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PERFORMANCE EVALUATION OF UPPER WARDHA IRRIGATION PROJECT USING REMOTE SENSING AND GIS

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ABSTRACT

In view of mounting pressure on improving freshwater use efficiency by all the sectors, the performance of existing irrigation projects must be assessed and improvement measures must be taken up. In the present study, the performance of Upper Wardha Irrigation project in Amravati district of India was evaluated using sixcomparative indicators.These indicators are classified into three groups namely, water-use performance, physical performance, and environmental performance. Remote sensing data from IRS P6 LISS-III sensors along with field observed data were used to derive inputs to estimate their performance indicators. The results indicate that water is excessively used in some parts of the command area while supply is inadequate in the tail region of the command. The water supply is not equally distributed among all the distributaries and within the distributary itself. There is no apparent problem of environmental degradation in terms of waterlogging, rising water table or soil salinity in the command area.

***Keywords:** Irrigation project, performance evaluation, performance indices, adequacy, equity, reliability*

INTRODUCTION

Irrigated agriculture will play a major role in determining the future food security of most Asian countries, and it will also be the major contributor to the additional food production required as the world population expands (Svendsen and Rosegrant 1994). On the other hand, increasing water scarcity has led to increased pressure on the irrigation sector to utilize water resources more efficiently (El-Magd & Tanton, 2005). Performance assessment is considered to be one of the most critical elements for improving irrigation water management (Abernethy and Pearce, 1987). Many researchers have tried to formulate the procedures for evaluating the performance of irrigation projects. Most of them have proposed different indicators to measure irrigation systems performance and used them on a number of irrigation systems (Molden et al. 1998; Bastiaanssen & Bos 1999; Molden & Sakthivadivel, 1999; Ray, et al. 2002; Droogers & Bastiaanssen, 2002; Bandara, 2003; Sener et al. 2007 and Karatas et al. 2009). Bastiaanssen & Bos (1999), Bastiaanssen et al. (2000) and Bos et al. (2005) have used the performance indicators derived using remote sensing as primary or supplementary input along with field data and have concluded that use of remote sensing improves the results of these exercises.

In the present study, the performance of Upper Wardha Irrigation project is evaluated using remote sensing data and ground observations to generate feedback to projects operation planning for improving the irrigation water management. Six different indicators representing four categories of performance of the project are estimated and utilized to evaluate the performance of the sub-commands within project area.

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STUDY AREA

Upper Wardha project is a multipurpose water resource project with the main objective of irrigating the command area which extends from 21^0 20' N, 77^0 55' E To 20^0 35' N, 78^0 20' E. The gross command area of the project around 116970 ha, whereas the total irrigable area is 70169 ha which is spread across Amravati and Wardha districts of Maharashtra, India. Wheat, Gram, Soyabean, Tur (Red Gram), Cotton, Ground Nut are the major crops grown in the command area.The canal regularly supplies water during *Rabi*season, however, with demand-based supply in Kharif season, total annual irrigation potential created by this project is around 75080 ha. In the present study performance of the project is assessed at the division level. Six division of Upper Wardha project considered under this study are: Division 1- Chandrabhaga branch canal; Division 2-Vidharbha branch canal (14 to 25 km); Division 3-Dhamangaon branch canal; Division 4-Devgaon sub-division; Division 5-Dhamangaon sub-division - Vidharbha branch canal (1 to 13 km); and Division 6-Jalka and Ghusali distributaries. The location of these division in command area of Upper Wardha Project is indicated in Figure 1.

METHODOLOGY

Selection of Performance Indicators

There are different dimensions of the performance evaluation studies globally. Some of the performance evaluation studies only assess the performance of an irrigation scheme based on the efficiency of the project. Some include economy and effectiveness with the efficiency for evaluating the performance of the project, some have also included quality of service and user satisfaction in the evaluation framework (Kouzmin et al., 1999). However, Bos et al. (2005) have proposed a framework to evaluate the performance of an irrigation project by estimating performance indicators pertaining to

