Comparison of performance indicators for the evaluation of irrigation scheme In Madhya Pradesh

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Abstract: The performance evaluation of the irrigation project is an important management tool to improve water use efficiency and financial viability along with the adoption of best management practices and the environmental sustainability of the irrigated agricultural system. It is important to evaluate the performance of the irrigation projects on a continuous basis to identify bottlenecks, constraints, managerial laps and other grey areas in the system and to provide direction for improvement in water resources development and management strategies to reap its full benefits on a long term basis. The Madhya Pradesh state has achieved a significant rise in irrigation and agricultural production in recent times. The same pace of sustainable development in the waters sector will be a key factor to meet the increasing future water demands in the state. This can be achieved through the formulation of strategies based on the performance evaluation of irrigation schemes. In the present study, the performance of the Kotwal-Pillowa complex irrigation project located in Madhya Pradesh has been evaluated using comparative indicators suggested by the International Water Management Institute (IWMI).
The performance evaluation analysis was carried for Rabi seasons of years 2005-06, 2009-10, 2013-14 and 2015-16. From the analysis, it was observed that the output per unit cropped area in Kotwal-Pillowa command was 13523 Rs/ha in the year 2005-05 and it was increased up to 45220 Rs/ha in the year 2013-14. The output per unit command area was seen increased from 28425 Rs/ha in the year 2013-14 to 51272 Rs/ha in the year 2015-16. Though the year 2015 was a dry year, output per unit of irrigation supply was better i.e. 6.53 Rs/m^3, this was because of a high gross return due to adaptation of proper water management practices and crop selection. The relative water supply index and the relative irrigation supply were seen improved with time and were found better in the year 2015-16. The water delivery capacity index analysis indicated that the dam's infrastructure is capable of delivering water to meet peak water demand. Thus it could be concluded that the performance of Kotwal-Pillowa irrigation project has been improved significantly in terms of its agricultural, water use based performance in the recent period especially after 2013-14, which is due to additional water supply from Gandhi Sagar dam on Chambal River, increased cropped area and adoption managerial practices. The performance evaluation has found to be a very simple method as comparative indicators are very easy to calculate by using field data and useful to assess the progress of irrigation projects against strategic goals and to formulate strategies to improve system operations.

Keywords: Performance evaluation; comparative indicators; SGVP; relative water supply; relative irrigation supply; water delivery capacity.

1. Introduction

Irrigation development is one of the most commonly practiced strategies to increase agricultural production, food security, rural livelihood, and rural development. However, food security issues in developing nations has always been aggravated by the rapid population growth and the consequent demand for food (FAO, 1997). To tackle the situation India has achieved significant

progress in creating the number of major, medium and minor irrigation projects after independence thereby increasing agricultural production in the country. Yet dissatisfaction with the performance of irrigation projects in the country is widespread. Despite their promises, irrigation projects typically perform far below their potential due to one or many reasons (Small and Svendsen, 1992). The low performance of the project may be due to inadequate management at the system and field level (Cakmak *et al*., 2004). Therefore, it is important to evaluate the performance of the irrigation projects on a continuous basis to identify bottlenecks, constraints, managerial laps and other grey areas in the system and to provide direction for improvement in water resources development and management strategies to reap its full benefits on a long term basis. The performance evaluation of the irrigation project is an important management tool to improve water use efficiency and financial viability along with the adoption of best management practices and environmental sustainability of the irrigated agricultural system. In the present study, the performance of the Kotwal-Pillowa complex irrigation project located in Madhya Pradesh has been evaluated using comparative indicators suggested by the International Water Management Institute (IWMI).

Madhya Pradesh is the second-largest state in India by area and the sixth largest state by population. The state has an agrarian economy; the major crops of Madhya Pradesh are wheat, soybean, gram, sugarcane, rice, maize, cotton, rapeseed, mustard and arhar. The State is not short of water resources, it has enormous potential for its development and achieved remarkable growth in the irrigation sector. Madhya Pradesh has been bestowed the prestigious Krishi Karman award by the Government of India for the last five years in a row in recognition of its outstanding performance in agriculture production. This has been made possible through the water sector restructuring program aided by the Central Government and sustainable water resources development strategies adopted by the State Government. These, in turn, facilitated the state to increase agricultural productivity and to improve the living standards of farmers. To keep the same pace of development more consistent and sustainable, it is imperative to evaluate the performance of irrigation schemes in terms of their agricultural production, water use performance, economic and social benefits using appropriate indicators. It will help the project authority to compare the performance of the project with the previous years or with other projects in the region and formulate strategies for further improvement in the system. It will also help to assess the impact and evaluate benefits of rehabilitation, restructuring and renovation work undertaken for the irrigation project. It will also help to assess the impacts of operation and management policy on the performance of the irrigation project.

