# ASSESSING MANAGEMENT INTERVENTIONS IMPACT WITH IIMI'S MINIMUM SET OF COMPARATIVE INDICATORS:

**The Case of Mahi-Kadana Project, India**

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## Abstract

The International Irrigation Management Institute (IIMI) has identified a minimum set of nine comparative indicators, which it would be possible to calculate in most systems with data compiled in the usual course of system operation. This paper describes the methodology adopted in computing the minimum set of indicators with routinely collected data by the operating agency and demonstrated the utilities of these indicators in assessing management interventions impact of a large gravity irrigation system in the western part of India.

The management interventions introduced along with introduction of rotational water supply distribution at distributary levels had dramatically improved the irrigation system performance, in the Mahi-kadana system where proper irrigation scheduling was not effectively implemented prior to interventions.

# ASSESSING MANAGEMENT INTERVENTIONS IMPACTS WITH IIMI'S MINIMUM SET OF COMPARATIVE INDICATORS:

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R. Sakthivadivel[1] and O.T. Gulati[2]

## Introduction

The International Irrigation Management Institute (IIMI) has identified a minimum set of nine comparative indicators, which it would be possible to calculate in most systems with data compiled in the usual course of system operation (Molden et al 1997). The indicators included in this set are:

Output per unit cropped area
Output per unit command area
Output per unit irrigation supply
Output per unit water consumed
Relative Water Supply (RWS)
Relative Irrigation Supply (RIS)
Water Delivery Capacity (WDC)
Return on investment
Financial self-sufficiency

Among the nine indicators, the first four are external indicators which essentially measure inputs to the irrigated agriculture system and outputs from it. The next three indicators relate to irrigation system which provides input to the irrigated agriculture system. These are essentially system measures rather than performance indicators which characterize the irrigation system water distribution. The last two are financial performance indicators which covers the whole irrigation system.

The main purpose of choosing this minimum set of comparative indicators is to help system managers, designers, planners and policy makers to compare performance within system (both spatially and temporally) and across systems designed and operated under diverse principles, with alternative:

- ways of allocating water (rationing water, giving water on demand, water markets);
- organizational approaches (farmer management, agency management, joint management);
- infrastructural approaches (proportional delivery system, variable flows, rotation supply, conjunctive use of surface and groundwater).

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Irrigation systems are nested systems (Small and Svendsen 1994). Any interventions introduced in one sub-system has an impact on other sub-systems too. For example, physical intervention such as lining of canal introduced in an irrigation system may improve the water delivery performance. One may measure the improved water delivery performance against the target set and ascertain the level of achievement against that target; however, better control of water delivery introduced by lining may induce farmers to change crops cropping pattern and cropping intensity. This action by farmers, in turn, may affect the agricultural economic system through price changes and market forces. Similarly, any policy level changes introduced at the national level such as import restriction of certain commodities may alter the cropping pattern in an irrigation system which in turn may necessitate changes in the water distribution practices. In other words, in the nested system, any physical or managerial interventions introduced at one level may affect and permeat through all other levels and therefore impact of these interventions can be better measured through output indicators suggested under IIMI's minimum set of comparative indicators than by process indicators which are related to targets set at particular level of system operation.

Many times, the impact due to an interventions cannot be isolated and measured at a sub-system level. For example, in the case of Mahi kadana project a decision was made by the managing agency that starting kharif 1993 season, rotational water supply at distributary level will be introduced and the distributaries when it is operated will run at full supply level only. Simultaneously, a target for the total irrigated area to be achieved for each season was also set. In order to achieve these objectives, rotational turns have been worked out in detail upto the distributary/minor level and wide publicity was given through farmer-agency meetings and through various media (news papers, radio, TV etc.) about the rotational water distribution. Also, a management information system was introduced for keeping track of water delivery and for collecting water charges. Lower level field functionaries were given intensive training at WALMI for operating the system under rotational water distribution. Strict enforcement of schedules and close monitoring of the implementation schedule were also put in place. Detailed planning and implementation of those planned decisions was carried out. All these interventions, complementary to each other, have helped in improving the system performance. Noting the efforts put forth by the agency in implementing the rotational schedule, farmers have also responded to rotational water supply to use the water economically at the stipulated time.

The activities described above and the process of implementation are all intertwined and intricately related; it would be difficult to measure the impact of individual interventions. For managerial interventions of the types described above IIMI's minimum set of comparative performance indicators is ideally suited to measure the performance output due to combined effect of all these interventions and compare them with those before interventions.

The main objective of this paper is two fold:

i. to describe the methodology adopted on computing IIMI's minimum set of comparative indicators and to demonstrate its utility in assessing management interventions impact. and

ii. to demonstrate that rotational water supply backed up with adequate planning and monitoring efforts can improve irrigation system performance to a significant level when used on schemes with no well defined scheduling.

The Mahi-Right Bank Canal (MRBC) command of Mahi-Kadana irrigation project was taken up as a case study. The rotational water supply (RWS) at distributary level was introduced starting Kharif 1993 season. Two years, one before the introduction of RWS (1991/92) and another after introduction of RWS (1995-96), having comparable water resources availability were taken up for applying the minimum set of indicators.

## Mahi-Kadana Irrigation Project

The Mahi-Kadana irrigation project is one of the major irrigation projects in the state of Gujarat in India. The headworks of the system comprising the Wanakbori weir was constructed in 1950 across the river Mahi at Wanakbori village in Kaira district, Gujarat (Figure 1). It facilitated the diversion of the river flow to the canal system with negligible storage upstream of the river. At the second stage in 1978, a major reservoir known as the Kadana reservoir (capacity 1200 mm3) was constructed 70 km upstream of the Wanakbori weir. The primary objective of constructing this reservoir was to augment the supply of water to the Mahi Right Bank Canal (MRBC) command area by creating an irrigation potential of 263,000 ha (CCA=212,000 ha). The Kadana reservoir gets filled three out of 4 years by the end of every monsoon season, thus providing assured water supply to the MRBC command area.