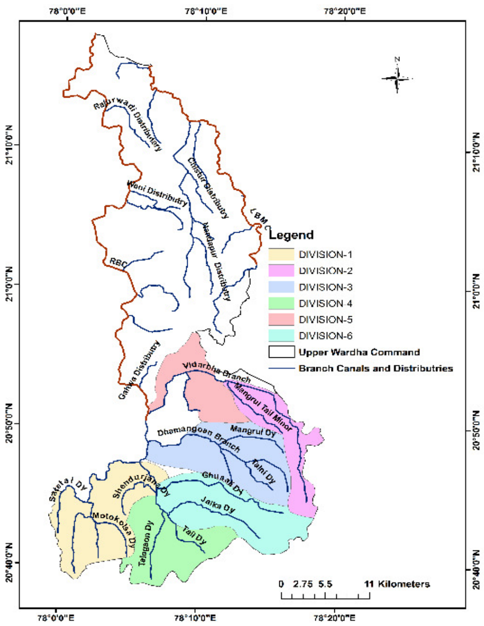

Figure 1. Location of Six division of Upper Wardha Project.

all the aspects of the irrigation project, by utilizing the observed data of all these aspects. The performance of irrigation projects are generally evaluated under water use performance, physical performance, and environmental performance (Sener, et al., 2007). In the present study, performance indicators representing each of these categories were selected from the literature. The description of each indicator used in the present study is given below:

i) Relative Water Supply (RWS)

The relative water supply (RWS) is an indicator of water use performance of the irrigation water delivery system. The indicator is derived by comparing water supplied with the water demand (Perry, 1996). The RWS is calculated as follows:

$$RWS = \frac{I + P}{ET_0} \quad (1)$$

Where, P is precipitation in mm, ET_0 is reference evapotranspiration in mm and I is the volume of irrigation water diverted in mm. The reference value of the RWS indicator is considered as 2.0 (Molden et al., 1998). Projects having RWS value more than 2 are considered as excess supply projects. The lower bound for RWS is, however, subjective to the project setup. This indicator also assesses the adequacy of water supply.

ii) Irrigation Efficiency (IE)

This is the most popularly used indicator to assess the physical performance of irrigation system (Bandara, 2003; Karataset al., 2009), defined as the ratio of actual irrigation water demand to irrigation water supplied;

$$IE = \frac{ET_0 - P_e}{I} \quad (2)$$

Where, P_e is effective precipitation in mm. Considering the 'standard' values of irrigation efficiency for different gravity irrigation techniques to be 0.6-0.65 (Berbel et al., 2015) and conveyance efficiency (0.85) achievable in surface irrigation projects, a value of 0.55 can be accepted as the reference value for irrigation efficiency for the large surface water irrigation schemes. However, it must be noted that irrigation efficiency alone cannot evaluate the physical performance of the irrigation system. Many aspects of irrigation system can't be represented by the irrigation efficiency, e.g., the area irrigated by the system and equity of distribution. To evaluate these aspects additional indicators complementary/supplementary to the previously discussed indicators are selected in the present study.

iii) Irrigation Ratio (IR)

To evaluate physical performance of the irrigation system along with irrigation efficiency the indicator that deals with the performance of the irrigation project in delivering water to all the stockholders, irrigation ratio, is selected. This indicator is calculated as a ratio of actual area irrigated to total potential area that could be irrigated (Sener et al., 2007) and evaluates the physical performance of the irrigation projects in the particular time period.

$$IR = \frac{Irrigated\ Land(ha)}{Irrigable\ Land\ (ha)} \quad (3)$$

The reference value of IR in a particular season can be as high as 1.

iv) Equity of Irrigation Supply

Equity of irrigation supply is one of the essentials of a good irrigation system (Michael, 1978). Equity of water distribution comes under physical performance of any irrigation system. There are several attempts made by researchers to evaluate the performance of irrigation system for equity, using a number of indirect methods based on parameters like vegetation index, spatial evapotranspiration, crop yield etc. (Bastiaanssen & Bos, 1999), however, the data requirement limits these approaches. Estimating or evaluating the equity of irrigation supply is very difficult in traditional *Warabandi* system due to non-availability of observed data pertaining to this objective of an irrigation system. In the absence of observed data, Upadhyaya et al. (2005) proposed to utilize the designed/actual *Duty*at canal (distributary or branch) level as an indicator of equity (in case of designed flow is released in each sub-command). Due to non-availability of detailed long-term data of actual canal discharge a simpler approach of 'designed duty' and 'seasonal cropping intensity of major crops' at distributary level is used in the present study, to analyse the equity of water distribution in Upper Wardha irrigation project.

a) Design Duty

The duty of a canal system is defined as the area that can be irrigated with a continuous non-stop supply of irrigation water at the rate of one cumec throughout the base period. It is expressed in hectare/cumec (Michal, 1978). The designed duty of each distributary is calculated using designed discharge and designed irrigation potential of that distributary. Ideally, the designed duty should be similar if not exactly the same for all the distributaries in particular project.

