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Research Article

IMPACT OF CLIMATIC VARIABLES ON TRANSITION COST OF IRRIGATION WELLS IN LEAST AND HIGHLY VULNERABLE DISTRICTS OF KARNATAKA

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Abstract: The study was conducted in least vulnerable districts (LVD) and highly vulnerable districts (HVD) of Karnataka based on composite vulnerability index. The results reveal that in case of LVD, the real investment increased from Rs 73233 in 1991 to Rs 309990 in 2016 with a growth rate of around 7 percent per annum. While real investment on borewell in HVD was Rs 128267 in 1987 and augmented to Rs 559594 in 2017 at the rate of 7.5 percent per annum. In LVD, real investment showed negative correlation with relative humidity (-0.03). On the contrary, real investment on borewell has positive association with wind speed (0.52), maximum temperature (0.25), minimum temperature (0.38) and average temperature (0.38). Further there is no association between real investment and the amount of rainfall received in LVD. In case of HVD, real investment showed negative correlation with precipitation (-0.12) and relative humidity (-0.10), in contrast to that, real investment on borewells has positive relationship with wind speed (0.27), maximum temperature (0.19), minimum temperature (0.26) and average temperature (0.25).

Keywords: Nominal and real investment, Vulnerability, Correlation

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Introduction

Climate change causes uncertainties to the supply side and management of water resources. It affects surface water resources directly through changes in the major long-term climate variables such as temperature, precipitation, relative humidity and evapotranspiration. The relationship between the changing climatic variables and groundwater is intricate and therefore poorly understood. Groundwater resources are related to climate change indirectly through the recharge of surface water resources. Unfortunately, in case of groundwater, there are no accurate or even approximate measurements of the draft as well as recharge, as both the figures are estimated ones. In the case of the draft, as water meters and electrical meters are not installed, water pumped by farmers are estimated only through cropping pattern. In the case of recharge, considering the type of aquifer, such as hard rock or alluvial, a certain portion of rainfall (around ten percent or less) is assumed to be the recharge volume at a flat rate across all areas.

The implications of climate change effects are increasingly felt by farmers with groundwater irrigation in hard rock areas, where the recharge is hardly 5 to 10 percent of the rainfall. In addition, these areas contribute to more than 60 percent of India's food production. Obviously, the economic impact of climate change will severely affect the food security as well as livelihood security including health security of farmers, as irrigation water is also used as drinking water. Pumping from deeper depths have resulted in fluoride water in different parts of Karnataka (Kolar, Tumkur and Gadag districts). Since groundwater is meeting 70 percent of the irrigation needs and 90 percent of drinking water needs of India [1]. Economic impact of climate change on groundwater will have profound impact affecting food, livelihood, health and economic security of farmers affecting seriously sustainable agriculture.

The present study was conducted in eight districts of Karnataka state *viz*. Bidar, Koppal, Kolar, Chitradurga, Davanagere, Shivamogga, Udupi and Dakshina Kannada. The study area was selected based on the composite climate vulnerability index [Table-1].

Table-1 *Composite index of vulnerability*

SN	Districts	Composite index	SN	Districts	Composite index
1	Bidar	0.677	16	Chamarajanagar	0.579
2	Kolar	0.658	17	Mysuru	0.574
3	Yadgir	0.638	18	Tumakuru	0.573
4	Koppal	0.636	19	Hassan	0.571
5	Raichur	0.628	20	Bengaluru rural	0.558
6	Chitradurga	0.628	21	Mandya	0.557
7	Kalaburagi	0.625	22	Belagavi	0.555
8	Ramanagara	0.604	23	Ballari	0.543
9	Vijayapura	0.602	24	Bengaluru urban	0.538
10	Gadag	0.599	25	Chikkamagaluru	0.531
11	Dharwad	0.596	26	Uttara kannada	0.530
12	Kodagu	0.594	27	Dakshina kannada	0.528
13	Chikballapur	0.593	28	Udupi	0.486
14	Bagalkot	0.590	29	Davanagere	0.486
15	Haveri	0.580	30	Shivamogga	0.440
Average=0.577					

Source: Shivakumara and Srikantha Murthy (2019) [2]

For easy comparison, districts were classified as least vulnerable and highly vulnerable using below mentioned criteria. The arithmetic mean $(\bar{x})$ and standard deviation (SD) of composite vulnerability index were calculated in order to demarcate boundaries between least and highly vulnerable districts.