Numbers of studies have been conducted all over the world for performance evaluation of the irrigation project. International Water Management Institute, Sri Lanka in their Research Report No. 20 suggested the Indicators for comparing the performance of irrigated agricultural systems. Molden et al., (1998) compared the performance of eighteen irrigation systems located in eleven different countries through various indicators. Murray-Rust and Snellen (1993) conducted a

research study on irrigation system performance assessment and diagnosis. Das et al., (1992) suggested 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. Mohamed (1992) conducted a multi-objective performance evaluation of irrigation systems in less developed countries. Burt et al., (1997) emphasized to standardize the definitions and approaches to quantify various irrigation performance measures. Droogers et al., (1999) concluded that if irrigation performance indicators are used only at a local scale, a misleading picture can be given on the regional scale. Mishra et al., (2001) computed a performance ratio and used it as an indicator for assessing the degree of uniformity in flow deliveries along the length of the canal in the Right Bank Main Canal system of the Kangsabati project in West Bengal. Droogers and Bastiaanssen (2002) reported that irrigation performance and water accounting are useful tools to assess water use and related productivity. Ray et al., (2002) computed multi-temporal remote sensing data-based performance indices for the distributaries of the Mahi Right Bank Canal command in Gujarat, India.

Styles and Marino (2002) described the irrigation performance for sixteen international irrigation projects in less developed countries and found that the performance of many projects was poor due to technical, financial, managerial, social, and institutional causes. Bandara (2003) used *NOAA* satellite data to assess the performance of three large irrigation systems in Sri Lanka during the year 1999. Upadhyaya et al., (2004) identified constraints in water delivery from the canal and developed performance indicators. Bhatta et al., (2006) compared the performance of agency-managed and farmer-managed irrigation systems of Chitwan, Nepal. Singh et al., (2013) carried out a case study to assess the performance of Lift Irrigation Scheme Sirsa-Manjholi in the Solan area of Shivalik Himalayas. Ingle et al., (2015) studies the performance of the Kalwande Minor Irrigation Scheme (KMIS) in Ratnagiri district of Maharashtra and observed that the output values were lower than recommended package of IWMI practices. Bos et al., (1994) Methodologies for assessing performance of irrigation and drainage management

The present study is carried out to evaluate the performance of the Kotwal-Pillowa joint irrigation project located in Bhind districts of Madhya Pradesh. The performance of the Kotwal-Pillowa irrigation project was evaluated using seven comparative indicators classified in two groups, agriculture and water-use or physical performance suggested by the International Water Management Institute (IWMI) Sri Lanka.

2. Materials and Methods

Study Area

The Kotwal-Pillowa joint project is a complex project having two separate dams Kotwal and Pillowa on two rivers on Asan and Sankh respectively falling in Sindh sub-basin of Chambal river in Morena district of Madhya Pradesh. The Kotwal-Pillowa project is located at 26°28’11"

E Longitude and 78°4’55" N Latitude. The location map of Kotwal-Pillowa project is shown in Figure 1. These both Kotwal and Pillowa dams are interconnected by Jararua connecting channel carrying water from Kotwal to Pillowa. Kotwal dam is supplemented by the Gandhisagar dam on the Chambal river contributing a major part of irrigation and also supplied by the Pagara dam located on the Asan river in the upstream of Kotwal. The gross command area of the Kotwal-Pillowa complex irrigation project is 121547 ha and the culturable command area is 120387 ha which falls in parts of Morena and Bhind districts. The network of Kotwal-Pillowa complex irrigation projects is shown in Figure 2. The details of dams such as catchment area, gross storage capacity and command area are given in Table 1. The climate of Bhind district characterized by a hot summer and general dryness except during the southwestern monsoon. Major crops grown in the command area during the rabi season are wheat, gram, mustard, lentil, pea, barley and other oil crops.

