

Statistical indices for the performance evaluation of Ukai right bank canal, Gujarat.

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Abstract- For optimizing the agricultural production from irrigated land and decision-making evaluation for command area development, the high resolution satellite data can give spatial information about various crops grown, crop yield which are basic need to evaluate any irrigation system. To achieve sustainable agricultural production, resources use efficiency needs to be enhanced along with bringing additional area under irrigation, the performance indicators have been suggested for the evaluation of irrigation systems. This paper describes a case study of part of Ukai-Kakrapar Project of the southern region in the state of Gujarat, known as Ukai Right Bank Canal Command. The statistical data of Rabi crops in command area are assessed and actual cropping pattern is identified by the integration of remote sensing data and GIS tools. The performance indicators analysis reveals that there is plenty of scope for improvement in performance of Ukai Right Bank Canal as well as water productivity in the canal command.

Index Terms—Performance indices, Water use efficiency (WUE), Relative water supply, Normalised Difference Vegetation Index (NDVI).

I. INTRODUCTION

India has made tremendous progress in development of its irrigation potential. However, only about two-third of the created irrigation potential in actually being utilized and overall project irrigation efficiencies is very poor. Applying water to crop through irrigation increases yield and production in agriculture. However, inappropriate management of irrigation schemes might lead to environmental problems such as a high water table and poor drainage and thus saliniation and pollution in addition to low quality irrigation water.

Assessing the performance of irrigated agriculture is necessary in order to evaluate the impact of agricultural and hydrological interventions. The performance of many agriculture systems is significantly below their potential due to number of short coming, such as poor design, construction, operation and maintenance.

Performance of an irrigation project can be measured in terms of technical efficiencies with which the water was provided to the crop root zone, total agricultural production

from the project and the equity (Reddye, 1986). Performance evaluation parameters of irrigation canal systems should involve factors such as command area, canal network, control structures, cropping patterns and weather conditions as well as human factors (Das et al. 1992).

II. STUDY AREA

The study area selected is command of Ukai Right Bank Canal, which was constructed after coming up of Ukai dam to provide irrigation facilities to 61,309 ha. of area lying between Narmada River and Kim River.

The study area forms part of Ukai-Kakrapar Project of the Southern region in the state of Gujarat, known as Ukai Right Bank Canal Command. It is located, as shown in the Figure: 1, between 21° 43' & 21° 21' North latitude and 72° 39' & 73° 7' East longitude in the southern region in the state of Gujarat, known as Ukai Right Bank Canal Command area.

The study area is covered in topo sheets No. 46C10, 46C11, 46C14, 46C15, 46G02 and 46G03.

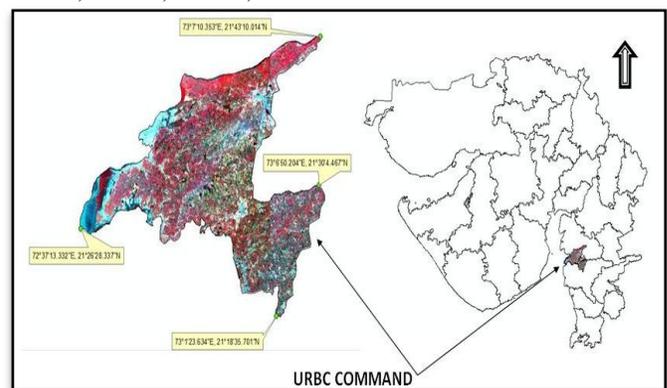


Fig.1 Satellite image of the Study area

III. METHODOLOGY

Any irrigation system can be evaluated by using the satellite remote sensing technique explained in the form of flowchart as shown in the Fig: 2

Performance assessment of irrigation system needs information like water release from the head and discharge schedule for irrigation watering, crop water requirements, effective rainfall, evapotranspiration, agriculture area irrigated both by canal and other than canal, actual delta achieved, ground truth data of the command of each branch, etc.

The topographic information of the command area containing general features including waterlogged and salt affected areas, are significant in the performance evaluation.

Satellite measurements expressed in digital raster maps containing information in every pixel at much smaller scales, up to a level of 20 to 30m, can be investigated by land use, land cover mapping using GIS. Spatially distributed information on irrigated crop area, crop water requirement, actual evapotranspiration which are derived, can be substantially contributed to performance assessment in space and time.

