Rainfall Pattern and Groundwater Fluctuation in Ramganga River Basin at Bareilly District, Uttar Pradesh, India

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Abstract— *Rainfall is an important factor in hydrological cycle that acts as the major source of all water resources on earth. The amount, intensity and areal distribution of rainfall are essential factors in many hydrologic studies and vary geographically, temporally & seasonally. Groundwater is the invisible and real indicator of the above complex processes happening in varying time and space. The process of variation of groundwater table of an unconfined aquifer due to rainfall is a complex one. It involves flow through unsaturated regions of the aquifer. The rate of infiltration depends upon soil moisture level present in the soil, type and density of cover and type of land use. Due urbanization and population growth, groundwater draft has increased and recharge due to rainfall has decreased resulting in a steady declination of groundwater table in the study area. For that, groundwater management has become need of the hour to tackle the emerging problem of groundwater depletion and water scarcity. Aim of the present study is to analyze the rainfall variation impacts on groundwater table in the study area. An attempt has been made to evaluate six rain gauge stations data of 10 years duration (2004-13) in determining the rainfall variation along with data of six observation well points situated on the same area to determine the groundwater table fluctuation during the same period (2004-13) so as to have a firsthand information about the groundwater table variation and its relation with the rainfall being received.*

Keywords— Rainfall, Groundwater level fluctuation, Unconfined aquifer, Infiltration, Hydrologic cycle.

I. INTRODUCTION

Rainfall is the important element of Indian economy. It is responsible for depositing most of the fresh water on the earth. Its intensity, duration and areal distribution vary geographically, temporally and seasonally (Vahid et al 2016) .In India over 80% of annual rainfall is received in four rainy months of June, July, August, and September. India being a tropical country depends greatly on rainfall for its water resources to get replenished regularly (Thilagavathi et al 2014). Surface water and groundwater are important components of the hydrological cycle and are interdependent (Goyal 2013) .The occurrence of drought and heavy precipitation are the most important climatic extremes causing both short and long term impacts on the ground water resources (Vahid et al 2016). The amount of water that will ultimately arrive at the water table is defined as natural ground water recharge (Md. Nurul et al 2014). Among the parameters governing groundwater fluctuation, recharge and draft are the two important factors. Though mean annual rainfall over India is 105 cm against global average of 70 cm, yet about 80% of the Indian territories fall under semi arid conditions (Rai, S.N. 2002) This is mainly because of uneven temporal and spatial distribution of rainfall, besides topographic and hydro-geological variations (Sankar and Sukumar 2011). In the last few decades, with the fast urbanisation, expanding industrialisation and increase in agricultural activities, the demand of water has increased manifold (Thilagavathi et al 2014) . Since the ground water is the most dynamic natural resource for a dependable urban / rural water supply and assured irrigation, It has been extensively exploited in the recent past causing lowering of water table, and also resulting in drying of dug wells, failure of bore wells and increase in power consumption in lifting it. Groundwater is often developed without proper understanding of its occurrence in time and space and is, therefore, threatened by overexploitation and contamination. For that reason, groundwater management is the key to combat the emerging problem of water security. Knowledge of water table depth and its response to rainfall is a crucial element for judiciously managing ground water resources for various purposes (Sankar and Sukumar 2011). The aim of this paper is to study the pattern of rainfall occurrences and its impact on groundwater table in the study area.