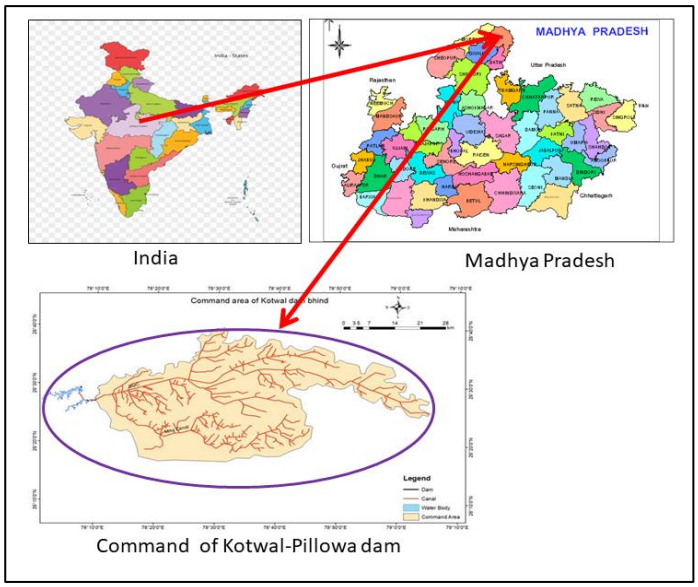

Fig. 1 location map of Kotwal-Pillowa project

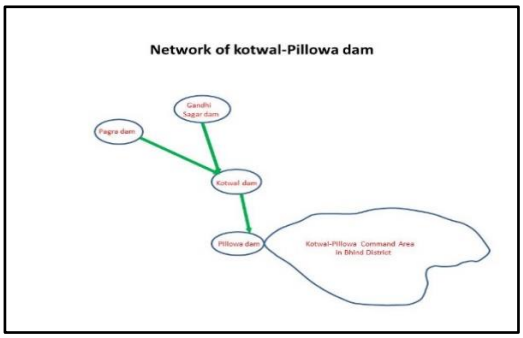

Fig. 2 Network of Kotwal-Pillowa complex irrigation project

Table 1 Details of Kotwal-Pillowa Complex Irrigation Project

Dams	Catchment Area (km^2)	Gross Storage Capacity (MCM)	Command area (ha)	Major Crops
Kotwal dam	1036	91.55	36830	Mustard Wheat Gram Lentil Pea, Barley and other oil crops.
Pillowa dam	257.42	23.186		
Pagara dam		160.00		
Gandhi Sagar dam (on Chambal river)		556.00 (Diverted to Kotwal Dam)	83557	
Total		830.736	120387	

Data collection

The study involves significant data collection from field and concern departments such as Crop area of each crop in command, yield of each crop in command area, local price of each crop, local price of base crop, value of base crop traded at world price, command area, irrigated cropped area, total water supply, surface diversions, net groundwater draft, rainfall, irrigation supply, diverted irrigation supply, canal capacity to deliver water at system head. The present study has been carried out for four selected years 2005-06, 2009-10. 2013-14 and 2015-16. The long term rainfall and meteorological data of Gwalior station were collected from the Indian Meteorology Department, Pune. Dam and command area related data of selected years were collected from the Gohad and Bhind divisional offices of the Water Resources Department. Agricultural information was collected from the Agricultural department. Primary information such as sowing and harvesting of different crops, their duration, crop stage which need irrigation, root zone depth of crop etc. were collected from the different sources including contacts with the local farmers and Water User Associations. The spatial information such as catchment area, water spread, command area, canal network was digitized to prepare thematic maps using ARC GIS using 1:50000 scale Toposheet no. 54F/11; 12; 15; 16, 54G/5; 6; 9; 10, 54I/3 and 54J/2; 4; 6; 7; 10; 11; 15. The Bhind Main Canal (BMC) covers Bhind and a small part of Morena districts as shown in the command area map in Figure 3.

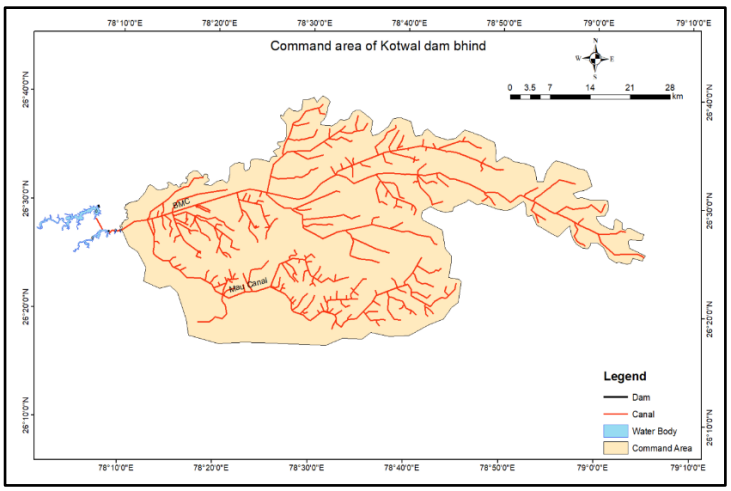

Fig. 3 Command area map of Kotwal-Pillowa irrigation project

Comparative Performance Indicators

International Water Management Institute (IWMI), Srilanka recommended nine indicators broadly categorized as agriculture, water use or physical and economic performance evaluation of the irrigation project as suggested by Molden et al. (1998). These nine indicators are namely, output per unit cropped area, output per unit command, output per unit irrigation supply, output per unit water consumed, relative water supply, relative irrigation supply, water delivery capacity, gross return on investment, and financial self-sufficiency. In the present study, the performance of the Kotwal-Pillowa irrigation project was evaluated using comparative indicators to evaluate its performance in terms of agricultural and water use performance. The comparative indicators were analyzed for Rabi seasons of years 2005-06, 2009-10, 2013-14 and 2015-16.

