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RESEARCH ARTICLE

Impact of Precipitation Variability on Ground Water Resources: A Comparative Assessment of Indian States

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Abstract

In recent years, many countries are witnessing climate change in the form of precipitation variability. Increasing demand of water because of growing consumption of water in various sectors in India is mounting enormous pressure on water resource management. Not only this, changes in cropping pattern and land-use pattern, over-exploitation of water storage and changes in irrigation and drainage are modifying the hydrological cycle in many climate regions and river basins of India. Therefore, this study aims to assess the precipitation variability and impact of climate change on ground water resources in selected sample regions in India. Source augmentation of restoration of water bodies and ground water has been taken as two components to assess the status of water resources. Linear regression model has been used in this study to calculate the actual correlation between annual mean rainfall and groundwater depth in the study area. Groundwater depth in this study has been taken as a dependent variable whereas impact of rainfall as an independent variable is examined in this study.

Keywords: Temperature; Precipitation; Source Augmentation; Impact Assessment; Climate Change

Introduction

Climate change has occurred in the past, is occurring now, and will occur in the future. The fluctuations range in magnitude from hundreds of millions of years to a few decades or less[1–5]. Global warming's primary issue is that climatic changes disrupt the water cycle. Studies indicate that the hydrological cycle is already being impacted in many cases[6–10]. As the warming process proceeds, it will exacerbate a variety of environmental concerns, the most serious of which will involve water supplies[10–13]. The relationship between groundwater and climate change is critical and cannot be stressed. The global amount of groundwater is estimated to be between 13% and 30% of the hydrosphere's total fresh water volume[14,15], and groundwater supplies 15% of the water utilized annually, with the remainder coming from surface water.

In the context of hydrology, climate change is anticipated to accelerate the hydrological cycle on a global scale, hence exacerbating the regional and temporal disparities in the allocation of hydrological resources [9,16]. The intensity of extreme rainfall events is expected to rise in many parts of the world as a result of global warming, even in places with decreasing mean rainfall (e.g., Wilby and Wigley, 2002). Thus, solutions for climate adaptation, such as emergency planning, engineering structure design, reservoir management, pollution control, and risk assessment, all rely on knowledge of the frequency of these catastrophic events (Kumke, 2001). Numerous research has been conducted on the problem of rainfall trends in India over the last century. Others have already examined long-term southwest monsoon/annual rainfall changes in India. Over the previous 50 years, long-term trends imply a large decline in the frequency of moderate-to-heavy rainfall events across the majority of India, as documented by Dash et al. (2009). This is supported by a large increase in the frequency and duration of monsoon breaks over India over the last few decades, as well as an increase in the frequency of extreme rainfall events (100 mm/day) in specific sections of the nation (Goswami et al., 2006). Not Just this due to the fact that trees are CO_2 sinks, reforestation in conjunction with new tree planting has been viewed as critical to keeping control over CO_2 levels in the atmosphere [10,17]. Any difference in precipitation regime and quantity, as well as temperature and evapotranspiration, has an effect on groundwater recharging. Groundwater recharge will often increase in locations with greater precipitation and vice versa. Groundwater recharge will also rise in locations with thawing permafrost [18,19]. The majority of the repercussions of changing the recharge rate will be negative. There is widespread consensus that many places with currently high precipitation are predicted to see increases in precipitation, whereas many areas with low precipitation and high evaporation, which are currently experiencing water scarcity, are expected to see rain declines [10,20]. With quickly changing conditions, the present infrastructure network will need to be rapidly reconfigured [18,21]. The main objective of this study is to analyze recent experiences in climate variability in terms of temperature and precipitation, to assess the impact of precipitation variability on regional water resources and groundwater availability and to determine vulnerability of regional water resources to climate change and identify key risks and prioritize adaptation responses.

This study entails the impact of climate change in terms of precipitation variability through an assessment of three sample states in India. Selection of sample states is based on the availability of homogeneous data. Precipitation variability, source augmentation of fresh water and ground water, status of groundwater resource in the sample states are the main components of assessments. Selected data has been validated through different government reports and primary studies. Finding of the study proves the seriousness of the issue and encourages the researchers and experts to explore more through presenting an innovative methodology and approach.