b) Seasonal Cropping Intensity of Major Crops

The seasonal cropping intensity of major crops grown in the command area is estimated at distributary level by comparing the area under major crops to the total cultivated area in the sub-command. Here, major crops refer to the crops which are considered in designed cropping pattern of the irrigation project and for which irrigation water is supplied. This indicator in conjunction with design duty or actual duty can evaluate the equity of distribution in the irrigation system.

v) Environmental Performance

In the present study, the environmental performance of the irrigation system is evaluated by analyzing the impact of the irrigation project in terms of groundwater level and soil salinity in the command area. The water level data of 45 observation wells spread in and around command area is analyzed to detect a trend in groundwater levels. In addition to this, feedback from farmers on the groundwater level in the last decade and any problems like waterlogging and soil salinity in the command are also analyzed to evaluate the environmental performance of the irrigation project.

Generation of Input Data

Remote sensing data, when used in conjunction with geographical information systems (GIS) have proved to be an effective tool for land use and crop identification (Anderson et al., 1976; Nirala and Venkatachalam, 2000; Su, 2000 and El-Magd & Tanton, 2003). Considering this, remote sensing data from Indian Remote Sensing Satellite, Resourcsat-1 (IRS P6)are used in the present study for crop acreage mapping during *Rabi* season of the year 2007-2008. Along with the remote sensing data, ground observed data of meteorological parameters, canal discharge and groundwater levels at observation wells are used in the present analysis.

Command Area Mapping

Irrigation schemes require updated information on the crop acreage and crop water demand of each crop grown in the command area. These information are difficult to obtain in real or near-real time using a traditional approach, due to the vastness of command areas (El-Magd & Tanton, 2005). The advantage of spatial and temporal coverage of remote sensing data is utilized in the present study, to generate the crop acreage map for *Rabi* season of the year 2007-2008. Six multi-spectral images of Linear Imaging Self Scanning Sensor - III (LISS-III) sensor onboard Resourcesat-1 satellite corresponding to 20/09/2007; 13/11/2007; 31/12/2007; 24/01/2008; 17/02/2008 and 12/03/2008are used for crop mapping in the present study.The modified approachof supervised classification suggested by Sakthivadivelet et al. (1999), the iterative methodology that combines maximum likelihood classification (supervised classification) with iso-clustering (unsupervised classification) to analyze the temporal satellite data, is used to derive crop acreage map in the present study. The accuracy of land use/crop acreage map is evaluated using ground truths collected during field visits.

Estimation of Irrigation Water Requirement Using Remote Sensing Inputs

The crop evapotranspiration (ET_a) constitutes the main input for irrigation water management and performance assessment of irrigation projects (Bastiaanssen et al., 1996). Mathematically, ET_a can be represented as a product of reference evapotranspiration (ET_0) and crop coefficient (Kc). Bausch and Neale (1987) have shown the usefulness of remote sensing data to represent the crop coefficient. Michael & Bastiaanssen (2000) mentioned that spatial maps of crop coefficients can help in better spatial estimation of ET_a. Choudhury et al. (1994) also investigated the theoretical possibilities of expressing Kc using a spectral vegetation index. The advantage of remote sensing derived crop coefficient over traditional crop coefficient is that it represents a real-time crop coefficient that responds to actual crop conditions in the field and captures the spatial variability.

In the present study, the seasonal ET_a is derived using point-based meteorological observations and remote sensing data. The combination method suggested by Ray & Dadhwal, (2001) is applied with some modifications. The daily meteorological data (temperature, relative humidity, wind speed at 2 m height, sunshine hours) is collected for four observation stations (Amravati, Warudbagagi, Sirpur, and Hinganghat) around study area from state hydrological data centre, Nasik. This data is used to estimate daily reference evapotranspiration (ET_0) using the FAO Penman-Monteith (FAO-PM) method (Allen et al., 1998). Continuous surfaces of monthly ET_0 are generated by interpolating monthly ET_0 using inverse distance weighted (IDW) technique in Arc GIS as suggested by Hashim et al. (1994), Ray and Dadhwal (2001). The remote sensing data from IRS-P6 LISS-III sensor is used to calculate normalized difference vegetation index (NDVI; Tucker, 1979 and Crippen, 1990) for every month in *Rabi* season of the year 2007-2008. The NDVI values from randomly selected points for each crop, grown in the command, are extracted for each month. The mean NDVI for each month and each crop is calculated. The regression analysis is performed between mean monthly NDVI of each crop with respective monthly crop coefficients (Kc) corresponding to each crop provide by Water and Land Management Institute (WALMI), (IDW) method. The crop coefficient (Kc) values for major crops grown in the command area are obtained from WALMI Aurangabad, India. These values of Kc represent the normal crop condition in the command area and since the canal is designed to supply water for *Rabi* season, it is assumed that the average Kc values are applicable

