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Opportunities for Agricultural Water Management Interventions in the Krishna Western Delta - A case from Andhra Pradesh, India

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Abstract Agricultural water management has gained enormous attention in the developing world to alleviate poverty, reduce hunger and conserve ecosystems in small-scale production systems of resource-poor farmers. The story of food security in the 21st century in India is likely t o be closely linked to the story of water security. Today, the water resource is under severe threat.

The past experiences in India in general and in Andhra Pradesh in particular, indicated inappropriate management of irrigation has led to severe problems like excessive water depletion, reduction in water quality, water logging, salinization, marked reduction in the annual discharge of some of the rivers, lowering of ground water tables due to pumping at unsustainable rates, intrusion of salt water in some coastal areas etc.

Considering the importance of irrigation water resource efficiency, Krishna Western Delta (KWD) of Andhra Pradesh was purposively selected for this in depth study, as the farming community in this area are severely affected due to severe soil salinity and water logging problems and hence, adoption of different water saving crop production technologies deserve special mention. It is quite disappointing that, canals, tube wells and filter points and other wells could not contribute much to the irrigated area in KWD. Due to less contribution from these sources, the net area irrigated also showed declining growth at a rate of −6.15 per cent. Regarding paddy production, both SRI and semi-dry cultivation technologies involves less irrigation cost (Rs. 2475.21/ha and Rs. 3248.15/ha respectively) when compared to transplanted technology (Rs. 4321.58/ha).

The share of irrigation cost in Total Operational Cost (TOC) was highest for transplanted technology of paddy (11.06%) followed by semi-dry technology (10.85%) and SRI technology (6.21%). The increased yield and declined cost of cultivation of paddy in SRI and semi-dry production technologies respectively were mainly responsible for the low cost of production of paddy in SRI (Rs. 495.22/qtl) and semi-dry (Rs. 532.81/qtl) technologies over transplanted technology (Rs. 574.93/qtl).

This clearly indicates that, by less water usage, paddy returns can be boosted by adopting SRI and semi-dry production technologies. Both the system-level and field-level interventions should be addressed to solve the issues/problems of water management. The enabling environment, institutional roles and functions and management instruments are posing favourable picture for executing the water management interventions in the State of Andhra Pradesh in general and in KWD in particular. This facilitates the farming community to harvest good crop per unit of water resource used in the production programme. To achieve better results, the Farmers' Organizations, Water Users Associations, Department of Irrigation etc., will have to aim at improving productivity per unit of water drop used and this must be supported through system-wide enhancement of water delivery systems and decision support tools to assist farmers in optimizing the allocation of limited water among crops, selection of crops based on farming situations, and adoption of appropriate alternative crops in drought years.

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1 Introduction

The story of food security in the 21st century in India is likely to be closely linked to the story of water security. In the coming decades, the farmers will need to produce enough food to feed many millions more people in the country, yet there are virtually no untapped and cost-effective sources of water for them to draw on as they face this challenge. Moreover, the farmers will have to face heavy competition for this water from non-agricultural sector usage. Irrigation played a vital role to achieve the food security and sustainable livelihoods especially in developing countries like India during the Green Revolution period through increased income, improved health and nutrition locally and by bridging the gap between production and demand nationally.

But today, this essential resource is under severe threat. Growing national, regional and seasonal irrigation water scarcities in the country posed several challenges for the Government to combat this situation. The challenge of growing irrigation water scarcity was heightened by the increasing costs of developing new irrigation water sources, degradation of soil in irrigated areas, depletion of ground water, inappropriate management of irrigation water leading to salinity, degradation of water related ecosystems, wasteful use of already developed irrigation water supplies often encouraged by the subsidies and distorted incentives of irrigation water usage.

No doubt, in India, the success of irrigation in ensuring food security and improving rural welfare has been impressive, but past experiences also indicated that inappropriate management of irrigation has led to severe problems like excessive water depletion, reduction in water quality, water logging, salinization, marked reduction in the annual discharge of some of the rivers, lowering of ground water tables due to pumping at unsustainable rates, intrusion of salt water in some coastal areas etc. Many water quality problems have also been created which lead to with drawls of irrigation water from agriculture. Moreover, poor irrigation practices accompanied by inadequate drainage have often damaged soils through over saturation and salt build-up.

The same is the case in the state of Andhra Pradesh in general and in Krishna Western Delta (KWD) in particular, where acute water scarcity, water logging and soil salinity are the major problems affecting the quality agriculture. The farmers in KWD faced a peculiar situation during the past three to four years, where they could not cultivate second (rabi) crop because of the acute water scarcity conditions.