Objectives

- Analyze recent experiences in precipitation variability
- To assess the impact of precipitation variability on regional water resources and groundwater availability.
- Suggest a way forward in this regard

Methodology

(1) Andhra Pradesh (2) Telangana and (3) Rajasthan states have been selected as a sample state to do a comparative assessment. Data has been collected through data collection from various government Reports, Websites, Census Reports, State Ground Water Boards, Irrigation department, Central water Commission, Ministry of Jal Shakti and other concerned Departments of Andhra Pradesh, Telangana and Rajasthan, In the present study Qualitative analysis of secondary data has also been taken up. SPSS software has been used in this study to find out the actual correlation between annual mean rainfall and groundwater depth in the study area. SPSS software allows us to run a linear regression model by making one variable as a dependent variable and a couple of variables as an independent variable. Groundwater depth in this study has been taken as a dependent variable whereas impact of rainfall as an independent variable is examined in this study. Within the limits of climate change this article examines the possibilities for sustainable development of water resources, both above and below ground, in selected Indian States.

Study area

Rajasthan, Andhra Pradesh and Telangana have been selected as a strata to compare the status of water resources as selected sample states present the diversity in their topographic, climatic, demographic and socio-economic conditions. Time and financial constraints limited the Authors to compare three states based on the data availability.

Introduction of Sample States

Andhra Pradesh

Andhra Pradesh the ”Rice Bowl of India” is present in the south-eastern part of the Precambrian Shield of India. Andhra Pradesh is traversed by three major, many medium and minor rivers making it a ”Riverine” state. It is drained by the Godavari, Krishna and Penna rivers majorly which flow into the Bay of Bengal and few areas by Vamsadhara and Nagavali originating in the Eastern Ghats. Geology of Andhra Pradesh ranges from the oldest Archaean group of rocks to recent alluvium. State depicts the spatial variation of Rainfall. Both southwest monsoon and northeast monsoon bring rainfall in the state. Southwest monsoon extends from June - September accounting for two- thirds of the annual rainfall whereas northeast extends from October - November accounting for the remaining one-third of the annual rainfall. Normal rainfall is 966.0 mm.

Rajasthan

Rajasthan also known as 'Rajputana'(Land of the kings) is situated in the northwest part of the country. Because 61% of the area is desert or semi-desert and is called India's desert. Rajasthan lies between latitudes 23°03'-30°12' N and longitudes 69°29'- 78°17'E. Rajasthan is characterized by a highly varied and complex geological sequence of rocks ranging from Archaean Bhilwara Supergroup to sub-recent alluvium as well as windblown sand. The Climate of Rajasthan varies with temperature and rainfall between West and East of Aravallis. The western part of Aravallis viz., Rajasthan Desert plains have extremely high range of temperatures in India compared to the eastern part of Aravallis. This peculiar characteristic of climate between east and west of Aravallis is termed the 'Climatic Divide'. Rajasthan's rainfall is highly erratic and it varies as high as 50 to 70%. Rajasthan receives the lowest Rainfall in India. The Average Rainfall is 52.26 cm. Rajasthan gets two seasons of rainfall one in the months of July-Sept holding 75% -90% and the other in the months of December-Feburary holding 10% of Rainfall.

Telangana

Telangana is strategically situated in the Deccan plateau of peninsular India. Telangana state was formed on June 2nd 2014 by the bifurcation of former Andhra Pradesh State and became the 29th state of India with Hyderabad city as its capital. It falls in the geographical coordinates of 15°46'N lat to 19°47'N lat and 77°16'E long to 81°43'E long. Telangana is segregated into two parts by Telangana Plateau and Golconda Plateau occupying the major portions in the North and South. Geologically Telangana is characterized by rock formations belonging to Archean to Quaternary age. Telangana falls in a semi-arid zone. South-west monsoon brings 80% of the annual rainfall and retreating monsoon accounts for 13% rainfall in Telangana. The average rainfall is 906.6 mm. The rainfall is uneven ranging 900-1500 mm in Northern

