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Assessment of Irrigation and Agriculture Potential of the Krishna River Basin using Geospatial Techniques

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Abstract:

Objectives: The objective of present work is an assessment of the irrigation potential of the canal network located over the Krishna River basin in Sangli district of Maharashtra and also the requirement of water in the crops lying in that region. **Methods/Statistical analysis**: Irrigation potential of the canals was calculated using the canal length derived from high resolution CARTOSAT-1 whereas for calculating the agriculture potential other factors such as Rainfall, Temperature, Soil type, Elevation, Water holding capacity were used. **Findings**: The study reveals that, Balance IP is estimated to be 526.801ha from the proposed IP and Satellite IP. Gaps are present in the minors and distributaries due to land acquisition problem. From results it can also be concluded that the major amount of Kharif crops lie at the higher elevation and the soil has comparatively low water holding capacity whereas Rabi crops lie at a lower elevation and the soil has comparatively higher capacity to hold water. Double crops or perennial crops are observed to grow near the canals. They are usually seemed to be grown on medium to low-lying areas and they have high water holding capacity. Due to irrigation, these crops are highly benefited. **Application/Improvements:** Irrigation is the efficient usage of fresh water, and with the growing scarcity of this essential natural resource, it is becoming increasingly important to maximize efficiency of water usage. It implies accurate management of irrigation and control of application depths in order to apply water effectively according to crop needs. Assessing irrigation and agriculture potential is an important activity in successful agriculture management.

Keywords: Agriculture Potential, Evapotranspiration, GIS, India, Irrigation Potential

1. Introduction

Agriculture sector is the mainstay of the Indian economy, contributing about 15 percent of national Gross Domestic Product (GDP) and also India's irrigated agriculture sector has been fundamental to India's economic development and reducing poverty. 28% of India's Gross Domestic Product (GDP) and 67% of employment is based on agriculture[1]. Primary source of livelihood in rural areas is agriculture, which account for 75% of India's population and 80% of its poor[1]. And, in turn, irrigation is the base for about 56%, possibly more of total agricultural output. India's major achievement is rapid expansion of irrigation and drainage. With the aim of stabilizing the agriculture market, there is a need of proper management of resources. The success of any agriculture is influenced by the availability of proper irrigational facilities[2]. The allocation and management of irrigable resources is becoming a difficult task due to increasing demands, decreasing supplies and improper distribution. A more

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effective use of water in both irrigated and rainfed agriculture will be essential to meet future food demands and growing competition for clean water[3,4,5]. Hence there is an urgent need to have accurate, reliable and timely data on various aspects of irrigable resources.

Monitoring the consumptive use of water by applying GIS and remote sensing techniques has been a topic of interest in the field of irrigation and water management practices with the increased demand for irrigation. Remote sensing data has been effectively used for agricultural and irrigation applications for several years. Geospatial techniques have been applied for selecting optimal multi-purpose river projects and maximizing irrigation potential for improved method of site selection and better planning of water supply schemes[6,7]. Remote sensing data of irrigation management has various scopes like crop water requirement, irrigation scheduling and performance evaluation etc[8]. GIS based performance evaluation will give the gap between water released and crop water requirement[9,10]. This kind of analysis will help in proper allocation of irrigation water and thereby decreasing chances of poor performance of irrigation systems[11]. The current study focuses on assessment of the irrigation and agriculture potential for Krishna river basin in Sangli district of Maharashtra using Geospatial Techniques.

2. Study Area

The area that is taken for the study of this project is Sangli District of Maharashtra which extends from 17°08'53.53"N to 74°29'25.05". It is located in the western part of Maharashtra. The study area has a geographical area of 95 thousand Ha. Elevation of the area ranges from 550–850 m. The area towards north, north east and south east is occupied by the hills whereas the area towards south west is surrounded by low-lying agricultural plains.

The total area cover 950 sq.km is a part of Krishna river basin. The basin has experienced dramatic changes in its hydrology in recent[12,13]. The water captured by hydrological structures such as dams and reservoir may change the patterns of the annual hydrological cycle[14,15]. In this paper Arphal Canal is taken as the study area which extends from Kanher Left Bank Canal onwards beyond 21 kms. It is 204 km long and part of its length has been planned as express canal (Figure 1, Figure 2).