In lieu of this, different water management interventions needs to be given more emphasis for sustaining the agricultural production with less water or to ensure more crop per drop of water used. The present paper highlights the changing irrigation scenario in the KWD, declining economic efficiency of irrigation water resource and the important water management strategies to be planned in this region so as to sustain the farmers in the agri-business, besides studying the conceptual framework of Integrated Water Resource Management (IWRM) in relevance to KWD.

Methodology

KWD was purposively selected for this study, as acute water scarcity prevailed in this area for the past three to four years and the quality of agricultural production was severely affected due to severe soil salinity and water logging problems. It is felt appropriate by the researcher that, the farming community in KWD needs to adopt different water saving paddy production technologies so as to sustain them in agri-business.

All the mandals (31), which fall under the KWD area, representing the two districts viz., Guntur (24) and Prakasam (7) were selected for this study. Both primary and secondary sources forms the database. The information/data pertaining to the irrigated area and area irrigated under different sources of the KWD were collected from the Chief Planning Offices of Guntur and Prakasam districts. Besides secondary sources, a sample of 120 farmers cultivating paddy were interviewed for eliciting the requisite information on cost of cultivation, identification and prioritization of researchable issues on irrigation water management. The following are the analytical techniques used for drawing realistic conclusions from the collected data/information :

- Compound Growth Rates (CGRs) were worked by semi-log method to study the growth in irrigated area and area irrigated under different sources in KWD. The following model was used to study the CGRs:

$$Y_t = Y_0(1+r)^t \longrightarrow \text{Equation 1}$$

where, Y_0= Initial value of Y (irrigated area), Y_t = Y's value at time t, r = compound (that is, over time) rate of growth of Y.

Let us take the natural log of above Equation 1 on both sides to obtain

$$\ln Y_t = \ln(Y_0(1+r)^t) = \ln Y_0 + t \cdot \ln(1+r) \longrightarrow \text{Equation 2}$$

Now, letting: 'a_O' = $\ln Y_0$ and 'b_O' = $\ln(1+r)$
Therefore, we can express the above Equation 2 as:

$$\ln Y_t = a_O + b_O \cdot t \longrightarrow \text{Equation 3}$$

Then, after adding an error term for each time period to allow for random
influences, Equation 3 takes the form

$$\ln Y_t = a_O + b_O \cdot t + \mu_t \longrightarrow \text{Equation 4}$$

The above model is like any other regression model in that the parameters a_O and b_O are linear. The only difference is that the regressand is the logarithm of Y and the regressor is 'time', which will take values of 1, 2, 3 etc. This model is referred to as semi-log, for only one variable (in this case the regressand) appears in the logarithmic form. In such model, the slope coefficient measures constant proportional or relative change in Y for the absolute change in the value of regressor, i.e., the variable 't'.
That is, multiplying the relative change in Y by 100, gives the percentage change, or the growth rate in Y for an absolute change in 't', the regressor. That is, 100 times b_O, gives the growth rate in Y; also referred to as the semi-elasticity of Y with respect to 't'.
The coefficient of the trend variable b_O, in the growth Equation4---8.23.1, gives the instantaneous(at apoint in time) rate of growth and the CAGR(growth over a period of time) can be computed by taking the antilog of the estimated b_O, subtracting 1 from it and multiplying the difference by 100. That is:

CGR = (antilog of b_O−1)*100

- Pearson's Correlation analysis of the following model was analysed to study the degree of association between irrigation cost and gross returns of paddy:

$$r = \frac{\sum XY - \frac{\sum X \cdot \sum Y}{n}}{\sqrt{\left[\sum X^2 - \frac{(\sum X)^2}{n}\right]\left[\sum Y^2 - \frac{(\sum Y)^2}{n}\right]}}$$

where, r = correlation coefficient, X = variable 1, Y = variable 2, n = no. of observations

't' values were worked out to test the significance of correlation coefficients by using the following formula :

$$t = \frac{r\sqrt{n-2}}{\sqrt{1-r^2}}$$

- Linear Regression Analysis of the following model was used to study the influence of irrigation cost on gross returns of paddy :

$$Y = ab^x$$
$$\text{Log } Y = \log a + b \log X + U$$

where, Y = Gross returns of paddy, a = Intercept, b = Regression Coefficient, X = Irrigation cost incurred, U = error term

't' and 'F' values were worked out to test the significance of individual regression coefficients and overall regression respectively.

- Garrett's ranking test was employed to prioritize the researchable problems pertaining to irrigation scenario in KWD.

$$\text{Per cent position} = \frac{100 \times (R_{ij} - 0.5)}{N_j}$$

R_{ij} : Rank given to the ith factor by jth individual
N_j : Number of factors ranked by jth individual

Besides these tools of analysis, simple mathematical tools like ratios and percentages were also employed to drawn relevant conclusions.