Standardized Gross Value of Production (SGVP)

The Standardized Gross Value of Production (SGVP) is developed for cross-system comparison, as there are differences in local prices at different locations throughout the world. To obtain SGVP, the equivalent yield is calculated based on local prices of the crops grow in Kotwal-Pillowa Command, compared to the local price of the predominant, locally grown, internationally traded base crop. SGVP was calculated as a formula given by Molden *et al.* (1998).

$$SGVP = \left[\sum AiYi \frac{P_i}{P_b}\right] P_{word} \qquad (1)$$

Where,
Ai is the area cropped with crop i
Yi is the yield of the crop I
Pi the local price of the crop I

Pb the local price of the base crop
Pworld is the value of the base crop traded at world prices

Agriculture performance

In order to compare the performance of Kotwal-Pillowa irrigation project four agriculture-based comparative indicators were used as these indicators provide the information for comparison on the basis of output per unit agriculture production, water consumed and water supply.

$$Output\ per\ unit\ cropped\ area\ \left(\frac{Rs}{ha}\right) = \frac{SGVP}{Irrigated\ cropped\ area} \quad (2)$$

$$Output\ per\ unit\ command\ area\ \left(\frac{Rs}{ha}\right) = \frac{SGVP}{Command\ area} \quad (3)$$

$$Output\ per\ unit\ water\ consumed\ \left(\frac{Rs}{m3}\right) = \frac{SGVP}{volume\ of\ \ water\ consumed\ by\ ET} \quad (4)$$

$$Output\ per\ unit\ irrigation\ supply\ \left(\frac{Rs}{m3}\right) = \frac{SGVP}{Diverted\ irrigation\ supply} \quad (5)$$

Where Standardized Gross Value of Production (SGVP) is the output of the irrigated area in terms of the gross or net value of production measured at local or world prices. Irrigated cropped area is the sum of the areas under crops during the time period of analysis. The command area is the design area to be irrigated. Diverted irrigation supply is the volume of surface irrigation water diverted to the command area, plus net removals from groundwater. The volume of water consumed by ET is the actual evapotranspiration of crops. The volume of water consumed by ET (m^3) is the actual evapotranspiration of crops. The evapotranspiration was estimated using a modified Penman method using climatic data such as temperature, wind speed, relative humidity, sunshine hours of Gwalior IMD station. For this purpose, the CROPWAT model program (FAO, 1992) was used. The actual crop water requirement (*ETc*) was calculated using the following equation (Doorenbos and Kassam, 1986).

$$ETc = K_c \times ETo \quad (6)$$

ETc is the actual evapotranspiration or crop water requirement, K_c is the crop coefficient and ETo is the reference evapotranspiration. All agricultural performance indicators were compared with the Kalwande Minor Irrigation Scheme (KMIS) in Ratnagiri district of Maharashtra (Ingle et al., 2015)

Water Use performance

To evaluate the water use or physical performance of the irrigation system mainly three indicators are used, they are Relative Water Supply (RWS), Relative Irrigation supply (RIS) and Water Delivery Capacity (WDC). They are meant to characterize the individual system with respect to water supply and finances (Molden et al, 1998). Relative water supply and relative irrigation supply are used as the basic water supply indicator. Both RWS and RIS relate supply to demand and give some indication as to the condition of water abundance or scarcity, and how tightly supply and demand are matched in Kotwal-Pillowa irrigation projects. Water delivers capacity is meant to give an indication of the degree to which irrigation infrastructure is constraining cropping intensities by comparing the canal conveyance capacity to peak consumptive demands in Kotwal-Pillowa irrigation projects. Three types of indicators, relative water supply (RWS), relative irrigation supply (RIS) and water deliver capacity (WDC) were used for evaluation of water use performance (Levine, 1982 and Perry, 1996).

RWS indicates whether enough water available in the dam to meet crop demand in the command area. The RWS relates the water made available for crops, including surface irrigation, groundwater pumped and rainfall against the crops need. This indicator provides information about the relative abundance or scarcity of water.

$$Relative\ water\ supply = \frac{Total\ water\ supply}{Crop\ demand} \qquad (7)$$

The RIS indicates whether crops are getting enough water and how canal irrigation supply and demand are matched. A value of RIS over one would suggest too much water is being supplied, possibly causing waterlogging and negatively impacting yields and a value less than 1indicates that crops are not getting enough water.

$$Relative\ irrigation\ supply = \frac{Irrigation\ Supply}{Irrigation\ Demand} \qquad (8)$$

Where:
Total water supply is the Surface diversions plus net groundwater plus rainfall.
Crop demand is the Potential crop ET or the ET under well-watered conditions.
Irrigation supply is the only surface diversions and net groundwater draft for irrigation.
Irrigation demand is the crop ET less effective rainfall.

Both RWS and RIS relate supply to demand, and give some indication of water abundance or scarcity, and how tightly supply and demand are matched. If irrigation system design constraining agricultural production then the water delivery capacity can suggest changes in irrigation infrastructure or cropping patterns to maximize cropping intensity. The water delivery capacity (WDC) is given below:

$$Water\ delivers\ capacity\ (\%) = \frac{Canal\ capacity\ to\ deliver\ water\ at\ system\ head}{peak\ consumptive\ demand} \qquad (9)$$

Where Canal capacity to deliver water at the system head is the present discharge capacity of the canal at the system head and Peak consumptive demand is the peak crop irrigation requirements for a monthly period expressed as a flow rate at the head of the irrigation system. WDC is meant to give an indication of the degree to which irrigation infrastructure is constraining cropping intensities by comparing the canal conveyance capacity to peak consumptive demands.