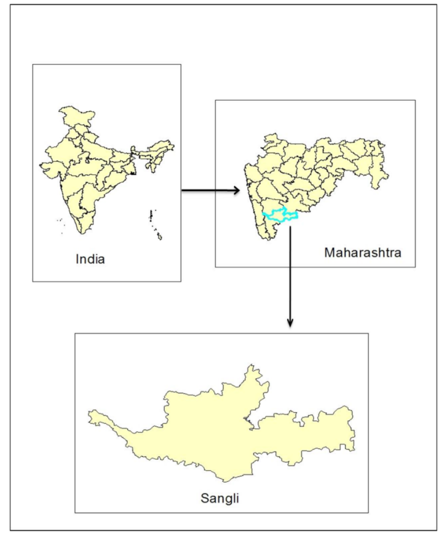


Figure 1. Location Map of the Study Area.

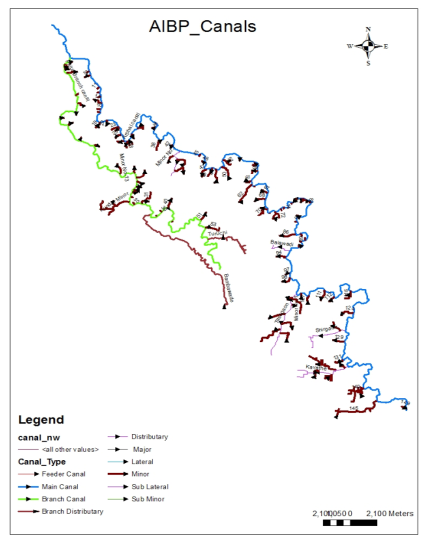


Figure 2. Canal Network for Study Area.

3. Materials and Methods:

3.1 Materials Used

3.1.1 Hardware/Software

The software's used in current study are Arc Map 10.1 and an image processing software ERDAS 2014. The statistical analysis was done Microsoft excel 2010.

3.1.2 Satellite Data

The satellite data such as Cartosat I, Landsat ETM+, SRTM has been used in the current study.

3.1.3 Climatic Data

The climate parameters such as temperature, rainfall and Evapotranspiration are considered for current study. The climatic data has been collected from Indian Meteorological Department.

3.1.4 Potential Evapotranspiration Data

The Hargreaves Potential Evapotranspiration (PET) method is used to calculate the potential evapotranspiration (Equation 1)[16].

Equation 1: Hargreaves Potential Evapotranspiration (PET)

$$\text{Potential Evaptranspiration (PET)} = 0.0075.R_a.C_t.\partial t^{1/2}.T_{avg.d}$$

In the above equation:

1. R_a = The total incoming straterrestrial Solar radiation
2. C_t = Temperature Reduction Coefficient
3. ∂t = The difference between mean monthly maximum and mean monthly minimum temperature
4. $T_{avg.d}$ = Mean temperature in the time step

3.1.5 Crop Evapotranspiration

The crop water need is determined by the amount of water evaporated by the crop. The Crop specific evapotranspiration is calculated by multiplying potential evapotranspiration by the crop coefficient (Equation 2)[17].

Equation 2: Crop Evapotranspiration

$$ET_c = K_c ET_0$$

Where Etc is crop evapotranspiration and Kc crop coefficient for the crop. Crop coefficient of the Kharif, Rabi and Perennial crop is estimated[18].

The Normalized Difference Vegetation Index (NDVI) was used to calculate the crop coefficient factor by using (Equation 3)[19].

Equation 3. Crop Coefficient

$$Kc = 1.25 \times NDVI + 0.2$$

3.1.6 Irrigation Data

The amount of water released and irrigation data in Arphal canal for Kharif 2008 and Rabi 2009 was collected from Arphal Irrigation Department, Karad, and Maharashtra. The total Gross Command Area (GCA) and Cultivable Command Area (CCA) was calculated.

3.1.7 Agriculture Data

Agriculture data including statistics of types of crops grown in the study area for Kharif 2008 and Rabi 2009 was collected from Arphal Irrigation Department, Karad, and Maharashtra.

3.1.8 Soil Data

Stratified Random Sampling was chosen for soil sampling. The strata were formed using attributes such as elevation and percentage of clay content in the soil. SRTM data was used for the generation of the TIN and DEM. In stratified random sampling a random sample is selected from each stratum by comparing the size of the stratum with total area. Eight soil samples at a depth of 6-8 inches were collected to analyze its water holding capacity. Figure 3 shows detailed methodology followed for soil sampling.