Results and Discussion

- Growth in irrigated area

The growth in area under different irrigation sources often indicate the potentiality of different sources in meeting the irrigation requirements of crops in KWD and the same was analyzed through Table 1. It is quite disappointing to note from the Table 1 that, canals, which form the major irrigation source of the delta, showed declining growth rate (-5.14%) with reference to area irrigated by this source for the period, 1991-92 to 2015-16. Similarly, tube wells and filter points and other wells could not contribute much to the irrigated area in KWD, as evidenced by the declining growth in irrigated area from these sources to a tune of −5.81

and −4.81 per cents respectively.

With the advent of Daruvu technology, which is particularly suitable for the sandy soils, tanks contribute a significant positive growth in irrigated area by 6.27 per cent. Lift irrigation is also contributing a significant growth in irrigated area in the delta by 5.98 per cent. This implies that, with the growing water scarcity in study area either due to erratic rainfall or less water releases into the canals, both tanks and lift irrigation sources are contributing much towards irrigating the crops. This further signifies the importance of water harvesting in the study area.

Due to less contributions from the canals, tube wells, filter points and other wells, the net area irrigated also showed declining growth at a rate of −6.15 per cent. However, with the advent of Daruvu technology and realizing the importance of water harvesting techniques and increased contribution from lift irrigation sources, the area irrigated more than once showed positive growth rate of 0.91 per cent, but non-significant. As a result, it could not compensate the declining trend of net area irrigated and hence, the gross area irrigated also showed significant declining growth rate of −4.16 per cent. This clearly implies that, the major irrigation sources viz., canals, tube wells and filter points and other wells could not contribute much towards the growth in gross irrigated area in KWD.

Table 1 Growth in irrigated area in KWD under different irrigation sources(1991-92 to 2015-16)

S. No.	Source	Growth Rate (%)
1	Canals	-5.14*
2	Tanks	6.27*
3	Tube wells & Filter points	-5.81*
4	Other wells	-4.81NS
5	Lift Irrigation	5.98**
6	Gross Area Irrigated	-4.16*
7	Net Area Irrigated	-6.15*
8	Area irrigated more than once	0.91NS

Note : **- Significant at 1% level, * - Significant at 5% level, NS − Non-Significant

Raw Data Source : Chief Planning Offices - Guntur and Prakasam districts

- Growth in crop-wise irrigated area

Having studied the growth pattern of overall irrigated area and source-wise irrigated area, it is important to study the growth in irrigated area under major crops cultivated in KWD, as it highlights the crops that are gaining more significance under irrigated situations and the analytical findings were presented through Table 2. It is quite interesting to note from the Table 2 that, paddy, which is the major crop cultivated in KWD under irrigated conditions is showed negative growth rate (-0.57%) regarding the growth under irrigated area. This might be due to declined contribution from canal irrigation source in the study area (Table 1). Turmeric and groundnut also exhibited negative growth trends to a tune of -4.21 and -0.68 percents respectively. Cotton, chillies and sugar cane, though showed positive growth trends, but turned out to be non-significant. This analysis further confirms the declined contributions from major irrigation sources in KWD.

Table 2 Growth in crop-wise irrigated area in KWD (1991-92 to 2015-16)

S. No.	Crop	Growth Rate (%)
1	Paddy	-0.57 NS
2	Cotton	9.12 NS
3	Chillies	7.18 NS
4	Turmeric	-4.21 NS
5	Sugar cane	2.98 NS
6	Groundnut	-0.68 NS

Note : NS − Non-Significant

Raw Data Source : Chief Planning Offices - Guntur and Prakasam districts

- Degree of association between irrigation cost and gross returns of different paddy production technologies

To study the degree of association between the irrigation cost incurred and gross returns realized across different paddy production technologies, correlation analysis was done and the analytical findings were presented through Table 3. It is quite interesting to note from the Table 3 that, there exists strong positive correlation between the selected variables for semi-dry production technology (0.68), implying that, with increased application of irrigation water the paddy yields were increased, thereby, leading to higher returns.

However, in case of paddy, for transplanted technology, there exists low and non-significant correlation between the irrigation cost and gross returns, (0.41) indicating that, the excess use of water do not contribute to higher returns. For semi-dry paddy, the moderately strong positive correlation between the variables indicates that, with increased irrigation application, the crop will respond better. Of course, this positive relationship is only up to a certain level of irrigation water application, as its indiscriminate usage proved non-significant relationship with gross returns in case of transplanted paddy.

