Decision support system for efficient water management in canal command areas

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A decision support system for canal water releases (CWREDSS) was developed to provide demand-based optimal canal water releases for reducing the gap between canal supplies and demands for increasing the water-use efficiency in canal command areas. The developed decision support system (DSS) was evaluated under different situations of the command area of Guvvalagudem major distributary of the Nagarjunasagar Left Canal, Andhra Pradesh, India, as a case study. Results indicate that the CWREDSS is capable of developing releases under different scenarios of varying cropping patterns, groundwater use situations and different rainfall probability levels of the study area, and reduced the gap between demands and supplies considerably. DSS provides suggestions/decisions under different situations of water deficit/surplus. CWREDSS will help irrigation engineers, agronomists and agro-meteorologists in the planning, operation and management of irrigation systems.

Keywords: Canal supplies and demands, command areas, cropping pattern, decision support system, water management.

THE establishment of large irrigation system in the developing countries of the Asian regions has significantly contributed to the development of agriculture in these countries. However, at present the operation and management of the irrigation systems are subjected to much criticism. Problems of low water-use efficiency (about 30–35%) and inequitable distribution of water among the beneficiaries are usually highlighted[1]. Most of the major irrigation command areas in India suffer from problems of inadequate and unreliable water supply, having wide gaps between irrigation potential created and utilized. This leads to temporal imbalance of water demands and supplies, excessive seepage losses and rise of groundwater table, resulting in problems of waterlogging and salinity[2–4]. In addition, failure of monsoon rains, resulting in water scarcity and drought lead to disputes among the water users. All these problems exists due to inadequate attention paid to the assessment of water resources, non-matching of canal water releases with rainfall, crop water requirements and change in the cropping pattern from what has been envisaged at the time of planning[4,5]. While short-term imbalances between water supplies and demands are inevitable, it is possible to reduce these considerably, if not totally, through development and adoption of appropriate water-management techniques and policies that take into account rainfall, changing cropping pattern and crop water demands.

Almost all the current canal water-release policies in India (warabandi, shejpali, block system, localized system and zonal system) are supply-based[6] and make little effort in meeting the actual water requirement of the existing cropping pattern and under actual level of groundwater exploitation. Optimization and simulation models were developed for providing operation policies for large systems to reduce the gap between the demands and supplies[6–11] (A. Mishra, unpublished). Optimization models provide operational guidelines; however, they do not incorporate heuristic, subjective and judgmental information, which is also needed for efficient operation of a water-resource system. Optimization models are not user-friendly and work on several assumptions.

The decision support system (DSS) is user-friendly, which incorporates 'knowledge' and expertise within the framework of the decision support mechanism. The DSS is an integrated assembly of models, data, interpretive routines and other relevant information that efficiently processes input data, runs the models and displays the results in an easy-to-interpret format[12]. DSS will help in the decision-making process, to understand the problem and explore various alternative courses of action. DSS helps the user to analyse facts and situations, to try out several different scenarios, and help in selecting the most appropriate decision. The available DSS for irrigation water management[12–17] is either non-comprehensive and does not consider actual multi-crop systems or does not account for water distribution on the basis of shorter time intervals (i.e. weekly) and do not incorporate the concept of equity. Keeping these considerations in view, in this study a decision support system for canal water releases (CWERDSS) was developed to provide demand-based water release strategies for reducing the gap between canal supplies and demands and to help irrigation engineers, agronomists and agro-meteorologists in planning, operation and management of irrigation systems efficiently. CREWDSS can reduce the water scarcity of the tail-end farmers and increase the water-use efficiency in canal command areas. CWREDSS was applied under different situations of the command area of Guvvalagudem major distributary of the Nagarjunasagar Left Canal, Andhra Pradesh (AP), India, to evaluate for its ability to develop releases and reduce the gap between demand and supply.

Development of DSS is an incremental process. The lifecycle of DSS involves four main stages: (1) knowledge acquisition, (2) problem structuring and system design, (3) problem encoding and (4) system testing[18].

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There are several sources of knowledge employed in the development of DSS. These sources are textbooks, manuals, research articles, personal experience and expert advice. The DSS was developed in the form of a computer program using the input interactive controls and algorithms of Visual Basic 6.0 programing language. The nested ‘If. . . Then . . . Else’ construct was extensively used as in interactive algorithm for the generation of alternative decisions using the input information.

Canal water releases at head works are the function of crop water requirement at field level, groundwater supplies, seepage losses in canal network, canal geometry and water availability. While developing releases, all these components have to be estimated. Keeping these in mind, six modules were developed for the DSS, i.e. evapotranspiration (ET_0), rainfall, crop, seepage loss, groundwater use and release module. Each module was made for estimating a particular component of canal water releases. The architecture of the DSS for canal water releases is presented in Figure 1. Each module contains the input menus, output menus, text boxes and radial boxes.