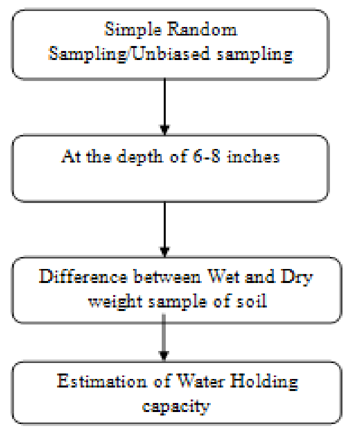


Figure 3. Methodology used for Soil data.

3.2 Methodology

The study is conducted in two steps. The first step includes computing Irrigation Potential (IP) and second step includes computing Agricultural Potential (AP).F igure 4 shows the detailed methodology followed for the study.

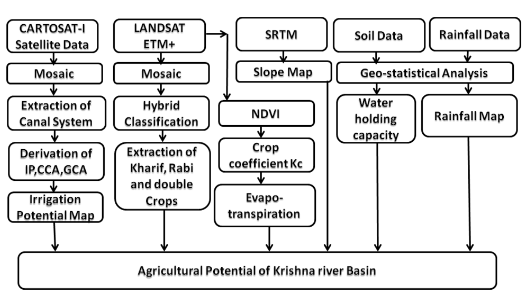


Figure 4. Methodology to Assess Agriculture Potential of Krishna River Basin.

3.2.1 Irrigation Potential (IP)

To compute irrigation potential first digitization of the canal network was done from Cartosat-I scenes. The irrigable command area of the project is 74000ha. The cumulative IP created up to 2007 is 69613ha. Following this, irrigation potential was calculated applying equation 4.

Equation 4: Equation for Irrigation Potential

$$\text{Satellite assessed IP (/ha)} = (\text{IP Proposed} \times \text{Satellite Derived Length}) / \text{Field Reported Length of canal}$$

3.2.2 Agricultural Potential (AP)

Agricultural potential for Kharif and Rabi season was assessed, for October 2008 and February 2009. The parameters as slope, evapotranspiration, precipitation, soil water holding capacity Irrigation Potential (IP) and productivity of crops were used to calculate the irrigation potential for the study area.

3.2.3 Geostatistical Analysis

The Geostatistical analysis of soil and climate parameters was done using Inverse Distance Weighted (IDW) method. The method considers the values which are close to one another are more alike than those that are farther apart. The values which are closest to the prediction location will have more influence on the predicted value than those farther away[20,21].

3.2.4 Classification of LANDSAT image

Hybrid Classification was used to extract Land Use Land Cover (LULC) Map for the study area. Hybrid Classification includes the advantages of both supervised as well as unsupervised classification. From LULC Kharif and Rabi crops were extracted (Figure 5, Figure 6).

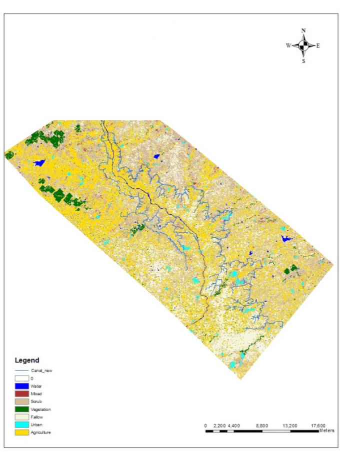


Figure 5. LULC October 2008.

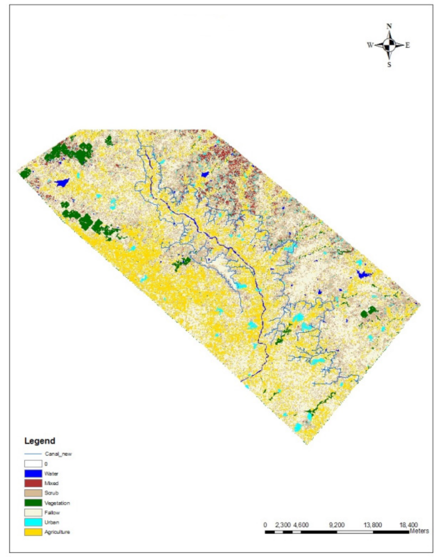


Figure 6. LULC February 2009.