3. Results and Discussion

Comparative Performance Indicators

Performance of the Kotwal-Pillowa irrigation project was evaluated for its agricultural and water use performance using seven comparative indicators as suggested by IWMI. The performance evaluation was carried out for the Rabi season of the years 2005-06, 2009-10, 2013-14 and 2015-16. The information on diverted irrigation supply, irrigation supply, total water supply, water delivering capacity at a canal head during those selected years is given in Table 2. The evapotranspiration was estimated using the CROPWAT 8.0 model and also given in Table 3.

Table 2 Input parameters information for Kotwal-Pillowa Irrigation Projects

Years	Diverted irrigation supply (MCM)	Irrigation supply (MCM)	Volume ET (MCM)	Total water supply (MCM)	Capacity of canal Head (Cumec)
2005-06	157.5	157.5	577.0	157.8	44.15
2009-10	280.4	280.4	478.0	283.5	44.15
2013-14	614.9	614.9	192.8	630.9	44.15
2015-16	725.4	725.4	379.3	740.4	44.15

The diverted irrigation supply during 2013-14and 2015-16 has increased as compared to the year 2005-06 and 2009-10. This has improved the total water supply in command of Kotwal-Pillowa after 2013-14.

Estimation of Standardized Gross Value Production (SGVP)

SGVP values estimated for Rabi crops grown in Kotwal-Pillowa irrigation project for the periods 2005-06, 2009-10, 2013-14 and 2015-16 has been shown in Table 3.

Table 3 Standardized SGVP

Years	Cropped area (ha)	Avg. Yield (ton/ha)	Production (Thousand ton)	SGVP (Cr. Rs)

2005-06	23133	1.21	33.5	31.28
2009-10	18959	1.25	31.2	46.65
2013-14	75802	1.59	146.1	342.77
2015-16	147639	1.79	339.2	618.28

In Kotwal-Pillowa command, the Mustard crop has been observed grown in the majority of the command area, hence considered as a base crop for the calculation of SGVP. It is also the most tradable crop in the region. The Cropped area in Kotwal-Pillowa command has increased from 23133 ha in 2005-06 to 147630 ha in 2015-16. The average yield and production have also found increased during this period. Thus the SGVP value in Kotwal-Pillowa command has been seen increased from Rs. 31.28 Cr. in the year 2005-06 to Rs. 618.28 Cr. in the year 2015-16.

Performance evaluation of the irrigation projects

In this analysis SGVP values of Kotwal-Pillowa irrigation project were used to evaluate seven indicators namely output per unit cropped area, output per unit command, output per unit irrigation supply, output per unit water consumed, relative water supply, relative irrigation supply, water delivery capacity. Year-wise comparative indicators evaluated for years 2005-06, 2009-10, 2013-14 and 2015-16 are shown in Table 4 which can easily be compared with each other during various years.

Table 4 Evaluated comparative indicators for Kotwal-Pillowa irrigation project

Year	SGVP (Lakh Rs)	Irrigated area (Thousand ha)	Command area (Thousand ha)	Effective Rainfall (mm/season)	Total ER (MCM)	Total water supply (cusec)	Diverted irrigation supply (MCM)	Volume ET (MCM)
2005-06	31.28	23.13	120.5	11.1	0.25	17176	157.54	57.78
2009-10	46.65	18.95	120.5	16.5	3.12	30570	280.40	47.86
2013-14	342.77	75.80	120.5	21.1	15.99	67042	614.93	192.84
2015-16	618.28	147.63	120.5	10.1	14.91	79095	725.49	379.35
Year	Total water supply DIS+TER (MCM)	CWR (mm/season)	Total CWR (MCM)	Irrigation supply (MCM)	IR (mm/season)	Total IR (MCM)	CCDWSH (cusec)	PCD (l/s/ha)
2005-06	157.80	249.81	57.78	157.54	244.92	56.65	44.15	0.35
2009-10	283.52	252.48	47.86	280.40	106.34	20.16	44.15	0.36
2013-14	630.93	254.41	192.84	614.93	233.96	177.34	44.15	0.35
2015-16	740.40	256.95	379.35	725.49	243.46	359.44	44.15	0.33
Year	PCD (cusec)	RWS	RIS	OPICA (Thou	OPCA (Thou	OPIS (Rs/m^	OPWC (Rs/m^3)	WDC

				Rs/ha)	Rs/ha)	3)		
2005-06	8.10	2.73	2.78	13.52	2.59	1.99	5.41	5.45
2009-10	6.83	5.92	3.20	24.60	3.86	1.66	9.75	6.47
2013-14	26.53	3.27	3.47	45.22	28.42	5.57	17.77	1.66
2015-16	48.72	1.95	2.02	41.87	51.27	8.52	16.30	0.90

Evaluation of agriculture performance

Evaluation of agriculture performance involves analysis of comparative indicators such as output per unit cropped area, output per unit of command area, output per unit water consumed and output per unit irrigation supply.