Least vulnerable districts

Mean minus standard deviation ($\bar{x}$ -SD) of composite vulnerability index to demarcate least vulnerable districts (0.440 to 0.528).

Highly vulnerable districts

Mean plus standard deviation ($\bar{x}$ +SD) of composite vulnerability index to demarcate the highly vulnerable districts (0.628 to 0.677).

Real investment on borewells

Following steps were taken to assess the trend of real investment by sample farmers in irrigation borewells. For each year of drilling borewells, investments on drilling and casing across all drilled irrigation borewells are added up. That reflects the total investment made in any specific year on all irrigation borewells. The nominal investment obtained is deflated using the 2011-12 wholesale price index as the base year = 100 to obtain the real investment on borewells. Since farmers may / may not strike a working borewell in their first attempt, the expenditure on failed borewells will also be considered and accounted for, if any, in previous years. The real investment on all borewells thus incurred during any given year is divided by the number of drilled borewells in that specific year. Real investment is measured per working borewell as it represents resource scarcity and magnitude of negative reciprocal externality. This is achieved by dividing real investment over that specific period on all borewells by number of functioning borewells.

Results and discussion

Real investment of borewell

The nominal expenditure on borewell depends on the depth of drilling and installation of casing, which depends on the probability of initial and premature failures controlled by negative reciprocal externalities. The marginal expenditure, of course, always depends on the time value of money, uncertainty and the opportunity cost. Therefore, the nominal investment is deflated on the basis of 2011-2012 wholesale price index. This analysis is carried out for both least vulnerable and HVD. Real investment on borewell in least and HVD of Karnataka are presented in [Tables-2] and [Tables-3]. The results reveal that, in case of LVD, the real investment increased from Rs 73233 in 1991 to Rs 309990 in 2016 with a growth rate of around 7 percent per annum. While real investment on borewell in HVD was Rs 128267 in 1987 and augmented to Rs 559594 in 2017 at the rate of 7.5 percent per annum. Real investment on borewell in least and HVD showing an increasing trend with a high magnitude over time is the true reflection of negative externality. Similar observations were made by Kiran Kumar (2014) [3] who studied real investment across the different groundwater institutions in eastern and central dry zone of Karnataka. The observations reveal that, real investment on borewell in HVD was found to be significantly higher than that in the LVD. Hence the hypothesis, transition cost of groundwater extraction is higher in highly vulnerable districts was accepted. This is for the reason that these districts are highly exposed to variation in the climatic variables.

Table-2 *Real investment on borewells in LVD*

Year	Average Drilling depth (feet)	Nominal Investment (Rs.)	WPI (2011-12)	Real investment (Rs.)
1991	250	21000	29	73233
1993	154	27720	34	81064
1994	180	32400	39	84147
1995	200	36000	42	86577
1997	180	32400	45	71348
2000	181	45250	53	84989
2001	290	72500	55	131443
2002	194	50440	57	88433
2003	220	72600	60	120699
2004	275	90750	64	141691
2005	320	121917	67	182214
2006	304	119880	71	168094
2007	295	107300	75	143649
2009	379	144608	84	172594
2010	323	163367	92	177966
2011	348	225000	100	225000
2012	348	285000	107	266604
2013	324	210000	112	186736
2014	290	296500	114	260373
2015	391	315000	110	287103
2016	419	346000	112	309990
CAGR				7.64

In both least and HVD, more or less, same growth rate in real investment was observed *i.e.*, about 7.5 percent per annum. However, in terms of absolute figures, the real investment in drilling borewells were high in HVD as compared to that in LVD.

