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GEO-STATISTICAL ANALYSIS OF THE CHANGE IN THE UNDERGROUND WATER LEVEL AT DISTRICT LEVEL IN INDIA

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Abstract

The general objective of this paper was to study the geostatistics of the change in underground water level at district level in India during the first and the second decade of 21st century. Underground water level data was collected from Central Ground Water Board (CGWB) Government of India. Irrigated area using underground water data at district level was collected from AQUASTAT – FAO database. Spatial Autocorrelation (Morans I) statistics was used to measure spatial pattern. Optimized Hot Spot Analysis was performed to create a map of statistically significant hot and cold spots using the Get is-Ord Gi statistic. The results show the spatial pattern of the ground water level change is highly clustered, the z-score of 32.68 verify that there is less than 1% likelihood that this clustered pattern could be the result of random chance. Under Ground Water level was found decreased in 137 districts with more than 90 percent confidence. The hot spots of high water change problem were found as 92, 24 & 21 respectively at the confidence level of 99%, 95% & 90%. The findings of the work will help the policy makers to develop the programmes to minimise the problem of the groundwater in the problem prone districts*

***Keywords**: Underground water level, spatial autocorrelation, Geographically Weighted Regression model.*

Introduction

The volume of gravitational water contained in the pores, fissures and fractures of the water-saturated strata of the Earth's crust represents the natural storage of water underground. The geographical distribution of ground water is closely related to the geological structure of the Earth's crust. It also depends considerably on the climatic factors: precipitation, condensation and evaporation, and particularly on the infiltration. Since runoff also depends on these factors, there is a strong relationship between ground water and runoff: ground water draining to rivers arc included in the volume of runoff, being its most stable contribution to the hydrograph especially during dry periods and drought (Shiklomanov et al., 2017).

In our rapidly changing world where there are many challenges regarding water, it is necessary to pay ample attention to groundwater and its role in securing water supplies and in coping with water-related risk and uncertainty(Van der Gun, 2012).

In the coming century, climate change and a growing imbalance among freshwater supply, consumption, and population will alter the water cycle dramatically. Many regions of the world are already limited by the amount and quality of available water. In the next 30 yr alone, accessible runoff is unlikely to increase more than 10%, but the earth's population is projected to rise by approximately one-third. Unless the efficiency of water use rises, this imbalance will reduce freshwater ecosystem services, increase the number of aquatic species facing extinction, and further fragment wetlands, rivers, deltas, and estuaries (Jackson et al., 2017).

Water is a naturally circulating resource that is constantly recharged. Therefore, even though the stocks of water in natural and artificial reservoirs are helpful to increase the available water resources for human society, the flow of water should be the main focus in water resources assessments. The climate system puts an upper limit on the circulation rate of available renewable freshwater resources (RFWR). Although current global withdrawals are well below the upper limit, more than two billion people live in highly water-stressed areas because of the uneven distribution of RFWR in time and space. Climate change is expected to accelerate water cycles and thereby increase the available RFWR. This would slow down the increase of people living under water stress; however, changes in seasonal patterns and increasing probability of extreme events may offset this effect. Reducing current vulnerability will be the first step to prepare for such anticipated changes (Oki, 2006).

Water resources of a country constitute one of its vital assets. **India** receives annual precipitation of about 4000 km3 (Kumar et.al, 2007). There is now clear evidence for an observed change in global surface temperature, rainfall, evaporation and extreme events since the start of 20th century (Mall et.al, 2007). Groundwater is the most preferred source of water in various user sectors in India on account of its near universal availability, dependability and low capital cost (Jhha et.al, 2007). Water scarcity has emerged, especially during the past decade, as an important theme in discussions on India's future. Global discourse suggests that India, and other developing countries in Asia and Africa, can respond to water scarcity-and the resultant water poverty (Shah et.al, 2007).

Irrigation is important in India where one-third of the land surface is semi-arid and the rainfall is seasonal and erratic. The irrigated area in the country has almost doubled during the last 25 years and now stands at 43 million ha. Groundwater contributes to 40 % of all irrigation. Apart from providing irrigation, groundwater has been contributing to irrigated agriculture in many other ways and has, therefore, become a vital factor in the country's plans for agricultural development (Jain, 1977).

The major objective of this work was to find the spatial pattern of water level decease at district level in India and to estimate hot spots of ground water level decease at district level in India.

2 Methods

2.1 Study Area

India is one of the oldest civilizations in the world with a kaleidoscopic variety and rich cultural heritage. It has achieved all-round socio-economic progress since its Independence. It covers an area of 32,87,263 sq. km (1,269,346 sq mi), extending from the snow-covered Himalayan heights to the tropical rain forests of the south. As the 7th largest country in the world, India stands apart from the rest of Asia, marked off as it is by mountains and the sea, which give the country a distinct geographical entity. Bounded by the Great Himalayas in the north, it stretches southwards and at the Tropic of Cancer, tapers off into the Indian Ocean between the Bay of Bengal on the east and the Arabian Sea on the west. Lying entirely in the northern hemisphere, the mainland extends between latitudes 8° 4' and 37° 6' north, longitudes 68° 7' and 97° 25' east and measures about 3,214 km from north to south between the extreme latitudes and about 2,933 km from east to west between the extreme longitudes. It has a land frontier of about 15,200 km. The total length of the coastline of the mainland, Lakshadweep Islands and Andaman & Nicobar Islands is 7,516.6 km ("Profile | National Portal of India," 2011).