The main irrigation seasons are kharif (15 June to 15 November), rabi (15 October to 15 March), and hot weather (15 February to 15 June). Paddy is the predominant crop grown using irrigation water and the other crops grown with significant area are cotton, tobacco, wheat, bajri and two seasonal crops such as sugarcane, banana and lucerne.
The average annual rainfall over the command is 823 mm with substantial variation in the annual rainfall from year to year (coefficient of variation = 366 mm). The mean daily maximum and minimum temperatures are respectively 41 °C and 11 ° C. The soils of the command are deep and alluvially deposited. The electrical conductivity (EC) of the soils ranges between 0.01 mmhos/cm to 5.2 mmhos/cm and the Ph between 8 and 9.8. The soils near the coastal zone characterized by more salt contents, high Ph and impervious subsoil's drainage are suitable for irrigating only one seasonal crop (Kharif).

The groundwater was the major source of irrigation in the MRBC command area prior to the introduction of canal irrigation. Even 15 years after the introduction of canal irrigation, groundwater continues to be major irrigation source. One hundred and seventy five thousand ha of MRBC is irrigated with groundwater resources annually. For less water consuming crops like tobacco, farmers prefer to rely on groundwater resources, while in the case of perennial crops (Banana), groundwater plays a supplementary role when the canals are off. After the introduction of fixed tariff policy in 1988, in which well owner is charged based on the horse power capacity of electric motor irrespective of actual consumption, groundwater use is increasing and it has become competitor for canal irrigation in tail reach areas. In MRBC command area , a good groundwater market exists and there are further development potentials.

The water distribution system consists of a main canal (73.6 km length) with six branch canals, 39 distributaries and minors and sub-minors having a total length of more than 2700 km. The main and branch canals are lined while the remaining distribution system is unlined. With number of cross regulators and escapes to control flow, the system is articulated.

The distribution system is basically a demand based supply system (Shejpali system) in which each irrigator has to apply to the irrigation agency before the start of the season stating the crop and area to be irrigated. Any irrigation availed from canal system without prior and timely sanction is dealt with as unauthorized irrigation and for which defaulter irrigator has to pay penal rates. Under the present project operating system, irrigation targets are decided in the beginning of each season. The irrigation target is usually decided based on the past performance of the project. The methodology adopted does not take into account variables like soil type, cropping pattern, crop growth stages and agro-climatic conditions in deciding the target setting of flow. Many times the canal operating days decided do not match with critical growth stages. The canal operating days are prolonged frequently and canals are operated almost continuously.

The MRBC command is managed by a superintending engineer, assisted by 3 executive engineers, 13 deputy executive engineers and 65 section officers. The field staff below the section officers are work assistants (Karkoons) and ditch-tenders (Chowkidars). There is a separate set of officials under each executive engineer to collect taxes.

## Rotational Water Supply at Distributary Canal Level

The MRBC project at the planning stage envisaged approximately 56,000 ha of fine and coarse paddy during the Kharif season. However, with the advent of adequate irrigation supply, kharif season paddy cultivation has increased to more than 100,000 ha, thereby requiring a very high peak demand in the months of September and October. The main canal of MRBC is designed for a discharge capacity of 200 $m^3/s$. This is not adequate to meet the peak demand of increased paddy cultivation of 100,000 ha. Inadequacy to draw maximum discharge at the peak period resulted in articulation through cross regulators leading to: increased human intervention and interference; inadequate and unreliable supplies; high wastage and seepage losses and low velocity in canals leading to siltation.

Also, in rabi and summer seasons, the project area was divided into two zones and was operated on an on/off basis with distributary canals running at less than full supply discharge. This zoned operation also necessitated articulation in system operation through cross-regulators. All the above factors have adversely affected the performance of the system.

To overcome these difficulties, it was decided starting kharif 1993 that all branch canals, distributaries, minors and sub-minors will be operated at full supply discharges and levels on a rotational basis. For this purpose, the rotational plan of all canals were prepared, and it was worked out that out of fifteen days of rotation, each canal will be closed for three days and for the remaining period it will be operated at full supply level and discharge only. The rotation plans were communicated for all including the lowest field functionaries and farmers.

For the rabi and summer season, it was decided to operate the whole project simultaneously on an on/off basis, instead of zoning. The canal operation schedules were decided much in advance of each season taking care to see that the proposed turns match water supply with critical growth stages of major crops and schedules were communicated to the field functionaries and farmers. For kharif 1993 it was decided that the canals will be operated from 20 June 1993. As per the schedule, the canals of MRBC project were thrown open on 20th June 1993. A wide publicity of the commencement of irrigation was given through TV and radio, in addition to normal procedures. This wide publicity and scheduled commencement on the indicated date enhanced farmers' confidence in the system management. Once the rotational plans were finalized and communicated, the canals were operated strictly according to the schedule.

For kharif 1993, a target of 110,000 ha was earmarked for irrigation by the management agency. From the proposed irrigated target area of 110,000 ha irrigation area targets were worked out for each system/sub-system and responsibility at different levels of hierarchy was fixed to achieve the target. While setting the target for each system/sub-system, the best previously achieved performance of irrigated area of each system was worked out. Then a number of meetings at different locations of the command was held with all field functionaries upto the level of chokidars, where each individual was encouraged to attain, at least the best of his performance achieved so far, and to exceed it by 5 to 10%. Thereafter, periodical review of progress achieved was monitored at all levels.