The three major indicators have been suggested for the performance assessment of irrigation systems. These are Adequacy, Equity and Agricultural outputs. Agricultural outputs are Output per cropped area and Output per unit irrigation supply.

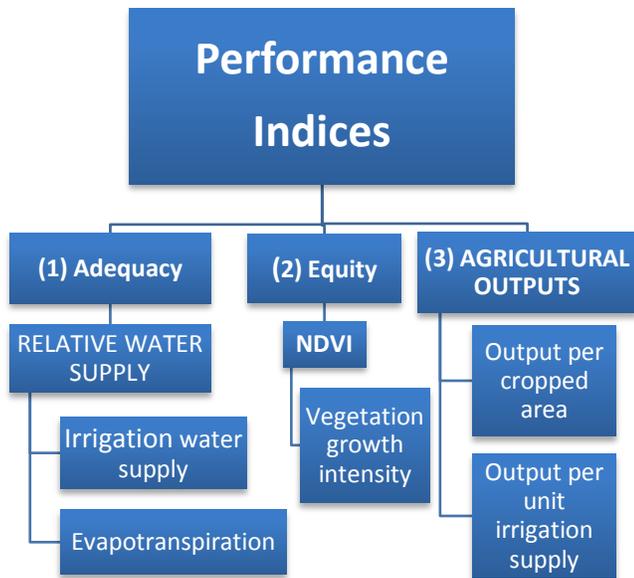


Fig.2 Methodology of Performance Evaluation of Canal Irrigation

IV. RESULT AND DISCUSSION

1. Adequacy

The relative water supply (RWS) which is derived from the ratio of actual water supplied in the canal to the amount of water required by the crop irrigated in the command in term of ETcrop can be used to compute the adequacy. The adequacy of water to irrigation system was characterized by estimating Relative Water Supply (RWS) to the command for the rabi season of 2012-13. The values of RWS have five categories i.e. Excessive water supply (RWS>3), High water supply (2.0<RWS<3.0), Moderate water supply (1.1<RWS<2.0), Adequate water supply (0.9<RWS<1.1) and water deficit (0.5<RWS<0.9). Adequacy, which can be expressed by:

$$RWS = \frac{(IR+RS)}{(ET+S\&P)} \quad \text{OR} \quad RWS = \frac{IWS}{ET_{CROP}}$$

Where, IR & IWS = Irrigation water supply, RN = Rainfall, ET = Evapotranspiration, S = Seepage, P = Percolation, RWS = (917.09/994.56) Day. Cusec, RWS = 0.92 (AW = Adequate Water)

The value of RWS has been found based on the two computed parameters i.e. actual water released from the head of main canal and the actual consumptive irrigation requirement base on ETcrop for the Rabi crops.

Looking to the criteria of water supply based on value of RWS, The obtained RWS value put this irrigation system into Adequate Water Supply (AWS) but it is just above the criteria of deficit, while for any healthy irrigation system should be in at least Moderate water supply (MWS) category. So, it can be stated that the supply of water through tail end canals is required to be increased.

2. Equity

To study the equity, the difference in cropped area and crop condition between head and tail zones, the command area of long distributaries should be divided into three, merely equal zones from head to tail using ENVI tool. Each division should be evaluated by NDVI value, agricultural land characteristics and growth condition with image processing software and visual interpretation. The value of Normalized Difference Vegetation Index of each division could be determined by image processing software using satellite image. Based on the statistics of NDVI value, the reduction in the agriculture land and vegetation growth intensity could be evaluated in the different division of each branch canal command. NDVI is defined by the following equation:

$$NDVI = \frac{NIR - IR}{NIR + IR}$$

The value of this index ranges from -1 to 1. The common range for green vegetation is 0.2 to 0.8. ROI of different classes like head, middle and tail reaches of Kosamba branch, Jitali branch and Hansot branch were extracted from

IRS Liss III data using ENVI imaging software. The DN values of different bands were generated using ENVI software from this band values NDVI of each class was computed using formula of NDVI.