2.2 Data Used

Central Ground Water Board (CGWB) Ministry of Jal Shakti, Department of Water Resources, River Development and Ganga Rejuvenation. Government of India. http://cgwb.gov.in/publications.html. India Districts ADM2 GADM. (2010). Retrieved September 30, 2017, from Arcgis.com website: https://hub.arcgis.com/datasets/2b37b84e67374fb98577c20ef8be6c62_0

2.3 Work Flow

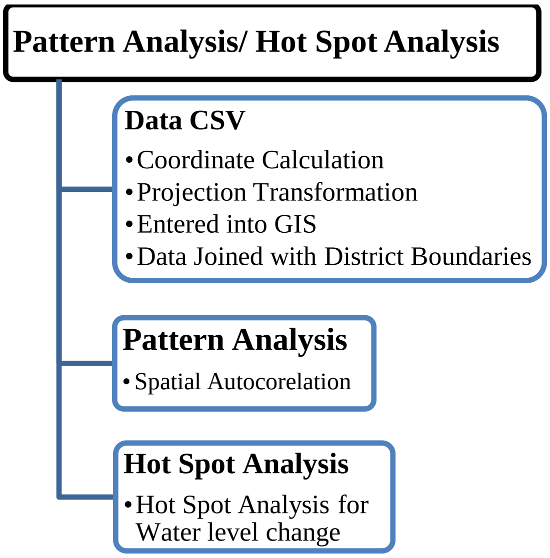

Figure 1 Work Flow

2.3 Data Analysis

2.3.1 Spatial Pattern

Measures spatial autocorrelation based on feature locations and attribute values using the Global Moran's I statistic.

The Moran’s I statistic for spatial autocorrelation is given as Eq.1:

$$I = \frac{n}{S_0} \frac{\sum_{i=1}^{n} \sum_{j=1}^{n} w_{i,j} z_i z_j}{\sum_{i=1}^{n} z_i^2} \quad (1)$$

Where, z_i is the deviation of an attribute for feature from its mean (x_i - $\underline{X}$), is the spatial weight between feature i and j, n is equal to the total number of features, and S_0 is the aggregate of all the spatial weights:

$$S_0 = \sum_{i=1}^{n} \sum_{j=1}^{n} w_{i,j} \quad (2)$$

The z_i-score for the statistic is computed as:

$$z_I = \frac{I - E[I]}{\sqrt{V[I]}} \quad (3)$$

Where:

$$E[I] = -1/(n-1) \quad (4)$$

$$V[I] = E[I^2] - E[I]^2 \quad (5)$$

2.3.1 Hotspot analysis

Getis-Ord Gi* statistic was used to identify hot spots.

The Getis-Ord local statistics is given as follows:

$$G_i^* = \frac{\sum_{j=1}^{n} w_{i,j} x_j - \bar{X}\sum_{j=1}^{n} w_{i,j}}{S\sqrt{\frac{\left[n\sum_{j=1}^{n} w_{ij}^2 - \left(\sum_{j=1}^{n} w_{i,j}\right)^2\right]}{n-1}}} \quad (6)$$

Where x_j is the attribute value for feature j. w_{ij} is the spatial weight between feature i and j. n is equal to the total number of features and:

$$\bar{X} = \frac{\sum_{j=1}^{n} x_j}{n} \quad (7)$$

$$z_I = \sqrt{\frac{\sum_{j=1}^{n} x_j^2}{n} - (\bar{X})^2} \quad (8)$$

Getis-Ord statistic is a z-score so no further calculations are required.

Given incident points or weighted features (points or polygons), creates a map of statistically significant hot and cold spots using the Getis-Ord Gi* statistic. It evaluates the characteristics of the input feature class to produce optimal results.

3. Results

Table 1 shows the Spatial pattern of water level decease at district level in India.

Table 1 Global Moran's I Summary

Moran's Index:	0.212155
Expected Index:	-0.001686
Variance:	0.000043
z-score:	32.68644
p-value:	0

Given the z-score of 32.68, there is a less than 1% likelihood that this **clustered pattern** could be the result of random chance.

Table 2 shows the Hot/Cold spots of ground water level decease in India during 2001-10 to 2011-17.

Table 2 Hot/Cold spots of ground water level decease in India during 2001-10 to 2011-17.

Water level change	Confidence level	No. of Districts
Under Ground Water level increased	Cold Spot - 99% Confidence	60
	Cold Spot - 95% Confidence	48
	Cold Spot - 90% Confidence	38
No Significant Change	Not Significant	311
Under Ground Water level decreased	Hot Spot - 90% Confidence	21
	Hot Spot - 95% Confidence	24
	Hot Spot - 99% Confidence	92
Total		**594**

Data Source: Central Ground Water Board, India.

Discussion

The major findings of this study are first there is more ground water change in the states of Punjab, Haryana, Delhi, Northeast part of the Rajasthan and Western Uttar Pradesh. Secondly the district lying in the western part of the Gujrat is also problem area. Thirdly in southern part of the India eastern districts of the Tamil Nadu are the worst hit areas

The major research question answered in the present work was to find the spatial and temporal variability in term of ground water change at district level. The research explored the potential use of hot spot analysis provided by ArcGIS platform for geospatial analysis. The findings will be helpful for all stockholders working to minimise the ground water problem.

Acknowledgement

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Conflict of interest

The authors declare no competing financial interests.

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