Output per unit cropped area

Comprehensive analysis of Table 4 indicated a significant rise of output per unit-cropped area during the Rabi season of Kotwal-Pillowa irrigation project from the year 2005-6 to 2015-16. Output per unit cropped area in different years is shown graphically separately in Figure 4. It is clearly seen that the Outputs per unit cropped area was 13523 Rs/ha in the year 2005-06 and increased to 45220 Rs/ha in the year 2013-14. However, with the same setup and infrastructure of the irrigation project, it was found dropped in the year 2015-16.

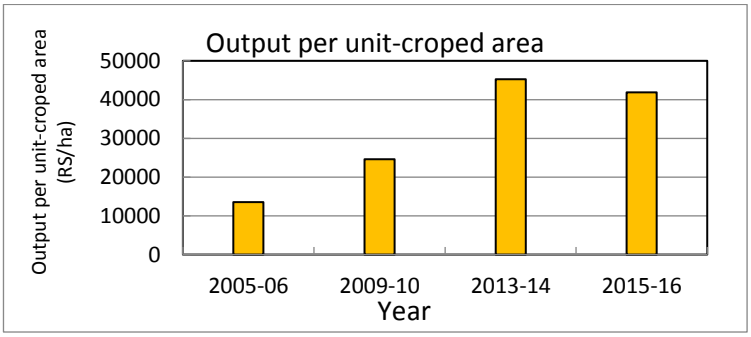

Fig. 4 Outputs per unit cropped area

On the detail examination, it was understood that the drop in indicator was due to a reduction in the base crop price in the world level in 2015-16 as compared to 2013-14. On comparison of output per unit cropped area of Kotwal-Pillowa with Kalwandey minor irrigation scheme (KMIS) in Chiplun, Ratnagiri districts of Maharashtra and other irrigation schemes. It was found quite low in case of Kotwal-Pillowa project. It suggests the need for improvement to increase production, reduction of cost of cultivation providing proper support price to the produce.

Output per unit Command Area

Analysis indicated a significant rise of output per unit-command area during the Rabi season of Kotwal-Pillowa irrigation project during the period from 2005-6 to 2016-17. Output per unit command area in different years is shown graphically separately in Figure 5. The production rate obtained varied between 2594 to 51272 Rs/ha during the Rabi season and the output per ha has been found increasing. The output per unit command area is compared for the last two years (i.e. 2013-14 and 2015-16). It is observed that the output per unit command area has increased 28425 Rs/ha in the year 2013-14 and 51272 Rs/ha in the year 2015-16. This indicates that there is a need to develop command area and increase the cropped area in the Kotwal-Pillowa project.

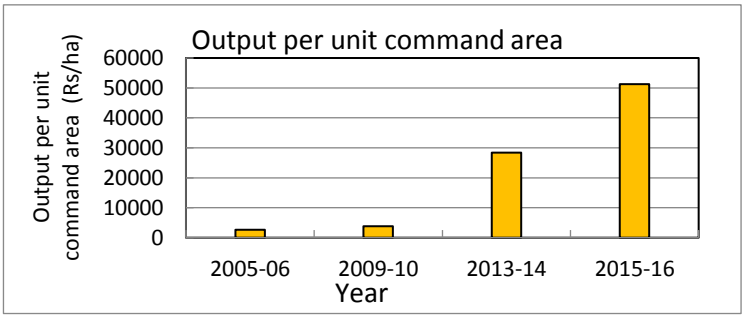

Fig. 5 Outputs per unit command area

Output per unit water consumed

The analysis of results indicated a significant rise of output per unit water consumed during the Rabi season of Kotwal-Pillowa irrigation project from the year 2005-6 to 2015-16. Output per unit-consumed in different years is shown graphically separately in Figure 6.

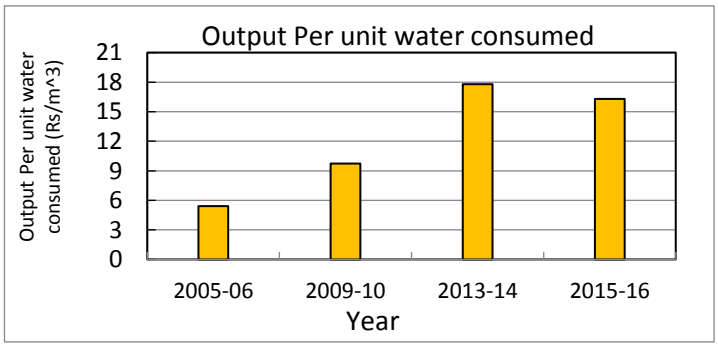

Fig. 6 Output per unit water consumed

From the analysis, it was observed that Output per unit water consumed was 5 Rs/m^3 in the year 2005-06 and increase to 17 Rs/m^3 and 18 Rs/m^3 during the year 2013-14 and 2015-16 respectively. The Output per unit of water consumed the year 2013-14 was higher as compared to 2015-16 which may be due to less water consumed and high gross returns.

