Asian Journal of Agricultural Extension, Economics & Sociology

38(1): 102-110, 2020; Article no.AJAEES.54528
ISSN: 2320-7027

Impact of Irrigation Water Shortage on Yield, Income and Employment of Farm Households in Tungabhadra Command Area of Karnataka

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Authors' contributions

This work was carried out in collaboration between both authors. Author PK designed the study, performed the statistical analysis, wrote the protocol, wrote the first draft of the manuscript, managed the literature searches and managed the analyses of the study. Author KBU gave the valuable suggestions and corrected the manuscript at all stages of the study. Both authors read and approved the final manuscript.

Article Information

DOI: 10.9734/AJAEES/2020/v38i130302
Editor(s):
(1) Dr. Ian McFarlane (Retired), School of Agriculture Policy and Development, University of Reading, UK.
Reviewers:
(1) Zuzana Vranayova, Technical University of Kosice, Slovakia.
(2) Clement Kiprotich Kiptum, University of Eldoret, Kenya.
Complete Peer review History: http://www.sdiarticle4.com/review-history/54528

Original Research Article

Received 01 December 2019
Accepted 06 February 2020
Published 24 February 2020

ABSTRACT

The study examined the impact of irrigation water shortage on yield, income and employment of farm households in Tungabhadra command area in Gangavathi taluk of Karnataka. Based on the extent of net irrigated area under canal, Gangavathi taluk of Koppal district was selected for the study. A total of 120 households among which 40 respondents from each water access regimes (head reach, mid reach and tail-end reach) were selected. The required field data pertaining to the year 2016-17 was collected through personal interview. The average gross annual household income of head reach farmers before and after water shortage (2015) was INR 6,35,293 and INR 5,59,970, respectively. Whereas, in tail-end reach, the average gross annual household income before and after water shortage was INR 5,66,263 and INR 4,19,895, respectively. The annual household employment in all the three regimes was affected due to irrigation water deficits but it was more significant in middle-reach regime. Bore wells and ponds acted as a supplementary source of irrigation in periods of water shortages. A good coordination should be built between

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different line departments in managing the water resources in the Tungabhdra basin and it should be coordinated in proper direction. There is a need for common vision and plan for water management based on administrative boundaries.

Keywords: Irrigation water shortage; command area; water access regimes; farm income; yield.

1. INTRODUCTION

India's agriculture has an extensive background which goes back to at least ten thousand years. Currently the country holds the second position in agricultural production in the world. Despite the steady decline in agriculture contribution to the country's GDP, agriculture is the biggest sector in the country and plays a key role in the socio-economic growth of the country. Irrigation in India helps to improve food security, reduce dependence on monsoon, improve agricultural productivity and create rural job opportunities. As per OECD (Organisation for Economic Co-operation and Development) environmental outlook 2050, India would face severe water constraints by 2050. Irrigation is a basic determinant of agriculture because its inadequacy is the most powerful constraint on the increase of agricultural production. Irrigation is frequently cited as an innovation that can improve rural livelihoods, food security and poverty reduction [1,2,3]. Rosegrant and Cai [4] emphasized that irrigation has enormous potential in farming to curb food insecurity and to release millions from chronic poverty. Irrigation has helped to enhance agricultural yields and outputs in arid and semi-arid environments and stabilized food production and cost [5,6].

1.1 Problem Statement

Tungabhadra command area is considered as a lifeline for Koppala, Bellary and Raichur districts in Karnataka. Tungabhadra Left Bank Canal (TLBC) supplies irrigation water to these districts of Karnataka. Irrigated agriculture in Tungabhadra Left Bank Canal (TLBC) is constrained by both technical and institutional factors. Due to population growth in Sindhnaur, Gangavati, Manvi and Raichur taluks, farm fragmentation has resulted in significantly increased cropping intensities, driving demand for irrigation water far beyond the original designed capacity. In future, *kharif* season irrigation supplies could become greater threat due to water stress on account of climate change. However, in the longer run, shortage will become more pronounced. Severely high temperatures in the area results in increased evaporation from storage reservoirs and higher crop water requirements. This is also coupled by lower irrigation efficiency in the command area.