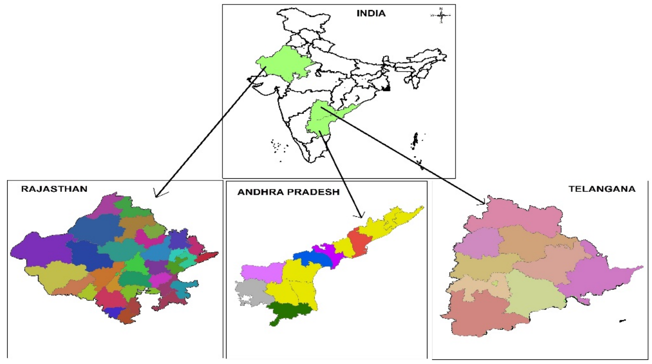

Fig. 1. Study Area: Rajasthan, Andhra and Telangana

Result and Discussion

Rainfall and Groundwater Depth- Andhra Pradesh

The average annual rainfall in Andhra Pradesh varies between 558 m to 1200 m, depending on the region. Most districts in the north-eastern (Figure 2) coastline region receive high rainfall, whereas southern districts near Telangana receive comparatively less. The coefficient of variation, on the other hand, is relatively high in southern regions and continues to decrease as one moves north-eastern in the state. This variation in rainfall has an impact on groundwater depth across the state, which may be shown on a map (Figure 3). Districts with substantial yearly rainfall fall into the group of districts with very shallow groundwater depths. Districts with minimal annual rainfall, on the other hand, reveal that the depth is extremely high in most part of the district.

Rainfall and Groundwater Depth- Telangana

The average annual rainfall in Telangana varies between 650 m to 1200 m, depending on the region. Districts in the north and north-eastern (Figure 4) region receive high rainfall, whereas southern districts near receive comparatively less rainfall hence coming under the first category. The coefficient of variation, on the other hand, is relatively high in southern districts and continues to decrease as one moves north-eastern in the state. This variation in rainfall has an impact on groundwater depth across the state, which may be shown on a map (Figure 5). Districts with substantial yearly rainfall fall into the group of districts with very shallow groundwater depths. Districts with minimal annual rainfall, on the other hand, reveal that the depth is extremely high in most parts of the district.