Output per unit irrigation supply.

The analysis of Table 4 indicated a significant rise of output per unit- irrigation supply during the Rabi season of Kotwal-Pillowa irrigation project from the year 2005-6 to 2015-16. Output per irrigation supply in different years is shown graphically separately in Figure 7. The result shown the output per unit of irrigation supply varied between 1 to 7 Rs/m^3 indicates significant variation during the study periods. It was higher for the year 2015-16 due to less water consumed and high gross returns. The increase in the Standardized Gross Value Production (SGVP) per unit irrigation supply can be achieved through orchard medical crops and vegetables.

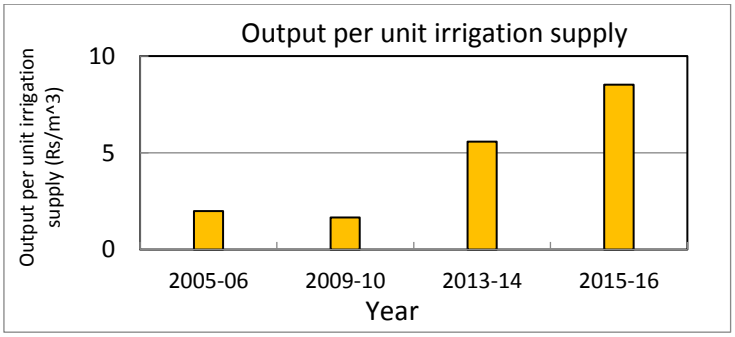

Fig. 7 Outputs per unit irrigation supplies

Evaluation of Water use performance

Evaluation of Water use performance involves analysis of three types of indicators, relative water supply (RWS), relative irrigation supply (RIS) and water deliver capacity (WDC).

Relative water supply (RWS)

The analysis of Table 4 indicated a significant rise in Relative water supply during the Rabi season in the year 2009-10. However, it was found quite low during other years. The year-wise Relative water supply (RWS) is shown in Figure 8.

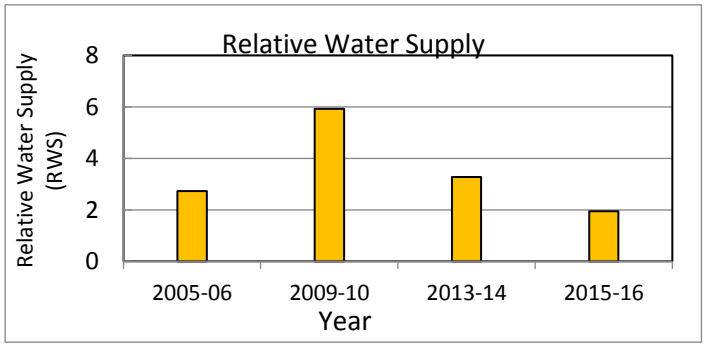

Fig. 8 Relative water supplies

The relative water supply indicators during Rabi-season in years 2005-06, 2009-10, 2013-14 and 2015-16 were found as 2.73, 5.92, 3.27 and 1.95 respectively. The value of more than 1.0 indicates that the total water supply is enough to meet the crop demand. Excess water supply was seen during the year 2009-10 and the relative water supply was better in the year 2015-16 as compared to other years during the study period. The relative water supply value of 1.91 was observed for Hayrabolu Irrigation Scheme in Turkey, 3.13 to 5.96 for Takez basin, Northern Ethiopia for the years 1998 to 2002, 1.14 for tail reach of Patna main canal command, Bihar and 1.41 to 4.04 for different irrigation schemes in Turkey for year 2001 and 2.49 Kalwande minor irrigation scheme. On comparison, it could be concluded that the Kotwal-Pillowa command is getting sufficient irrigation water.

Relative irrigation supply (RIS)

The analysis of Table 4 indicated a significant rise in Relative irrigation supply during the Rabi season in the year 2009-10. However, it was found quite low during other years. The year-wise Relative irrigation supply (RIS) is shown in Figure 9.