II. DESCRIPTION OF THE STUDY AREA

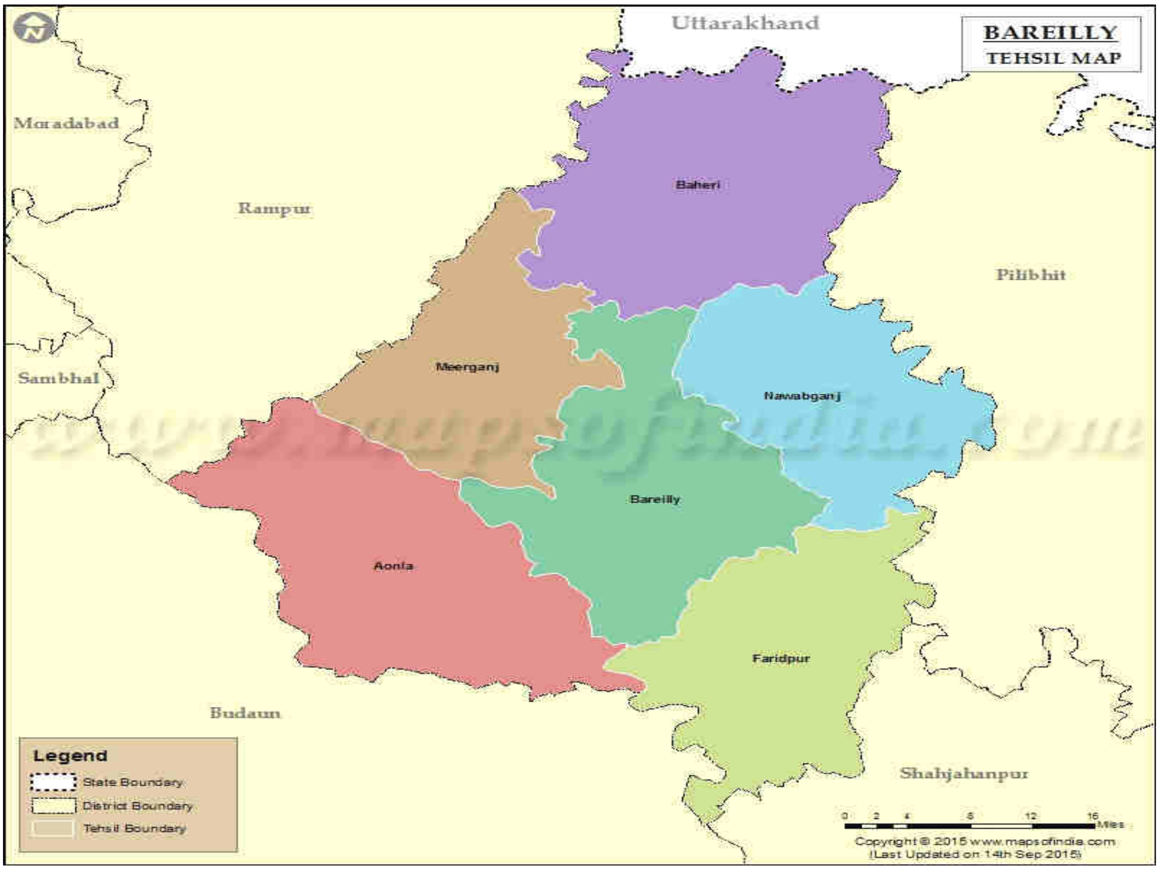

Fig.1: Map of the study area Tehsil-wise, showing its six Tehsils.

The Study area, Bareilly district is located in north western segment of Uttar Pradesh between latitudes 28°1′ to $28^0$54′ North and longitude 78°58′ to 78^o58′ East, and lies in northern India. It is a level terrain, watered by many streams, the general slope being towards the south. The soil is fertile and highly cultivated. The Ramganga River, which receives most of the hill torrents of the Kumaun Mountains through its tributaries flows through this district. The Deoha is another drainage artery and receives many minor streams. For the administrative convenience the Bareilly district, has been divided into six Tehsils, which are (1) Bareilly Sadar, (2) Baheri, (3) Aonla, (4) Nawabganj, (5) Faridpur and (6) Mirganj. The rain gauge stations and groundwater well points are established in these tehsils. The geographical area is around 4,120 km^2. The main economic activity is agriculture. The main crops grown are: Wheat, Sugarcane, Rice, Mentha, oilseeds, vegetables etc..

2.1 Rainfall and Climate:

(a) Rainfall: The summer monsoon is the major source of rainfall, which generally lasts from mid-June to mid- October. July and August months are said to be the wettest months.

(b) Temperature: The maximum mean monthly atmospheric temperature has been recorded during the month of May and minimum during January.

(c) Humidity: During the peak monsoon period (i.e. August and September) and in mid winter season (during December) the relative humidity is at highest level ranging between 79% and 84%. While it is lowest around 38% during peak summer months of April and May.

2.1Geomorphology

(a) In general, the area shows the following distinctive geomorphic units:

1. Lower piedmont plain of Tarai 2. Older alluvial plain or upland 3. Younger alluvial plain or low land
4. Meander flood plain

(b) Soils:

The soil of the district, can be classified into three major groups, based on its texture and composition characteristics. Bareilly Type-1 (Tarai soils) Bareilly Type-2 (Khadar or low-land soils) Bareilly Type-3 (Upland or Bangar soils)

III. MATERIAL AND METHODOLOGY

The daily rainfall data of the six rain gauge stations representing the study area were collected from Nazarat, District Collectorate, Bareilly and tabulated to calculate the monthly and seasonal rainfall for the respective rain gauge stations. The average annual rainfall of the study area is calculated for the period of thirty years (1984-2013) from the records of the six rain gauge stations obtained from Hydro met Division, India Meteorological Department Website. The Pre and Post monsoon ground water table data for all the six stations were collected from the office of senior Hydro-geologist Bareilly zone Bareilly and tabulated to calculate the fluctuation of water table season-wise and station wise during the study period (2004-2013). To achieve the framed objectives, the collected rainfall data are categorized year-wise, season-wise, and station-wise. Finally, the data are interpreted by preparing various charts and diagrams.