During rabi and summer, water was released from Kadana reservoir 48 hours in advance of stipulated start date and within 48 hours water could reach the tail of the system. The two seasons had in all ten rotations and in all the ten rotations, water was released on the scheduled date without any delay.

## Data Used and Data Collection Methodology

Most of the data used in this analysis are secondary data which are routinely collected by the agencies involved in managing the system except farmers survey data which was collected by commissioning a special study.

The following secondary data were collected:

- Daily indent of water from main canal
- Daily releases of water from main canal
- Actual area irrigated during season and related data
- Planned rotations
- Revenue recovery from irrigation
- Revenue recovery from other uses
- Targets and achievements
- Rainfall data
- Budget requirement and allotment, actual expenditure on O&M, works and establishment.
- Crop area estimation data from Irrigation Department

Reference evapotranspiration (Eto) for different months were calculated for Baroda IMD station using Penman Montieth method by FAO - CROPWAT program. The crop coefficient (Kc) for different crops were calculated as per the procedure outlined in FAO publication no 24. Growth period of different crops were taken as per crop variety in the Mahi command area. Sowing and harvesting period were used as per Gujarat Agricultural University recommendations. Seasonal crop water requirements on a fortnightly basis were calculated for the kharif, rabi and hot weather seasons.

Effective rainfall was taken as 60 percent of total rainfall for Baroda district which has clay - loamy soil while it was assumed to be 70 percent for Kheda district which has loamy soil. For ponded paddy, seepage and percolation losses were taken as 3mm/day. To compute gross irrigation requirement, water course losses were taken as 30 percent, physical system losses 20 percent and operational losses 10 percent of release at head regulator.

Crop yields estimated from three sources: Agriculture Department of the State of Gujarat; Irrigation Department; and farmers' survey data - were used in the analysis. Farm harvest prices were collected from two different sources: the Department of Agriculture and the farmers' survey data.

Most of the groundwater data used in this analysis were obtained from a report prepared by the Central Groundwater Board based on their recently completed comprehensive study of groundwater development in Mahi-Kadana project (CGWB 1996).

## Design of Farmers' Survey Data Collection

The MRBC distributaries were divided into three reaches forming head, middle and tail commands. From each command, two distributaries were selected using random numbers. From each selected distributary, six villages were selected using random sampling method. Initially, a field trip was made to selected distributaries and from the Red Book maintained by the Irrigation Department, the sample villages were identified. In each village, six farmers were selected by random sampling. The primary data was collected from selected farmers using a questionnaire and interviewing the farmers through trained investigators.

## Analysis of Results

### Overview

Two representative years 1995/96 and 1991/92, one before the introduction of interventions (1991/92) and one after the introduction of intervention (1995/96) based on climatic and water resource availability, were selected for the analysis.

Evaluation of agricultural production, the main out put of irrigation, poses certain problems when it is required that the evaluation has to permit comparison of performance across systems and in different time periods within a system in a common unit. In order to preserve the relative importance of crops within an economy, and at the same time allow conversion to a common international unit, output of every crop is expressed as equivalent output of a base crop, which should be a major internationally traded crop of the scheme, by using the ratio between the local prices of the two commodities. Wherever possible, it is preferable that wheat is chosen as the base crop, as it is the largest traded crop. The total equivalent output is converted to US $ of a reference year by using the average international price of the base crop in that year.

Wheat has been chosen in this study as the base crop for performance assessment. Wheat is the major crop in rabi, the winter dry season, but yield of wheat is only a fraction of the yields that are obtained in colder climates in India. Rice is grown over a larger area in both kharif and rabi seasons. However, wheat is chosen as the base crop as it is to be preferred for the reasons cited previously.

For 1995/96, data was available from a number of sources. Some of the data items overlap, thereby permitting comparison of alternative sources. Of most importance for this study is the data relating to crop area, crop production and prices of farm produce obtained from the Irrigation Department (ID), the State Department of Agriculture (AD) and a farmer survey (FS) conducted specially for this study. A number of permutations are possible, taking data of different types from different sources. Of these, four were chosen for further analysis as they carry more meaning.

| Set | Crop Area | Crop Yield | Price of Produce |
|---|---|---|---|
| 1 | ID | AD | AD |
| 2 | ID | ID | AD |
| 3 | FS | FS | FS |
| 4 | FS | AD | AD |

Note : ID crop cuts encompassed only 5 main crops in the cropping pattern: for the remaining crop, the AD crop cut estimates were used. For crops with low intensity in the farmer survey data, yield from the AD crop cuts and AD prices were used as the sample sizes in the FS data were very small.

For 1991/92 only one set of data was available - irrigated crop area from ID, and yields and prices from AD, corresponding to set 1 in 1995/1996.

**Irrigated Crop Area**

Area of crops irrigated in the three seasons - summer 1995, kharif 1995 and rabi 1995-96, as registered by the ID, and as estimated from the farmer survey, are shown in Table 1. From ID records of area irrigated, the irrigated crop intensity works out to a less than 100%. The average crop intensity in the FS sample was about one third higher. Discussions with ID officers suggested that one major reason for this large difference could be the encroachment of cultivable command area (CCA) by urbanization; there has been no demarcation, which could show how much of the original command has been lost. It appeared that some tail reach areas bordering the command boundaries should also be omitted as water had never reached there, and these areas might not have received due representation in the FS. On the other hand, the area actually irrigated is likely to be higher than that sanctioned by the ID. It was judged that adjusting the CCA downward by 15% for applying the crop intensity obtained form the FS would give an irrigated crop area which could be considered an upper bound, while the ID recorded area would be a lower bound. The effective CCA after this adjustment is 0.181 million ha. Table 1 shows the estimate of crop area obtained by applying the FS intensity over the adjusted CCA.

