Rainfall Analysis & Assessment of Irrigation Water in a Command of Drought Affected Bundelkhand Region (M.P.), India

R.K Jaiswal[1*] T. Thomas[1] R.V. Galkate[1] S. Singh[2]
[1] Scientist, National Institute of Hydrology, RC Bhopal, WALMI Campus, Bhopal (M.P.)
[2] Scientist, National Institute of Hydrology, Jal Vigyan Bhavan, Roorkee (Uttarakhand)
e-mail of corresponding author: rkjaiswal_sagar@yahoo.co.in

ABSTRACT

Optimal utilization of existing water resources is an issue of utmost importance in India because of considerable variability of rainfall in space and time coupled with its inadequate and uneven distribution. The Bundelkhand part of Madhya Pradesh experiences frequent drought that result in adversely affecting both water and crop production in this region. In the present study, an attempt has been made to assess irrigation water requirement under different rainfall and cropping pattern in Benisagar command situated in drought prone Rajnagar block of Chhattarpur district of M.P. The probability analysis of rainfall has been carried out determine rainfall in dry, average and wet rainfall years. The Cropwat 8.0 software has been used to compute irrigation requirement for different 10-day periods under variable scenarios of rainfall, efficiencies and cropping patterns. From the analysis, it has been observed that the design cropping pattern may require 11.94 Mm^3 water which amount to 28.34 Mm^3 (70% conveyance and 60% application efficiency) in average rainfall years. The data related to reservoir inflows and crop water requirement indicated that the reservoir may not be able to fulfill the complete demand of designed as well as existing average cropping pattern in dry rainfall years and it is recommended to increase efficiencies by reduce losses, development of drought warning system and suggest alternative cropping pattern before showing of crops in dry/drought years.

Key words: Evaotranspiration,crop coefficient, conveyance efficiency, application efficiency, cropping pattern

1.0 INTRODUCTION

The agricultural sector usually holds the largest share of the water and becomes the target of other sectors when it comes to the issue of regional water supply reallocation in most of the developing countries. The water requirement of crops depends on the climate and the crop. More water is required to produce crops in the arid region than in the humid region. Crops like paddy and sugarcane require much larger amount of water than finger millet and pearl millet. In India after independence, the development of irrigation potential was given top priority for enhancing the agricultural production and productivity to meet the growing food needs of increasing population. However, the performance of many irrigation systems does not commensurate with the investments made. Many of the projects have failed to realize the envisaged irrigation potential and a large gap exists between potential created and utilized and it is necessary to estimate crop water requirement for crops in commands to manage supply of water scientifically.

The accurate estimation of irrigation water demand is also essential for developing a rational policy for sustainable water resources. The rainfall is a basic input for fulfilling the crop water requirement in any region. For planning of irrigation and efficient operation of water resources projects, crop water requirement of crops under different rainfall scenarios and probability analysis of rainfall are essential in arid and drought affected region. Irrigation water requirements are usually defined to avoid crop stress implicitly assuming that maximum yield is desired. Improvements in irrigation management are urgently needed in regions where water resources for irrigation are being depleted. Prasad *et al.* (1996)[1] presented a study in Mahendragarh distributary canal in Haryana State to estimate net irrigation water requirement of crops under 17 minors for kharif and rabi seasons of 1992–93 period using IRS-1B satellite geocoded FCC images. Manoli et al (2001)[2] presented a prototype spatial decision support system for the evaluation of water demand and supply management schemes. Santos *et al*. (2008)[3] used a water balance model with satellite-based remote-sensing to estimate evapotranspiration (ET) to provide accurate irrigation scheduling guidelines for individual fields. Delavar et *al*. (2009)[4] introduced a real-time modeling approach for optimal water allocation during drought. Raut et al (2010)[5] used FAO model Cropwat with the help of agro-meteorological and remote sensing data (1986–1998 and 2008) to calculate irrigation water requirements of wheat and mustard crops grown in western Yamuna canal command. In the present study, Cropwat 8.0 software has been used to estimate crop water requirement under variable rainfall and cropping pattern scenarios in the command of Benisagar reservoir project.