Table-3 *Real investment on borewells in HVD*

Year	Average Drilling depth (feet)	Nominal Investment (Rs.)	WPI (2011-12)	Real investment (Rs.)
1987	190	25400	20	128267
1990	215	32000	25	126925
1992	210	37800	32	119773
1993	190	34200	34	100014
1994	240	54300	39	141025
1995	300	54000	42	129865
1996	260	65000	43	149438
1998	250	69000	48	143413
1999	260	46800	50	94192
2000	180	75600	53	141993
2001	285	58425	55	105925
2002	283	57913	57	101534
2003	220	104217	60	173263
2004	215	126979	64	198256
2005	293	142100	67	212379
2007	347	168925	75	226151
2008	230	221125	81	273972
2009	280	220516	84	263192
2010	287	256750	92	279695
2011	356	389500	100	389500
2012	401	425300	107	397848
2013	438	486000	112	432160
2014	490	658900	114	578617
2015	583	546000	110	497645
2017	800	624600	112	559594
CAGR				7.34

The finding implies that widespread cultivation of water guzzler crops like sugarcane and paddy has led to overexploitation of groundwater and there by increased investment on borewells in HVD. The hypothesis, There is positive relation between groundwater extraction and transition cost was accepted. The farmers in the HVD relied mainly on groundwater which acts as buffer against unreliability of surface irrigation and coupled with erratic rainfall. As a consequence, the farmers' are drilling borewells to higher depths leading to overexploitation of groundwater in the study area. The result of the study is supported by the research conducted by Shruthi Rajesh, *et al*., (2015) [4], on climate change and the status, trends and drivers of change in land use, water, air and forest resources of Karnataka state. The results of which revealed that in Karnataka the net availability of groundwater declined from 16.3 billion m^3 annually to 15.3 billion m^3 annually between 1992 and 2004 and to 14.8 billion m^3 in 2009. Overdraft of groundwater for irrigation has resulted in a decline in water levels making it increasingly difficult and expensive for people to have continued access to water even for drinking. Furthermore, irrigated rice is a heavy water consumer and it needs around 5000 liters of water to produce 1 kg of rice. The existing water rights and water rates (minimal) and free electricity would worsen the condition. The increase in depth of groundwater table in north–west India has three major negative effects [5]. (1) higher ground water pumping costs (2) growing tube well infrastructure costs and (3) abating groundwater quality. Ultimately the groundwater becomes unusable because of upwelling of salts from the deeper level. The share of borewells irrigation has increased exponentially, indicating the increased usage of ground water for irrigation by farmers. Incentives such as credit for irrigation equipment and subsidies for electricity supply further worsened the situation, leading to a sharp fall in water table.

Association between area under groundwater irrigation and climatic variables

Precipitation, temperature and evapotranspiration directly affect the recharging of groundwater and indirectly affect the extraction or discharge of groundwater. In some semiarid and arid areas, even small changes in precipitation can lead to significant changes in groundwater recharging. To measure the association between real investment on borewell and climatic variables, correlation coefficient analysis was done using the six important climatic variables *viz*., precipitation, wind speed, relative humidity, maximum temperature, minimum temperature, average temperature and the real investment. The results are presented in the [Tables-4] and [Tables-5].