In the ID recorded area, millet does not occur in Kharif. Most farmers would plan to raise millet on rainfall and so would not have requested sanctioning. But in the course of the season the crop might have been irrigated in some areas, and all such areas might not have been recorded. A small area recorded would also have been merged with other crops. In the case of tobacco, the ID compilation does not distinguish between tobacco sown in kharif (July - August) and that sown in rabi (October - November), while this distinction is available in farmer survey.

## Yield of Major Crops

Crop cutting exercises for estimating production of major crops are conducted by the AD under a state-wide program, and by the ID for monitoring performance in the scheme. The procedures used for selecting the sample plots are somewhat different. The minimum sample size for the AD exercise is dictated by a national program arrived at obtaining reliable estimates of production at district and state levels. Yields from irrigated and unirrigated areas are separately estimated, but these are considered applicable only at district level. For this study a compilation was made of yields from irrigated fields in the 10 talukas covered by command and the results averaged. Some 15 to 30 crop cuts each were available for the major crops - rice (kharif), rice (summer), tobacco, wheat, millet (kharif), millet (summer), and groundnut (summer). The compilation included fields irrigated from any one or more sources, not just those irrigated from Mahi waters in the scheme. District averages were used for certain other crops, and state averages for others that occurred in the cropping pattern.

The ID exercise allocated 72 samples for each of rice (kharif), millet (summer), wheat and groundnut. The samples were from the scheme command, and had all received surface supplies from the Mahi.

Table 2 presents yields obtained from the three sources for the various crops in the scheme for the seasons covered by the study. The most noticeable variance is in the yield of wheat, with the farmer survey giving a yield which is only 44% of the estimate from the AD crop cutting exercise and 34% of the ID estimate. Limited inquiries have not brought out any plausible reason for this large difference. A contrasting situation occurs in respect of yield from tobacco. Yield from the farmer survey is 70% higher than the AD estimate. Tobacco is harvested in more than one cut; it is learned that official yield estimates from cotton and tobacco are often lower than the actuals for this reason. But the large difference indicates need for further inquiry. In the case of summer millet, again the farmer survey estimate is very low compared to the AD and ID estimates; it is possible that groundwater irrigated tobacco crop (which farmers normally use) gives much higher yield than that irrigated from surface water. The small number of surface irrigation reported in the farmer survey supports this hypothesis.

It must be mentioned that farmer survey data is internally quite consistent. The standard errors of estimate of yield of wheat, tobacco (rabi), tobacco (kharif) and summer millet are 2%, 2.5%, 3.9% and 6% of the respective means.

## Prices of major crops

Table 2 also gives farm harvest prices of crops, as recorded by the AD, and as reported by the farmers during the survey. The most important discrepancy is in the price of groundnut, with the AD price being 3 times that reported by the farmers. The prices reported by the farmers are remarkably uniform, with very small variance. Because groundnut is of relatively low importance in the scheme, no special effort has been made to find the reason for this discrepancy. One plausible explanation is that farmers sold undried groundnut from the field directly to buyers who came to buy in the fields. In that case the yield that could have been taken to the market would have been lower than that reported by the farmers.

## Modeling Water Balance

The water balance model proposed by Perry (1996) is easy to apply where there is not much cultivation other than irrigated agriculture by the scheme. In the Mahi-Kadana Scheme, there is considerable area irrigated using only groundwater which influences the water balance calculations. First of all, groundwater use in certain fraction of the command area reduces the "loss" which enters into the calculation of return to consumed water. In addition, it does not seem appropriate to load drainage and other losses of this area on the output of the surface scheme. On the other hand, there is information on the water balance of the whole geographical area from a recent study (CGWB 1995) which could be used to cross check some of the components of the water balance if effects in the complementary groundwater irrigated area could be modeled. From these considerations, it was decided to work out balances for two notional areas, one consisting essentially of the surface irrigated area, and the other the rest of the geographical area, in which irrigation under groundwater alone is practiced. For the second area, the groundwater input is the `canal inflow' with no conveyance losses down to farm inlet.

From data obtained from the Department of Agriculture, and the CGWB study mentioned above, it was estimated that annual irrigation intensity in the command area was about 120%. This was used to estimate the groundwater irrigated area. Estimates of pumpage, surface runoff and outflow at boundaries quoted in the CGWB report were used to fix various parameters for the models for the two areas. Finally, the total `losses' due to net inflow to groundwater and outflow from the area were divided between the two areas in proportion to the external water input, viz. rainfall plus surface water supplied. A typical output of water balance study for 1995/96 is shown in Table 3. The different components of water balance studies are depicted in Figure 2.

Experience with the above methodology suggests that the simple water balance model can be adapted to more complex environments with good prospect for yielding reasonable estimates of the various components of the water balance for the whole system.

## IIMI's minimum set of Indicators

Standardized gross value of output (SGVO) was calculated with the four sets of data for 1995/96 and with the one set of data for 1991/92, with international price of wheat in 1995 taken as US$ 165. It is seen that for 1995/96, the SGVO is nearly the same for the four data sets, the difference between the highest and lowest being less than 5% of the mean. External performance indicators computed, preceded by important data used for these computations, are shown in Table 4.

The first two indicators give return to land. Cropped area is computed by counting area assigned to every crop once, irrespective of whether it is single-seasonal, two-seasonal or perennial. In 1995/96, cropped area is less than the nominal command for the cropping pattern recorded by the ID, whereas it is greater in the case of the estimate from the farmer survey. Correspondingly, return to cropped area is higher than that to command area in the former case, less in the latter. It is noted that with the FS return to cropped area is less than that the ID area estimate; return to command area is nearly the same in the two cases. Annual irrigation intensity is computed counting two-seasonal crops twice and perennial crops thrice. The performance indicator figures show a striking improvement of performance, all round, in 1995/96 compared to 1991/92. Cropped area and irrigation intensity both are higher by more than 20%. Gross value of output is higher by 70%. It is worth mentioning that such a ready comparison of performance, which has automatically adjusted for price level differences between the years, has not been available before.

