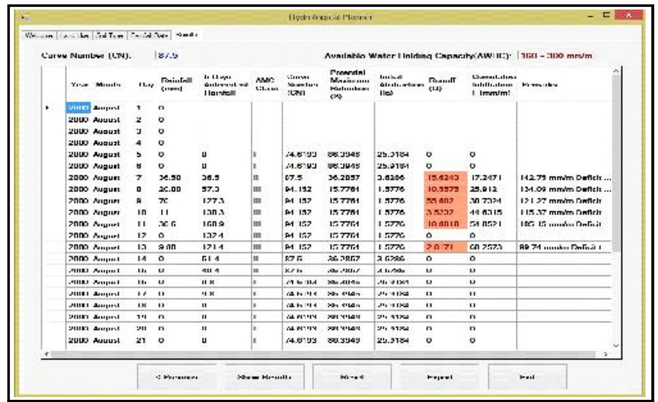

Fig. 4 : The DSS frame displaying the results of micro watershed

(Fig. 4). The measured runoff quantity in each corresponding rainfall events were compared with the output runoff of the developed software and found satisfactory (Table 1).

Conclusion :

The DSS package will find its use with the officials of the state agriculture and watershed Departments, who are in charge of planning and development of watersheds. The researchers, NGOs, policy makers, educational institutions, research and development institutions would also find it useful. The main advantage of this software is that it will reduce the labour and time required for the hydrological computations in watershed analysis, while being accurate and resourceful. Future programme of work:

The software was tested for selected agro-climatic region. This can be applied for various agro-climatic regions.

This study can be extended for various watersheds

Table 1 : Measured rainfall-runoff and estimated runoff pertaining to micro watershed in Bijapur district

Sr. No.	Rainfall data		Runoff (mm)	
	Date	Depth (mm)	Measured	Estimated using hydrological planning
1.	07/08/2000	36.50	0	15.62
2.	08/08/2000	20.80	8.65	10.55
3.	09/08/2000	70.00	49.70	55.60
4.	10/08/2000	11.00	0	3.52
5.	11/08/2000	30.60	0	18.80
6.	13/08/2000	9.80	0	2.81
7.	22/08/2000	14.50	0	0
8.	25/08/2000	10.50	0	0
9.	27/08/2000	3.70	0	0
10.	28/08/2000	10.29	0	0

pertaining to other different agro-climatic zones including high rainfall zones.

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