NDVI VALUES OF BEANCH CANALS FROM HEAD TO TAIL		
HANSOT BRANCH	JITALI BRANCH	KOSAMBA BRANCH
•0.258 •0.182 •0.121	•0.153 •0.192	•0.147 •0.109 •0.130

Table: 1 NDVI Value of Head to Tail of Each Branch Canal

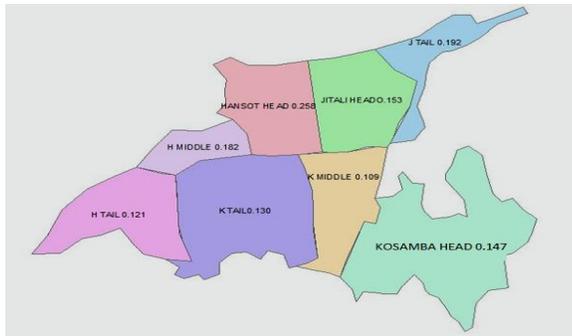


Fig.3 NDVI Value of Each Division in the Branch Canal Command

NDVI value of Hansot and Kosamba branch are decreased from head to tail so cropped area decreased from head to tail reach. The middle division of the Kosamba branch command is declined by big fall in NDVI value which shows that the area is highly affected by saline land and water logging, in addition in this area the fishing development ponds have been developed, which affect the crop growth. While in Jitali branch NDVI value increase from head to tail i.e. tail reach of Jitali branch located near the Bank of Narmada river so other than canal irrigation done from Narmada river.

3. Agricultural output

The two basic comparative performance indicators relate output to unit land and water. These “external” indicators provide the basis for comparison of irrigated agriculture performance. Where water is a constraining resource, output per unit water may be more important, whereas if land is a constraint relative to water, output per unit land may be more important.

A. Output per cropped area

For computation of output per cropped area, the required data of crop productions for last four years and market values

of crops were obtained from agriculture department. Based on the interview survey with the farmers of different villages of URBC command, the values of output per cropped area have in three category i.e. deficit (< Rs. 2,00,000), moderate (Rs. 2,50,000 - Rs. 2,00,000) and profitable (> Rs. 2,50,000). Using these data of crop production in Rs. and previously calculated cropped area of rabi season, output per cropped area has been computed as given below,

Output Per Cropped Area

$$(\text{Rs./Ha}) = \frac{\text{Crop Production}}{\text{Cropped Area}}$$

$$G_{vpi} = \frac{\sum(C_j X P_j)}{CA}$$

Where,

G_{vpi} = Given value of production in jth season

C_j = Crop production of jth crop (tonne)

P_j = Market price of jth crop per tonne

CA= Cropped area

Year	Production	Cropped area	Output per cropped area (Rs./ha)	Avg. Output per cropped area (Rs./ha)
	$\sum(C_j X P_j)$	CA	$G_{vpi} = \frac{\sum(C_j X P_j)}{CA}$	
2009-10	Rs.7,336,146,511	36400 ha	201,542.49	204,319.86
2010-11	Rs.7,416,238,422	36400 ha	203,742.81	
2011-12	Rs.7,455,099,642	36400 ha	204,810.43	
2012-13	Rs.7,541,487,361	36400 ha	207,183.72	

Table:2 Output per Cropped Area

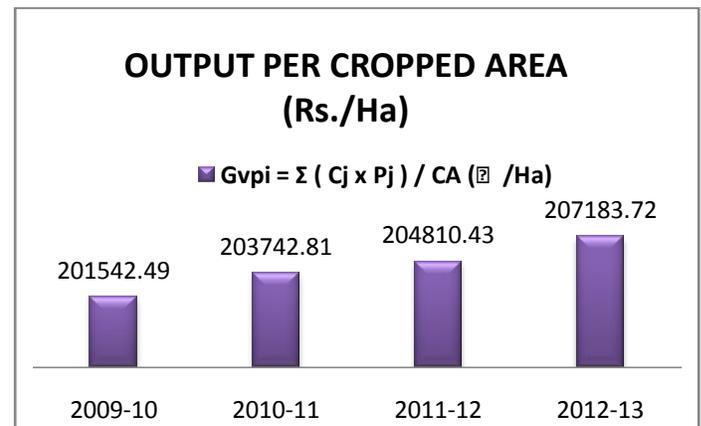


Fig:4 Output per Cropped Area

As per above chart, the output per cropped area for last four years were in moderate category. So obtained output per

cropped area for rabi season in URBC command are satisfactory but not very good.

Looking to the crop productions in Rs./ha it has been observed that crop productions increase every year, due to awareness of farmers towards water use and adoption of cash crops supported by irrigation water supply by URBC.