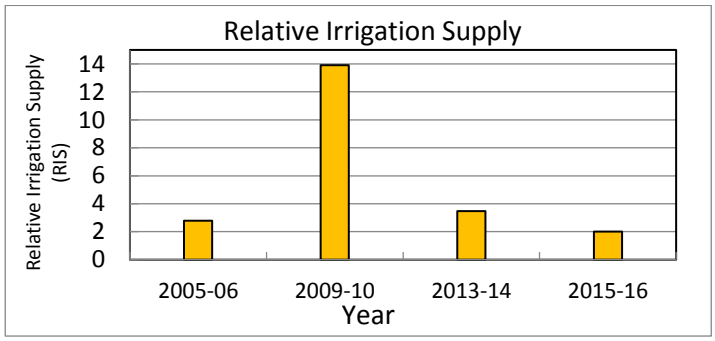

Fig. 9 Relative irrigation supplies

The relative irrigation supply indicator during Rabi-season in years 2005-06, 2009-10, 2013-14 and 2015-16 was found as 2.78, 13.90, 3.4 and 2.01 respectively. The value of more than 1.0 indicates that the irrigation supply by the canal is enough to meet the irrigation demand. Excess water supply was seen during the year 2009-10 and the Relative irrigation supply is better in the year 2015-16 as compared to during the study period. others irrigation projects the relative irrigation supply value was found between 0.41 to 4.81 for eleven different countries, 1.55 for the Hayrabolu Irrigation Scheme in Turkey, 1.4 and 0.77 for Nura Era and Wonji estate of Ethiopia and 3.33 to 6.68 for Takez basin and the RIS Kalwande minor irrigation scheme was 1.27. This indicates that the Kotwal-Pillowa command is getting sufficient irrigation water.

Water delivery capacity (WDC)

The year-wise water delivery capacity for the Rabi season of Kotwal-Pillowa irrigation project from year 2005-6 to 2016-17 has been shown separately in Figure 10.

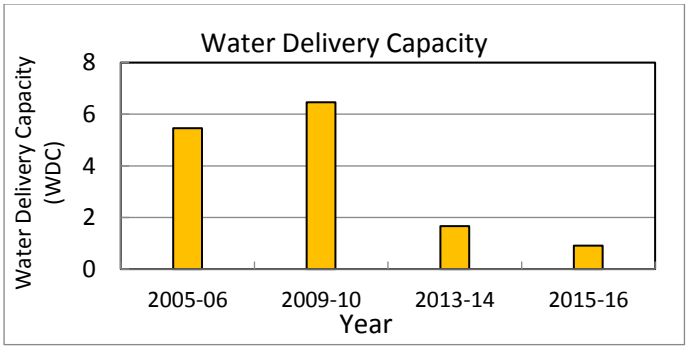

Fig. 10 Water delivery capacities

Water delivery capacity indicator during Rabi-season in years 2005-06, 2009-10, 2013-14 and 2015-16. It is indicated that water delivery capacity in the year 2013-14 was better as compared to other seasons. Higher value in the year 2009-10 indicated that its capacity has a lesser constraint to meet crop water demands.

5. Conclusions

The performance evaluation of the irrigation project is an important management tool to improve water use efficiency and financial viability along with the adoption of best management practices and environmental sustainability of the irrigated agricultural system. The performance evaluation of the Kotwal-Pillowa, a complex irrigation project of Madhya Pradesh has been carried out for selected years 2005-06, 2009-10, 2013-14 and 2015-16 using comparative indicators suggested by International Water Management Institute (IWMI). This has been found very helpful to understand, how the improvement in diverted irrigation supply, increase in command area and other management practices have helped to improve the performance agricultural and physical performance of the project.

The Kotwal-Pillowa complex irrigation project is supplemented by the Gandhi Sagar dam on the Chambal river and the Pagara dam providing irrigation 1.21 lakh ha area in Morena and Bhind districts. On comparison of recent performance of the irrigation project to its pasts, it was observed that the output per unit cropped area was 13523 Rs/ha in the year 2005-06 and it was increased up to 45220 Rs/ha in the year 2013-14. The output per unit command area was seen increased from 28425 Rs/ha in the year 2013-14 to 51272 Rs/ha in the year 2015-16.

Though the year 2015-16 was a dry year, output per unit of irrigation supply was better i.e. 6.53 Rs/m^3, this was because of a high gross return due to adaptation of proper water management practices and crop selection like vegetable, cash crop and more horticulture. The Relative Water Supply (RWS) index should be nearly 1.0 and it was 1.95 in the year 2015-16. The RWS of the

Kotwal-Pillowa project found better as compared to other irrigation projects in India and worldwide. Similar results were also found in the case of the Relative Irrigation Supply (RIS) index and the Kotwal-Pillowa project has been found performing well.

The Water Delivery Capacity index analysis indicated that the dam's infrastructure is capable of delivering water to meet peak water demand. Thus it could be concluded that the performance of Kotwal-Pillowa irrigation project has been improved significantly in terms of its agricultural, water use based performance in the recent period especially after 2013-14, which is due to additional water supply from Gandhi Sagar dam on Chambal river, increased cropped area and adoption of appropriate managerial practices. The performance evaluation has found to be a very simple method as comparative indicators are very easy to calculate by using field data and useful to assess the progress of irrigation projects against strategic goals and to formulate strategies to improve system operations.

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