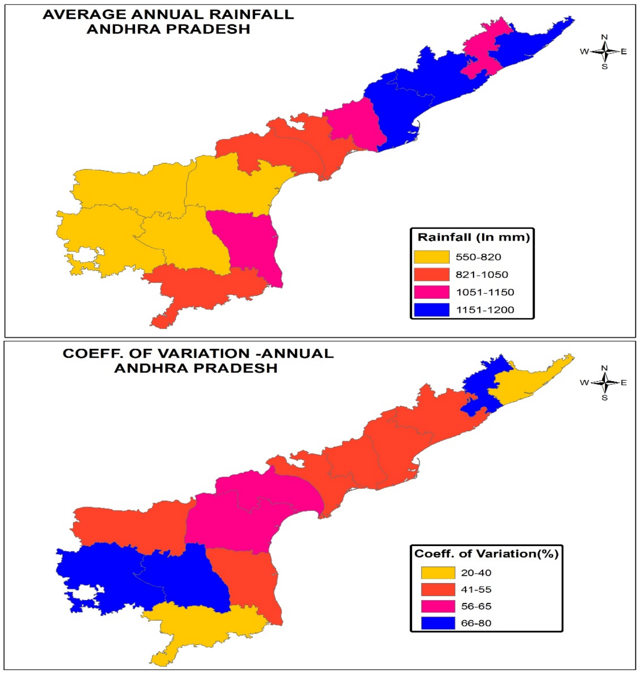

Fig. 2. Annual Rainfall and Coefficient of Variance – Andhra Pradesh

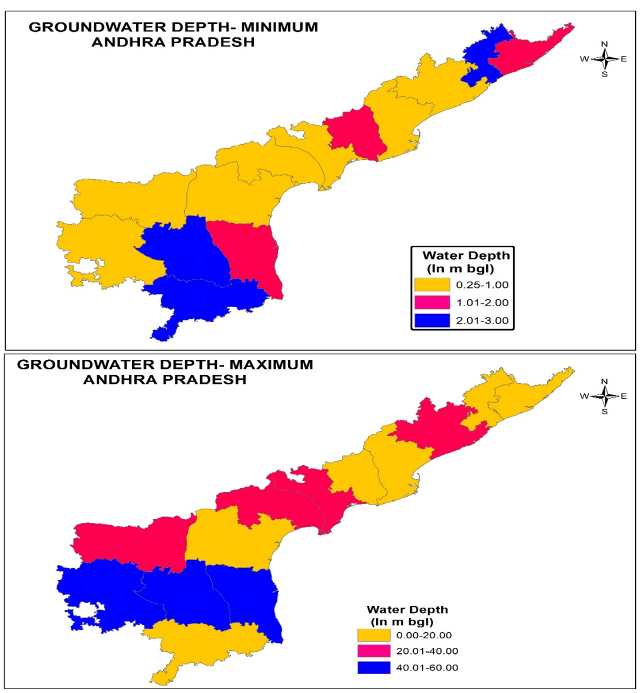

Fig. 3. Groundwater Depth Minimum & Maximum- Andhra Pradesh

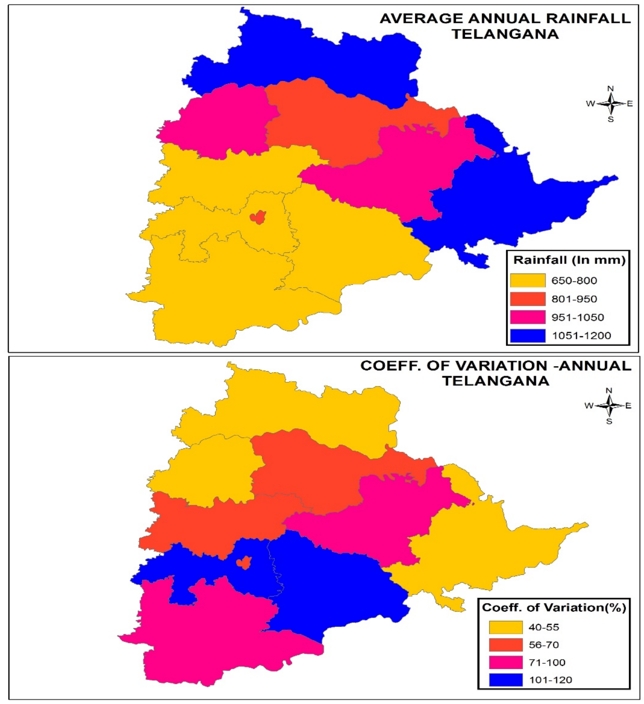

Fig. 4. Annual Rainfall and Coefficient of Variance – Telangana

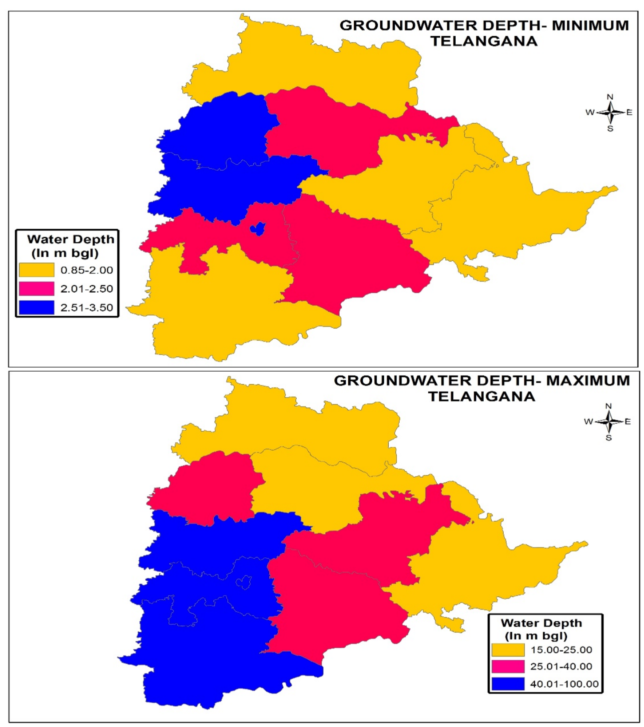

Fig. 5. Groundwater Depth Minimum & Maximum- Telangana

Precipitation Variability in Selected Sample States

The average annual rainfall in Rajasthan varies between 200 m to 1000 m, depending on the region. Districts in the south and south-eastern (Figure 6) region receive high rainfall, whereas western districts near receive comparatively less rainfall hence coming under the first category. The coefficient of variation, on the other hand, is relatively high in northern districts and continues to decrease as one moves south-eastern and western part of the state. This variation in rainfall has an impact on groundwater depth across the state, which may be shown on a map (Figure 6). Districts with substantial yearly rainfall fall into the group of districts with very shallow groundwater depths. Districts with minimal annual rainfall, on the other hand, reveal that the depth is extremely high in most parts of the district.

