



## Effect of global climate change on groundwater resources using geostatistics and linear regression method

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### General Note



Article is recommended to print as color version in recycled paper. *Save Trees, Save Climate.*

### ABSTRACT

Groundwater is one of the important natural resources useful for irrigation, drinking, industries etc. Groundwater usage is increasing day by day and to prepare the long term management strategy for groundwater development, it is important to understand the past groundwater level scenario. Global climate change has large impact on the natural resources and it is necessary to quantify its effects. The objective of the present study is to analyze spatial and temporal variability in the groundwater and rainfall with respect to climate change over Wainganga Sub-basin. Groundwater level data has been obtained from 41 observation wells of Wainganga sub-basin Nagpur District, Maharashtra, India. Linear regression and geostatistical method were used to analyze the spatial and temporal variation of groundwater within the basin. Groundwater level trends and rainfall were observed from 1990 to 2012 within Wainganga sub-basin and it is found that the groundwater levels may be correlated with the climate variability. Groundwater level trends were also analysed for La Nina and El Nino years for past 22 years using geostatistics tool within Geographical Information

System (GIS) environment. Study also identifies sub-watersheds which were observed to be more affected by climate change within Wainganga sub-basin and necessary measures are suggested depending upon the severity.

**Keywords:** Groundwater, climate, geostatistics, La Nina, El Nino

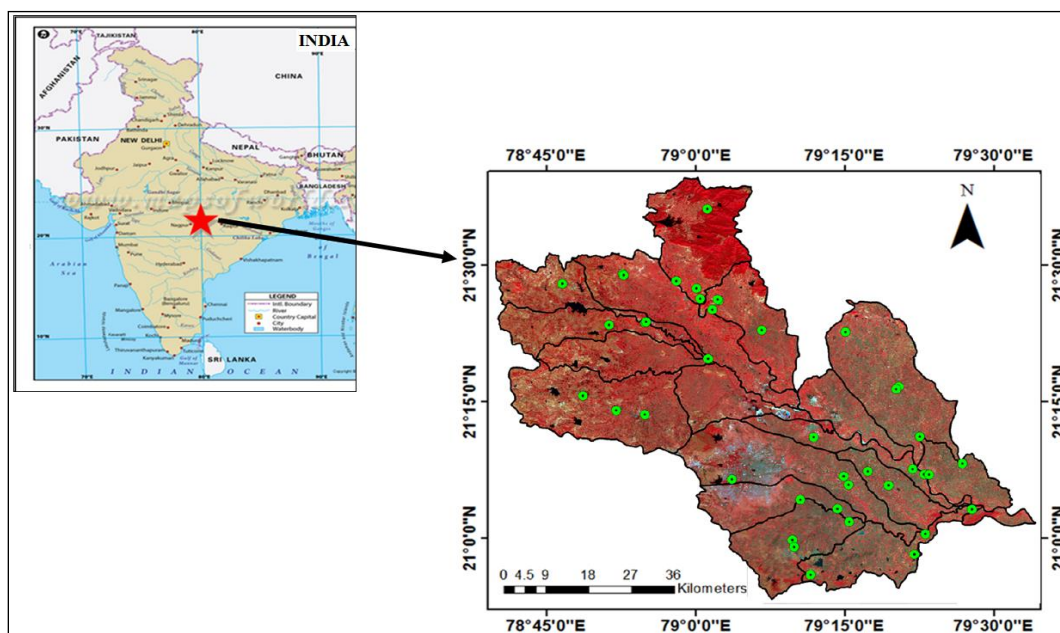
## 1. INTRODUCTION

Global climate change is a change in average weather conditions or in the time variation of weather around longer-term average conditions (NRC, 2010). It has direct relation to the hydrologic cycle which may influence the surface and groundwater resources. Particularly, groundwater is the important natural resources useful to satisfy various needs for drinking, irrigation, industries etc. Approximately 92 % of water for irrigation in India which is largely dependent on the agriculture is met through groundwater. As indicated in the preliminary consolidated report on effects of climate change on water resources, the annual groundwater draft in India is 231 km<sup>3</sup> out of which 213 km<sup>3</sup> is for irrigation use and 18 km<sup>3</sup> is for domestic and industrial use (NWM, 2008). Changes in the global climate have large impact, sometime specific region within the country may face floods like situation and at the same time some of region can face severe drought. Various studies have been carried out in the past based on the effect of global climate changes on groundwater resources at regional or basin level (Grechushnikova et al. 2015). Simonovic (2010) presented an approach for the assessment of climate change impacts on a local watershed scale to assess the spatial distribution of the vulnerability and risk with respect to change in global climate condition. Wang and Zhao (2015) studied the spatio-temporal variability of groundwater depth in desert-oasis ecotone and it was observed that the natural seasonal fluctuation in climate did not have a significant impact on groundwater depths but other local factors such as intensive irrigation were the major factors responsible for groundwater level fluctuation. Scanlon et al.(2006) described the Impacts of climate variability and LU/LC changes on groundwater recharge in semiarid and arid regions; higher recharge occurred in SW regions of US in El Nino years as compared with La Nina years. Analysis of the impact of change in groundwater related hydrological fluxes using integrated hydrological modelling (Stoll et al., 2011). Dragoni and Sukhija (2008) analyzed various methods for studying the relationships between climate change and groundwater and presented the main areas in which hydrogeological research should focus in order to mitigate the likely impacts. Green et al. (2011) stated that the Impacts of climate change on groundwater are due to natural and human induced variability and it can be quantified effectively by understanding the joint behaviors of climate and groundwater. Kidmose et al. (2013) attempted to estimate the impact of climate change on future groundwater levels using extreme value statistics. Susilo et al. (2013) developed one-dimensional GWL fluctuation model using Excel for the tropical peat land areas under the effect of El Nino Southern Oscillation (ENSO). Tirkey et al. (2012) performed spatio-temporal rainfall trend analysis using interpolation in GIS and provided conceptual understanding for developing large water harvesting structures in those regions which shows an increase in rainfall, and the need for developing a number of small water harvesting structures to recharge the groundwater in rainfall declining zones.

The objective of the present study was to understand the effect of global climate changes on groundwater resources at the basin level. Wainganga basin was selected for the study and within this basin 18 sub watersheds were selected. Linear regression and geostatistical methods were applied within GIS environment; effects of El Lino and La Nina years on the groundwater level and rainfall within the basin was observed, data were used from 1990 to 2012. It was observed that the impacts of global climate change were recorded during these periods and which have been discussed for some sub watersheds within the basin in this study.

## 2. STUDY AREA

Wainganga basin is selected as the study area which is in Nagpur district of Maharashtra, India. It lies between north latitudes 20°35' and 21°44' and east longitudes 78°15' and 79°40' and falls in Survey on India topo-sheets 55 K, O and P, with an elevation about 310 m above mean sea level. Kanhan and Pench are the main rivers flowing through the district. Major crops in entire district are jowar, cotton, wheat and pulses. Nagpur district has a semi arid climate; winter lasts from October to February and December & January are severely cold months. The average day temperature is about 27°C while that of night is about 14° C and sometimes it can drop down even by 5°C. From the month of March temperature starts increasing. May is the hottest Month, with average temperature of about 40°C rising even upto 47°C. Nagpur district mainly experiences rainfall from southwest monsoon. It rains from June to September. The western parts of the district receive an average rainfall of 800 mm to 900 mm and other parts of district receive 1000 mm to 1200 mm annual rainfall. Wainganga basin has 40 sub-watersheds within Nagpur district, out of which 18 sub-watersheds are selected for study (Figure 1) and its total geographical area is approximately equal to 3320 km<sup>2</sup>. Nagpur district has varied geological set up; it has all the rocks types like igneous, sedimentary and metamorphic. The subwatersheds were selected on different geologic formations. Observation well data for 18 sub-watersheds were obtained from CGWB and GSDA.