1.1 Study Area & Data Used

The Benisagar project is a medium project consists of an earthen dam constructed on confluence of river Khurar with river Rantiya which are tributaries of river Ken and supplemented by Beniganj weir constructed on river Banne near village Satna of Rajnagar tehsil. The catchment area of dam is 76.85 km^2 and length of river Khurar upto dam site is 15 km. The gross storage capacity and dead storage capacity of the Benisagar reservoir is 27.59 Mm^3 and 1.37 Mm^3 respectively. The location map of the study area has been given in Fig 1.

The gross command area of the project is 6802.46 hectare while the cultivated area is 6267 ha. The proposed irrigable area in the command through dam was 4170 hectare with proposed cropping pattern consists of Maxican wheat in 3000 hectare, ordinary wheat in 300 ha and soybean in 870 ha. The data used in the analysis included rainfall data of Rajnagar block from 1988 to 2009. Meteorological data including maximum and minimum temperature, humidity, wind speed, sunshine hours of Khajuraho/Bhopal have been used in Cropwat 8.0 model and detailed soil analysis in eight different places have been carried out to define soil characteristics of Benisagar commend.

2.0 METHODOLOGY

The appropriate design and management of irrigation system and the judicious application of water in the field require reliable information on consumptive use of various crops grown in the command area. The water requirement may be defined as the quantity of water, regardless of its source, required by a crop or diversified pattern of crops in a given period of time for its normal growth under field conditions at a place. The water applied in the field during irrigation acts as a carrier for nutrients for plants and a major part of applied water lost through transpiration with little uses by plants for building tissues. The crop water requirement includes evapotranspiration, application losses and special needs. Application losses include the loss of water during water application and unavoidable. Special needs include water required for land preparation, transplantation and leaching etc. In the present study, Cropwat 8.0 software has been used for computation of irrigation requirement and scheduling under different rainfall, cropping pattern scenarios and is being described below:

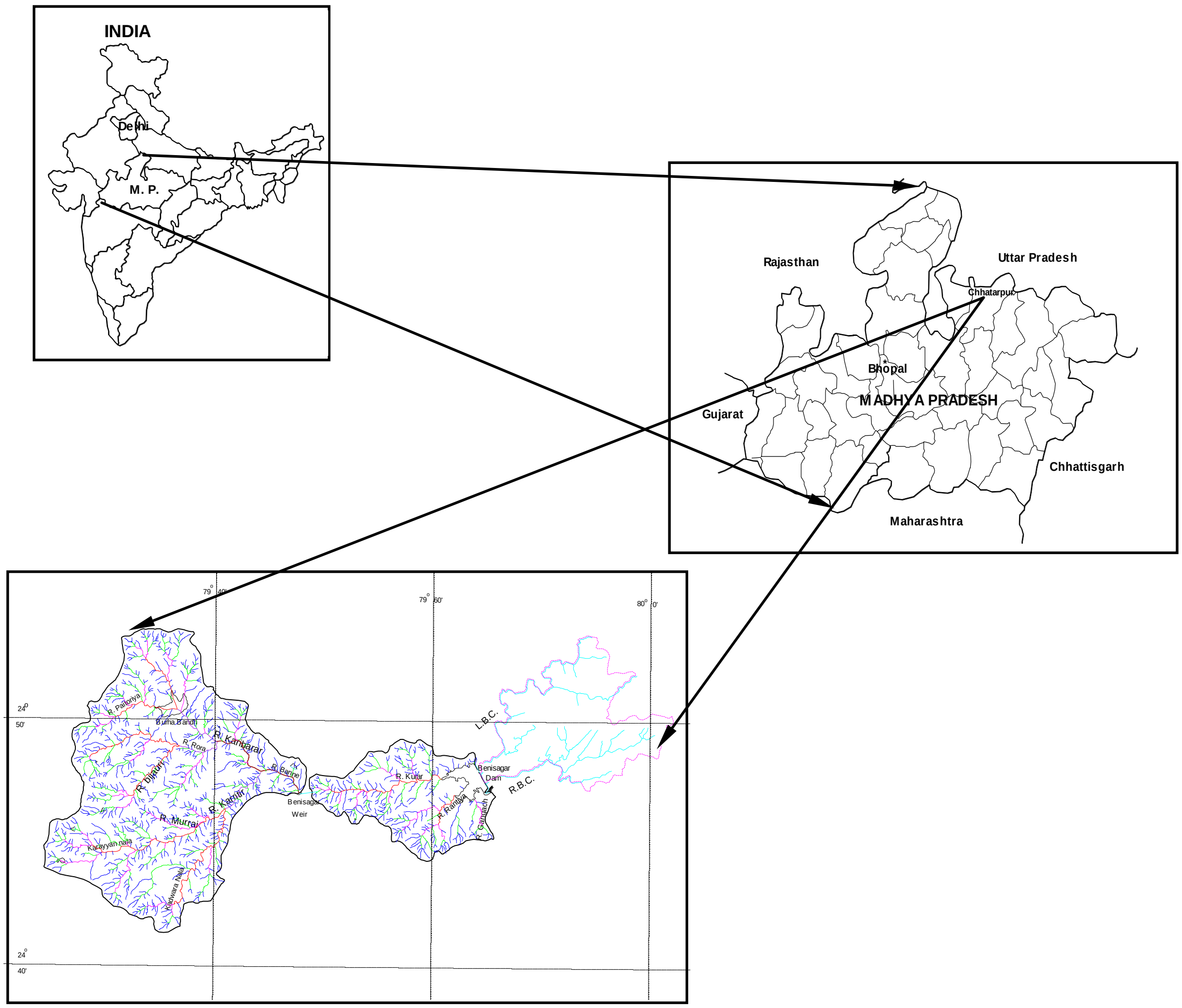

Fig. 1: Location map showing the Benisagar command in Chhattarpur district (M.P.)

2.1 Cropwat 8.0

The Cropwat 8.0 for Windows is a computer program for the calculation of crop water requirements and irrigation requirements based on soil, climate and crop data. In addition, the program allows the development of irrigation schedules for different management conditions and the calculation of scheme water supply for varying crop patterns. The Cropwat 8.0 can also be used to evaluate farmer’s irrigation practices and to estimate crop performance under both rain-fed and irrigated conditions. All calculation procedures used in Cropwat 8.0 are based on the two Food &Agriculture Organization (FAO) publications of the Irrigation and Drainage Series, namely, No. 56 "Crop Evapotranspiration - Guidelines for computing crop water requirements” and No. 33 titled "Yield response to water". The Cropwat uses Penman-Monteith equation for computation of evapotranspiration for reference crop. The reference crop may be defined as a hypothetical crop with an assumed height of 0.12 m having a surface resistance of 70 sm^{-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 Penman-Monteith equation to estimate ET_0 can be expressed as:

$$ET_0 = \frac{0.408\Delta(R_n - G) + \gamma \frac{900}{T+273} u_2 (e_s - e_a)}{\Delta + \gamma(1 + 0.34u_2)} \quad \text{….(1)}$$

where, ET_0 is reference evapotranspiration (mm/day), R_n is net radiation at the crop surface (MJ/sq. m/day), G is soil heat flux density (MJ/sq. m/day), T is mean daily air temperature at 2 m height (°C), u_2 wind speed at 2 m height (m/sec), e_s is saturation vapour pressure (kPa), e_a is actual vapour pressure (kPa), (es – ea) is saturation vapour pressure deficit (kPa), Δ is the slope vapour pressure curve (kPa /°C) and γ is psychrometric constant (kPa/°C).The development of irrigation schedules in Cropwat 8.0 is based on a daily soil-water balance using various user-defined options for water supply and irrigation management conditions. Scheme water supply is calculated according to the cropping pattern defined by the user, which can include up to 20 crops. The rainfall is the basic inputs for determination of requirement of crop water requirement (CWR). The rainfall contributes to a greater or lesser extent in satisfying CWR, depending on the location. During the rainy season in tropical and some semi-tropical regions, a great part of the crop's water needs are covered by rainfall, while during the dry season, the major supply of water should come from irrigation. The Cropwat 8.0 offers the possibility to use following methods to calculate the effective rainfall:

1. Fixed percentage of rainfall
2. Dependable rain
3. Empirical formula
4. USDA Soil Conservation Service Method
5. Rainfall not considered

2.2 Rainfall Data Processing

For programming of irrigation water supply and management, rainfall data of dry, normal and wet years are generally used. For determination data for dry, normal and wet years, the yearly rainfall data are used and assigned in descending order and given a rank from 1, 2, 3, 4, ….m. The webull formula is used to determine plotting position. A graph is plotted on semi-log paper with rainfall on ordinate and plotting position on abscissa with log scale. A regression line is plotted to estimate dependable yearly rainfall at 20%, 50% and 80% probability. The rainfall at 20%, 50% and 80% probability of exceedance are called annual rainfall for wet, normal and dry year respectively. The daily, decadal or monthly rainfall values for normal, dry and wet years can be computed using the following formulas.

For dry years

$$p_{i(dry)} = \frac{p_{i(av)} * P_{dry}}{P_{av}} \quad \text{….(2)}$$

Where, $p_{i(dry)}$ is the rainfall for i^{th} period of dry year, P_{dry} is the annual rainfall at 80% probability of exceedance and P_{av} is the average annual rainfall. Similarly, rainfall for wet and average years can be computed replacing P_{dry} values. In the analysis, the irrigation water requirement have been estimated for dry, average and wet rainfall years considering design cropping pattern at the time of project inception and actual average cropping pattern in recent average rainfall years and designated as different scenarios as:

1. Design cropping pattern in dry rainfall year
2. Design cropping pattern in average rainfall year
3. Design cropping pattern in wet rainfall year
4. Existing cropping pattern in dry rainfall year
5. Existing cropping pattern in average rainfall year
6. Existing cropping pattern in wet rainfall year

The climate data, rainfall, crop coefficients and crop periods of different crops proposed in the design cropping pattern and existing cropping pattern have been assigned and crop water requirement on 10-daily basis were determined with the help of Cropwat 8.0 software. The data in the software can be given directly by typing or pasted from excel files (Fig. 2). The irrigation water requirement at field has been computed considering 10% additional water for field preparation, leaching, soil moisture for erosion control and other special requirements. Similarly, 70% field application efficiency and 60% conveyance efficiency have been used to compute the gross irrigation water required at the head of reservoir.

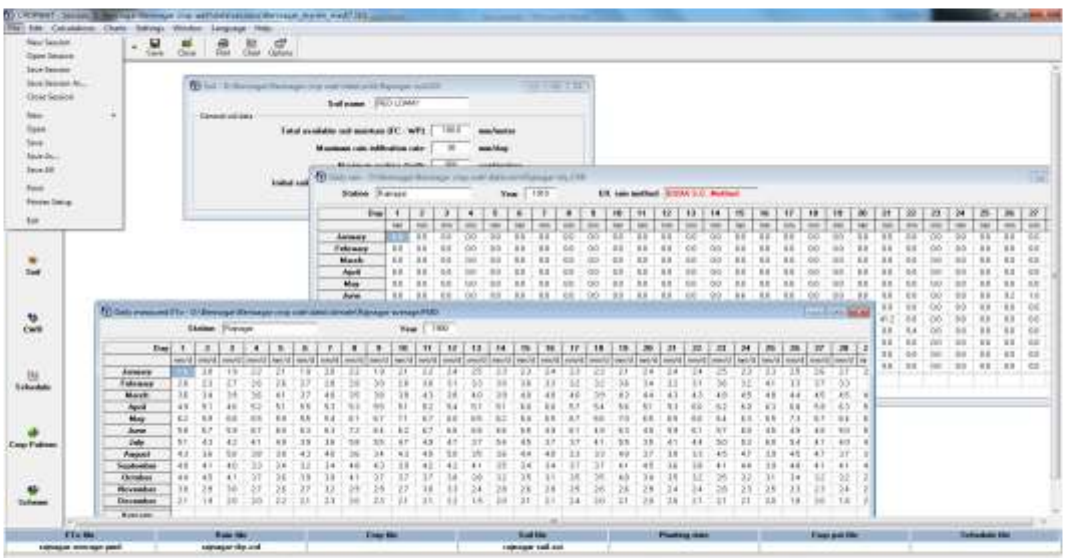

Fig. 2: Data entry in Cropwat 8.0 software

3.0 ANALYSIS OF RESULTS

The crop water requirement during average, dry and wet rainfall year separately for designed as well as existing average cropping pattern in Benisagar command has been computed using Cropwat 8.0 software. For determination of rainfall for dry, average and wet years, the methodology suggested by FAO has been used and results obtained from the analysis are given below.