Even though the TBP (Tungabhadra Project) command area is canal fed, farmers in this region are facing irrigation water shortage since 2015. Canal water in TBP area is released in the month of July, only after monsoon rains with rise in the water level in Tungabhadra dam. Whenever there is low rainfall in the catchment area, the dam water level will be low (reduced to dead storage) and the command area authority would not be able to release water to the canals regularly. Paddy being predominant crop in TBP command area of Gangavathi Taluk, almost all the farmers grow paddy as the major crop and everyone depends on the irrigation water from the dam.

If farmers start raising paddy nursery after release of canal water, transplanting will be delayed to August-September and then every operation is delayed and the yield gets affected. In the command area, irrigation water supply has been decreasing over the years due to low rainfall and accumulation of silt in the reservoir. As a consequence of this, for the past five years, the command area authority is not releasing water regularly. Due to this problem, farmers are cultivating only one crop instead of two paddy crops in a year. This has led to problems like decreased paddy production in the region, thereby causing decreased household income and employment opportunities.

In any large-scale irrigation system like Tungabhadra Command Area, there will be inequality in distribution of irrigation water. The head reach farmers and the tail-end reach farmers are in very different positions. Narrowly selfish head reach farmers would ignore the shortage that they generate for those lower in the system [7]. But if the head reach farmers get most of the water, those at the tail end farmers will have either lesser or no access to irrigation water. So, during water shortage periods, the condition of tail-end farmers becomes still worse and they have to suffer more from this situation than that of head and middle reach farmers. The

water shortage problem results into limitation in cropping option, the reduction in crop yield, income and employment opportunities in tail-end reach than in head and middle reach.

Designed cropping pattern has been specified to adopt semi-arid crops for the irrigated basin but water intensive crop like paddy dominate in the basin. A combination of social inequity and economic marginalization have forced people living in extreme poverty to overexploit soil and forestry resources, with damaging impacts on water resources. Violation of rules (regarding irrigation water use and suggested cropping pattern) is prominent and it is difficult to manage in Tungabhadra command area [8]. The present study focuses on the impact of irrigation water shortage on yield, income, and employment of farm households in Tungabhadra Command Area.

Ostrom and Gardner [7] reported that agricultural yields and crop farm household income of farmers depend on whether they can be assured of water during the winter and spring seasons, when water becomes progressively scarcer. The average crop intensity achieved at the tail end of the system (228%) was slightly higher than at the head end (221%). Irrigation enables households to improve their crop productivity, grow high valued crops and generate higher incomes and employment. Inequity in water distribution translates into productivity differences, with lower productivity varied from 1.7-3.4 t/ha at the head and from 1.2-2.9 t/ha at the tail [9]. Tyagi et al. [10] conducted study in North West India and their results revealed that tail reach farmers of watercourses had 8-10 per cent lower yield as compared to head reach farmers. Analysis by Rahut et al. [11] indicated that farmers with water scarcity problem had lower yield and household income and were food insecure and due to water scarcity the household income was less in the range of rupees 8032-10741 Pakistani rupees.

2. MATERIALS AND METHODS

In the present study, simple random sampling technique was adopted for the selection of sample respondents. Gangavathi taluk of Koppal district coming under Tungabhadra command area of Karnataka was purposively selected because Gangavathi is considered as the “Rice bowl of Karnataka”. A total of 120 sample farmers comprising 40 each from three water access regimes (head reach, mid reach and tail-end reach) were selected for the study.

2.1 Primary Data

General information regarding socio-economic status, size of land holdings, costs and returns of different crops and also the relevant data on variables related to the study etc., were collected from the sample respondents using pre-tested, well-structured schedule through survey method for the agricultural year 2016-17. Villages in the command area of Gangavathi taluk were selected based on the assumption that villagers’ vulnerability would increase as access to reliable irrigation water decline.