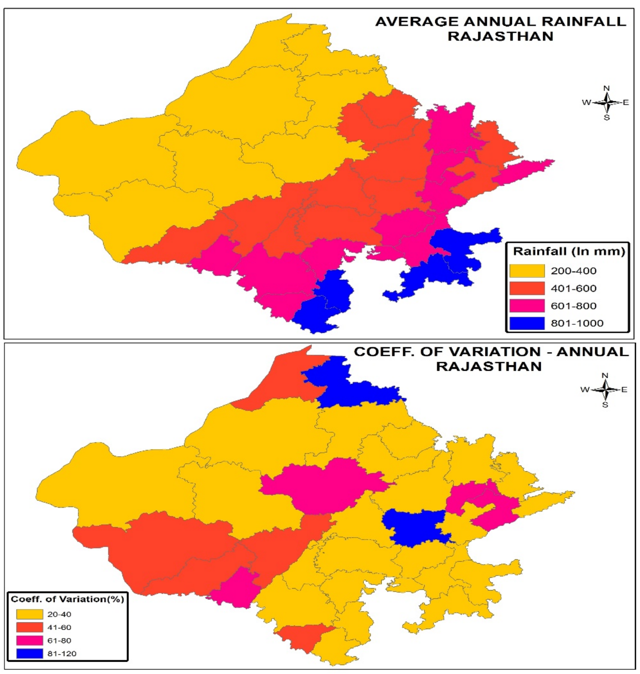

Fig. 6. Annual Rainfall and Coefficient of Variance – Rajasthan

Table 1. Variables Entered/Removed (b)

Model	Variables Entered	Variables Removed	Method
1	Mean Annual Rainfall(a)	.	Enter

a All requested variables entered, b Dependent Variable: Groundwater Maximum Depth

The above table (Table 1) obtained through a linear regression test in SPSS. It provides the basic characteristics of the model viz. level of groundwater depth as a dependent variable whereas mean annual rainfall as independent variable.

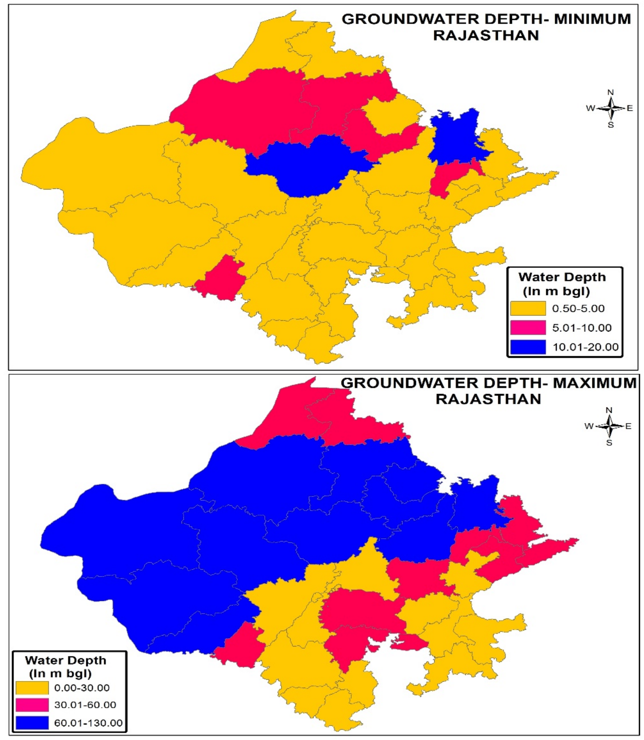

Fig. 7. Groundwater Depth Minimum & Maximum- Rajasthan

The model summary table is as under.

Table 2. Model Summary (b)

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.664(a)	.440	.390	13.30672

a Predictors: (Constant), Mean Annual Rainfall, b Dependent Variable: Groundwater minimum depth

The R-value represents the correlation between maximum groundwater depth, and amount of rainfall received; the value is greater than 0.4 or 40%, which is considered for further analysis; and the value is.664 or 66.4 percent(Table 2), which is very good for model fit. Because the R-squared value is larger than 0.4, the total variance explained by the variables is greater than 0.4, indicating that the model is successful and accurate enough to describe the water usage, which is 0.440 or 44.0 percent. The reduced R-square informs us how common the discoveries are.