3.1 Rainfall for Dry, Average and Wet Years

For estimation of daily rainfall for dry, average and wet years, the probability analysis of annual rainfall has been carried out. The probability of exceedance (p) has been computed for annual rainfall using Weibull plotting position and a graph has been plotted on semi log paper with probability of exceedance on abscissa and annual rainfall on ordinate (Fig. 3). The best-fit line plotted with this graph has been used for estimation of annual rainfall at 20%, 50% and 80 % probability (p). The equation obtained for computation of annual rainfall (P_p) at any probability of exceedance (p) is given below.

$$P_p = 2009.9 - 690.63 * \log(p) \qquad \text{....(3)}$$

The annual rainfall at 20%, 50% and 80% probability were computed as 1111.24 mm, 836.37 mm and 695.38 mm respectively. The rainfall obtained for dry, average and wet years have been used for computation of effective rainfall in Cropwat 8.0 software.

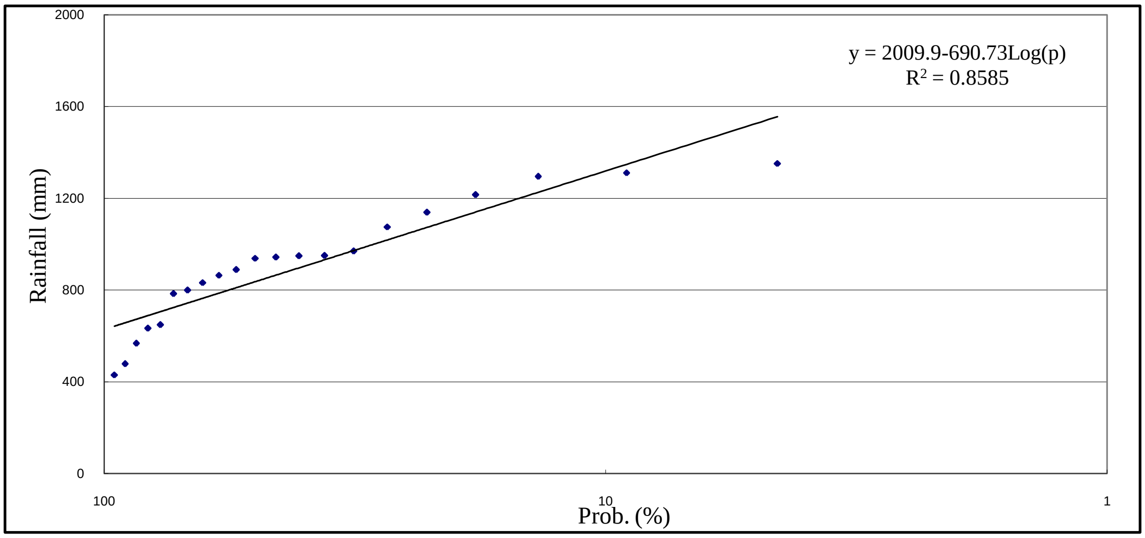

Fig 3: Probability analysis of annual rainfall

3.2 Computation of Crop Water Requirement

The designed cropping pattern in Benisagar project consists of 3300 ha wheat in rabi and 470 ha soybean in kharif season. But it has been observed that the project is unable to irrigate the design crops and an existing copping pattern for Benisagar command has been obtained by taking average of various crops in average rainfall years. The existing average cropping pattern with canal irrigation consists of 1407.66 ha wheat and 970.39 ha gram in rabi season with no water supplies during kharif season. As the cultivation does not start simultaneously in whole command areas, wheat has been divided in three parts and soybean in two parts on the basis of showing dates. The showing date of first part of wheat (wheat 1) has been considered as Oct 25 with 25% area is under cultivation. The showing date of second part of wheat (wheat 2) is considered as Nov 01 with 50% of total area brought under cultivation and lastly remaining 25% of wheat is shown on Nov 11 at last (wheat 3). In case of soybean, 50% area (Soybean 1) has been considered to be shown on June 25 and remaining 50% area (soybean 2) on July 05. The date of showing of gram has been considered as Nov 20 each year. The crop calendar for design pattern and existing cropping pattern with canal irrigation has been given in Fig. 4.