In the ET_0 module the ET_0 of each crop for each period can be computed using the following relationship[19] (eq. (1)):

$$ET_C = ET_0 \times K_C, \tag{1}$$

where ET_C is the crop evapotranspiration (in mm/week), ET_0 the reference evapotranspiration (in mm/week), and K_C the crop coefficient (in fraction).

The crop module contains various menus and text boxes for crop information (Figure 2). In this module, the inputs are crop acreage, crop planning, crop growth stages, crop coefficients, special needs and application efficiency. Crops grown in khariff and in rabi season were included. In this module crops like paddy, maize, sunflower, block gram, cotton and chilli, which are generally grown in the Nagarjunasagar canal command area were included. Other crops than these may be entered in the additional text box provided in the module. For crops grown in the selected command area, crop coefficients, crop growth stages and days of growth stages are provided. Total water requirement (TWR) of a given crop, in a particular period is equal to the sum of the crop consumptive use (ET_C) and special water need (if any) of that crop during the period. In this module, a small screen is also provided for special needs such as land preparation, percolation losses and leaching requirement and pre-sowing irrigation (eq. (2)).

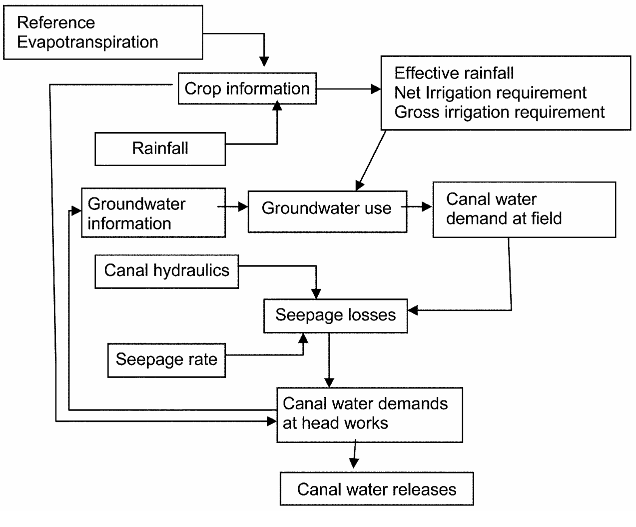


Figure 1. Architecture of the decision support system for canal water releases.

$$TWR = ET_C + SWN, \tag{2}$$

where TWR is the total water requirement (in mm), and SWN the special water need (in mm).

To account for loss of water incurred during field application, an efficiency factor is considered when calculating the gross irrigation water requirement of crops at field level. The module will calculate the gross irrigation requirements using eq. (3).

$$GIR = \left(\frac{NIR}{\eta}\right), \tag{3}$$

where η is the application efficiency (in %), GIR the gross irrigation water requirement (in mm), and NIR the net irrigation water requirement (in mm).

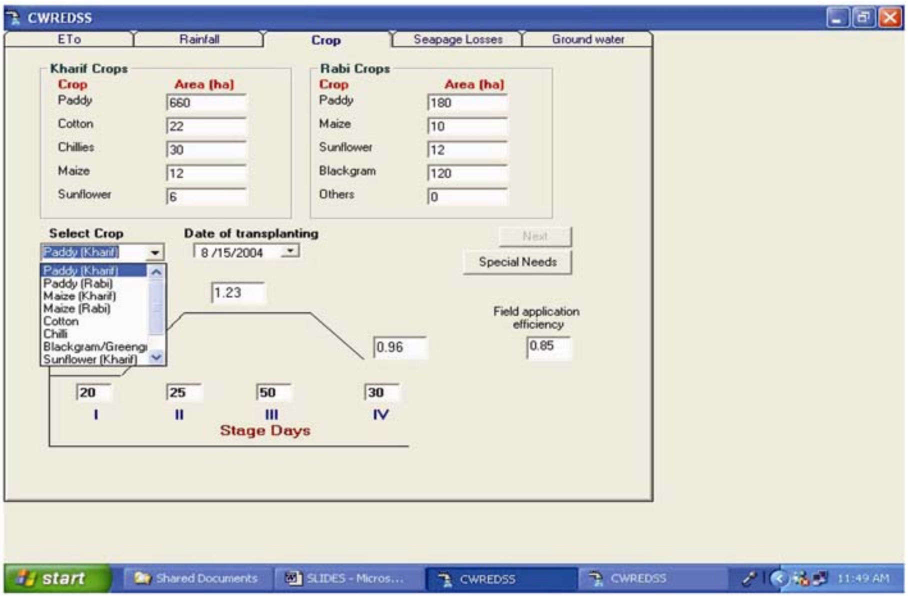
From the crop production point of view, only that portion of the total rainfall should be considered as effective rainfall (ER), which is useful directly and/or indirectly for the production of crops at the site where it falls. In the rainfall module, the effective rainfall of each individual crop was calculated using the USDA–SCS method by incorporating a slight modification in this method[20] (H. S. Gulati, unpublished). Once TWR and ER for different crops in a given period are known, NIR of that crop on the ith day can be computed as follows (eq. (4)):

$$NIR_i = TWR_i - ER_i. \tag{4}$$

Weekly canal water demand at field level was calculated by deducting the groundwater supply from the total irrigation demands in that week. The groundwater use was estimated using eq. (5).

$$GWU = \left(\frac{N \times Q \times H \times t}{1000}\right) \times 3600, \tag{5}$$

where GWU is the Groundwater use (in m^3), N the number of wells, Q the pump discharge (in l/s), H the working hours per day, and t the time interval (in days).