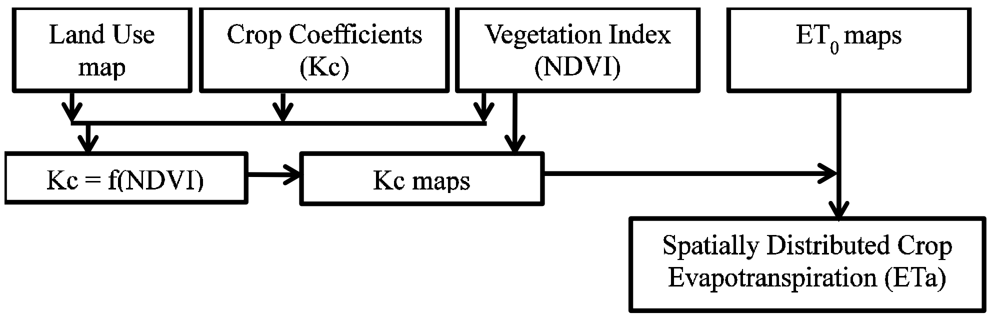

Figure 2. Flowchart of methodology used for ET_a estimation.

Aurangabad. These empirical equations are used to derive monthly crop coefficient maps from monthly NDVI maps. Monthly ET_a is estimated for each pixel by multiplying monthly Kc maps with monthly ET_0 maps. The flowchart of this procedure is shown in Figure 2.

Performance of Upper Wardha Irrigation project is evaluated at division level using the six performance indicators selected from the literature and discussed as above. The value of irrigation water requirement of the total irrigated area in the respective division is estimated using the seasonal ET_a map derived by fusing traditional ET_0 and remote sensing derived Kc. The irrigation supply of each division is taken from records of irrigation authority.

RESULTS AND DISCUSSION

Assessment of Crop Acreage in the Command Area

Multi-spectral and temporal satellite data from IRS P6 LISS-III sensor is used to generate crop acreage map of the Upper Wardha Command area. The modified iterative approach of using maximum likelihood techniques and iso-clustering technique with knowledge-based correction at the final step is used to generate the seasonal crop acreage map of the command area. The Upper Wardha command area is majorly covered by Soyabean/Red Gram, Wheat, Gram, and Cotton. The accuracy of crop acreage map is tested using well-distributed ground information collected during field visits. The classification error matrix indicatedan overall classification accuracy (Congalton, 1991) of 94.5%.

Spatial Irrigation Water Requirement

Daily meteorological data from four stations around the study area are used to estimate reference evapotranspiration using FAO-PM method. The point-based monthly ET_0 values are interpolated using inverse distance weighted throughout the command area. The NDVI values for each crop from well-distributed points for each month are obtained using point data extraction tool of ArcGIS. The relation between NDVI and Kc of each crop on the temporal scale is analyzed as suggested by Ray and Dadhwal, (2001). The parameters of the regression equation between NDVI and Kc are given in Table 1.

Table 1. Parameters of regression equation between NDVI and Kc (Kc = m*NDVI+c)

Crops	m	C	r^2
Gram	3.368	0	0.968
Wheat	3.290	0	0.987
Cotton	1.068	0.617	0.845
Red Gram	3.781	0	0.972

The monthly spatial Kc maps are generated using these equations and monthly NDVI & crop acreage maps. The spatial crop evapotranspiration (ET_a) is calculated using Kc maps and ET_0 maps. The seasonal ET_a is estimated by aggregating monthly ET_a at each pixel. The seasonal ET_a maps of Upper Wardha command area is shown in Figure 3. The seasonal ET_a estimate is used as a seasonal water requirement of each crop hereafter. The value of seasonal water requirement varies higher than 450 mm for healthy Wheat and less than 150 mm for poor Gram crop.