The climate data including max and min temperature, wind speed, sunshine hour have been given to compute reference crop evapotranspiration (ET_0) that ultimately used to estimate crop water requirement with the help of crop coefficients, rainfall and soil properties in Cropwat

8.0 software. The detailed soil analysis on eight sites have been carried out to determine field capacity (FC) and permanent wilting point (PWP) using pressure plate apparatus and infiltration rate using double ring infiltrometer. The crop water requirement for design cropping pattern and existing pattern on 10-day basis have been computed separately for dry, average and wet rainfall years considering the consumptive use and 10% extra water for field preparation, leaching, soil moisture requirement for erosion control and other special needs. The requirement of irrigation water (IWR) have been computed considering 60% efficiency during conveyance and further 70% efficiency during field application. The crop water requirement and gross irrigation water required at the head of reservoir in dry, average and wet rainfall years for designed cropping pattern and existing cropping pattern has been given in Table 1.

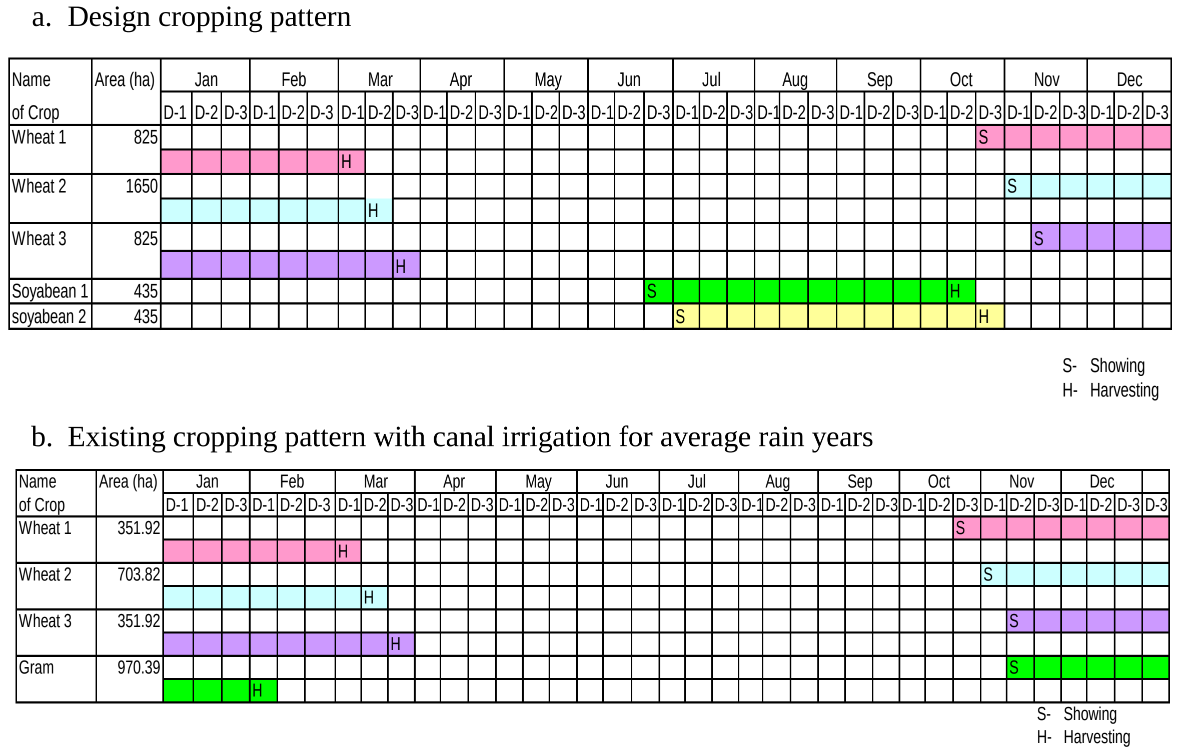

Fig. 4: The crop calendar of Benisagar project for design and actual average cropping pattern