Kharif Crops

Crop	Area (ha)
Paddy	660
Cotton	22
Chillies	30
Maize	12
Sunflower	6

Rabi Crops

Crop	Area (ha)
Paddy	180
Maize	10
Sunflower	12
Blackgram	120
Others	0

Select Crop: Paddy (Kharif)

- Paddy (Kharif)
- Paddy (Rabi)
- Maize (Kharif)
- Maize (Rabi)
- Cotton
- Chilli
- Blackgram/Greengi
- Sunflower (Kharif)

Date of transplanting: 8 /15/2004

1.23

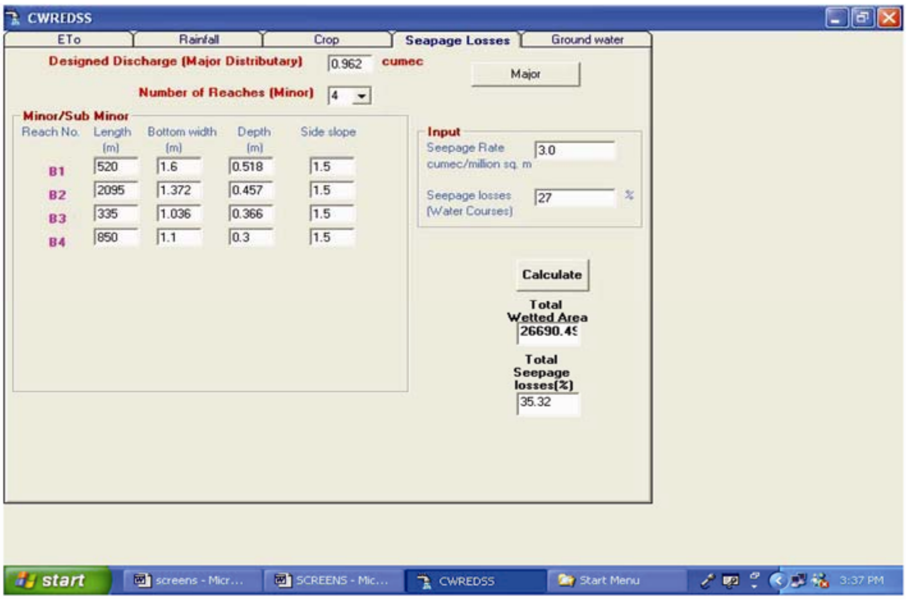
0.96

Field application efficiency: 0.85

Stage Days

I	II	III	IV
20	25	50	30

Figure 2. Screen showing the crop module of CWREDSS.



Designed Discharge (Major Distributary) 0.962 cumec

Number of Reaches (Minor) 4

Minor/Sub Minor

Reach No.	Length (m)	Bottom width (m)	Depth (m)	Side slope
B1	520	1.6	0.518	1.5
B2	2095	1.372	0.457	1.5
B3	335	1.036	0.366	1.5
B4	850	1.1	0.3	1.5

Input

Seepage Rate cumec/million sq. m 3.0

Seepage losses (Water Courses) 27 %

Total Wetted Area 26690.4

Total Seepage losses(%) 35.32

Figure 3. Screen showing hydraulic details of minor and estimated seepage losses.

A substantial part of the total water released at the canal head works is lost in the main canal, branches, distributaries, minors and watercourses before it reaches the field. These losses mainly include seepage and evaporation losses. Generally evaporation losses in the canal network are ignored in comparison to seepage losses. These seepage losses depend upon the type of soil and the ratio of the wetted area to the discharge rate in a channel. In this module, seepage losses in the canal network are estimated based on actual canal geometry and constant seepage rate (Figure 3).

In the release module, canal releases are developed based on the crop water demands, groundwater utilization, seepage losses in the canal network, canal capacity and existing operation policies of the selected canal command area. In this module, the crop water demands were calculated by crop module, groundwater use estimated by groundwater use module and seepage losses estimated by seepage losses module. These modules were linked and canal water demands at field and head works were estimated. The flow chart of the release module is presented in Figure 4. The rules related to canal operation policies, canal geometry, and canal capacities were applied in the program in the form of 'If. . . Then . . . Else' statements. The rules that were incorporated for canal releases are:

- The releases should not be greater than the designed capacity of the canal.
- The releases should not be less than 40% of the designed capacity of the canal.