Project Performance Evaluation

Seasonal values of irrigation supply through canal is obtained from the canal authorities and irrigation water requirement of crops is estimated using the approach described in the pervious section. The performance of six divisions of Upper Wardha project is evaluated using performance indicators derived using remote sensing and field data. The analysis period in the present case is *Rabi* season which receives a negligible amount of rainfall, so water input through rainfall is ignored while calculating these performance indicators.

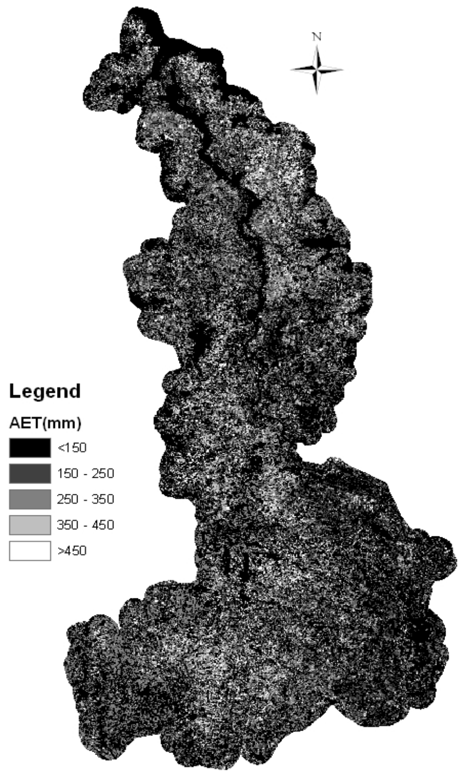

Figure 3. Seasonal ET_a map of Upper Wardha command

Relative Water Supply (RWS)

The RWS indicates the adequacy of irrigation supply. The seasonal values of RWS for six division are shown in Table 2. The irrigation systems having RWS more than 1 and less than 2 are termed as a system providing adequate supply to the crops (Molden et al., 1998). Assuming irrigation efficiency around 65 %, RWS value more than 1.5 indicates excess supply of water similarly, RWS values less than 1 indicates inadequate supply, from Table 2 it is clear that first three divisions (i.e. Division-1, Division-2, and Division-3) are having adequate irrigation water supply, farmers in Division-1 are using excess water, Division-6 is having RWS values just more than one which indicates probable/slightwater inadequacy. However, Division-4 and Division-5 with RWS values less than 1 indicates inadequate water supply to the crops. The lowest value of RWS is in Division-4, tail division of the Upper Wardha Project. This result supports the general impression that water does not reach the tail section of the canal, due to excessive use of water in other areas.

Irrigation Efficiency

Irrigation efficiency is the commonly used performance indicator of an irrigation system. Assuming water application efficiency around 0.60 and conveyance efficiency of lined canal system around 0.85, the overall efficiency that can be achieved will be around 0.51, this value is used as reference values of evaluating the performance of irrigation system. The irrigation efficiency values of different divisionsare listed inTable 2.The irrigation efficiency value of 0.28, 0.41 and 0.45 in Division-1, Division-2, and Division-3, respectively, indicate excess water supply in these divisions and irrigation efficiency value of 0.55 in Division-6 indicates adequate and efficient supply in Division-6. Value of irrigation efficiency greater than the reference value in Division-4 and Division-5 indicates inadequate water supply in these divisions.

Table 2. Performance indicators representing adequacy of supply and physical performance of the irrigation project

	RWS	Irrigation Efficiency	Irrigation Ratio
Division 1	1.82	0.28	0.35
Division 2	1.42	0.41	0.33
Division 3	1.34	0.45	0.40
Division 4	0.68	0.92	0.65
Division 5	0.85	0.79	0.53
Division 6	1.06	0.55	0.63

Irrigation Ratio

The ratio of actual area irrigated by the project to the total potential area that could be irrigated in a particular time periodis called irrigation ratio (Seneret al., 2007). Higher irrigation ratio indicates the better performance of the irrigation system in terms of supplying water to the majority of stakeholders/farmers in the command area. The irrigation ratio values estimated for six divisions of Upper Wardha project are given in Table 2. High irrigation ratio values in Division-4 Division-6 and Division-5 indicates better water distribution in these divisions, whereas lower values of irrigation ratio in Division-1,2 and 3 indicates faulty distribution system which fails to cater to the demands of all farmers in these sub-commands. It is noteworthy here, that even with an inadequate supply of water the distribution system works of Divisions 4 and 5 works much better than the divisions with adequate supply (e.g. Divisions 1, 2 & 3). Division 6 is the only division in this project command having an acceptable level of performance in terms of adequacy, and distribution of water to all the stakeholders. Division-4 shows the highest potential of water distribution to the farmers, however, this particular division receives an inadequate supply of water. So, in case of the performance Upper Wardha Project needs to be improved with a minimum investment of financial resources, the option could be enhanced the supply of water to Division-4 and 5 for improving adequacy scenario in these divisions and overall efficiency of the project.