IV. RESULTS AND DISCUSSION

4.1 Rainfall analysis:

4.1.1 Pattern of seasonal variation and spatial distribution of rainfall:

Monthly rainfall pattern in the study area shows a similar trend at all the six rain gauge stations, Table 1. and [Figure 2(a) to Figure 2(f)]. It is observed from the figures that almost entire (about 92-95 %) rainfall occurs in four months of Monsoon season (mid June to mid October). The balance amount of rainfall (about 5-8% only) is received during the months of November to May [Table 2 and Figure 2(g) and 2(h)]. It is also observed from Table 2 and Figure 2(h) that Baheri station which is located in the northern portion of the study area regularly receives maximum rainfall and Aonla station located in the southern part of the study area receives minimum rainfall. The other four rain gauge stations namely Mirganj, Bareilly Sadar, Nawabganj, and Faridpur, receive equally moderate amount (1018.59, 925.09, 921.85, and 882.56 mm respectively) of rainfall.

4.1.2 Spatial distribution of rainfall at various rain gauge stations:

It is observed from table 4 and [figure 3(b)] that rainfall received at Baheri rain gauge station is always higher than the district average during all the months (monsoon and non monsoon) of the study period (2004-2013). It is also observed from the [figure 3(c)] that Aonla rain gauge station always received less than the average rainfall during the entire period of study (2004-2013). The rain gauge station at Mirganj also received good amount of rainfall during the monsoon season. The rainfall received at this station was higher than the study area average in the months of June, July, August and September [figure (b)]. The rain gague station at Bareilly sadar, Nawabganj and Faridpur experienced similar pattern of rainfall occurrences. It is evident from the [figure 3(a), 3(d), and 3(e)] that these three stations received higher than the average rainfall during June, July and September while they received less than the average rainfall during the month of August.

Table 1: Monthly Rainfall during 2004-2013 at various rain gauge stations in the study area (mm)

Month	Bareilly Sadar	Baheri	Aonla	Nawabganj	Faridpur	Mirganj	Average
June	129.25	204.87	25.61	130.42	126.78	128.43	
July	278.45	512.29	64.03	271.6	302.79	306.56	
Aug.	247.62	536.3	67.04	253.67	226.03	291.16	
Sep.	188.49	293.5	36.69	175.3	164.67	205.55	
Oct.	17.47	50.46	6.31	25.05	18.15	22.19	
Nov.	1.16	4.12	0.52	4.41	3.65	1.8	
Dec.	1.41	1.2	0.15	2.05	0.35	2.47	
Jan.	5.54	11.8	1.47	3.8	3.6	8.3	
Feb.	16.75	37.24	4.66	13.24	8.99	23.04	
March	5.5	15.8	1.98	11.08	7.5	9.41	
April	5.99	11.35	1.42	11.83	5.64	6.65	
May	27.45	55.28	6.91	19.4	14.41	13.03	
Total	925.09	1734.21	216.27	921.85	882.56	1018.59	949.76

(Source: Nazarat, collectorate, Bareilly; and Hydro met Division, India Meteorological Department)