2.2 Analytical Techniques

Tabular presentation was employed to compile, compare and contrast the socio-economic status, cost and returns, income and employment in the study area. In order to facilitate interpretation of findings, measures like percentages, averages and statistical tests were worked out wherever necessary.

2.3 Head, Mid and Tail Reach

The total length of the canal in Gangavathi taluk was divided into three parts based on the length along the canal from the dam.

Head reach: 0-15 km length along the canal from the dam
Mid reach: 15.1-30 km length along the canal from the dam
Tail reach: 30.1 km to beyond length along the canal from the dam

The crops cultivated in head reach of the study area were mainly paddy and small area of sugarcane due to assured availability of canal water. The major crops in middle reach were paddy, cotton, chickpea. Similarly, major crops cultivated in tail-end reach were paddy, chickpea, sorghum and cotton.

3. RESULTS AND DISCUSSION

3.1 Socio-economic Characteristics

The average family size of the respondents was four, six and five in head, mid and tail-end reach regions, respectively and the difference was found statistically significant (Table 1). The family size of mid-reach farmers was bigger than both head and tail-end reach farmers indicating that more number of family labour availability. The sample respondents had an average land

holding of 4.77, 4.96 and 6.06 acres in the head, mid and tail-end reach, respectively which showed that average land holding of tail-end reach farmers was more compared to head and middle reach farmers. There was a significant difference among the land holdings of three regimes.

Both head and middle reach sample respondents had taken two crops in a year with the help of supplementary irrigation but due to water shortage, many farmers in tail-end reach were able to take only one crop in a year (Table 1). The annual household income of head, mid and tail end reach farmers were INR 6,35,293, INR 6,25,163 and INR 5,66,263, respectively which indicated that the household income of the tail end reach farmers was low compared to head and middle reach farmers.

3.2 Yield, Income and Employment Security

It was observed that farmers obtaining lower returns from land, due to irrigation deficits, increased towards the tail-end of the irrigation system as water availability is insufficient to satisfy the crops physiological needs. It is well known that tail-end users of irrigation systems receive less water [12]. Instead of lack of irrigation water per se, reduced availability and access to the services it provides, often complicated by competing demands, and are considered as the causes of vulnerability [13].

The effects of reduced irrigation water availability, in terms of unreliability, and lack of access to water on yield, income and employment were shown by considering three different water access regimes i.e., head, mid and tail-end reach. Here, 2015 is considered as the base year to demarcate between before and after water shortage because from 2015 onwards there was low rainfall (Appendix 1) and accumulated silt in the reservoir resulted in the reduction in the storage capacity of the reservoir leading to the shortage of irrigation water and irregular release of water from the command area authority (Appendix 2).

3.2.1 Yield, income and employment before and after water shortage in different water access regimes

Results indicate that yield of paddy crop before and after irrigation water shortage in head reach regime was more when compared to middle and tail-end reach regimes because of water shortage problem and inequitable distribution of irrigation water supply in three different regimes. After water shortage problem, the yield in tail-end reach regime (60.30 q/ha) decreased significantly (Table 2). This implies that farmers do not have an adequate water supply to optimally cultivate all their land at the tail region of the irrigation system [14].

The level of paddy yield after water shortage problem decreased in all the three water access regimes but it was more pronounced in tail-end reach (Table 2). Crop production functions relate plant yield to water use and are influenced by other farming inputs, such as fertilizer, as well as site and crop specificities [15]. Crop production can be seriously affected by unforeseen climatic variations, including water (rainfall and irrigation) supply, found mostly in tropical zones [16], making economic returns to inputs uncertain for cultivators. The shortage of irrigation water in the Tungabhadra reservoir was mainly due to low rainfall and a huge amount of silt accumulation in the reservoir overtime reducing the water storage capacity of the dam. This problem of water shortage affected almost all the paddy growing farmers in the study area especially the tail-end reach farmers.