B. Output per unit irrigation supply

For computation of output per unit irrigation supply, the required data of crop productions for last four years and market values of crops were obtained from agriculture department. Using these data of crop production in Rs. and Irrigation Supply from head regulator of URBC canal were collected from Surat irrigation circle office of rabi season, output per unit irrigation supply has been computed as given below,

Output Per Unit Irrigation Supply

$$(\text{Rs./m}^3) = \frac{\text{Crop Production}}{\text{Diverted Irrigation Supply}}$$

$$G_{vpi} = \frac{\sum(C_jXP_j)}{V_{div}}$$

Where,

G_{vpi} = Given value of production in jth season

C_j = Crop production of jth crop (tonne)

P_j = Market price of jth crop per tonne

V_{div} = Volume of surface irrigation water diverted to the command area

Year	Production	Diverted irrigation supply (m ³)	Output per unit irrigation supply (Rs. /m ³)	Avg. output per unit irrigation supply (Rs. /m ³)
	$\sum(C_jXP_j)$	V_{div}	$G_{vpi} = \frac{\sum(C_jXP_j)}{V_{div}}$	
2009-10	Rs.7,336,146,511	269252679.4 m ³	27.21	27.60
2010-11	Rs.7,416,238,422	269252679.4 m ³	27.54	
2011-12	Rs.7,455,099,642	269252679.4 m ³	27.68	
2012-13	Rs.7,541,487,361	269252679.4 m ³	28.00	

Table: 3 Output per Unit Irrigation Supply

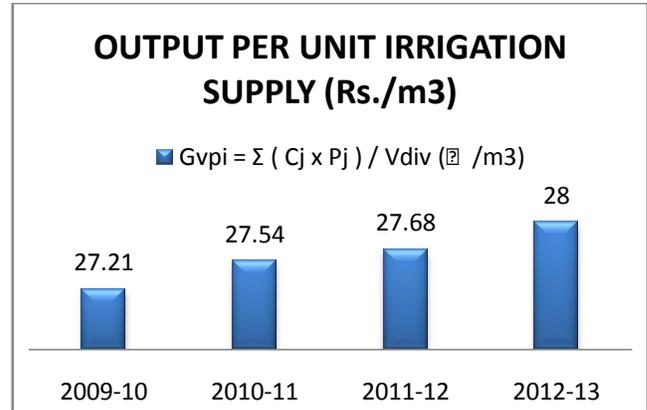


Fig. : 5 Output per Unit Irrigation Supply

The yield per unit irrigation water observed that the value in Rs./m³ is increasing every year. As cropping pattern deviating from design pattern and production per volume of water diverted is increasing from 2009-10 to 2012-13, it shows an increasing trend. The reason can be best described by adoption of more cash crops as compared to previous years. This concept is relatively new and made the interpretation difficult.

V. CONCLUSIONS

Amongst the three major indicators have been suggested for the performance assessment of irrigation systems, viz; adequacy, equity and agricultural outputs, the third index is found more significant for precise evaluation of canal irrigation system. Agricultural outputs are Output per cropped area and Output per unit irrigation supply.

In case of the 1st performance index adequacy, the calculated RWS value falls under the category of Adequate Water Supply (AWS), however it is just above the deficit. Hence, it is required to increase RWS value of water supply of existing irrigation systems, so as to reach it up to the category of Moderate water supply (MWS).

Equity (2nd performance index) known from the NDVI values indicates that tail reaches of Hansot and Kosamba branch canals can't get sufficient water for irrigation so improvement is required in irrigation system. The middle division of the Kosamba branch command is declined by a big fall in NDVI value which shows that the area is highly affected by saline land and water logging, in addition to this in this area fishing development ponds have been developed which also affects the crop growth. In Jitali branch NDVI value increases from head to tail indicating tail reach is located near the Bank of Narmada river and Narmada river water is also used for irrigation in addition to canal irrigation. So looking to the obtained NDVI values of different branch canals from head to tail, it can be stated that the tail regions of different canals need more water supply.

Considering agricultural outputs (3rd performance index), it is observed that, Output Per Cropped Area and Output Per Unit Irrigation Supply are increasing every year from 2009-10 to 2012-13. Improvement is observed in terms of the outputs of irrigated agriculture every year due to awareness of farmers towards water use and adoption of cash crops.

Statistical indices indicate that there is a minor difference in production, water supply and water use and there is scope for improvement of command area development works for efficient on-farm water management. Training and awareness campaign and frequent dialogue to establish linkage between canal managers and water users is very essential to improve the performance of the canal system.

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