**Figure 1** Map of the study area with the location of observation wells and sub-watershed boundary

### 3. METHOD

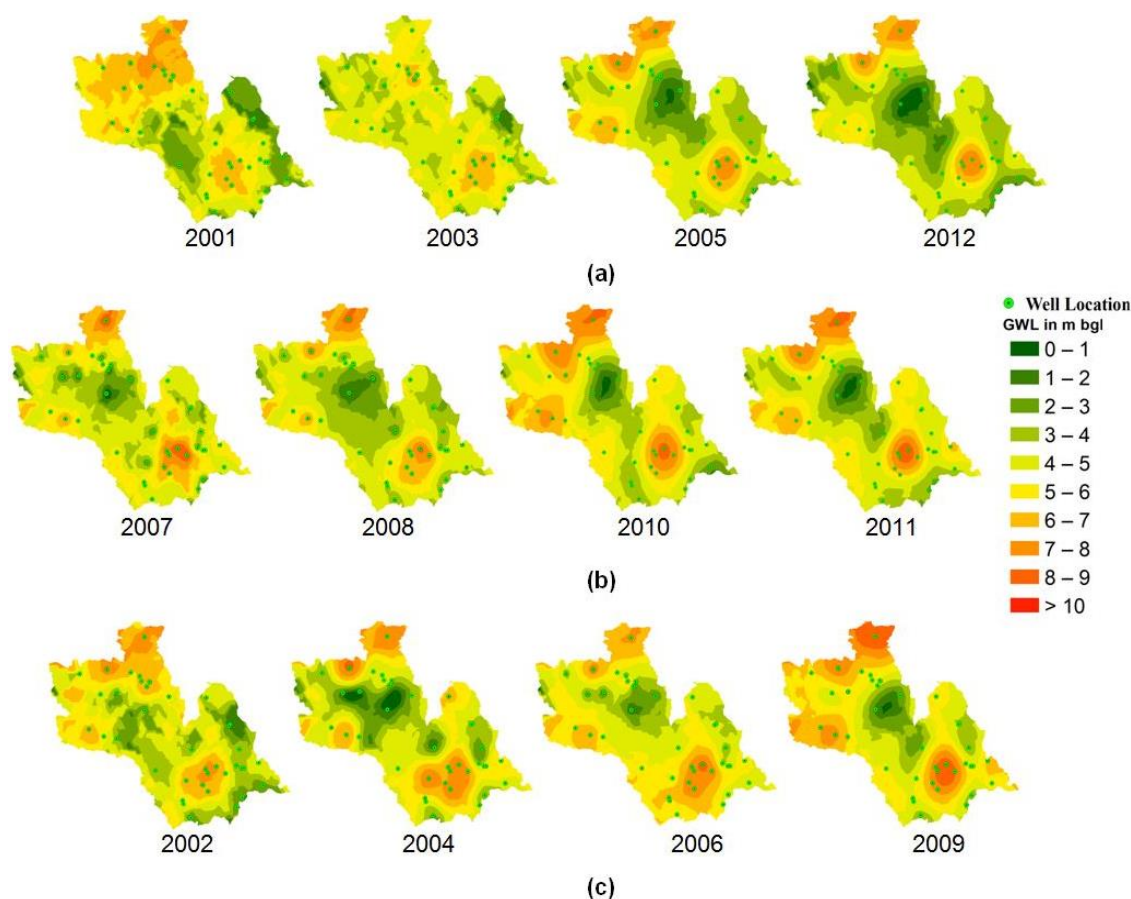
To assess the impact of climate change on groundwater resources, groundwater level data of 41 observation wells for post monsoon season and average monthly rainfall data from June to September throughout the basin for 1990 to 2012 have been used for analysis. Groundwater level data were obtained from the Central Ground Water Board (CGWB) and Groundwater Surveys and Development Agency (GSDA), rainfall data from Indian Metrological Department (IMD). National Oceanic Atmospheric Administration (NOAA) uses Oceanic Nino Index (ONI) to identify El Nino (warm) and La Nina (cool) events. ONI is the running 3 months mean Sea Surface Temperatures (SST) anomaly for the Nino 3.4 region i.e., 5°N-5°S, 120°-170°W (NOAA 2015). Events are defined as 5 consecutive overlapping 3-month periods at or above the +0.5° anomaly for El Nino events and at or below the -0.5 anomaly for La Nina events. Based on these Oceanic Nino Index (ONI) (Table 1) year 1995,1998, 1999, 2000, 2007, 2008, 2010, 2011 were identified as La Nina years and 1991, 1992, 1997, 2002, 2004, 2006, 2009 were EL Nino years while 1993, 1994, 1996, 2001, 2003, 2005, 2012 were non El Nino and La Nina Years. Spatio-temporal analysis was done separately for El Nino, La nina and Normal years respectively, within GIS environment using geostatistical method and linear regression method. Changes in the groundwater levels within the basin were observed by creating groundwater level map using geostatistical method. Regression analysis was performed between rainfall and groundwater level from 1990 to 2012 years.