From the Table 2, it was evident that the annual household income of farmers in all the three water access regimes significantly reduced after water shortage problem but it was significant in tail-end reach farmers. The annual gross household income of head reach farmers before and after water shortage problem was INR 6,35,293 and INR 5,59,970, respectively. In tail-end reach, the annual gross household income before water shortage was INR 5,66,263 and after water shortage problem it was INR 4,19,895.

This can be attributed to the reduction of yield in all the three water access regimes due to irregular and inadequate supply of irrigation water. And the income of the tail-end reach farmers was most affected compared to head and middle reach farmers due to less access to irrigation water. However, in the head reach of the canal, annual gross household income after water shortage was 1.3 times higher than the income of tail reach farmers supporting earlier findings of head-tail differences in terms of irrigation deficits. It confirms the difference in the magnitude of income lost to irrigation deficits in both regimes.

Table 1. Socio-economic features of sample respondents

Sl. no.	Particulars	Head reach (n=40)	Middle reach (n=40)	Tail-end reach (n=40)	Significance (F test)
1	Family size (no.)	4	6	5	6.53*
2	Education level of family head (No. of years of schooling)	7	6	8	2.09^{NS}
3	Landholding (acres)	4.77	4.96	6.06	3.36**
4	The area under paddy (acres)	4.77(100)	4.76(95.97)	5.9(97.36)	-
5	No. of crops taken in a year	2#	2#	1	-
6	Annual household income (INR)	6,35,293	6,25,163	5,66,263	0.06^{NS}
7	Change in household income	100.00	-1.60	-10.87	-

Note: Figures in parentheses indicate per cent to total sample respondents
** -Significance at 5%, ** -Significance at 1%, # - With supplementary irrigation*

Table 2. Yield, income and employment before and after water shortage in different water access regimes

Particulars		Paddy yield (q/ha)Kharif	Annual household gross income (INR)	Annual household employment (in days)
Head-reach	Before WS	82.15	635293	640
	After WS	80.10	559970	538
	Difference	2.05(2.50)	75,323(11.86)	102(15.94)
	t-test	0.85	2.05*	3.65**
Mid-reach	Before WS	76.25	625163	918
	After WS	70.58	501728	675
	Difference	5.67(7.44)	1,23,435(19.75)	243(26.47)
	t-test	1.19	2.53*	5.9**
Tail-end reach	Before WS	69.14	566263	594
	After WS	60.30	419895	442
	Difference	8.84(12.79)	1,46,368(25.85)	152(25.56)
	t-test	5.42*	4.68**	13.71

*Note: a) ** - Significant at 1% and *- Significant at 5%.*
b) Figures in parentheses indicate per cent decrees in yield, income and employment to total yield, annual household income and employment respectively, c) WS- Water shortage
d) Only paddy crop is considered for the analysis of yield as paddy was the major crop grown in the study area

The annual household employment in all the three regimes was affected due to irrigation water deficits but it was more significant in middle-reach regime (Table 2). The annual household employment in head reach before and after irrigation water problem was 640 and 538 days, respectively. In middle reach, the annual household employment before water shortage was 918 days and after water shortage, it reduced to 675 days. In tail-end, annual household employment was reduced from 594 to 442 days.

Annual household employment was most affected in mid reach because farmers were in dilemma whether they receive water or not. Sometimes they receive water and sometimes they won't, this created a sort of confusion and they did not take up allied enterprises as seen in case of tail reach farmers. The farmers in tail reach were aware of the irrigation water shortage and they engaged themselves in other allied farm activities and non-farm activities.

Not only do overall results provide evidence of the commonly held wisdom of higher prevalence of water scarcity in the lower reaches of irrigation systems, they also suggest that increased irrigation water deficits at the tail of canals are indicative, by inference, of farmers' higher vulnerability at the tail of the system [14]. The results indicated that irrigation water shortage increase towards the tail of the canal, thereby increasing the vulnerability of the farmers.