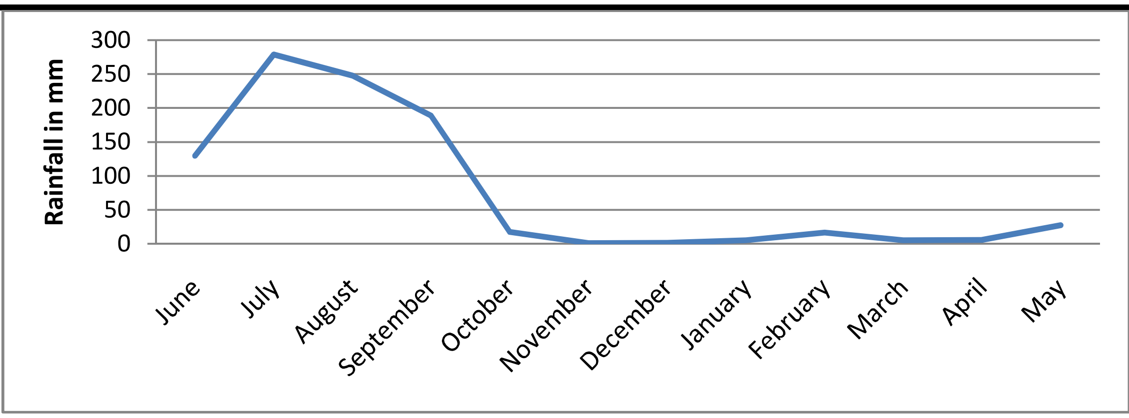

Fig.2(a): Monthly pattern of rainfall at Bareilly Sadar rain gauge station

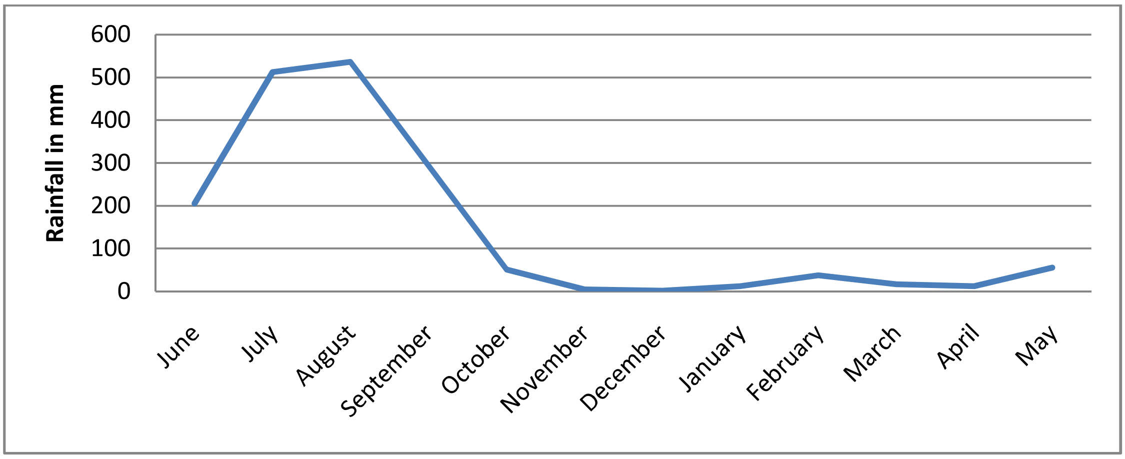

Fig.2(b): Monthly pattern of rainfall at Baheri rain gauge station

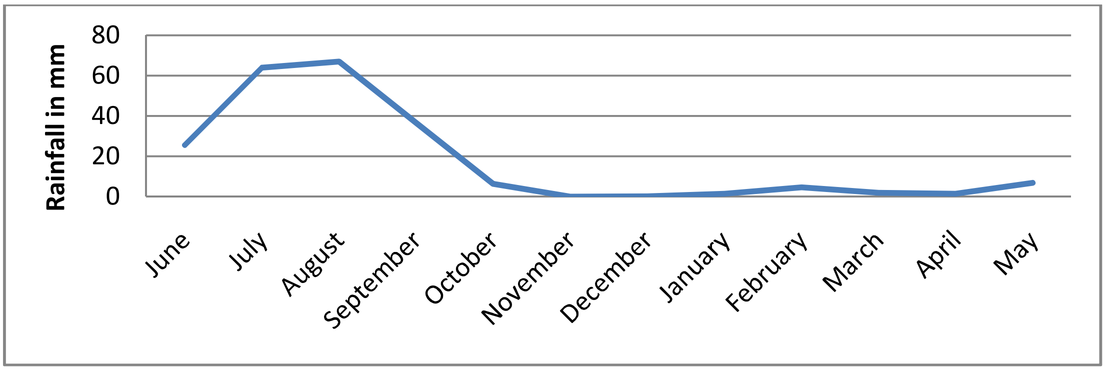

Fig.2(c): Monthly pattern of rainfall at Aonla rain gauge station

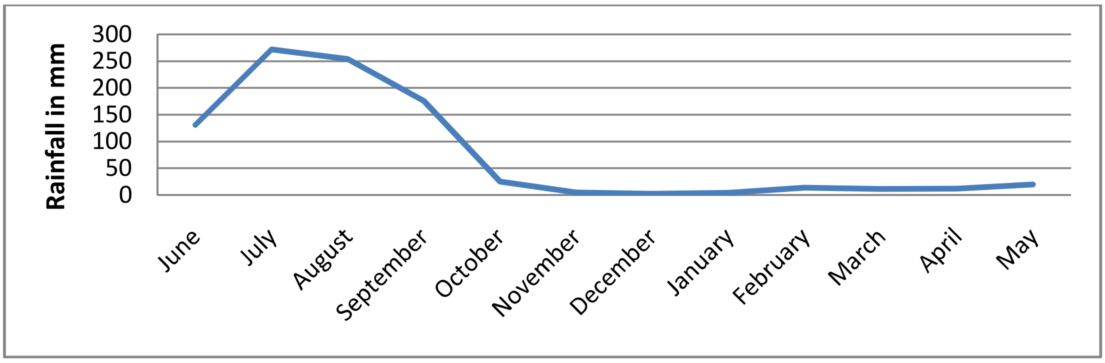

Fig.2(d): Monthly pattern of rainfall at Nawabganj rain gauge station

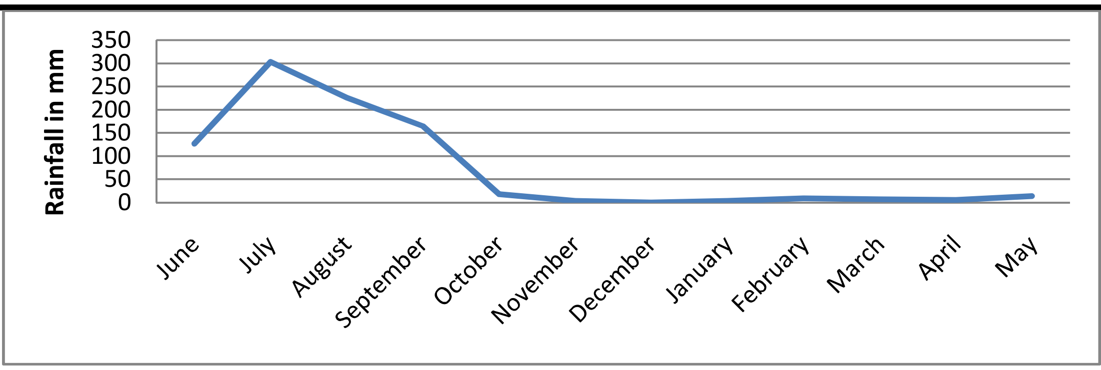

Fig.2(e): Monthly pattern of rainfall at Faridpur rain gauge station