Figure 4 shows that ≥80% of the total weeks of the canal water demands are within the range of 60–110% of the canal capacity, the system will provide releases without any suggestions or options. Otherwise, it will provide a set of options for that situation. If canal water demands are found lesser than 60% of the canal capacities in at least 20% of the weeks of canal operation, the system will indicate the exact number of weeks that are likely to have water demands less than 60% of the canal capacity during both kharif and rabi. The rationale behind ≥80% of the total weeks of canal water demands is being within the range of 60–110% of the design capacity is that for releases less than 60% of design capacity, there will be more seepage losses. Also, it is not advisable to run the canals more than the design capacity[21].

This module provides the status of weekly water demands and supplies. It also provides alternative suggestions/decisions that may be taken to handle water deficit/surplus situations effectively (Figure 5).

The final outputs of this DSS are weekly GIR of various crops and canal water releases at the head of the distributary canal.

The developed CWREDSS was applied for the command area of Guvvalagudem major distributary of the Nagarjunasagar Left Canal (Figure 6), to evaluate its ability to develop releases and reduce the gap between demand and supply. The Guvvalagudem Major Distributary Command area is located in irrigation block no. 18 of the Nagarjunasagar Left Main Canal Command area, which is 18–20 km from Khammam town, AP, on its southwestern side. The gross command area of the distributary is 830 ha and the net command area is 730 ha. The net command area consists of 660 ha wet (paddy) and 70 ha irrigated dry area. The entire canal network is unlined. The major distributary has three minors, namely high-level canal, Katkur minor and 6R minor. Water is released from this canal usually in the first week of August and closed in the third week of April. From August to December, water supply is continuous and from January to April it is intermittent.

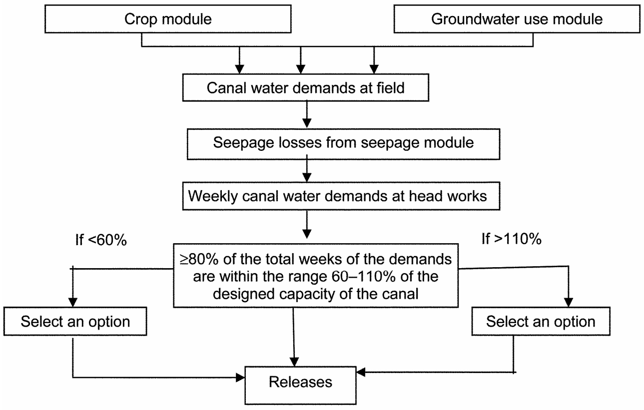


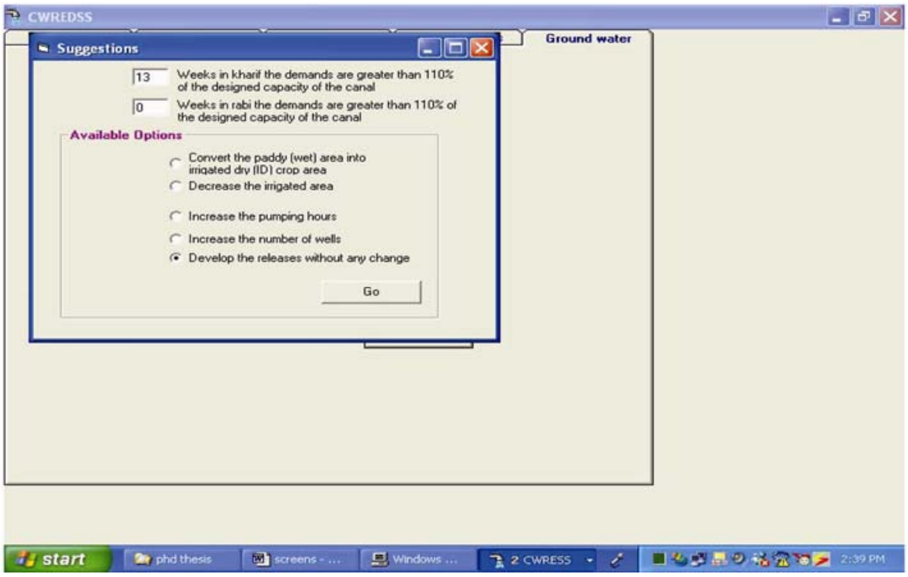
Figure 4. Flow chart for release module.

The climate of the study area is tropical wet and dry. It is characterized by a long dry period that spreads over winter and early summer. The summer, which is hot and dry, is followed by monsoon rains. The mean daily temperature varies from 30°C to 36°C during April–June, and from 20°C to 24°C in December and January. The mean maximum temperature ranges between 40°C and 43°C in May. The annual normal rainfall is 1030 mm. More than 75% of it is received during the southwest monsoon season, i.e. from June to September, with July being the wettest month. Soils of the command area are red sandy loam. The major crops grown in the area are paddy, cotton and chillies. Maize, sunflower and black gram are also grown in the area. Paddy crop is grown in the wet area. The other crops are grown in irrigated dry areas.