For 1995/96, return to irrigation supply is nearly the same for the four data sets, and also return to water consumed. The total water consumed include crop consumptive use, non-beneficial ET, loss to deep groundwater and loss to non-recoverable drainage. If, instead, only crop consumptive use is used, then return to water consumed would nearly double to the values presented in Table 4.

Relative water supply and relative irrigation supply are somewhat lower for the data sets with the FS area estimate, than for the sets with ID estimate. Irrespective of these differences, both RWS and RIS values are high indicating that they use much higher quantum of water than what is needed. A value of 3.90 for RWS and nearly 3.0 for RIS during 1991/92 are high values indicating poor management of discharges and consequent wastage, probably most of it through operational losses, which would have resulted in high drainage outflow from the system.

Water delivery capacity, which is defined as the ratio of the discharge capacity at the head of the scheme to the peak consumptive requirement, is about 2.5. In other words, an overall water conveyance efficiency of 40% will have to be obtained between the head of the canal system and effective addition to soil moisture in the root zone if peak consumptive requirement is to be met. It may be noted that at that time all the channels in the system will be operating close to the capacity.

The system performance in 1995/96 compared to 1991/92 has been uniformly good. The results are very revealing indicating how the system performance has improved to a very great extent after the introduction of rotational water supply at distributary level and other management interventions. Some of the salient results of improvement in 1995/96 over 1991/92 (based on data set 1 in 1995/96) are :

- Cropped area has increased by 12 percent
- Irrigation intensity has increased by 23 percent
- Total water supply decreased by 14 percent while net irrigation requirement increased by 21 percent
- Gross value of output has increased by 73 percent
- Gross value of output/unit irrigation supply has increased by 66 percent
- Relative irrigation supply has decreased by 30 percent
- Gross return on investment has increased from 30 percent to 52 percent.

The above analysis demonstrate that IIMI's minimum set of comparative performance indicators can be effectively used to assess management interventions impact.

**Conclusions**

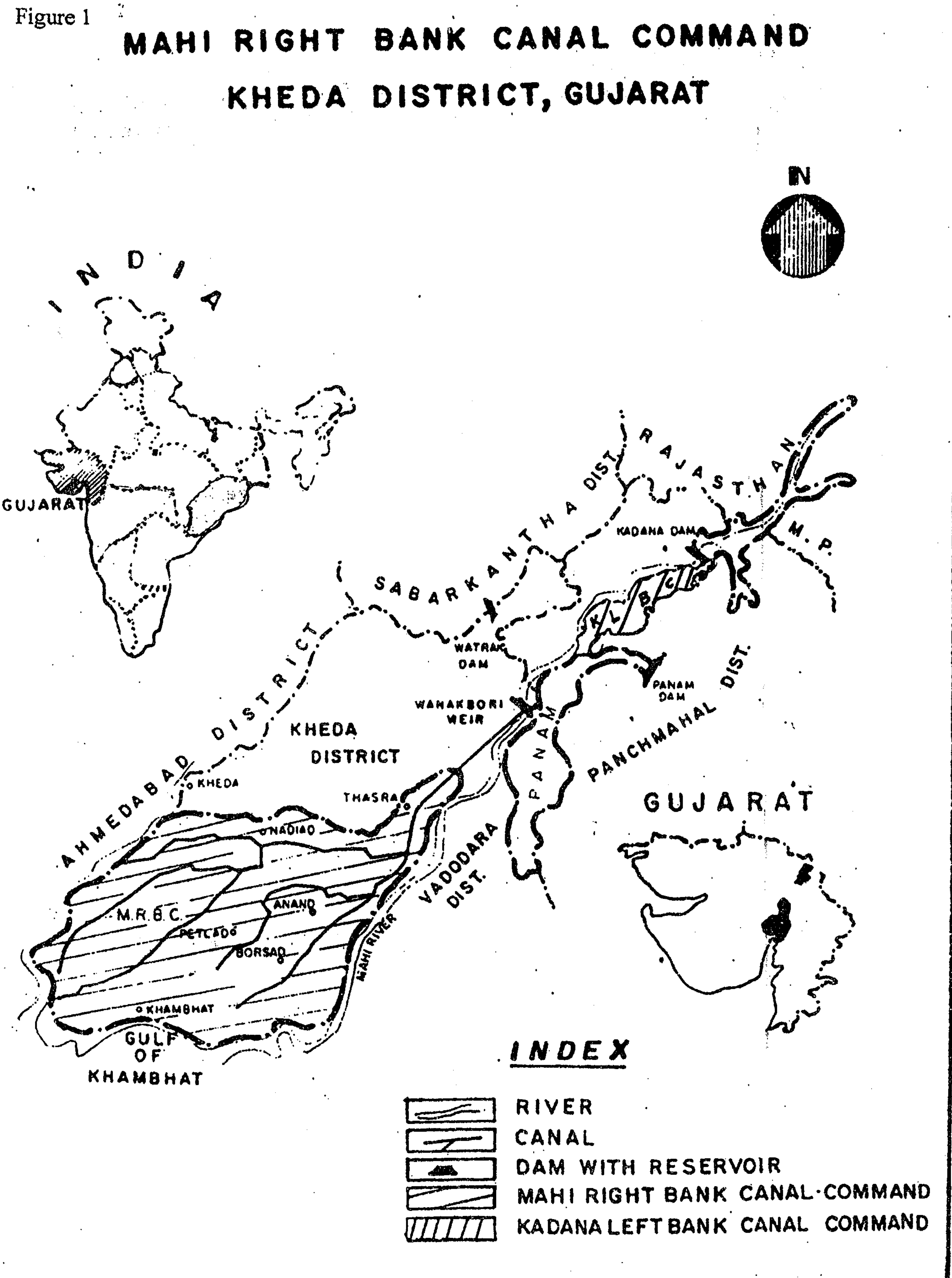
It is concluded that :