The adjusted R-square indicates the generalisation of the results, or the variation in the sample results. It is essential to have a minimum difference between R-square and Adjusted R-square, and the same number is.390 or 39.0 percent, which is a little difference, therefore it is good. As a result, the model summary table is a great place to start.

In order to conduct this analysis, the P-value and 95% confidence level for this table were determined in advance. As

Table 3. ANOVA (b)

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	1533.208	1	1533.208	8.659	.013(a)
	Residual	1947.758	11	177.069		
	Total	3480.965	12			

a Predictors: (Constant), Mean Annual Rainfall, b Dependent Variable: Groundwater Maximum Depth

Table 5. Residuals Statistics (a)

	Minimum	Maximum	Mean	Std. Deviation	N
Predicted Value	1.1123	1.2111	1.1762	.03333	13
Residual	-.85496	1.41245	.00000	.71144	13
Std. Predicted Value	-1.915	1.049	.000	1.000	13
Std. Residual	-1.151	1.901	.000	.957	13

a Dependent Variable: Groundwater Maximum Depth

a result, a p-value of less than 0.05 is considered statistically significant. As a result, the impact is significant. As a result, the findings are extremely important. Similarly, the F ratio is a measure of how well a model predicts a given variable after taking into account the model's inaccuracies. An efficient model can be created with a F ratio of 8.659, which is larger than 1. It explains the appropriateness of sample for carrying out the test. There is a chance to reject the null hypothesis that there is a significant difference in groundwater depth and rainfall received, based on these results because the ANOVA's p-value is below the tolerable significance level. There is a strong correlation between annual rainfall and groundwater depth (Table 3).

Table 4. Coefficients(a)

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	81.316	18.132		4.485	.001
	R_M	-.055	.019	-.664	-2.943	.013

a Dependent Variable: Groundwater Maximum Depth

The estimated (predictors) of the independent variables and the dependent variable were shown to be related in this study. The anticipated value increases or decreases by the same percentage for each unit change in parameter estimates. The use of effect size and parameter estimates in univariate analysis of variance, which is also used in cross-sectional approaches, is still an option. Regression parameters like R square and adjusted R square value (0.440 and 0.390) are identical to those in the previous approach, which is fixed effects dummy variable (t values, significant levels), but the regression value of the dummy variable is different because it is coexisting with different dummy coexistence. This is shown in the tables above. As a result of this study, it is clear that depth of ground water and mean annual rainfall has a strong correlation with the factors examined (Table 4).

State-level performance on water resource management ranking according to Composite Water Index Scores

The composite water index score is 68 out of 100 in Andhra Pradesh and 48 and 50 in Rajasthan and Telangana respectively the score of the Telangana is 50 (Figure 8)

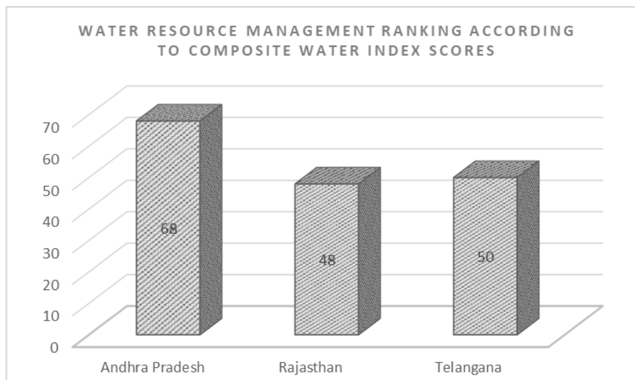

Fig. 8. Water resource Management Ranking

Source: Based on NITI Aayog report on Composite Water Management Index June 2018

Source augmentation and restoration of water bodies

The study focuses on the restoration of surface water bodies, such as rivers, ponds, and tanks, to boost irrigation potential in the state by reducing seasonal variations in water availability. This component includes only one indicator, which measures the area currently irrigated by restored water bodies out of the total irrigation potential of restored water bodies. The source augmentation of Groundwater focuses on the identification and recharging of critical groundwater resources. (Note: Base Year is 2015-16 and the Current Year is 2016-17)