3.2.5 Slope

The Shuttle Radar Topography Mission (SRTM) satellite image was used to calculate slope of the study area. Using ARCGIS the spatial analysis of the image was done to generate the slope map (Figure 7).

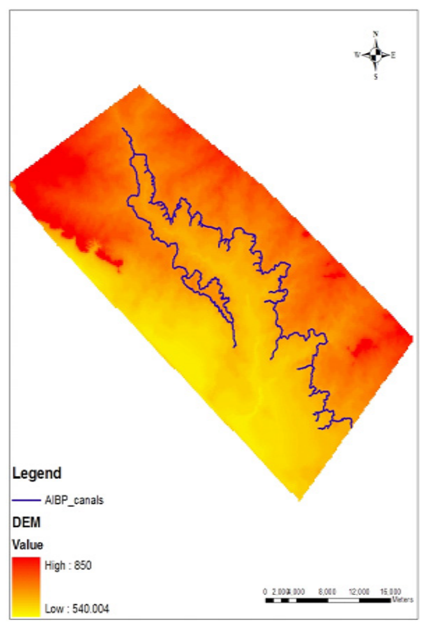


Figure 7. Digital Elevation Map (DEM).

3.2.6 Water Holding Capacity

The soil water holding capacity was calculated using soil samples collected from the field[22] (Figure 8).

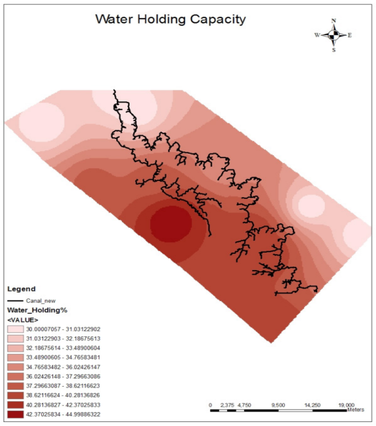


Figure 8. Soil Water holding Capacity Map.

3.2.7 Spectral Analysis

The Normalized Difference Vegetation Index (NDVI) is the most common ratio index for vegetation. NDVI is an index calculated from reflectance measured in the visible and near infrared channels (Equation 5). The NDVI is the ratio of contrasting reflectance between maximum absorption of red wavelength due to chlorophyll pigments and maximum reflectance of infrared wavelength owing to leaf cellular structure23,24. It is related to the fraction of photosynthetically active radiation.

Equation 5: NDVI Formula

$$NDVI = \frac{(NIR - R)}{(NIR + R)}$$

NDVI map for Kharif and Rabi season generated to calculate crop coefficent and in turn to calculate crop evapotranspiration for the study area. Figure 9 and Figure 10 shows the NDVI map.

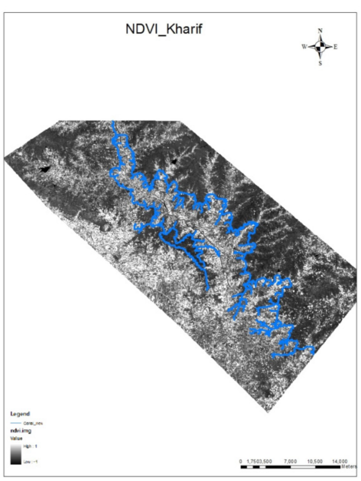


Figure 9. NDVI Map for Kharif Season.

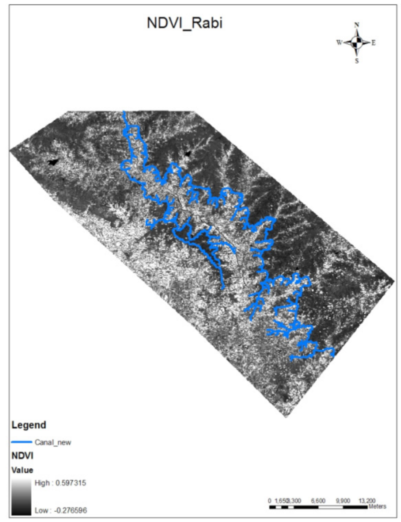


Figure 10. NDVI Map for Rabi Season.

4. Results and Discussions:

The canal network was monitored with the help of high resolution CARTOSAT-1 to study the gaps present in the irrigation infrastructure. The relationship between irrigation potential, CCA and amount of GCA was established (Figure 11).