1. The four data sets used for the analysis show that the computed performance indicators do not vary by more than 10 percent from their mean values except for the output/unit cropped area indicator which is roughly 20 percent. All data sets give usable results. For monitoring and evaluation purposes, any one of these data sets can be used consistently.
2. The IIMI's minimum set of comparative performance indicators can be used with routinely collected data by the managing agencies for assessing management interventions impact.
3. Introduction of rotational water supply at distributary levels coupled with increased management efforts in terms of planning, implementing and monitoring can dramatically improve irrigation system performance, especially in Mahi-Kadna system where proper irrigation scheduling is not effectively implemented prior to interventions.

**References:**


1. CGWB (Central Groundwater Board) 1995. Groundwater investigations in Mahi-Right Bank Canal Command, Final Report, New Delhi, India.
2. Perry, C.J. 1996. A note on "Quantification and measurement of a minimum set of indicators of the Performance of Irrigation Systems". International Irrigation Management Institute (IIMI) January 1996.

Figure 1


MAHI RIGHT BANK CANAL COMMAND
KHEDA DISTRICT, GUJARAT
N
INDIA
GUJARAT
RAJASTHAN
SABARKANTHA DIST.
KADANA DAM
M.P.
K.L.B.C.
WATRAK DAM
PANAM DAM
WANAKBORI WEIR
KHEDA DISTRICT
PANCHMAHAL DIST.
AHMEDABAD DISTRICT
KHEDA
THASRA
PANAM
GUJARAT
NADIAD
VADODARA DIST.
M.R.B.C.
ANAND
PETLAD
BORSAD
MAHI RIVER
KHAMBHAT
GULF OF KHAMBHAT
INDEX
RIVER
CANAL
DAM WITH RESERVOIR
MAHI RIGHT BANK CANAL COMMAND
KADANA LEFT BANK CANAL COMMAND

3. Molden, D.J., R Sakthivadivel, Christopher J. Perry and Chalotte de Fraiture. A minimum set of indicators for corporative performance assessment, Research Report (forthcoming), International Irrigation Management Institute (IIMI), Sri Lanka

## Figure 2 - Water Balance Components of Mahi-kadana Project

(Units $10^6 m^3$)