The developed CWREDSS was evaluated for developing canal water releases under different cropping patterns, groundwater use situations and different rainfall probability levels of the selected canal command area. The canal water demands and releases developed by the CWREDSS under these situations were compared with the canal water releases provided by the canal authorities and the gap between them was determined.

The DSS was used for the development of releases under three different cropping patterns of the selected canal command area. The results of cropping pattern-I are presented in Figure 7, which reveals that there is wide gap between demand and water releases provided by the canal authority. The gap between demand and water releases provided by the CWREDSS is minimal. In the khariff season for most of the weeks the CWREDSS developed water releases closely matched the canal water demands compared to water releases developed by the canal authorities during this period. The canal releases developed by the CWREDSS during the rabi season (from Standard Week 51 to Standard Week 16) were intermittent, i.e. one week off and one week on. The developed releases are taken into account of canal operation policies existing in that selected canal command area due to that, the weekly water releases developed by the CWREDSS for rabi season significantly differ from the demands. But the average release of two weeks, i.e. one on-week and one off-week is close to the demands.

The gap between weekly canal water demand and canal water releases was determined (see Table 1). Table 1



13 Weeks in kharif the demands are greater than 110% of the designed capacity of the canal

0 Weeks in rabi the demands are greater than 110% of the designed capacity of the canal

Available Options

○ Convert the paddy (wet) area into irrigated dry (ID) crop area
○ Decrease the irrigated area
○ Increase the pumping hours
○ Increase the number of wells
● Develop the releases without any change

Figure 5. Screen showing that demands are 110% more than the design capacity of the canal.

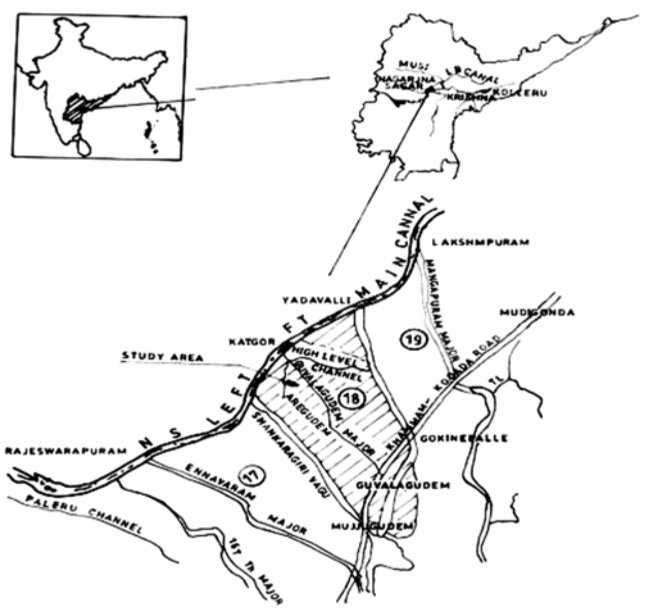


Figure 6. Line sketch of Lalbahadur canal network and its command area, Nagarjunasagar Project, Andhra Pradesh, India.

reveals that there is wide gap between demand and water releases provided by the canal authority. The gap between demand and water releases provided by CWREDSS is minimal. For cropping pattern-I, weekly average water releases provided by the canal authorities was in surplus/deficit to the tune of 18.2%. The water releases provided by CWREDSS was in deficit/surplus to the tune of 1.5%. For cropping pattern-II, weekly average water releases provided by the canal authorities was in surplus/deficit to the tune of 15.4%. The releases provided by CWREDSS brought it to 2.5%. For cropping pattern-III, the weekly water releases provided by the canal authorities were in surplus/deficits to the tune of 27.2%. The CWREDSS brought it up to 2.2%.

Similarly, the gaps between annual canal water demand and canal water releases were determined (see Table 2). Table 2 reveals that there is wide gap between demand and water releases provided by the canal authority. The gap between demand and water releases provided by CWREDSS is minimal. For the cropping pattern-I, annual water releases provided by the canal authorities were in deficit to the tune of 8.8%. The water releases provided by the DSS brought these deficits into surplus to the tune of 0.75%. For cropping pattern-II, annual water releases provided by the canal authorities were in surplus to the tune of 5.5%. The releases provided by the DSS brought this surplus to 2.1%. For cropping pattern-III, the annual water releases provided by the canal authorities were in huge deficit amounting to 23%. The DSS brought this deficit down up to 2.6%.

From Tables 1 and 2 it can be observed that there is huge deficit for cropping pattern-III. This was due to more area under paddy cultivation. This may be noted from the canal releases developed by CWREDSS, minimized the variable demands and supplies and reduced the gap between two through providing the same amount of water, just by moderating the canal releases. Also, it may be noted that cropping pattern-I appears to be the most appropriate for the selected command area, as it results into the least gap between the canal water supplies and demands. CWREDSS also helps develop optimal cropping pattern where the gaps between demands and supplies are minimum.