It is interesting to note that, in case of SRI production technology of paddy, there exists negative and significant correlation (-0.91) between the selected variables, indicating that, with reduced irrigation supply to the crop, the yields were increased, thereby leading to higher returns. In SRI technology, the field was maintained under saturated condition only (upto panicle initiation stage) and this enables the crop to develop profuse root system and good number of tillers (45-50 tillers/hill).

This directly contributes to higher yield and returns in SRI production technology of paddy. This signifies that, less water usage in paddy production can contribute to higher yields. The excess of irrigation water used in cultivating paddy under transplanted technology (ie., over and above the SRI production technology), can be properly exploited to cultivate the second crop or by regulating the flow to the tail end commands.

Table 3 Correlation analysis between irrigation cost and gross returns of selected crop enterprises

S. No.	Crop	Correlation coefficient
1	Paddy (SRI)	-0.91**
2	Paddy (Transplanted)	0.41NS
3	Paddy (semi-dry)	0.68*

Note: **-Significant at 1% level, *-Significant at 5% level and NS – Non-Significant

Raw Data Source : Personal interviews with the farmers

- Influence of irrigation cost on the gross returns of selected crop enterprises

Having studied the degree of association between the irrigation costs and gross returns, it is important analyze the impact of change in irrigation cost over gross returns across different paddy production technologies. It is interesting to note from the Table 4 that, this model is statistically significant for SRI and semi-dry production technologies (except for transplanted technology of paddy), as indicated by the significant values of Co-efficient of Multiple Determination (R^2).

Table 4 Influence of irrigation cost on the gross returns of selected crop enterprises

S. No.	Crop	Intercept	X_1(IC)	R^2
1	Paddy (Transplanted)	5.18	0.12NS	0.38NS
2	Paddy (semi-dry)	2.97	0.97*	0.72**
3	Paddy (SRI)	8.06	-1.97**	0.81**

Note: IC – Irrigation costs, **-Significant at 1% level, *-Significant at 5% level and NS – Non-Significant

Raw Data Source : Personal interviews with the farmers

A close perusal of the Table 4 revealed that, irrigation costs exerted significant positive impact on the gross returns of the semi-dry production technology of paddy, as for every one per cent increase in irrigation costs, the gross returns will increase by 0.97 per cent. It is interesting to note that, in case of SRI production technology of paddy, the irrigation cost is exerting significant negative impact on the gross returns.

To be more precise, for every one per cent increase in irrigation cost, the gross returns will decrease by 1.97 per cent. This signifies the fact that, with less water usage in SRI production technology, the yields will increase, thereby leading to higher returns. This implies that, the judicious use of irrigation resource in semi-dry production technology will fetch higher returns. This is further confirmed from the transplanted technology of paddy, as the indiscriminate increase in irrigation cost could not boost the gross returns to a significant extent. This suggests that, the excess use of irrigation water in case of paddy could not account much for boosting the gross returns.

Hence, recommendation of less water use paddy production technologies should assume more significance in KWD, as they yields two benefits viz., enable the farmers to cultivate second crop and the excess water (over and above the quantity recommended for SRI technology) can be regulated to the tail end commands. With increasing cropping intensity, the number of man days of employment will increase significantly in KWD. As the KWD harbours significant number of working population (farmers and agricultural labour) in agriculture to a tune of 66 per cent of total population of KWD, the increase in cropping intensity through economizing the water usage, will sustain them in agri-business.

- Comparative economics of paddy cultivation under different water management interventions

To highlight the importance of different water saving crop production technologies in sustaining the farming community in agri-business through increasing the cropping intensity and number of man days of employment, comparative economics of paddy cultivation was studied under different water management situations. Paddy was selected for this study because, it is the major crop cultivated in the KWD and it is the major water-consuming crop, thereby, not allowing the farmers to cultivate second crop in rabi season.