Farmers depending only on canal irrigation water are at a disadvantage during the dry/summer season. This is likely to spin off and indirectly affect employment opportunities for landless agricultural labourers.

Bore well and ponds acted as a supplementary source of irrigation in periods of water shortages and are the just partial solution to shortage of irrigation water but cannot fully compensate for the deficit caused by inadequate canal water supply. In absolute terms, the economic impact of irrigation deficits was higher at the tail of the canals, which underlines the economic vulnerability of farmers located at the tail end of the irrigation system and whose livelihood depends on irrigated paddy crop.

3.2.2 Comparison of income from different sources in three water access regimes

Income from different sources and its per cent contribution to the total annual household income in three different water access regimes are presented in Table 3. Results give a clear comparison between before and after water shortage. It was evident that the contribution of income from crop production was highest in all the cases followed by income from allied activities and then income from non-farm activities. Because sample respondents of the study area were all farm households and the main source of income to them was from crop production followed by income from allied activities such as livestock enterprises, poultry etc. The contribution of income from non-farm activities such as wage labour, other occupations, business activities etc., to the total farm household income was very less in all the three regimes.

In head-reach, gross income from crop production before and after water shortage was INR 5,81,287 and INR 5,06,289, respectively. Annual gross income from allied activities was same (INR 34,356) before and after water shortage (Table 3). Income from allied and non-farm activities did not change after water shortage problem but only income from crop production decreased significantly due to insufficient irrigation water supply from the Tungabhadra dam.

Annual income from crop production reduced from INR 4,97,639 to INR 3,75,654 after water shortage in middle reach (Table 3). Income from crop production alone contributed 79.60 per cent and 74.87 per cent before and after water shortage problem, respectively. In middle reach, income from allied activities was INR 87,849 (14.05%) and INR 87,849 (17.51%) before and after water shortage problem, respectively. Income from non-farm activities was INR 39,675 (6.35%) and INR 38,225 (7.62%) before and after water shortage, respectively.

In tail-end reach regime, income from crop production to the total household income occupied a predominant position as in case of head and mid reach regime. The income from crop production reduced after 2015 due to the shortage of water and unreliable water supply and less access to the tail-end reach farmers. In tail-end reach, most of the sample farmers possessed livestock to sustain their family income as against the mid and head reach regime. Income from non-farm activities increased after water shortage problem in tail-end because the water shortage severely affected the farmers in tail-end and they have engaged themselves in allied activities and non-farm activities like construction activities, business activities etc. Farmers with the water scarcity problem have a lower yield (wheat, maize and rice) and household income and are food insecure. Poverty levels were higher in the range of 7-12 per cent for the household facing water scarcity problem [11].

It can be concluded that income from crop production was less in tail-end reach compared to head and middle reach because of less availability and accessibility of irrigation water to the tail-end farmers than middle and head reach farmers. During summer season many of the tail-end reach farmers left their lands fallow and few members in middle-reach cultivated paddy using other supplementary sources. But in head-reach, almost all farmers were able to cultivate even in summer season.

Income from allied activities was more in tail-end reach followed by mid-reach and head reach because in head-reach farmers had adequate water supply to optimally cultivate all their lands and they were assured about the water availability but mid and tail-end reach farmers did not have adequate water supply to optimally cultivate all their land. Hence, livestock rearing was a major contribution to livelihoods and income generation in mid and tail reach farmers. The presence of fallow land or under-cultivation in irrigated areas shows that land is under used and suggests increased vulnerability to water shortage problem.