Design Duty

Equity of water distribution is a very important aspect of the irrigation system, however, it is very hard to assess due to non-availability of data. An innovative approach of comparison of design duty is used in the present study, for assessment of equity in water distribution. Duty of a canal isexpressed as the area with the full-grown crop that can be irrigated by supplying 1 cumec water continuously during the entire base period of that crop. The design duty at distributary and branch level of the entire Upper Wardha project is presented in Tables 4 a and 4b. Ideally, the duty (design and actual) of all parts of the irrigation project must be same, however, practically small variations are acceptable. In the present case, the lowest value of design duty is around 401 ha in Motikolsa distributaryin Division-1 whereasthe highest value is around 8970 ha in Kasarkheda distributary in Divison-3. The difference in design duty at distributary and branch canal level (Table 3) hints the non-equity in the distribution of water even if the system is operated at a designed level. The actual duty of all the distributaries cannot be calculated due to non-availability of observed discharge data for the study period.

65.63% in the sub-command of Dongargaon distributary. Though the variation in cropping intensity may be governed by many other reasons, it is undeniable fact that water supply/availability governs the cropping pattern. In case of Divison-1 which receives excess water, ideally, the seasonal cropping intensity in all the distributaries (i.e. Chandrabhaga distributary, Motikolsa distributary, Satephal distributary, Shendurjana distributary, and Nimgavan distributary) of this division should be high. Detailed analysis of Annexure-1 indicates that the highest value of seasonal cropping intensity of major crops, 39.10%, is in Shendurjana distributary, which is head distributary of Chandrabhaga branch canal system. Conversely, the seasonal cropping intensity in Chandrabhaga distributary, which is tail distributary of Chandrabhaga branch canal system, is lowest, 8.27%, this variation within branch canal system indicates that water is not equally distributed within the branch command. Also, the large variation in cropping intensity of major crops along with variations in design duty in all distributaries indicates inequitable water distribution in the command area.

Table 3. Design Duty of all Distributaries and Branch Canal

Distributary	Design Duty (ha/cumec)	Distributary and Branch	Design Duty (ha/cumec)
Rajurwadi Dy.	1457.88	Ghusali Dy.	1352.59
Wani Dy.	501.44	Shendurjana Dy.	698.12
Warkhed Dy.	611.42	Talegaon Dy.	813.51
Bharsawadi Dy.	914.59	Jalka Dy.	1330.58
Kaundnyapur Dy.	770.07	RBMC Tail Dy.	1367.86
Jahagirpur Dy.	834.00	Belora Dy.	730.73
Gahwa Dy.	761.05	Sirsoli Dy.	556.93
Anjansingi Dy.	762.38	Chistur Dy.	1034.37
Wasad Dy.	2062.57	Jalgaon Dy.	972.48
Mangrul Dy.	2458.13	Takarkheda Dy.	718.64
Vidarbh Tail Dy.	1379.66	Nandpur Dy.	701.14
Mangrul Dy.	1440.55	Dongargaon Dy.	616.89
Kasarkheda Dy.	8970.89	Deoda Dy.	879.61

Seasonal Cropping Intensity of Major Crops

To support the findings of non-equitable water distribution in the canal system, the seasonal cropping intensity of major crops with respect to the total cropped area in the command at the distributary level is calculated and analyzed. In Upper Wardha canal command, surface water is utilized to cultivate Gram and Wheat during *Rabi* season. If the water is distributed equally in all parts of the command, the cropping intensity of these crops should be higher in all parts, whereas it is clear from Annexure-1 that cropping intensity of Wheat and Gram is as low as 8.27% in the sub-command of Chandra bhaga distributary and as high as