Hence, the economics of paddy cultivation under different water management situations was studied, as it guides the farmers in practicing the best technology for which the BCR is highest. Three important water management technologies viz., transplanted, semi-dry and SRI were studied in-detail. Transplanting method is normally followed by the farmers, where as, semi-dry and SRI production technologies were less adopted by the farmers. Even though semi-dry method is an age-old practice, but the farmers were habituated to cultivate paddy under transplanted condition only, because of the irrigation facilities bestowed in KWD. SRI cultivation is relatively a modern water saving technology, but it is less adopted in KWD, as the farmers were less trained on this technology. The analytical findings were presented through Table 5. A close perusal of the Table 5 reveals that, SRI production technology of paddy contributes more benefits to the farmer, as indicated by the highest BCR of 2.19 followed by semi-dry (1.97) and transplanted (1.75) production technologies. It is quite interesting to note that, SRI production technology benefited the farmers over semi-dry and transplanted technologies through increasing the paddy yield. On the other hand, semi-dry paddy benefited the farmers over transplanted technology through reduction in the cost of cultivation. Both SRI and semi-dry production technologies involves less irrigation cost (Rs.2475.21/ha and Rs.3248.15/ha respectively) when compared to transplanted technology (Rs.4321.58/ha). The reduction in irrigation cost in SRI and semi-dry paddy production technologies is significant, as indicated by the decline to a tune of 42.73 and 24.84 percents respectively over transplanted technology. This clearly indicates that, by less water usage, paddy returns can be boosted by adopting SRI and semi-dry production technologies. Even though the Total Operational Costs (TOC) incurred in SRI cultivation are higher (mainly due to land preparation and levelling, organic manures and weeding) than transplanted and semi-dry production technologies, the increased contribution from yield boosted the net returns. The lower irrigation cost in SRI production technology is an heartening aspect for benefiting the farmers to produce more crop per unit of water resource used.

The lower paddy yield in semi-dry production technology is compensated by the declined cost of cultivation, thereby contributing higher BCR over transplanted technology. The increased yield and declined cost of cultivation of paddy in SRI and semi-dry production technologies respectively were mainly responsible for the low cost of production of paddy in SRI (Rs. 495.22/qtl) and semi-dry (Rs. 532.81/qtl) technologies over transplanted technology (Rs. 574.93/qtl). To have a clear picture about the importance and relative advantages of these water saving paddy production technologies over transplanted method, the details were shown through Table 6.

Table 5 Comparative economics of paddy cultivation under different water management situations (Rs/ha)

S. No.	Particulars	Transplanted paddy#	Semi-dry paddy##	SRI### Cultivation
1	**OPERATIONAL COSTS**			
2	Land preparation & leveling	1954.26	1024.12	2465.37
3	Seed & transplanting	7821.19	2867.18@	6582.19
4	Org. manures	2063.51	1896.26	5894.23
5	Fertilizers	8792.26	8125.31	6147.26
6	Weeding	3018.47	4158.21	5012.57
7	Plant protection	4258.12	4726.15	4326.84
8	Irrigation	4321.58	3248.15	2475.21
9	Harvesting, threshing, winnowing, & bagging.	6852.13	6758.29	6957.16
10	**Total Operational Cost (TOC)**	**39081.52**	**29936.49**	**39860.83**
11	**Fixed Costs**			
12	Interest on Working capital	455.95	349.26	465.04
13	Land Revenue	200.00	200.00	200.00
14	Depreciation	584.13	498.28	574.19
15	Rental value of owned land	2485.26	1984.17	2557.48
16	Interest on fixed capital	474.18	348.28	496.18
17	**Total Fixed Costs**	**4199.52**	**3379.99**	**4292.89**
18	**Total Costs**	**43281.04**	**33316.48**	**44153.72**
19	**Gross Returns**	**118942.40**	**98797.40**	**140872.80**
20	**Net Returns**	**75661.36**	**65480.92**	**96719.08**
21	**BCR**	**1.75**	**1.97**	**2.19**
22	Yield (qtls/ha)	75.28	62.53	89.16
23	Cost of production (Rs/qtl)	574.93	532.81	495.22
24	Man days of employment (No./acre/season)	68.19	74.28	71.57

Note : @ - Direct sowing of paddy

- Nursery seedlings of 25 days age will be transplanted in main filed. The main field was maintained under water logged condition up to a depth of 5 cm till harvesting stage.

- Germinated paddy will be sown directly in the main field. Alternate wetting will be done upto the panicle initiation stage and later standing water will be maintained up to a depth of 5 cm when canal water is available.

- 8-12 days old nursery will be transplanted in the main

field. The main field will be maintained in a saturated condition (without water logging) up to the panicle initiation stage and later standing water will be maintained up to a depth of 5 cm.

Raw Data Source : Personal interviews with sample farmers (n = 120)

Table 6 Advantages of practicing water saving paddy production technologies (semi-dry and SRI) over normal transplanted method.