Table 1: Crop Water Requirement under Different Scenarios in Benisagar command

SN	Cropping Pattern	IWR in dry rainfall year (Mm^3)		IWR in average rainfall year (Mm^3)		IWR in wet rainfall year (Mm^3)	
		Crop water requirement	G.W.R.	Crop water requirement	G.W.R.	Crop water requirement	G.W.R.
1.	Designed cropping pattern	13.69	32.60	11.94	28.43	11.52	27.50
2.	Existing cropping pattern	6.69	15.93	6.60	15.72	6.40	15.24

From the analysis, it has been observed in average rainfall years 28.43 Mm^3 water may be required at the head of reservoir for design cropping pattern, which is more than the present available live storage capacity. If the losses due to evaporation and seepage are included, the total water requirement will be much more than present storages. Therefore, it is necessary to reduce conveyance and field application losses by various management practices in field and canal lining and efficient operation. Presently, only 6.60 Mm^3 water is being used effectively by the existing crops with gross water requirement of 15.71 Mm^3. Therefore, about 42% of water is being used in irrigation for growth of crops and this need to be increased by reducing losses and efficient management. From the analysis, it has been observed that the assumption of application and conveyance efficiencies in combination seems quite close to real situation in Benisagar command.

4.0 CONCLUSIONS

Computation of irrigation water requirement and planning reservoir releases are important aspects for sustainable development of command and getting maximum benefits from available water. Variable irrigation requirements due to frequent drought situation in Bundelkhand region demand efficient mechanism of water supply in the command. The drought analysis of Rajnagar block indicated that the mean seasonal rainfall of this station is 968.38 mm and the probability of 75% of mean seasonal rainfall is 74.34%, which is less than 80% and hence this block can be considered as drought prone block and hence it is necessary to estimate irrigation water requirement in the command for efficient management of available water resources. The present cropping pattern in average years may use 6.60 Mm^3 consumptively with total release of 20.01 MCM (present live storage). The gross water requirement for designed and average existing cropping pattern in dry years have been computed as 32.60 Mm^3 and 15.93 Mm^3 respectively considering conveyance efficiency as 60% and field application efficiency as 70%. The data related to reservoir inflows and crop water requirement indicated that the reservoir may not be able to fulfill the complete demand of designed as well as existing average cropping pattern in dry rainfall years and it is recommended to increase efficiencies by reduce losses, development of drought warning system and suggest alternative cropping pattern before showing of crops in dry/drought years. The Cropwat 8.0 software used in the analysis able to determine the crop water requirement and irrigation releases for any existing pattern in the command and can be used efficiently with limited knowledge of computers for efficient planning of reservoir water releases.

REFERENCES

[1] Prasad VH, Chakraborti AK and Nayak TR (1996) Irrigation command area inventory and assessment of water requirement using IRS-1B satellite data. J Indian Society of Remote Sensing 24:85-96

[2] Manoli E, Arampatzis G, Pissias E, Xenos D and Assimacopoulos D (2001) Water Demand and supply analysis using a spatial decision support system. Global NEST: The International Journal 3(3):199-209

[3] Santos C, Lorite IJ, Tasumi M, Allen RG and Fereres E (2008) Integrating satellite-based evapotranspiration with simulation models for irrigation management at the scheme level. Irrigation Science 26:277-288

[4] Delavar M, Moghadasi M, and Morid S (2009) A real time model for optimal water allocation in irrigation system during droughts. Journal of Irrigation and Drainage Engineering 10:1943-4774

[5] Raut S, Sarma KSS and Das DK (2010) Study of irrigation and crop water requirements and growth of two Rabi crops grown in a semi arid region using agrometeorology and remote sensing. J Indian Society of Remote Sensing 38:321-331.