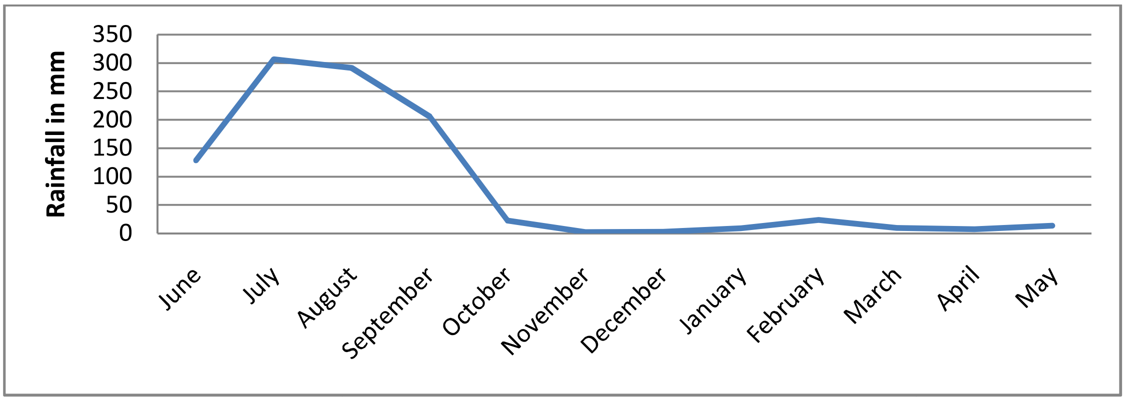

Fig.2(f): Monthly pattern of rainfall at Mirganj rain gauge station

Table 2. Percentage contribution of rainfall by Monsoon and Non-monsoon rain in the study area (2004-13)

S.No.	Raingauge Station	Monsoon Rainfall (mm)	contribution By monsoon rain (%)	Non-monsoon Rainfall (mm)	% contribution By Non-monsoon rain (%)
1	Bareilly Sadar	861.29	93.1	63.8	6.9
2	Baheri	1597.42	92.11	136.79	7.89
3	Aonla	199.68	92.3	17.11	7.7
4	Nwabganj	856.04	92.86	65.81	7.14
5	Faridpur	838.42	95	44.14	5
6	Mirganj	953.89	93.65	64.7	6.35