S. No.	Features	Transplanted method	Semi-dry method	SRI method
1	Time of planting	Usually delayed due to late release of canal water (2nd fortnight of Aug)	Timely sowing can be done with the onset of summer showers (June)	Timely sowing can be done with the onset of summer showers. (June)
2	Time of transplantation	25 DAS	-	8-12 DAS
3	Irrigation cost (Rs/ha)	Highest (4321.58)	Lower than transplanted method (3248.15)	Lowest (2475.21)
4	Possibility of second crop	Very low chance. Because of indiscriminate water usage in kharif season, low rainfall and less water in the reservoirs.	Yes. The crop season was started in time and less water used for kharif paddy. Bright chances for taking up pulse crop during rabi season.	Yes. The crop season was started in time and less water used for kharif paddy. Bright chances for taking up pulse crop during rabi season.
5	Major factor influencing returns	Market price.	Decline in cost of cultivation.	Drastic increase in yield.
6	No. of man days of employment/ acre/season	Lowest (72.51)	Highest (88.13)	Higher than transplanting method (74.21)

Note : DAS – Days After Sowing

- Economic efficiency of irrigation water resource

The efficient use of irrigation water resource can be better studied by working out the share of irrigation cost in TOC and by computing its economic efficiency in the production programme and the analytical findings were presented through Table 7.

It is clear from the Table 7 that, the share of irrigation cost in TOC was highest for transplanted technology of paddy (11.06%) followed by semi-dry technology (10.85%) and SRI technology (6.21%). Of course, the share of irrigation cost in TOC not only depends upon the irrigation cost alone, but also on the extent of use of other resources in the production programme, as they directly contribute to the TOC.

It is interesting that, both in SRI and semi-dry paddy production technologies, the share of irrigation cost in TOC is lower compared to transplanted technology. This is because, in SRI production technology, the field was maintained under saturated condition up to the panicle initiation stage. In semi-dry technology, alternate wettings will be given to the crop up to the panicle initiation stage.

In case of transplanted technology, the main field was always kept under water-logged condition. However, irrespective of any production technology practiced in paddy, after panicle initiation stage, 5 cm depth of water is maintained in the main field, as panicle initiation and flowering are the critical moisture sensitive stages of the crop. However, the share of irrigation cost in TOC of selected crops do not give the correct picture about the efficiency of irrigation water usage, as it depends on several factors like duration of the crop, extent of use of other resources, farming situation etc.

Table 7 Efficient use of irrigaxtion water resource for selected crop enterprises in KWD

S. No.	Crop	% share of irrigation cost in TOC	Economic efficiency of irrigation resource
1	Paddy (Transplanted)	11.06	27.52
2	Paddy (semi-dry)	10.85	30.42
3	Paddy (SRI)	6.21	56.91

Note : TOC – Total Operational Cost

Raw Data Source : Personal interviews with the farmers

To get a meaningful picture about the efficient use of irrigation water resource, the economic efficiency was worked out by computing the ratio between gross returns and irrigation cost incurred for the selected crop enterprises. The Table 7 reveals that, the ratio was significantly highest for SRI production technology of paddy (56.91). It is quite interesting to note from the table that, for transplanted technology of paddy, the economic efficiency of irrigation water resource is very low to a tune of 27.52.

This implies that, this resource was not effectively contributing to the gross returns of paddy under transplanted scenario. A comparative picture with the SRI and semi-dry production technologies indicates that, the efficiency can be boosted by judiciously using the irrigation water resource rather than its indiscriminate application. Hence, there lies an immense need to exploit this resource use in paddy. The higher economic efficiency of irrigation water resource in SRI production technology of paddy is really an encouraging aspect for planning different water saving technological interventions in paddy.

- Prioritization of researchable issues in KWD

As the funds available for agricultural research are declining over a period, but the expectations are still on the rise, there lies an immense need to prioritize the researchable issues/problems of KWD such that, the most urgent problem should be tacked first. Accordingly, Garrett's ranking test was employed to prioritize the researchable problems of the KWD and the findings were shown through Table 8.

It is clear that, all the sample farmers unanimously expressed about the water management problems in KWD. It is interesting to note that, both the system-level and field-level interventions should be addressed to solve the issues/problems of water management. Besides addressing the water management problems, there is an immense need to develop varieties suitable for soil salinity and water logging situations and also to suit to the less water availability situations, to develop cost-effective package of practices in the light of IWRM and to standardize the water requirement data for different paddy production technologies.

Table 8 Garrett's ranking of prioritization of researchable problems in KWD

S. No.	Researchable Issues	Score	Rank
1	Delay and untimely release of canal water affecting crop yields	81.28	I
2	Declining yields and cropping intensity due to water logging and soil salinity problems	73.19	II
3	Increased cost of cultivation of agricultural crops especially in problematic soils	70.18	III
4	Standardization of water requirement data/information for paddy grown under different water management production technologies	57.08	
5	Lack of situation specific crop varieties (paddy and black gram) suitable to salinity and water logging conditions and less water /drought conditions.	51.12	
6	Low prices for agricultural commodities in the market economy	48.35	

Raw Data Source : Personal Interviews held with the farmers

- Planning IWRM on the lines of paradigm shifts

The analytical findings pertaining to the growth pattern of irrigated area, contributions of different irrigation sources towards irrigating the crops, economic analysis of major crop enterprises cultivated and their contribution towards number of man days of employment, economic efficiency of irrigation water resource in cultivating the crops, degree of association between irrigation cost and gross returns of selected crop enterprises and the influence of irrigation cost on the gross returns will enable to understand the impact of irrigation resource in influencing the agri-business. Further, the other important finding that, through less water usage, the crop production can be sustained, that too with higher returns and increasing periods of employment. This is really an encouraging aspect, as the dissemination of technology on these lines will definitely enable the farming community to increase their cropping intensity and there lies more scope to regulate the water flow from head reaches to the tail end reaches of canal commands for increasing the cropped area in KWD.