Environmental Performance

The irrigation water supply changes the natural water balance of a command area, which may affect the environment adversely if the water supply is too excess or too less. The general problems those arise in surface irrigation projects are waterlogging or rising groundwater level and soil salinity due to excess water use; groundwater depletion if surface water is inadequate and excess groundwater is pumped to meet the irrigation demand. The environmental performance of Upper Wardha irrigation project is evaluated by analyzing groundwater level data and soil salinity in the command area. The groundwater level data of 45 observation wells spread across the command area are obtained from the Groundwater Survey and Development Authority, Pune. The groundwater level data are analyzed for trends in groundwater levels in all the divisions. The spatial average of groundwater level in two seasons per year in six divisions for a period of eight years (2000-2008) are shown in Figure 4. In addition to this, the feedback from farmers on groundwater levels in the last decade and any problems like water logging and soil salinity in the command is also analyzed to evaluate the environmental performance of the irrigation project. The trends in groundwater levels and data from feedback indicate that there is no problem of water logging or soil salinity in the command, the average groundwater levels (Figure 4) also confirms this.

actual evapotranspiration is estimated using these crop coefficient maps. The information on canal water supply for the season is obtained from canal command authorities. Using these inputs along with information collected from different organization and field survey, six performance indicators are calculated to assess the performance of Upper Wardha Irrigation Project.

The values of RWS, irrigation efficiency and irrigation ratio indicates that water is supplied in excess in three out of the six division (i.e. Division-1. Division-2 and Division-3) and two division (Division-4 and Division-5) are receiving less than actual demand. Though the results of RWS hints inadequate supply in Division-6, using values of irrigation ratio and irrigation efficiency it can be concluded that Division-6 receives adequate water. The higher value of irrigation ratio in Division-4 and 5, even with an inadequate supply of water, indicates the potential of these divisions in improving the overall performance of irrigation project with no or minimal investment of resources. Further, the large variation in design duty and seasonal cropping intensity of major crops with respect to total cropped area indicates that water is not equally distributed in all distributaries in the command area. The lowest value of irrigation efficiency and irrigation ratio and highest value of RWS in Division-1