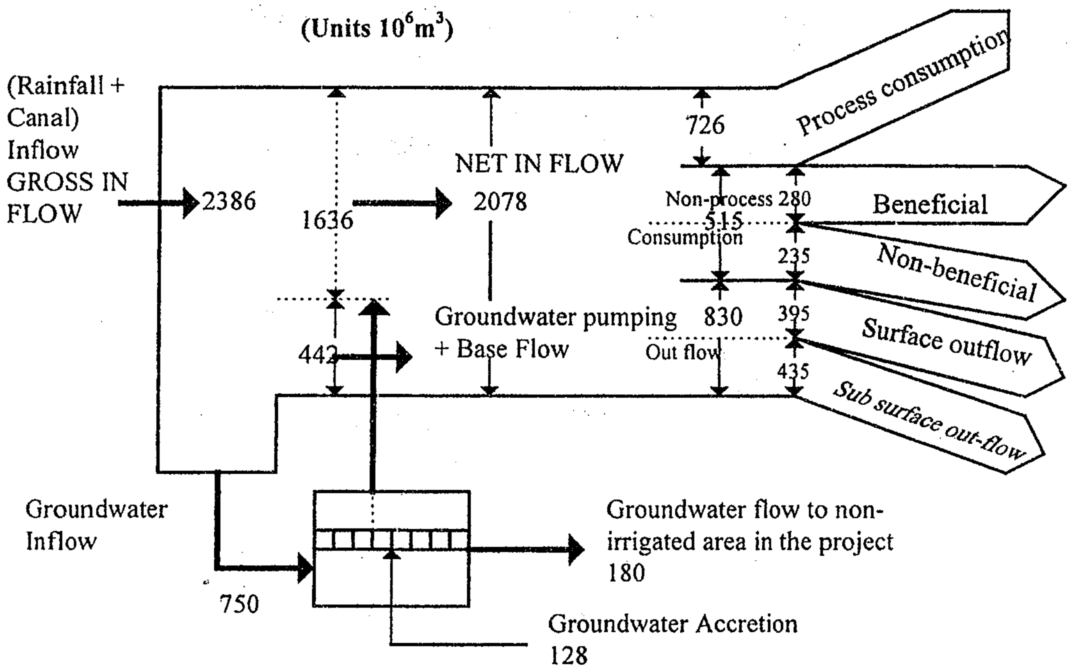


TABLE 1 SEASONAL IRRIGATION IN 1995/96 - AREA AND INTENSITY

| | Irrigation Dept Record Area ha | Irrigation Dept Record Intensity % | Farmer Survey Estimate Area ha | Farmer Survey Estimate Intensity % |
|---|---|---|---|---|
| KHARIF | | | | |
| Rice | 86936 | 40.87 | 93360 | 43.89 |
| Millet | | | 3797 | 1.79 |
| Other | | | 2658 | 1.25 |
| Two Seasonal | | | | |
| Cotton | 5293 | 2.49 | | |
| Castor | 1119 | 0.53 | | |
| Tobacco (kh-rb) | 13801 | 6.49 | 21514 | 10.12 |
| RABI | | | | |
| Wheat | 24981 | 11.75 | 34947 | 16.43 |
| Mustard | 14200 | 6.68 | 1284 | 0.60 |
| Other | 3632 | 1.71 | 3797 | 1.79 |
| Two Seasonal | | | | |
| Cotton | 5293 | 2.49 | | |
| Castor | 1119 | 0.53 | | |
| Tobacco (kh-rb) | 13801 | 6.49 | 21514 | 10.12 |
| Tobacco (rb-su) | | | 21641 | 10.17 |
| SUMMER | | | | |
| Millet | 26253 | 12.34 | 27914 | 13.12 |
| Rice | 11089 | 5.21 | 15367 | 7.23 |
| Groundnut | 7514 | 3.53 | 6545 | 3.08 |
| Other | 257 | 0.12 | | |
| Two Seasonal | | | | |
| Tobacco (rb-su) | | | 21641 | 10.17 |
| PERENNIAL | | | | |
| Banana | 7688 | 3.61 | 3706 | 1.74 |
| Sugarcane | 4509 | 2.12 | 1266 | 0.60 |
| Irrigation - kharif | 119390 | 56.11 | 126300 | 59.38 |
| Irrigation - rabi | 75244 | 35.37 | 88153 | 41.45 |
| Irrigation - summer | 57318 | 26.94 | 76438 | 35.94 |
| Annual Irrigation | 251953 | 118.42 | 290891 | 136.77 |

Note: Intensity based on official CCA of 212694 ha

TABLE 2

## HARVEST PRICES AND YIELDS IN 1995/96

| Crop | Farm Harvest Price | | Yield | | |
|---|---|---|---|---|---|
| | Agriculture Department Rs./tonne | Farmer Survey Rs./tonne | Agriculture Department tonne/ha | Irrigation Department tonne/ha | Farmer Survey tonne/ha |
| Rice (K) | 5644 | 5120 | 4.47 | 4.89 | 5.27 |
| Rice (S) | 5644 | 5460 | 6.20 | 4.19 | 4.91 |
| Millet (K) | 4508 | 4600 | 1.13 | | 1.21 |
| Millet (S) | 4508 | 5520 | 2.12 | 2.79 | 0.71 |
| Maize | 4639 | | 1.28 | | |
| Groundnut | 11659 | 4000 | 1.90 | 2.00 | 1.87 |
| Castor | 7822 | | 1.67 | | |
| Tobacco (K) | 14730 | 14440 | 2.04 | | 3.50 |
| Tobacco (R) | 14730 | 13420 | 2.04 | | 3.46 |
| Pulse | 14753 | | 1.26 | | |
| Wheat | 4230 | 4790 | 2.21 | 2.85 | 0.97 |
| Gram | 10633 | | 1.00 | | |
| Mustard | 10996 | | 1.37 | | |
| Potato | 4435 | | 21.07 | | |
| Cotton | 19250 | | 1.77 | | |
| Sugarcane | 700 | | 90.00 | | |
| Banana | 1000 | | 63.54 | | |

# TABLE 3 WATER BALANCE STUDY OUTPUT

| | Unit | <---- Surface Irrigated Area ----> kharif | rabi | summer | Year | <---- G'water Irrigated Area ----> kharif | rabi | summer | Year | <----- Whole Geographical Area -----> kharif | rabi | summer | Year |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Geographical Area | ha | 212694 | 212694 | 212694 | 212694 | 138985 | 138985 | 138985 | 138985 | 351679 | 351679 | 351679 | 351679 |
| Irrigation Intensity | % | 56.11 | 35.37 | 26.94 | 118.42 | 56.12 | 39.57 | 19.43 | 115.12 | | | | |
| Irrigated Crop Area | ha | 119346 | 75223 | 57310 | 251879 | 78000 | 55000 | 27000 | 160000 | 197346 | 130223 | 84310 | 411879 |
| SOURCES | | | | | | | | | | | | | |
| Canal Inflow | '000 m3 | 1102340 | 606610 | 838040 | 2546990 | 0 | 0 | 0 | 0 | 1102340 | 606610 | 838040 | 2546990 |
| Rainfall | '000 m3 | 1276717 | 0 | 0 | 1276717 | 834271 | 0 | 0 | 834271 | 2110988 | 0 | 0 | 2110988 |
| Groundwater | '000 m3 | 7500 | 149780 | 77497 | 234777 | 120898 | 309405 | 192625 | 622928 | 128398 | 459185 | 270122 | 857705 |
| | | 4 | 70 | 36 | 110 | 87 | 223 | 139 | 448 | 37 | 131 | 77 | 244 |
| Drains | '000 m3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Total Water Delivered | '000 m3 | 2386557 | 756390 | 915537 | 4058484 | 955170 | 309405 | 192625 | 1457200 | 3341727 | 1065795 | 1108162 | 5515684 |
| SINKS | | | | | | | | | | | | | |
| Irrgtd Crop Cons Use | '000 m3 | 726100 | 392589 | 364531 | 1483219 | 409095 | 220365 | 146178 | 775637 | 1135194 | 612953 | 510709 | 2258857 |
| | mm | 608 | 522 | 636 | | 524 | 401 | 541 | | | | | |
| Other Consumptive Use | '000 m3 | 280165 | 0 | 0 | 280165 | 183034 | 0 | 0 | 183034 | 463200 | 0 | 0 | 463200 |
| Non-Beneficial ET | '000 m3 | 235380 | 97025 | 162201 | 494606 | 116547 | 29703 | 15619 | 161869 | 351927 | 126728 | 177820 | 656476 |
| | mm | 111 | 46 | 76 | 233 | 84 | 21 | 11 | 116 | 100 | 36 | 51 | 187 |
| To Drain | '000 m3 | 394895 | 36345 | 78817 | 510057 | 64505 | 13305 | 6660 | 84469 | 459400 | 49650 | 85477 | 594526 |
| To Groundwater | '000 m3 | 750017 | 230431 | 309988 | 1290436 | 181988 | 46033 | 24169 | 252190 | 932006 | 276463 | 334157 | 1542625 |
| BALANCE | '000 m3 | 0 | -1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Net to Drains | '000 m3 | 394895 | 36345 | 78817 | 510057 | 64505 | 13305 | 6660 | 84469 | 459400 | 49650 | 85477 | 594526 |
| Net to Groundwater | '000 m3 | 742517 | 80651 | 232491 | 1055659 | 61090 | -263372 | -168457 | -370739 | 803607 | -182722 | 64034 | 684920 |
| Outflow fr G'water | '000 m3 | | | | | | | | | 490200 | 0 | 39061 | 529261 |
| Accretion to G'water | mm | | | | | | | | | 89 | -52 | 7 | 44 |
| Net Outflow from Area | '000 m3 | | | | | | | | | 949600 | 49650 | 124538 | 1123788 |
| External Water Input | '000 m3 | | | | 3823707 | | | | 834271 | | | | 4657978 |
| Share in Ext Wtr Input | | | | | 0.821 | | | | 0.179 | | | | 1.000 |
| Share in Drain Outflow | '000 m3 | | | | 488043 | | | | 106483 | | | | 594526 |
| Share in G'water Outflow | '000 m3 | | | | 434468 | | | | 94794 | | | | 529261 |
| Share in G'water Storage | '000 m3 | | | | 127779 | | | | 27879 | | | | 155659 |
| Gross Value of Output | US$ Mill | | | | 189.66 | | | | | | | | |
| Water Consumed | '000 m3 | | | | 3028116 | | | | | | | | |
| GVO/Unit Water Consumed | US$/m3 | | | | 0.063 | | | | | | | | |