This really demands more technological interventions relating to the standardization of water requirement data for different water saving paddy production technologies, as the situation in KWD is getting worse year by year in relation to irrigation water availability. Of course, keeping the uncontrollable natural factors aside, it is possible regulate the irrigation system in KWD, as the execution of water saving production technologies are feasible in the farmers' fields and the situation is more demanding now. This needs systematic planning and implementing the important strategies/concepts of IWRM ie., enabling environment, institutional roles and functions and management instruments, as shown through figure 1, and this will definitely promote the agricultural scenario through improving the irrigation efficiency in KWD.

A close perusal of the Figure 1 clearly depicts an interesting picture that, the present scenario in the KWD is very congenial to implement different water management strategies of IWRM, as they are encouraged not only by the efficient actions of different interventions, but by the congenial environment prevailing for executing these interventions. The environment in the State in general and in KWD in particular, with reference to the execution of various developmental activities in agriculture, that too in relation to the water management aspects, will definitely exert strong motivating force for planning the technological interventions relating to the water management.

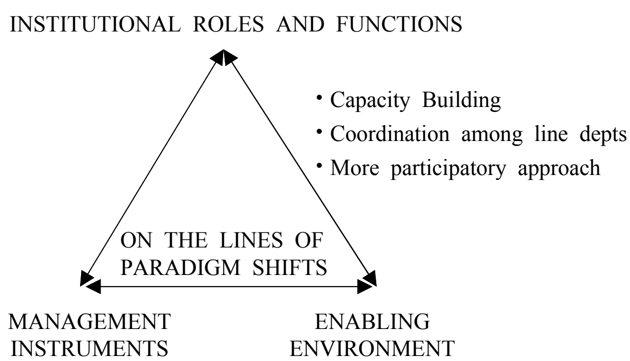
As water scarcity is the present crisis now and it may prevail in the future also, due to increasing competition arising from the household and industrial sectors, there is an immense need to plan and implement water saving crop production technologies in agriculture. This is because, agriculture is the major sector contributing to State's income and providing employment to a significant number of rural population. The enabling environment, institutional roles and functions and management instruments are posing favourable picture for executing the water management interventions in KWD.

This facilitates the farming community to harvest good crop per unit of water resource used in the production programme. However, the application of these concepts of IWRM should be planned on the lines of various paradigm shifts identified in KWD (Table 9) in the light of acute water scarcity, salinity and water logging problems. This will definitely boost the profitability in agricultural production and thereby, sustain the farming community in the agri-business. Giving more emphasis on the paradigm shifts is also helpful to identify the actual potential areas, where enough thrust is required to achieve desired benefits from the technological interventions. Moreover, they will definitely pave the right way to improve the agricultural scenario in KWD suiting to the present needs and to the challenges emerge in the ensuing future.

Table 9 Important paradigm shifts identified to plan technological interventions of IWRM in KWD

S. No.	Paradigm shift	
	Shift from	Shift to
1	Farmers perceive water as a 'Free Good'	Farmers should be convinced that, water as a 'finite, vulnerable and economic (scarce)' good.
2	Farmers were treated as a mere 'Recipient' of technological interventions	The accountability of farmers in adopting the technological interventions will be given more importance by involving them in cost sharing.
3	More crop production with no emphasis on cost-effectiveness	More crop production with due emphasis on cost-effectiveness through IWRM
4	Application of water to the crop fields as and when it is available in the sources (canals/tanks/wells etc)	Application of water as per the recommended quantity at the critical moisture sensitive stages (CMSS) of crops and standardization of water requirement data to the crops (farming-situation wise).
5	Lack of coordination between the Farmers' Organizations (FOs)/Water Users' Associations (WUAs) and officials from Agriculture and Irrigation departments	Bringing system level interventions to coordinate the FOs/WUAs and officials from Agriculture and Irrigation departments, such that the water releases match with acreage of crops and crop growth stages.
6	Flooding the fields with irrigation water	More emphasis on micro-irrigation (more crop per drop of water used)
7	Application of chemical amendments to restore saline affected lands in water logged areas as a temporary solution.	Installation of sub-surface drainage system to restore saline affected lands in water logged areas on a permanent basis.
8	Paddy as a second crop	Improving the profitability of cropping pattern by suggesting equally remunerative crops but with less water requirements.
9	Participation of farm women in water management is neglected	More emphasis on the role of farm women in collecting and safeguarding the irrigation water.
10	More emphasis on production/unit of land under cultivation	More emphasis on production/ unit of irrigation water resource used or irrigation cost incurred.