CWREDSS was used to develop canal water releases for a given cropping pattern of the command area under

Table 1. Gaps between weekly canal water releases and demands

	CP-I: Gaps between		CP-II: Gaps between		CP-III: Gaps between	
Standard week	Canal authority releases and demands (%)	DSS developed releases and demands (%)	Canal authority releases and demands (%)	DSS developed releases and demands (%)	Canal authority releases and demands (%)	DSS developed releases and demands (%)
31	25.52	0.00	24.11	2.50	38.24	0.00
32	24.69	0.00	24.84	0.00	32.22	0.00
33	26.69	0.00	24.41	1.80	45.45	0.00
34	36.92	9.03	26.22	6.32	35.98	2.35
35	21.98	0.00	11.85	0.00	25.98	0.00
36	19.25	0.00	14.71	0.00	31.44	0.00
37	1.09	0.00	25.35	1.50	5.23	0.00
38	35.33	0.00	21.69	1.80	26.01	0.00
39	45.19	9.10	22.27	4.23	62.57	0.00
40	49.95	0.17	8.08	3.30	49.72	0.00
41	37.13	0.00	34.58	6.80	46.51	0.00
42	10.10	0.00	10.86	0.00	22.55	0.00
43	11.73	0.00	2.21	0.00	3.30	0.00
44	8.39	0.00	11.17	2.14	20.79	0.00
45	23.66	6.36	21.65	4.88	14.20	4.59
46	20.25	2.18	35.64	4.88	3.93	0.00
47	27.21	9.78	37.40	7.48	14.68	6.87
48	21.66	2.91	29.23	5.10	9.77	0.00
49	17.47	0.00	9.17	0.00	3.11	0.00
50	18.91	0.00	22.90	2.55	38.20	4.35
51	48.25	9.10	20.83	0.00	40.01	5.71
52	19.86	0.00	24.62	12.17	42.13	7.32
1	0.00	0.00	0.00	0.00	0.00	0.00
2	13.47	0.00	21.46	7.74	48.72	7.56
3	0.00	0.00	0.00	0.00	0.00	0.00
4	32.87	0.00	21.62	2.50	51.74	7.79
5	0.00	0.00	0.00	0.00	0.00	0.00
6	10.71	1.97	3.28	0.00	55.65	6.60
7	0.00	0.00	0.00	0.00	0.00	0.00
8	6.90	0.00	22.89	4.14	57.64	10.79
9	0.00	0.00	0.00	0.00	0.00	0.00
10	21.38	0.00	5.23	0.00	59.66	11.12
11	0.00	0.00	0.00	0.00	0.00	0.00
12	21.26	4.92	14.65	4.75	57.71	5.06
13	0.00	0.00	0.00	0.00	0.00	0.00
14	15.52	0.00	16.97	6.87	63.30	0.00
15	0.00	0.00	0.00	0.00	0.00	0.00
16	8.09	5.83	5.06	2.69	66.43	0.00
Average	18.20	1.50	15.40	2.53	27.20	2.17

CP, Cropping pattern.

Table 2. Gaps between annual canal water releases and demands

	Surplus or deficits	
Cropping pattern	Gap between actual canal releases and demands (%)	Gaps between DSS developed releases and demands (%)
Cropping pattern-I	–8.8	+0.75
Cropping pattern-II	+5.5	+2.1
Cropping pattern-III	–23.0	–2.6

three different groundwater-use situations of the selected area. The three selected situations were (1) the existing number of wells in the command area, (2) by doubling the existing number of wells, (3) zero level of groundwater use. Figure 8 reveals that there is not much difference between the demands and releases under these three groundwater-use situations. The gap between demand and release under groundwater use from the existing number