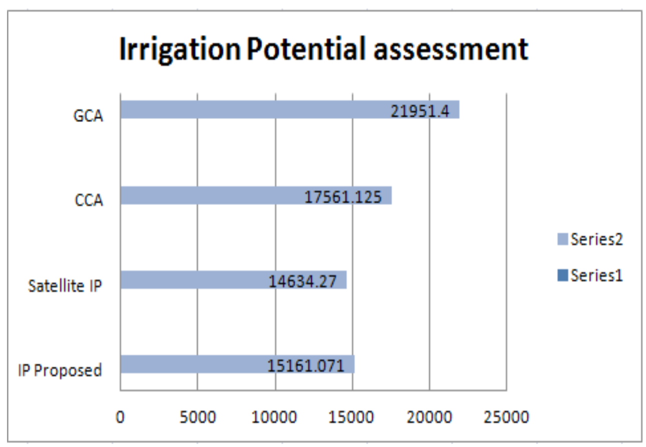


Figure 11. Irrigation Potential Assessment.

The spatial distribution and acreage estimation was done for Kharif and Rabi crops. It was observed that total area occupied by Kharif crops is 12,582.077ha and Rabi crops is 12,023.64ha out of which the percentage occupied by each crop was determined (Table 1). It was observed that, major crops cultivated in region are Jawar, Wheat, Rice, Maize and Groundnut (figure 12, figure 13).

Table 1. Percentage of Crop Distribution

Sr.No	Kharif Season		Rabi Season	
1.	Jawar	48%	Jawar	51%
2.	Groundnut	29%	Greenpeas	21%
3.	Rice	19%	Maize	15%
4.	Cotton	4%	Wheat	13%

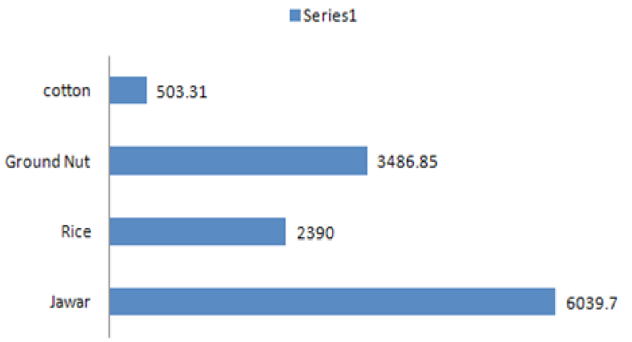


Figure 12. Crop Acreage Distribution (Kharif).

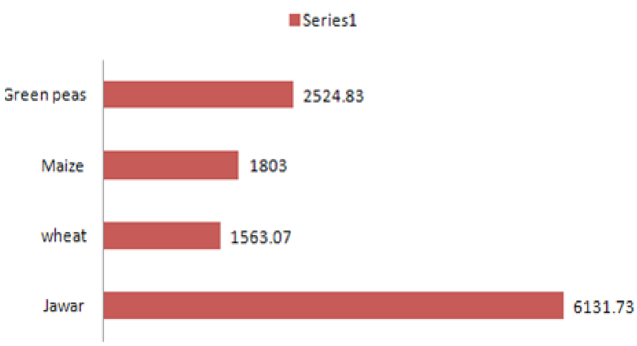
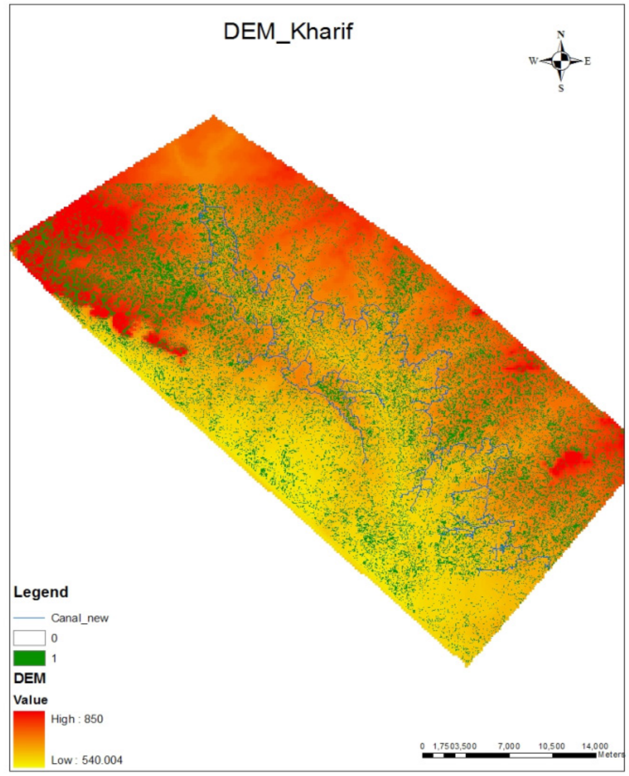


Figure 13. Crop Acreage Distribution (Rabi).