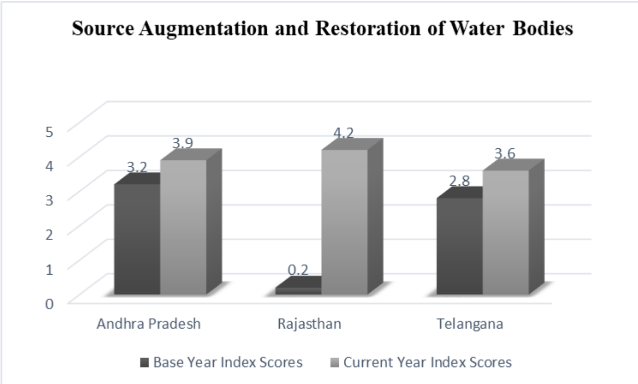

Fig. 9. Source augmentation and restoration of water bodies

Source: NITI Aayog report on Composite Water Management Index June 2018

The score of the source augmentation and restoration of water bodies in the base year is 3.2 in Andhra Pradesh and the current year score is increased that is 3.9, the score of Rajasthan is 0.2 in the base year and the current year score is increased that is 4.2, the score of Telangana is 2.8 in the base year and the current year score is increased that is 3.6 Figure 9. Study concludes that there is an increase in the source augmentation and restoration of water bodies because of increasing awareness among grass-root level stakeholders and effort of Government and Non Government Organizations in Rajasthan to conserve the water.

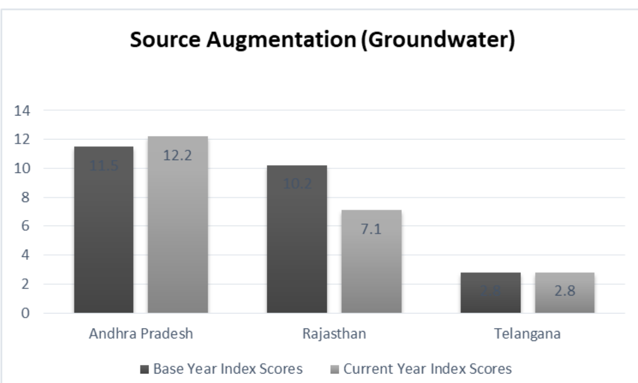

Fig. 10. Source augmentation (Groundwater)

Source: NITI Aayog report on Composite Water Management Index June 2018

The score of source augmentation (Groundwater) in the base year was 11.5 in Andhra Pradesh which increased to 12.2, the score of Rajasthan also depicts decrease from 10.1 the base year to 7.1 current year but compared to these two state status Source Augmentation of Groundwater is slow Figure 10.

Even after mild rainfall, most of the districts in the research area had a deep groundwater level, according to the findings. The association between groundwater level and climate change is found to be similar in all three sample states, highlighting the impact of climate change on groundwater levels. The irregularity in rainfall affects the depth of groundwater in all three states, as seen by the map of rainfall and groundwater depth.

Conclusion

The linear regression analysis shows a high level of variation in the rainfall in three selected sample states, witnessing the change in climate since the last few decades. The diminishing trend of ground water level in three sample states reflects the criticality of ground water resource availability for near future. Analysis of climate change and ground water both depends upon temporal variation of one to three decades. Study reveals that there is an increase in the source of surface water augmentation because of development of conservation techniques at all level. But the level of groundwater is declining in Rajasthan during last few decades that shows the impact of climate change on the state. Although the trend analysis of ground and surface water restoration has increased in Andhra Pradesh and Telangana compared to the base year but it is not sufficient as per the demand of water in respective states. Besides that the demographic increase in India is putting enormous pressure on the use of groundwater as it is not possible to cater the requirement of potable water during the non-monsoon season in the selected sample states. Majority of the population in respective states, still depends upon agricultural and other primary sectors. Paddy crops are the dominant crops and groundwater availability is an essential requirement in absence of surface water availability during the non-monsoon season. The study concludes that irregularity in rainfall is resulting in less percolation of water into the surface affecting the level of groundwater in all three states, as validated through the map of rainfall and groundwater depth. The impact of precipitation variability is affecting not only the socio-economic condition but also questioning the sustainability of groundwater resources in the region. Although, effort of water holders are praiseworthy in conserving the available surface and rainwater but it still requires to be implemented at macro level to bring a homogeneous development of rural and urban regions. There is considerable gap between the infrastructure created and service available at the household. Strengthening of mega projects through international collaborations for better sustainability of projects, the operations and maintenance of projects and capacity development programs, such as Asian Development Bank (ADB) and United Nation's development funds for developing countries will strengthen the water resource development.

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