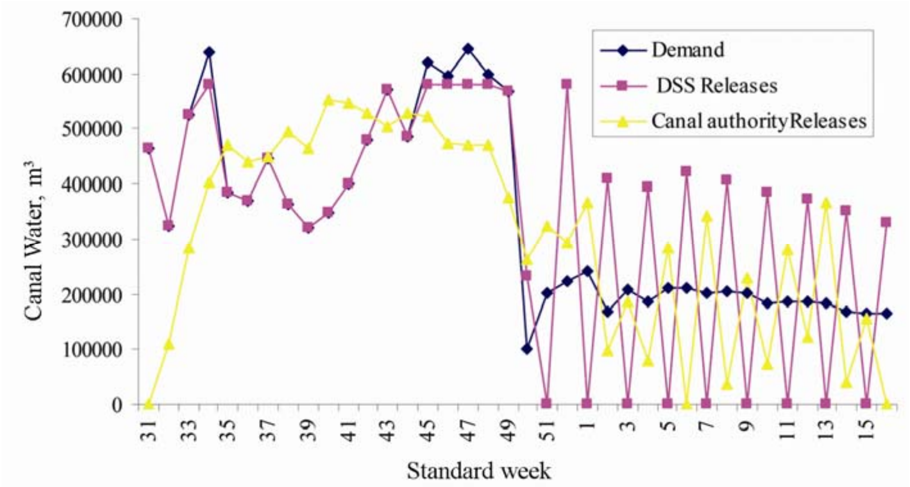
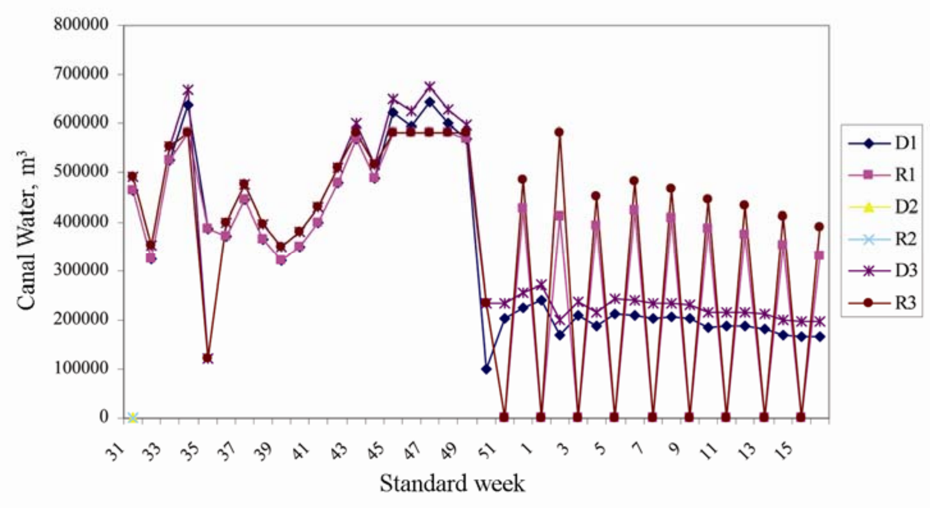


Figure 7. Canal water demands and canal releases corresponding to cropping pattern-I.



D1, Demand under zero well	R1, DSS release under zero well
D2, Demand under existing number of wells	R2, DSS release under existing number of wells
D3, Demand under doubling the existing number of wells	R3, DSS release under doubling the existing number of wells

Figure 8. Demands and supplies under three different groundwater-use situations.

of wells is 0.45% deficit. If the number of wells in the command area is doubled, the gap between demand or release may increase up to 1.3% surplus. The gap between demand and release may be increased up to 1.9% deficit in case zero groundwater utilization.

From the above result it can be concluded that the CWREDSS is capable of developing releases under different groundwater-use situations of the command area. Since the groundwater use in the command area is small (only 18 wells in whole area), doubling the present level of groundwater use or stopping it altogether is not likely to make any significant difference to the gap between the canal water releases and demands (only up to 1.97%, Figure 8). This will help in better utilization of groundwater resources of the command area.

The DSS was used to develop releases under these different probable rainfall levels for a given cropping pattern. Figure 9 reveals that different gaps may result in canal water demand and release with rainfall considering at 80% probability level. The annual gap between demand and release under rainfall at 60% probability resulted in 1.37% deficit, whereas for rainfall at 80% probability, this gap increased to 4.37% deficit.

The study developed a DSS, namely CWREDSS, for providing demand-based optimal canal water releases for reducing the gap between canal supplies and demands, thereby increasing the water-use efficiency in canal command areas. CWREDSS will determine crop evapotranspiration, total crop-water requirement, effective rainfall and irrigation water requirement of crops. This

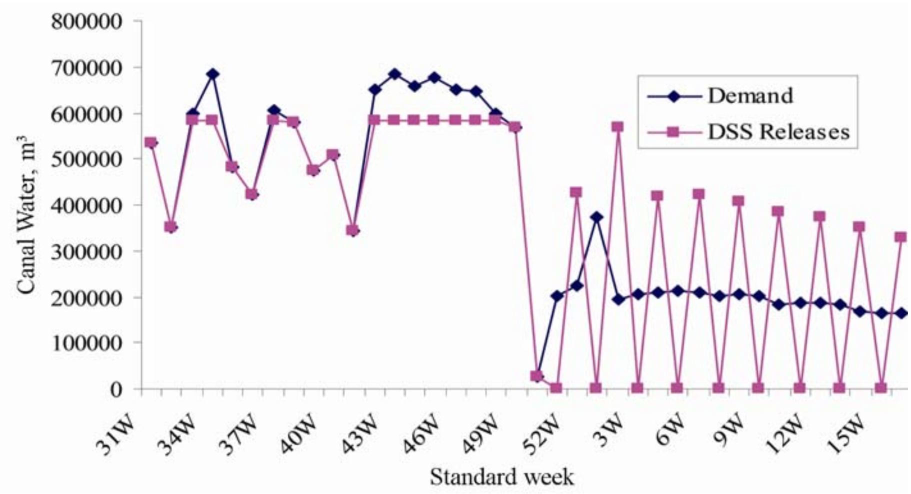


Figure 9. Canal water releases under rainfall at 80% probability.