The elevation of the study area varies between 540–850 m. It was observed that for Kharif season elevation greater than 630m i.e. higher elevation and for Rabi season it varies between 450m–540m which is low lying area. The water holding capacity of soil in the area varies between 30–45 %. The water holding capacity varies between 30% to 37% and 39% to 45% for Kharif and Rabi season respectively.

It was observed that Evapotranspiration for the study area varies between 0.6 mm to 0.8 mm and 3.3 mm to 4.06 mm for Kharif and Rabi season respectively. Figure 14 and Figure 15 shows the evapotranspiration maps for Kharif and Rabi seasons respectively.



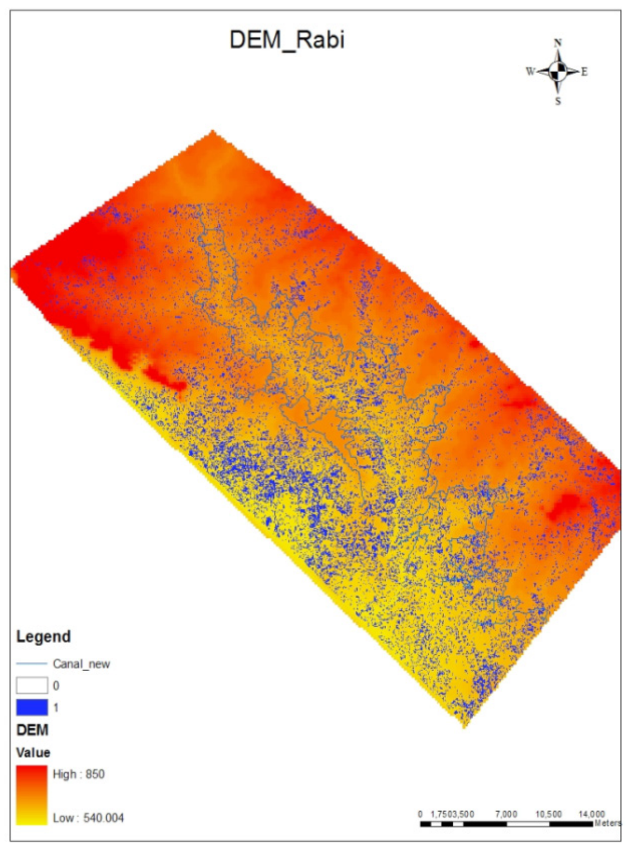


Figure 14. Elevation for Kharif and Rabi Season.