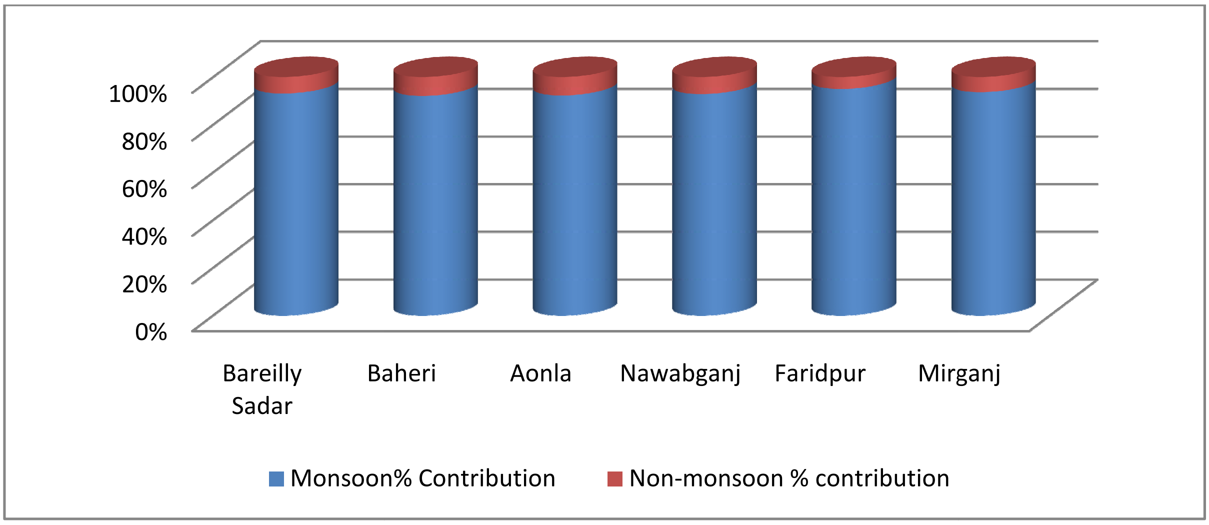

Fig.2(g): Percentage contributions by Monsoon and Non-monsoon rains on total annual rainfall

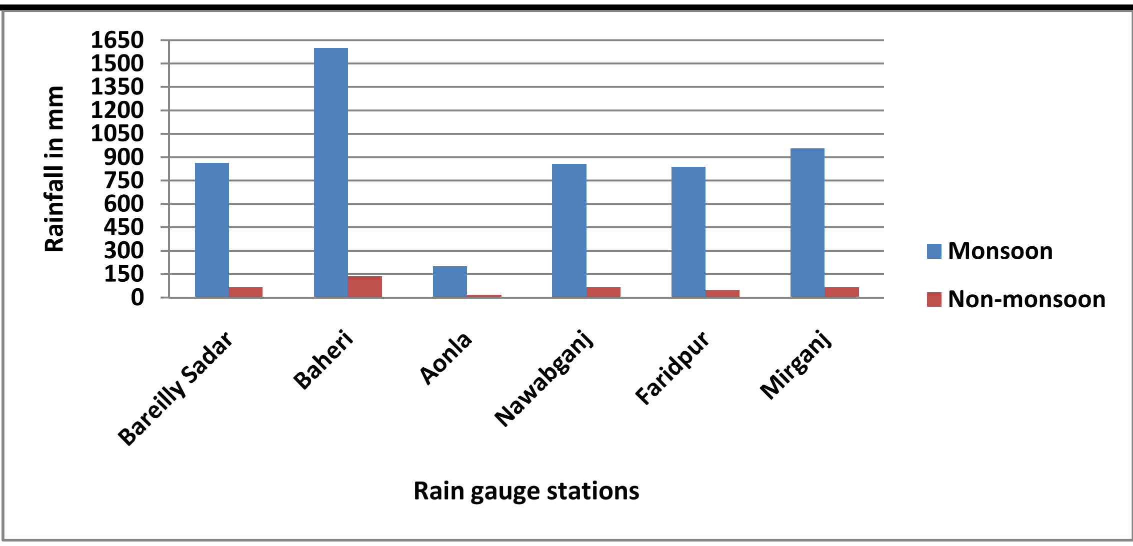

Fig.2(h): Seasonal (Monsoon and Non-monsoon) and rain gauge station-wise variation of rainfall

Table 3. Long term (1984-2013) Average monthly rainfall of the study area, district Bareilly

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Average	11.9	17.05	10.12	8.61	21.85	106.04	247.16	254.8	151.57	23.34	2.93	5.08

(Source: Nazarat,(Collectorate), Bareilly; and Hydro met Division, India Meteorological Department)

Table 4. Monthly variation of rainfall (mm) from its long term (30 years: 1984-2013) monthly average