Table-4 *Correlation between real investment on borewells and the climatic variables in LVD*

	Real Investment	Precipitation	Wind speed	RH	Temp. Max	Temp. Min	Temp. average
Real Investment	1.00						
Precipitation	0.00 (0.98)	1.00					
Wind speed	0.52 (0.006***)	0.00 (0.99)	1.00				
RH	-0.03 (0.90)	0.72 (0.00***)	-0.24 (0.24)	1.00			
Temp. Max	0.25 (0.20)	-0.61 (0.009***)	-0.14 (0.50)	-0.81 (0.00***)	1.00		
Temp. Min	0.38 (0.05**)	0.10 (0.63)	-0.58 (0.001)	0.08 (0.70)	0.49 (0.01***)	1.00	
Temp. average	0.38 (0.05**)	-0.28 (0.16*)	-0.44 (0.02)	-0.41 (0.03**)	0.85 (0.00***)	0.87 (0.00***)	1.00

*Note: *** indicate 1 percent level of significance ** indicate 5 percent level of significance, * indicate 10 percent level of significance*

Table-5 *Correlation between real investment on borewell and the climatic variables in HVD*

	Real Investment	Precipitation	Wind speed	RH	Temp. Max.	Temp. Min.	Temp. average
Real Investment	1.00						
Precipitation	-0.12 (0.51)	1.00					
Wind speed	0.27 (0.14)	-0.57 (0.00***)	1.00				
RH	-0.10 (0.60)	0.86 (0.00***)	-0.41 (0.02**)	1.00			
Temp. Max.	0.19 (0.29)	-0.88 (0.00***)	0.33 (0.07*)	-0.89 (0.00***)	1.00		
Temp. Min.	0.26 (0.16)	-0.05 (0.78)	-0.21 (0.26)	0.01 (0.95)	0.36 (0.04**)	1.00	
Temp. average	0.25 (0.17)	-0.59 (0.00***)	0.06 (0.73)	-0.61 (0.00**)	0.86 (0.00***)	0.78 (0.00***)	1.00

*Note: *** indicate 1 percent level of significance ** indicate 5 percent level of significance, * indicate 10 percent level of significance*

The results of the analysis in LVD [Tables-4] reveals that, real investment showed negative correlation with relative humidity (-0.03). On the contrary, real investment on borewell has positive association with wind speed (0.52), maximum temperature (0.25), minimum temperature (0.38) and average temperature (0.38). Further there is no association between real investment and the amount of rainfall received in LVD.

In case of HVD [Tables-5], the results reveal that, real investment showed negative correlation with precipitation (-0.12) and relative humidity (-0.10), in contrast to that, real investment on borewells has positive relationship with wind speed (0.27), maximum temperature (0.19), minimum temperature (0.26) and average temperature (0.25).

Since, precipitation and relative humidity have positive influence on groundwater level, the negative correlation coefficients were observed between precipitation, relative humidity and real investment.

In conclusion, real investment on borewells would increase with increase in wind speed, temperature and decrease with increase in relative humidity. However, in HVD, as the precipitation increases the real investment decreases.

Similar results were obtained by Zhao, *et al*., (2019) [6] in the study on effect of climatic and non-climatic factors on groundwater levels in the Jinghuiqu district of the Shaanxi Province, China showing that temperature had a higher negative correlation with groundwater levels ($p < 0.05$). Consequently, groundwater levels in the dry period decreased significantly (0.62 m/year) compared to groundwater levels in the wet period.

The evidences also correlated with the study conducted by Golam, *et al*., (2017) [7] which revealed that groundwater level reduced by 0.15-2.01 m, with an average of 1.04 m in different temperature change scenarios during the irrigation months (January to April). However, changes in groundwater levels are statistically significant at a confidence level of 95 percent only for a temperature increase of at least 2°C. The outcomes also demonstrate that a decline in groundwater level by 0.15-2.01 m caused an increase in irrigation cost by 0.05-0.54 thousand BDT ha^{-1}. In this way, climate change specifically influences the groundwater irrigation cost and farm profits.

Conclusion

The impact of climatic variables on transition cost of groundwater irrigation are marginally higher in highly vulnerable districts as compared to least vulnerable district.

Research Category: Agricultural Economics

Abbreviations: LVD: Least Vulnerable Districts, HVD: Highly Vulnerable Districts
CAGR: Compound Annual Growth Rate

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