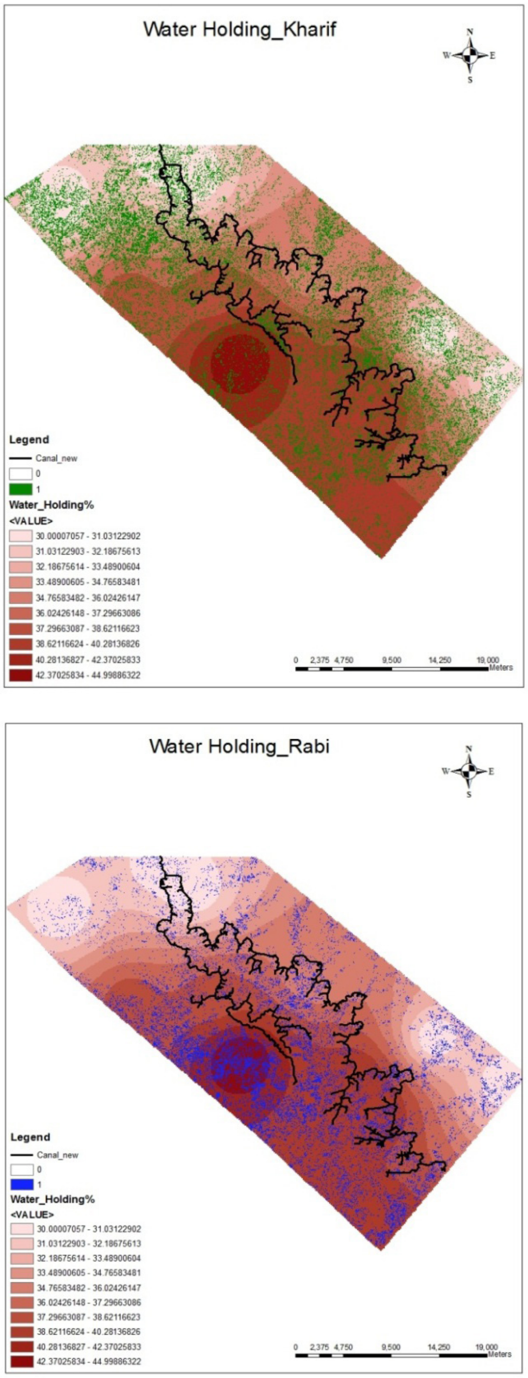


Figure 15. Water Holding Capacity for Kharif and Rabi Season.

To observe the amount of water loss due to evaporation and transpiration the relationship between evapotranspiration and soil water holding capacity for both the season was identified. The study reveals that for Rabi the association was found to be 0.78 whereas in case of Kharif the association was 0.70 (Figure 16, Figure 17).

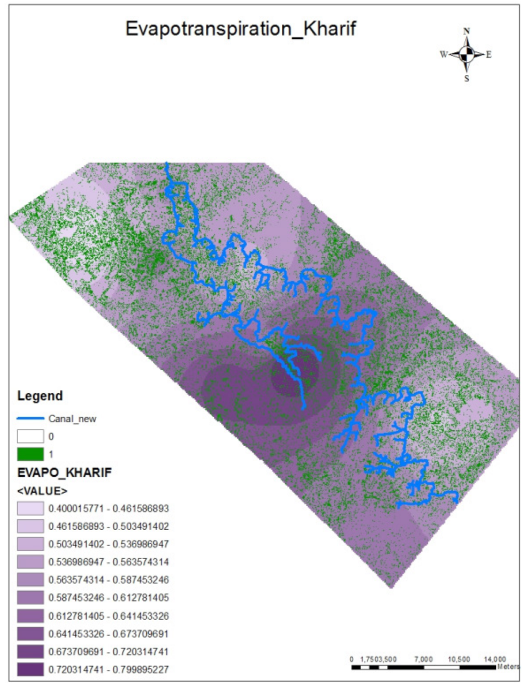


Figure 16. Evapotranspiration Kharif Season.

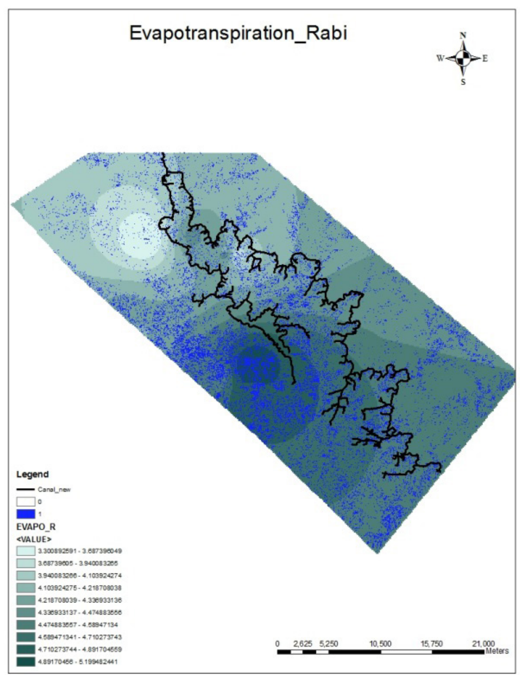


Figure 17. Evapotranspiration Rabi Season.

The study has identified crop wise water requirement by finding the gaps between water required for healthy vegetation, water provided and this was also compared with the average evapotranspiration (Figure 18, Figure 19).