**Table 1** Oceanic Nino Index (ONI) from 1990 to 2012

(Source: [http://www.cpc.ncep.noaa.gov/products/analysis\\_monitoring/ensostuff/ensoyears.shtml](http://www.cpc.ncep.noaa.gov/products/analysis_monitoring/ensostuff/ensoyears.shtml))

Year	DJF	JFM	FMA	MAM	AMJ	MJJ	JJA	JAS	ASO	SON	OND	NDJ
1990	0.1	0.2	0.2	0.2	0.2	0.3	0.3	0.3	0.4	0.3	0.4	0.4
1991	0.4	0.3	0.2	0.2	0.4	<b>0.6</b>	<b>0.7</b>	<b>0.7</b>	<b>0.7</b>	<b>0.8</b>	<b>1.2</b>	<b>1.4</b>
1992	<b>1.6</b>	<b>1.5</b>	<b>1.4</b>	<b>1.2</b>	<b>1.0</b>	<b>0.8</b>	<b>0.5</b>	0.2	0	-0.1	-0.1	0
1993	0.2	0.3	0.5	0.7	0.8	0.6	0.3	0.2	0.2	0.2	0.1	0.1
1994	0.1	0.1	0.2	0.3	0.4	0.4	0.4	0.4	0.4	<b>0.6</b>	<b>0.9</b>	<b>1.0</b>
1995	<b>0.9</b>	<b>0.7</b>	<b>0.5</b>	0.3	0.2	0	-0.2	<b>-0.5</b>	<b>-0.7</b>	<b>-0.9</b>	<b>-1.0</b>	<b>-0.9</b>
1996	<b>-0.9</b>	<b>-0.7</b>	<b>-0.6</b>	-0.4	-0.2	-0.2	-0.2	-0.3	-0.3	-0.4	-0.4	-0.5
1997	-0.5	-0.4	-0.2	0.1	<b>0.6</b>	<b>1.0</b>	<b>1.4</b>	<b>1.7</b>	<b>2.0</b>	<b>2.2</b>	<b>2.3</b>	<b>2.3</b>
1998	<b>2.1</b>	<b>1.8</b>	<b>1.4</b>	<b>1.0</b>	<b>0.5</b>	-0.1	<b>-0.7</b>	<b>-1.0</b>	<b>-1.2</b>	<b>-1.2</b>	<b>-1.3</b>	<b>-1.4</b>
1999	<b>-1.4</b>	<b>-1.2</b>	<b>-1.0</b>	<b>-0.9</b>	<b>-0.9</b>	<b>-1.0</b>	<b>-1.0</b>	<b>-1.0</b>	<b>-1.1</b>	<b>-1.2</b>	<b>-1.4</b>	<b>-1.6</b>