KEY CONCEPTS OF IWRM



Conjunctive use of surface water, ground water and rainfall

- Recycling of drainage water
- Reclamation of problematic soils
- Popularization of water saving technologies

- Micro irrigation systems
- Sustainability concept in production systems
- Evaluation of Socio-Economic welfare
- Formulation of policy instruments
- Restoration of ecological balance

State Policies

- Increased budgetary allocation towards irrigation sector
- Subsidy allocation to popularise Micro-irrigation (90%)
- WUAs in 1997(Participatory approach)
- Foreign Collaborative projects &foreign direct investments

Legislations of State Govt.

- Andhra Pradesh Farmers' Management Of Irrigation Systems Act, 1997
- Neeru- Meeru – 2000
- Intensification of Watershed Development Programme (IWDP) – 2000
- AP Water, Land and Tree Act (APWLTA) – 2002
- Massive Promotion of Micro Irrigation (MPMI) – 2003
- Task Force on Agriculture- 2003
- Farmers Call Centre – Expert Team – 2003
- Technology Mission on Agril-2004

Conclusions and Suggestions

To conclude, the irrigation water usage in KWD showed low economic efficiency. Further, the declined contributions from the major irrigation sources and the declined growth in irrigated area of major crop enterprises cultivated in KWD calls for systematic planning and implementation of IWRM on the lines of different paradigm shifts identified in lieu of acute water scarcity and prevalence of soil salinity and water logging problems. In view of the declining irrigation water potential and identified and prioritized researchable issues in KWD, the following suggestions must be looked into:

- Promoting cost-effective crop production technologies with major reference to irrigation water resource were immensely useful to sustain the agri-business in KWD both in terms of increasing cropping intensity and regulating the water flow to the tail end commands.
- Both the system level and field level management interventions need to be addressed for improving the irrigation water usage efficiency in KWD. To achieve better results, participatory approach by involving all possible stakeholders viz., Farmers' Organizations, Water Users Associations, Department of Agriculture, Department of Irrigation, District Water Management Agency, Women groups, NGOs etc., should deserve special attention. This facilitates the researchers to plan the water management strategies more effectively and efficiently so as to combat the declining economic efficiency of irrigation water resource in KWD. Major agrarian water-saving improvements from irrigation in KWD in the future will be realized largely through the management and innovative design of integrated water delivery and field irrigation systems.
- The Farmers' Organizations, Water Users Associations and Department of Irrigation will have to aim at improving productivity per unit of water consumed. However, doing so will require major systematic cultural, managerial, engineering and institutional changes. This must be supported by system-wide enhancement of water delivery systems, advanced site-specific irrigation technologies that include self-propelled sprinklers and microirrigation systems, and other supporting monitoring, modeling and control technologies. Decision support tools will be needed to assist farmers in optimizing the allocation of limited water among crops, selection of crops based on farming situations, and adoption of appropriate alternative crops in drought years.
- Carefully managed deficit irrigation on agronomic crops in KWD would provide the greatest potential for substantially reducing agricultural water use because of the larger land areas that are involved. High-value crops may also produce some water savings through various deficit irrigation strategies, but their impact will be much lower because they generally occupy less than 10-15 per cent of irrigated area (location specific). However, deficit irrigation strategies still must be developed for most crops.
- Advanced irrigation technologies and state-of-the-art delivery systems, will be needed to be able to be able to fully implement successful deficit irrigation strategies. Precision agriculture tools such as site-specific water and nutrient applications will play an important role.
- Managing and developing infrastructure and policies for water security to equitably satisfy the demands of all users of this limited resource will be a challenging and lengthy task. Changes in policy and incentives will clearly become necessary. However, water and land resources and their many complex and competing uses must be considered in a comprehensive regional and international framework. Improvements should be systematic, not concentrated on only one or two components of the hydrologic system.

Further, as the basic concepts of IWRM viz., enabling environment, institutional roles and functions and management instruments are posing favourable picture for the effective implementation of water saving crop production technologies in KWD and modernizing the irrigation systems, there lies an immense need to address the prioritized researchable issues of water management in the ensuing future.

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