TABLE 4 EXTERNAL PERFORMANCE INDICATORS - 1995/96 and 1991/92

| | | 1995/96 | | | | 1991/92 |
|---|---|---|---|---|---|---|
| | | Data Set 1 | Data Set 2 | Data Set 3 | Data Set 4 | |
| Command Area | ha | 212694 | 212694 | 212694 | 212694 | 212694 |
| Cropped Area | | | | | | |
| Single Seasonal: | | | | | | |
| kharif | ha | 86936 | 86936 | 99815 | 99815 | 80751 |
| rabi | ha | 42813 | 42813 | 40028 | 40028 | 38908 |
| summer | ha | 45113 | 45113 | 49826 | 49826 | 43110 |
| Two Seasonal: | | | | | | |
| kharif - rabi | ha | 20213 | 20213 | 21514 | 21514 | 15419 |
| rabi - summer | ha | 0 | 0 | 21641 | 21641 | 0 |
| Perennial | ha | 12197 | 12197 | 4972 | 4972 | 3018 |
| Total Cropped Area | ha | 207272 | 207272 | 237796 | 237796 | 181206 |
| Annual Irrigation Intensity | % | 118.42 | 118.42 | 136.77 | 136.77 | 95.28 |
| Surface Water Delivered | Mm3 | 2547 | 2547 | 2547 | 2547 | 2465 |
| Pumped from Groundwater | Mm3 | 235 | 235 | 307 | 307 | 180 |
| Pumped from Drainage | Mm3 | 0 | 0 | 0 | 0 | 0 |
| Total Irrigation Delivered | Mm3 | 2782 | 2782 | 2854 | 2854 | 2645 |
| Effective Rainfall | Mm3 | 1277 | 1277 | 1277 | 1277 | 1976 |
| Total Water Supply | Mm3 | 4058 | 4058 | 4130 | 4130 | 4621 |
| Crop Consumptive Use | Mm3 | 1483 | 1483 | 1577 | 1577 | 1186 |
| Non-Beneficial ET | Mm3 | 495 | 495 | 495 | 495 | 477 |
| Loss to Groundwater | Mm3 | 128 | 128 | 133 | 133 | 376 |
| Loss to Drainage | Mm3 | 923 | 923 | 898 | 898 | 1273 |
| Total Water Consumed | Mm3 | 3028 | 3028 | 3102 | 3102 | 3312 |
| Net Irrigation Requirement | Mm3 | 1127 | 1127 | 1265 | 1265 | 886 |
| Gross Value of Output | US$ Mill | 189.91 | 198.31 | 189.41 | 198.64 | 109.59 |
| Output / Unit Cropped Area | US$/ha | 916 | 957 | 797 | 835 | 605 |
| Output / Unit Command Area | US$/ha | 893 | 932 | 891 | 934 | 515 |
| Output / Unit Irrigation Supply | US$/m3 | 0.068 | 0.071 | 0.066 | 0.070 | 0.041 |
| Output / Unit Water Consumed | US$/m3 | 0.063 | 0.065 | 0.061 | 0.064 | 0.033 |
| Relative Water Supply | | 2.74 | 2.74 | 2.62 | 2.62 | 3.90 |
| Relative Irrigation Supply | | 2.47 | 2.47 | 2.26 | 2.26 | 2.98 |
| Water Delivery Capacity | | 2.56 | 2.56 | 2.39 | 2.39 | 2.91 |
| Gross Return on Investment | % | 52 | 54 | 52 | 54 | 30 |
| Financial Self-sufficiency | % | 53 | 53 | 53 | 53 | |