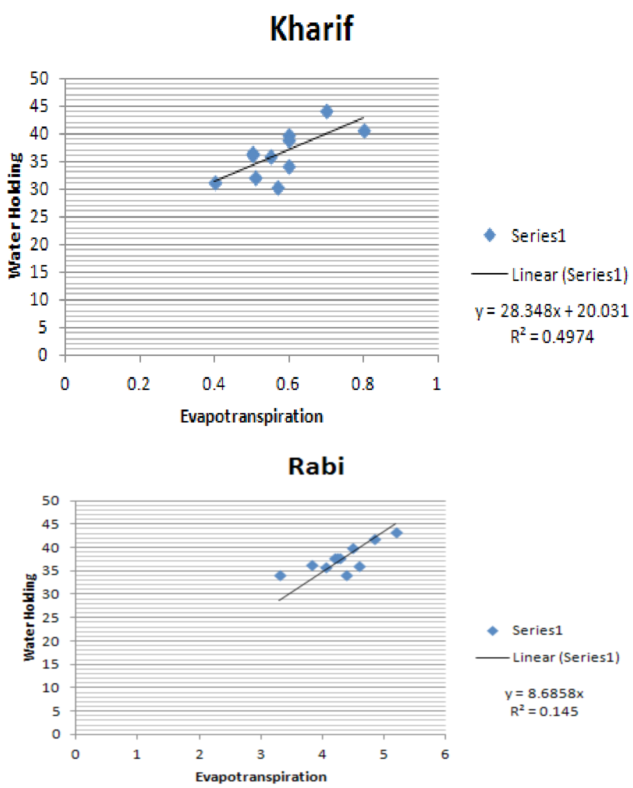


Figure 18. Evapotranspiration vs. Water Holding capacity (Kharif and Rabi Season).

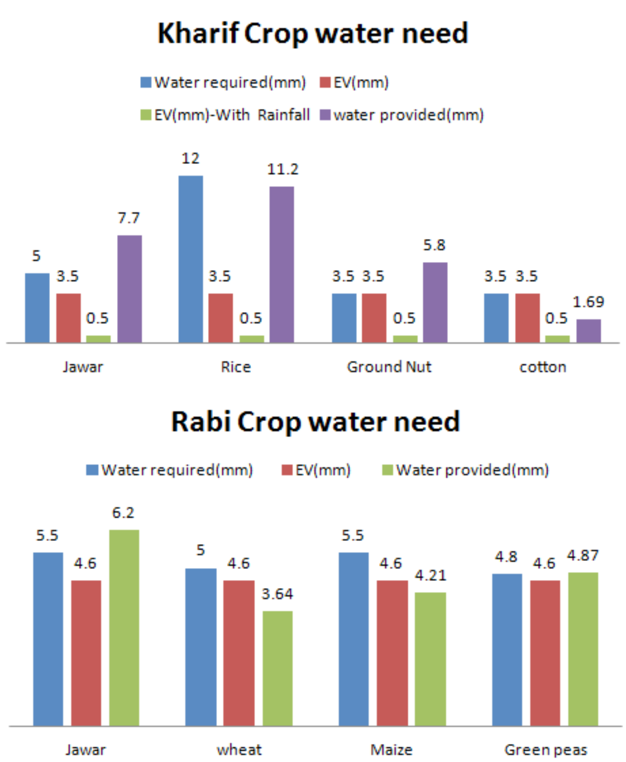


Figure 19. Crop Wise Water Requirment (Kharif/Rabi).

5. Conclusion

The study reveals that, Balance IP is estimated to be 526.801ha from the proposed IP and Satellite IP. Gaps are present in the minors and distributaries due to land acquisition problem. From results it can also be concluded that the major amount of Kharif crops lie at the higher elevation and the soil has comparatively low water holding capacity whereas Rabi crops lie at a lower elevation and the soil has comparatively higher capacity to hold water. Double crops or perennial crops are observed to grow near the canals. They are usually seemed to be grown on medium to low-lying areas and they have high water holding capacity. Due to irrigation, these crops are highly benefited.

Evapotranspiration is maximum in the area where the soil has maximum water holding capacity and vice versa. When water holding capacity and Evapotranspiration are related, the regression comes out to be 0.7, which is a stronger value correlating factor. In case of Kharif crops when there is shortage of precipitation or drought, water requirement for the cotton is more than what is provided which can be balanced by diverting excessive water from the water provided to groundnuts. In case of Rabi crops, 1000-1200 cum of more water should be discharged into the canals to meet the requirement of certain crops like wheat and maize.

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