Station	Jan	Feb	March	April	May	June	July	Aug	Sep	Oct	Nov	Dec
Bareilly Sadar	-6.36	-0.3	-4.62	-2.62	5.6	23.21	31.29	-7.18	36.92	-5.87	-1.76	-3.67
Baheri	-0.1	20.19	5.68	2.74	33.43	98.83	265.13	281.5	141.93	27.12	1.2	-3.88
Aonla	-10.43	-12.39	-8.14	-7.19	-14.94	-80.43	-183.13	-187.76	-114.88	-17.03	-2.4	-4.93
Nawab Ganj	-8.1	-3.81	0.96	3.22	-2.45	24.38	24.44	-1.13	23.73	1.71	1.49	-3.03
Faridpur	-8.3	-8.06	-2.62	-2.97	-7.44	20.74	55.63	-28.77	13.1	-5.19	0.73	-4.73
Mirganj	-3.6	5.99	-0.71	-1.96	-8.82	22.39	59.4	36.36	53.98	-1.15	-1.12	-2.61

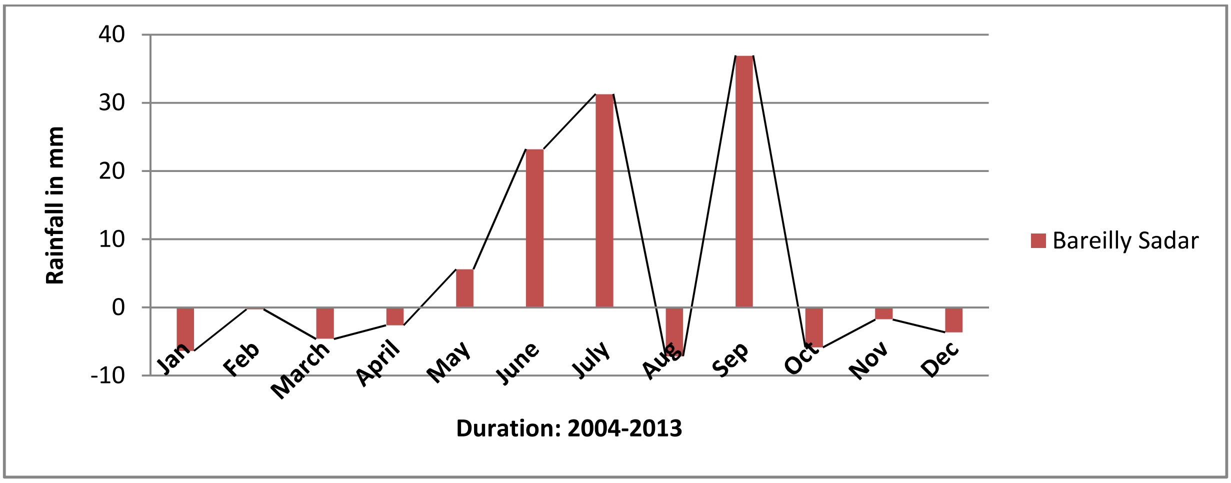

Fig.3(a): Monthly variation of rainfall from its long term monthly average at Bareilly Sadar rain gauge station

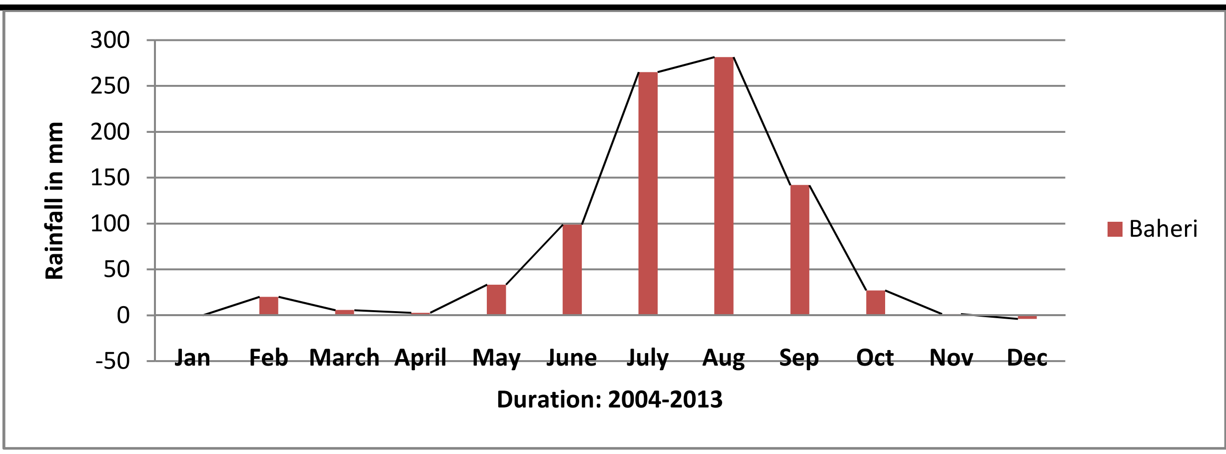

Fig.3(b): Monthly variation of rainfall from its long term monthly average at at Baheri rain gauge station