<b>2000</b>	<b>-1.6</b>	<b>-1.4</b>	<b>-1.1</b>	<b>-0.9</b>	<b>-0.7</b>	<b>-0.7</b>	<b>-0.6</b>	<b>-0.5</b>	<b>-0.6</b>	<b>-0.7</b>	<b>-0.8</b>	<b>-0.8</b>
<b>2001</b>	<b>-0.7</b>	<b>-0.6</b>	<b>-0.5</b>	-0.3	-0.2	-0.1	0	-0.1	-0.1	-0.2	-0.3	-0.3
<b>2002</b>	-0.2	-0.1	0.1	0.2	0.4	<b>0.7</b>	<b>0.8</b>	<b>0.9</b>	<b>1.0</b>	<b>1.2</b>	<b>1.3</b>	<b>1.1</b>
<b>2003</b>	<b>0.9</b>	<b>0.6</b>	0.4	0	-0.2	-0.1	0.1	0.2	0.3	0.4	0.4	0.4
<b>2004</b>	0.3	0.2	0.1	0.1	0.2	0.3	<b>0.5</b>	<b>0.7</b>	<b>0.7</b>	<b>0.7</b>	<b>0.7</b>	<b>0.7</b>
<b>2005</b>	<b>0.6</b>	<b>0.6</b>	<b>0.5</b>	<b>0.5</b>	0.4	0.2	0.1	0	0	-0.1	-0.4	-0.7
<b>2006</b>	-0.7	-0.6	-0.4	-0.2	0.0	0.1	0.2	0.3	<b>0.5</b>	<b>0.8</b>	<b>0.9</b>	<b>1.0</b>
<b>2007</b>	<b>0.7</b>	0.3	0	-0.1	-0.2	-0.2	-0.3	<b>-0.6</b>	<b>-0.8</b>	<b>-1.1</b>	<b>-1.2</b>	<b>-1.3</b>
<b>2008</b>	<b>-1.4</b>	<b>-1.3</b>	<b>-1.1</b>	<b>-0.9</b>	<b>-0.7</b>	<b>-0.5</b>	-0.3	-0.2	-0.2	-0.3	-0.5	-0.7
<b>2009</b>	-0.8	-0.7	-0.4	-0.1	0.2	0.4	<b>0.5</b>	<b>0.6</b>	<b>0.7</b>	<b>1.0</b>	<b>1.2</b>	<b>1.3</b>
<b>2010</b>	<b>1.3</b>	<b>1.1</b>	<b>0.8</b>	<b>0.5</b>	0	-0.4	<b>-0.8</b>	<b>-1.1</b>	<b>-1.3</b>	<b>-1.4</b>	<b>-1.3</b>	<b>-1.4</b>
<b>2011</b>	<b>-1.3</b>	<b>-1.1</b>	<b>-0.8</b>	<b>-0.6</b>	-0.3	-0.2	-0.3	<b>-0.5</b>	<b>-0.7</b>	<b>-0.9</b>	<b>-0.9</b>	<b>-0.8</b>
<b>2012</b>	<b>-0.7</b>	<b>-0.6</b>	<b>-0.5</b>	-0.4	-0.3	-0.1	0.1	0.3	0.4	0.4	0.2	-0.2