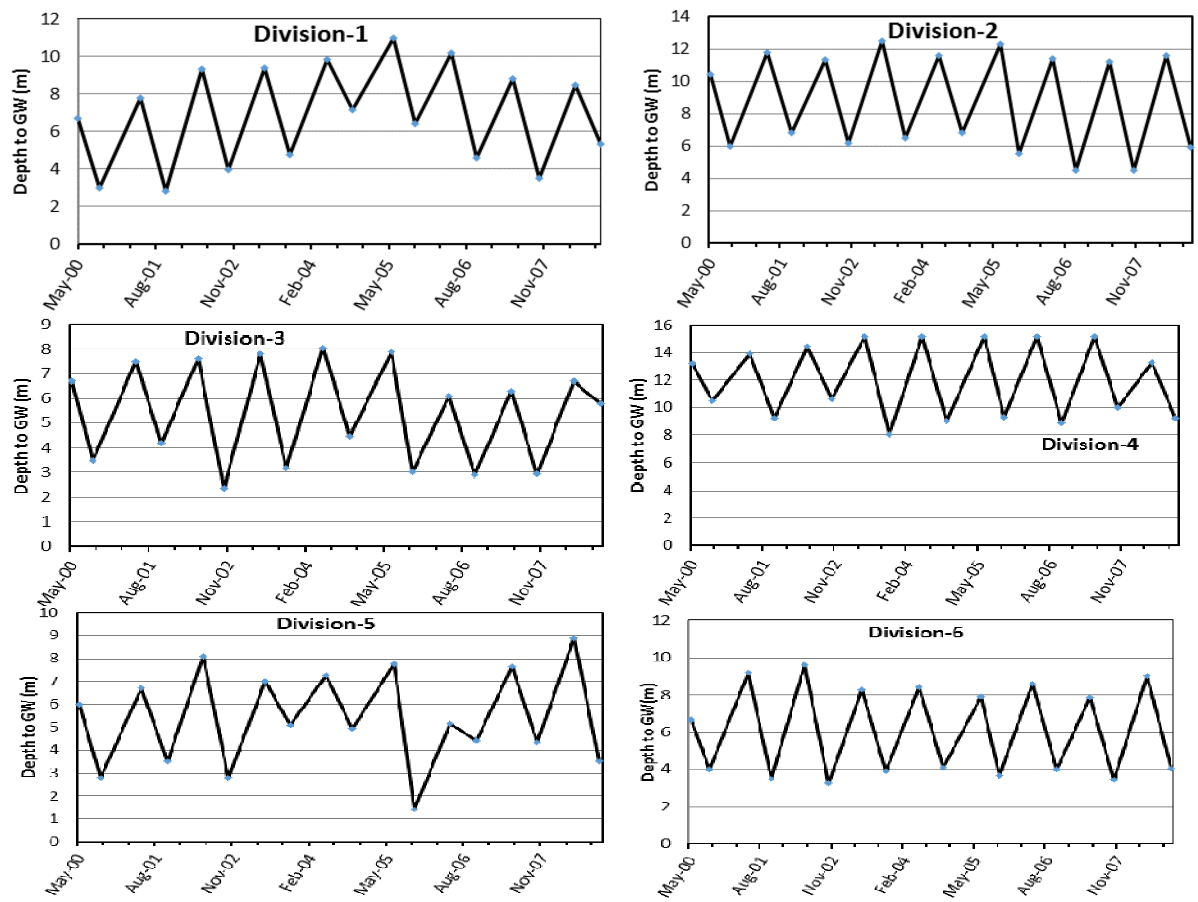

Figure 4. Average depth to groundwater for last eight years in different divisions.

CONCLUSIONS

In the present study, an attempt has been made to evaluate the performance of irrigation projects using remote sensing and ground data derived performance indicators. The temporal LISS-III data is used to generate the crop acreage map for the *Rabi* season of the year 2007-2008. Monthly vegetation index (NDVI) are used to generate spatially distributed crop coefficient maps and spatially distributed indicates that excess water is used in this division, however, the lower values of seasonal cropping intensity and large variation in these values among all the distributaries of Division-1, indicates that water is not equally distributed from head to tail within this division. Additionally, it was observed that the project has no unfavorable impact on the environment. The integration of Geo-spatial techniques helps in estimating the irrigation water requirement and performance indicators in a spatially distributed and efficient manner. The irrigation authorities can use these performance indicators as feedback to improve the performance of the irrigation system. The geo-spatial approach makes the performance evaluation process less dependent on field data and makes less time consuming compared to traditional approaches.

ACKNOWLEDGEMENTS

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Annexure -1 : Seasonal cropping intensity of major crops with respect to total cropped area

Name of canal sub-command	Length of canals (m)	Area Under Rabbi Crops w. r. t. Total Cropped Area (%)			Name of canal sub-command	Length of canals (m)	Area Under Rabbi Crops w. r. t. Total Cropped Area (%)		
		Wheat	Gram	Total			Wheat	Gram	Total
Rajurwadi Dy.	43046.28	25.81	25.68	51.50	LBMC Tail Dy.	35936.00	12.02	16.86	28.89
Belora Dy.	20408.09	19.59	11.45	31.04	Mangrul Dy.	43266.21	18.25	17.25	35.50
Bharsawadi Dy.	59430.13	26.07	24.11	50.18	Motokolsa Dy.	15883.83	11.29	16.21	27.50
Chandrabhaga Dy.	22635.42	2.69	5.58	8.27	Nandapur Dy.	19900.46	6.43	41.32	47.75
Chistur Dy.	14388.99	14.88	47.01	61.89	RBMC Tail Dy.	46357.01	24.09	19.28	43.37
Dangargaon Dy.	13169.47	19.81	45.82	65.63	Satephal Dy.	14118.73	15.60	7.67	23.27
Deoda Dy.	28020.67	17.61	31.14	48.75	Shendurjana Dy.	19955.73	28.41	10.68	39.10
Dhamangaon Tail Dy.	19709.90	5.41	28.61	34.02	Sirsoli Dy.	18593.11	19.62	19.95	39.57
Gahwa Dy.	50386.67	34.51	10.30	44.81	Takarkhed Dy.	18814.17	8.93	28.98	37.91
Ghusali Dy.	58460.41	15.15	16.55	31.71	Talegaon Dy.	52540.98	29.91	16.55	46.46
Jahangirpur Dy.	45369.04	34.04	12.16	46.20	Talni Dy.	22218.66	14.35	22.89	37.24
Jalgaon Dy.	15253.90	13.90	48.90	62.80	Mangrul Minor	43266.21	8.46	24.17	32.63
Jalka Dy.	241.50	21.99	19.50	41.50	Vidarbha Tail Dy.	34153.87	4.80	17.53	22.33
Nimgavan Dy.	30649.44	5.31	12.52	17.83	Wani Dy.	38678.26	21.01	12.75	33.76
Kasarkheda Dy.	23712.40	26.97	19.22	46.19	Warkhed Dy.	50154.01	22.99	21.07	44.06
Kaudnyapur Dy.	29824.74	29.17	10.03	39.20	Wasad Dy.	51236.37	33.15	19.37	52.52

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