system will also determine the seepage losses in the canals, groundwater use, canal water demands at the head of the canal and finally, will develop canal-water releases by accounting for water demands and canal capacity. The DSS provides suggestions under different water deficit/surplus situations. CWREDSS will help irrigation engineers, agronomists and agro-meteorologists in the planning, operation and management of irrigation systems. The developed DSS was evaluated under different situations of the case study area. From the results it can be concluded that the CWREDSS is capable of developing releases under different scenarios of varying cropping patterns, groundwater-use situations and different rainfall probability levels of the study area, and reduced the gap between demand and supply considerably. CWREDSS can also be used to determine the most suitable cropping pattern for efficient utilization of the water resources of a canal command area. The CWREDSS software was distributed to officials of Nagarjunasagar Project (NSP), Khammam Division, AP. They were tested for some canal command areas and the results obtained are encouraging. This software is also available free of cost to users at different command areas.

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Physico-chemical, biochemical and microbial characteristics of soils of mangroves of the Andamans: a post-tsunami analysis

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The mangroves of the Bay Islands accounting for 18% (383 km^2) of the total Indian mangroves were adversely affected by the December 2004 tsunami. Changes in topography, salinity and massive water inflow have led to extensive soil degradation and associated nutrient losses in these mangroves. The major aim of the study was to determine whether the December 2004 tsunami had any effects on soil physico-chemical (pH, electrical conductivity of saturation extract (EC), clay, cation exchange capacity (CEC), organic carbon (OC), total N (TN), Bray phosphorus (P), exchangeable cations (Ca, Mg, K and Na)) and biochemical/microbial parameters (Microbial biomass–C (C_{MIC}), –N (N_{MIC}), N-flush, basal respiration and hydrolytic enzyme activities). The post-tsunami soil samples (disturbed sites) were characterized by higher levels of EC, Na and Mg, while the pre-tsunami soils samples (undisturbed sites) had higher levels of OC, P, K and CEC. The study also revealed marked reductions in microbial biomass and activity in the disturbed sites. C_{MIC}, N_{MIC}, N-flush, basal respiration, and activities of hydrolytic enzymes like BAA-protease, casein-protease, phosphomonoesterase, β-glucosidase, arylsuphatase, invertase, carboxy methyl cellulase and dehydrogenase were considerably lower in the disturbed sites. Higher levels of metabolic quotient (qCO_2) in the disturbed soils indicated comparatively more stressed soil microbial community with reduced substrate utilization efficiency. Apparently, microbial activity was limited by the supply of biologically available substrates like OC in the disturbed sites. Contrarily, the more direct supply of nutrients from decomposing plant litter and the indirect supply of nutrients from the mineralization of organic matter led to significantly higher microbial activity in the undisturbed sites.

Keywords: Biochemical properties, mangrove forests, microbial biomass carbon, soil enzymes, soil microbial activity.

MANGROVES cover an area of around 15 mha (or 1,50,000 km^2) worldwide, with close to 40% of this area found in the countries affected by the December 2004 tsunami. Presently, less than 50% of the area remains, and of this over 50% is degraded due mainly to anthropogenic factors like conversion to fish ponds, agricultural land, etc.[1]. Of the country's total area under mangrove vegetation, 70% is recorded on the east coast and 12% on the west coast. The Bay Islands (Andaman and Nicobar) account for 18% of the country's total mangrove area[2,3]. The insular mangroves exist in the Bay Islands on many tidal estuaries, small rivers, neritic islets and lagoons, accounting for 18% (383 km^2) of the total Indian mangroves. As would be expected, the mangroves along the Andamans coast were adversely affected by the 2004 tsunami.

However, the extent of damage is still not clear and it may take sometime before the final impacts are known, since the deposit of silt may clog the pores of the aerial roots of mangroves, and thus suffocate them. Changes in topography, soil salinity and freshwater inflow from upstream may also adversely affect the mangroves and other coastal forests in the longer term (http://www.fao.org/newsroom/en/news/2005/89119/index.html accessed on 01/02/2008). One of the major consequences of the tsunami is the extensive soil degradation and associated nutrient losses.

In order to minimize soil degradation and to adopt management techniques that contribute to the maintenance or recovery of soil fertility, the soil quality should be ascertained in order to understand the limits that can be set to its use and treatment. Of all the parameters that determine soil quality, biological and biochemical variables are the most sensitive to changes occurring in a soil[4,5] and provide rapid and accurate information on changes in soil quality due to their sensitivity to environment stress[6], role in degradation[7] and strong influence on microbially mediated processes like nutrient cycling,

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