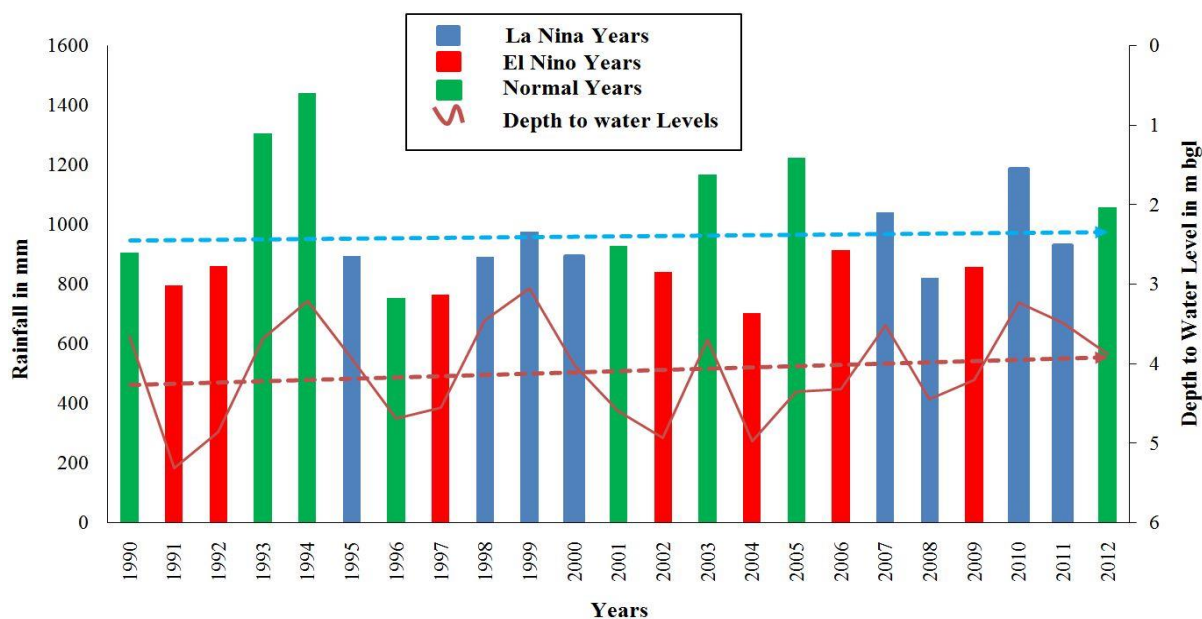


**Figure 2** Comparison of groundwater level maps of study area for Normal (a) La Nina (b) and El Nino (c) years

#### 4. RESULT AND DISCUSSION

Groundwater level maps were created using kriging interpolation technique within GIS. Comparison of different groundwater levels for different La Nina, El Nino and Normal years have been presented (figure 2). Depth to water level in the basin ranges from 0 to 14 m bgl; It was observed that the spatial changes in the groundwater level over entire area reflects the similar scenario for different El Nino and La Nina years (figure 2 and 3). It was observed from the constant trend line for groundwater level, average depth to water level was 4 m bgl for 22 years (figure 3). Average depth to water level for La Nina years was 3.5 m bgl (figure 4.a) while for both El Nino and Normal years it was 4.5 m bgl (figure 4.b and 4.c). For the study area, there is not much variation in the amount of rainfall

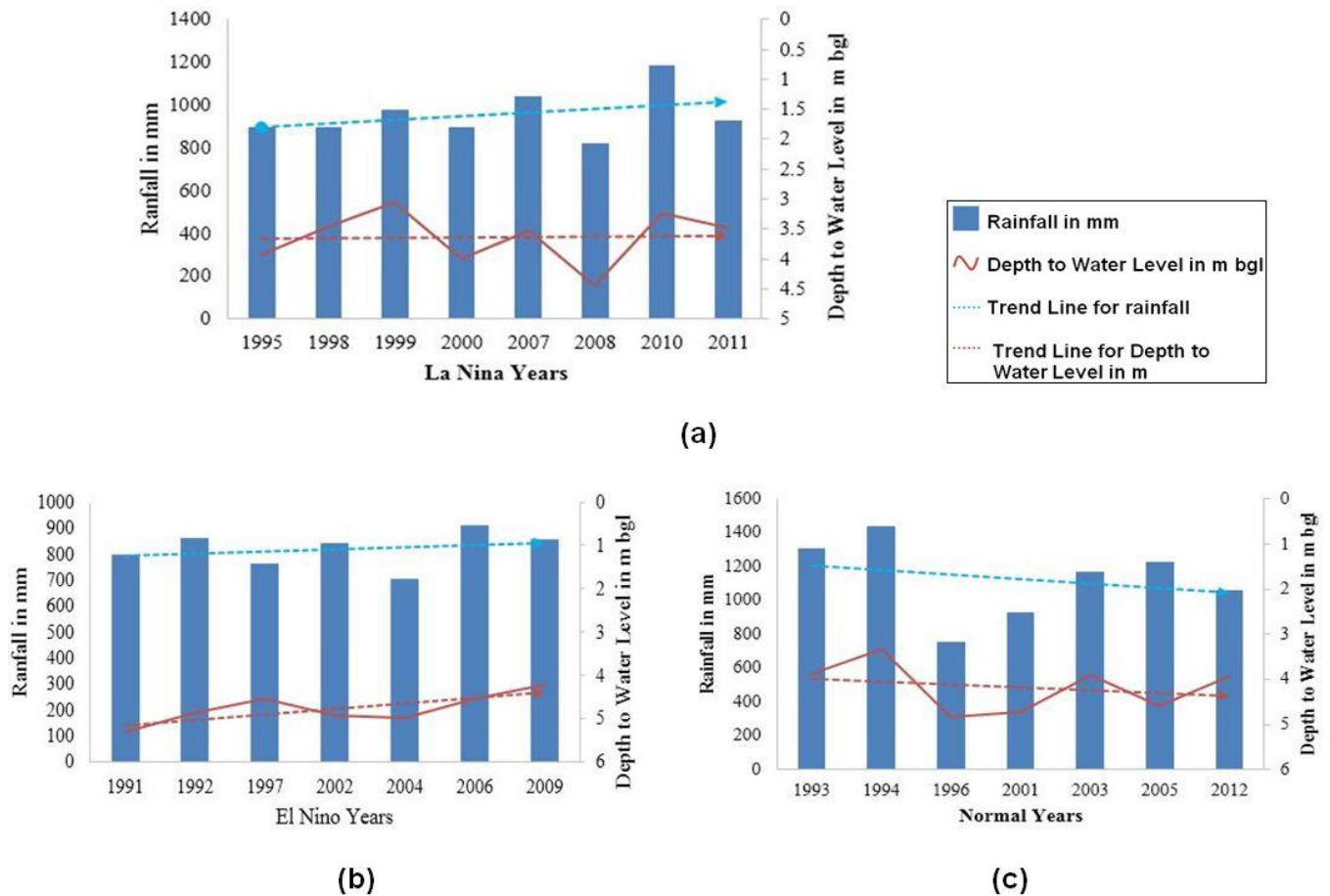
in El Nino and La Nina years and hence it was observed that changes in the groundwater level for these years are also almost similar over entire basin. Depth to water level in north western parts of the study area is low and ranges from 7 m to 14 m bgl, because these areas are located at higher elevations and the recharge potential of the area is less. Depth to water level observed at south western part of the study area is more which ranges from 7 m to 14 m bgl. It might be happening due to the excessive pumping of groundwater for mining activity. To observe the changes due to El Nino, La Nina and Normal years in the central part of the study area (Table 2), three sub-watersheds WGK2, WGK5 and WGKK3 were selected and the comparative spatial variation in depth to water level in percentage were tabulated. Effect of La Nina and El Nino years can be observed for sub-watersheds WGK2 and WGK5. For La Nina years, percentages of area under 0 m to 4 m bgl were more and conversely it was less in El Nino years. For sub-watershed WGKK3, depth to water level ranges from 0 m to 4 m bgl and this level is constant for all El Nino, La Nina and normal years. In all the three selected sub-watersheds, agricultural activity is more prominent and also water table elevation is relatively high compared to other parts of the study area which may be because of more return flow.