Table 3. Comparison of annual gross income from different sources before and after water shortage in different water access regimes (INR)

Sl. no.	Particulars	Head-reach		Mid-reach		Tail-end reach	
		Before WS	After WS	Before WS	After WS	Before WS	After WS
1	Gross Income from crop production	581287(91.50)	506289(90.41)	497639(79.60)	375654(74.87)	451197(79.68)	412795(98.31)
2	Gross Income from allied activities	34356(5.41)	34356(6.14)	87849(14.05)	87849(17.51)	111178(19.63)	111178(26.48)
3	Gross Income from non-farm activities	19650(3.09)	19325(3.45)	39675(6.35)	38225(7.62)	3888(0.69)	7100(1.69)
	Gross Annual household income	635293(100)	559970(100)	625163(100)	501728(100)	566263(100)	419895(100)

Note a) WS- Water shortage b) Figures in parentheses indicate per cent to total annual household income

4. CONCLUSION

Results from the analysis showed that the yield of paddy crop in head reach regime is more when compared to mid and tail-end reach regimes because of water shortage problem and inequitable distribution of irrigation water supply in three different regimes. After water shortage problem the yield in tail-end reach regime was decreased significantly. In the head reach of the canal, annual gross household income after water shortage was 1.3 times higher than annual household income of tail reach farmers. The annual household employment in all the three regimes were affected due to irrigation water shortage but it was more significant in mid-reach regime. In mid reach, the annual household employment before water shortage was 918 days and after water shortage, it was reduced to 675 days. In tail-end, annual household employment was reduced from 594 to 442 days.

The results showed that irrigation water shortage increase towards the tail of the canal. Farmers depending only on canal irrigation water are at a disadvantage during the summer season. In absolute terms, the economic impact of irrigation shortage was higher at the tail of the canals, which underlines the economic vulnerability of farmers located at the tail end of the irrigation system.

5. POLICY RECOMMENDATIONS

Awareness among farmers needs to be created regarding advantages of diversified farming and also there is a need for evolving suitable crop plan with modern farming practices. Farmers should engage themselves in allied activities such as livestock, poultry, fisheries etc., along with crop production to sustain their household income. Farmers should be educated regarding the research-based recommendations and water saving technologies on the farm which would enhance crop productivity and income, thereby strengthening livelihood security of the farmers. A good coordination should be built between different line department in managing the water resources in the Tungabhadra basin and it should be coordinated in proper direction. There is a need for common vision and plan for water management based on administrative boundaries.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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APPENDIX

1. Actual annual rainfall from 2007-2016 in Koppal district (mm)

Sl. no.	Year	Gangavthi	Koppal	Kushtagi	Yelburga	Total
1	2007	580.00	815.00	877.00	625.00	722.00
2	2008	465.00	575.00	611.00	587.00	553.00
3	2009	948.00	917.00	913.00	902.00	921.00
4	2010	690.00	871.00	702.00	737.00	751.00
5	2011	361.00	480.00	396.00	435.00	417.00
6	2012	398.00	413.00	382.00	368.00	392.00
7	2013	536.00	594.00	611.00	507.00	560.00
8	2014	581.00	807.00	779.00	765.00	725.00
9	2015	**349.00**	539.00	553.00	483.00	472.00
10	2016	408.00	582.00	474.00	331.00	449.00

Source: Koppal district at a glance (2015-2016), Department of Agriculture, Government of Karnataka

2. The Comparative and annual rate of loss of capacity of Tungabhadra Reservoir over the years

Sl. no.	Year of survey	Capacity of TB reservoir in		Loss of capacity in		No. of years (interval)	Loss of capacity per annum	
		Mcum	TMC	Mcum	TMC		Mcum	TMC
1	**1953**	3751.10	132.47	-	-	-	-	-
2	**1993**	3157.50	111.50	593.63	20.96	40	14.84	00.52
3	**2004**	2954.50	104.34	202.94	07.16	11	18.44	00.65
4	**2008**	2855.80	100.85	98.69	03.48	4	24.67	00.87
			Total	895.28	31.61	55	16.27	00.57

Source: Command Area Development Authority. Tungabhadra Project, Munirabad

Peer-review history:
The peer review history for this paper can be accessed here:
http://www.sdiarticle4.com/review-history/54528