**Figure 3** Relation and trends between average Rainfall and Depth to water level from 1990 to 2012 years of 18 sub-watershed within Wainganga basin

**Table 2** Comparison of spatial variation in depth to water level (DWL) of three sub-watershed (area in %) within Wainganga basin for El Nino, La Nina and Normal years

Years Sub- watershed	El Nino years (Area in %)			La Nina (Area in %)			Normal year (Area in %)		
	0 m to 4 m	4 m to 6 m	6m to 10m	0 m to 4 m	4m to 6 m	6m to 10m	0 m to 4 m	4m to 6 m	6m to 10m
WGK2	68.23	27.31	32.64	92.17	7.78	0.00	67.76	19.66	12.59
WGK5	48.12	18.27	33.61	58.94	4.98	34.19	43.28	23.44	33.28
WGKK3	98.28	2.29	0.00	96.88	0.33	0.00	93.81	6.19	0.00



**Figure 4** Comparison of average Rainfall and Depth to water level for different La Nina, El Nino and Normal years of 18 sub-watershed within Wainganga basin

## 5. CONCLUSION

In this study, temporal and spatial changes in groundwater level depth were analyzed from 1990 to 2012 for different El Nino, La Nina and normal years. It was observed that the groundwater level varies sub-watershed wise within the Wainganga basins while rainfall pattern over the basin is approximately constant with time and space. It was observed from the past data that La Nina and El Nino pattern do not have drastic effects on rainfall. Sub watersheds WGKN4 and WGKN5 are more affected by anthropogenic activity (mining) which may overexploit the aquifer. Changes in groundwater levels are not only governed by Global Climate change, along with it, there can be several parameters that may affect it. Local parameters such as the usage of water for agriculture, drinking, Industry etc., and geology and hydrogeology of the area are other parameters that may affect the groundwater resources. Study suggests that effect of global climate change on groundwater regime must be studied in details so that various recharge techniques be used effectively to enhance the recharge.

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