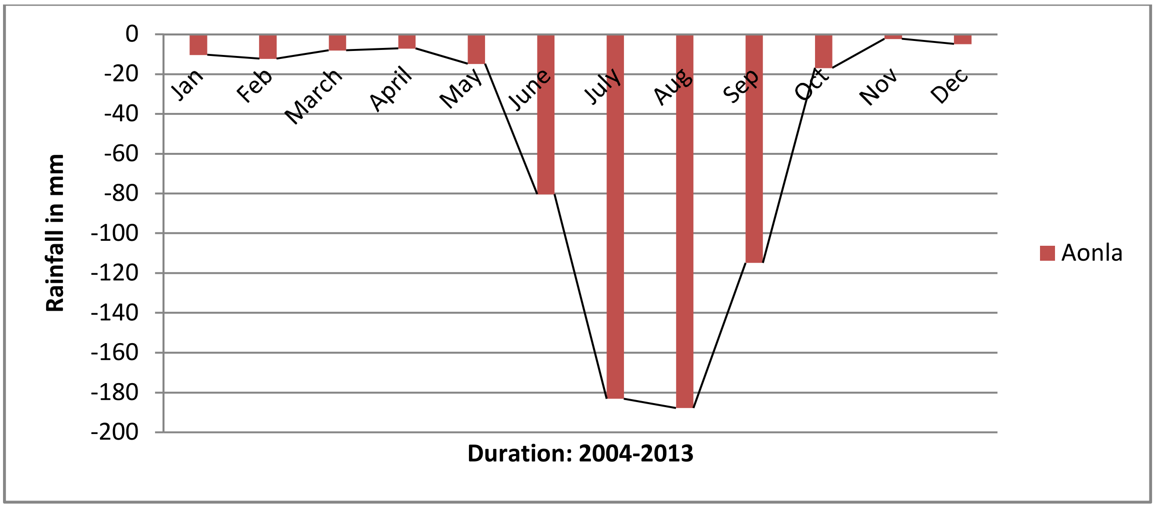

Fig.3(c):Monthly variation of rainfall from its long term monthly average at Aonla rain gauge station

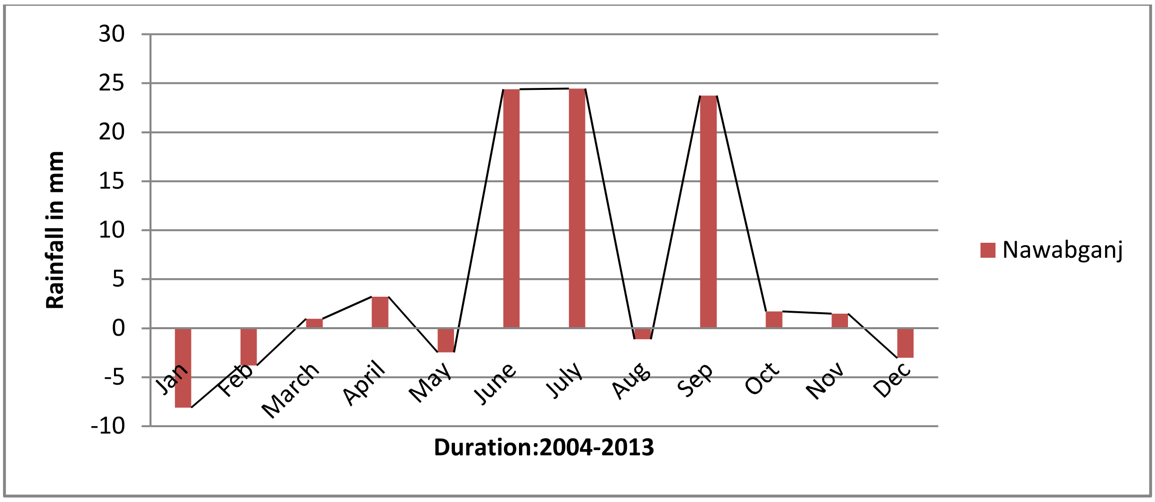

Fig.3(d): Monthly variation of rainfall from its long term monthly average at at Nawabganj rain gauge station

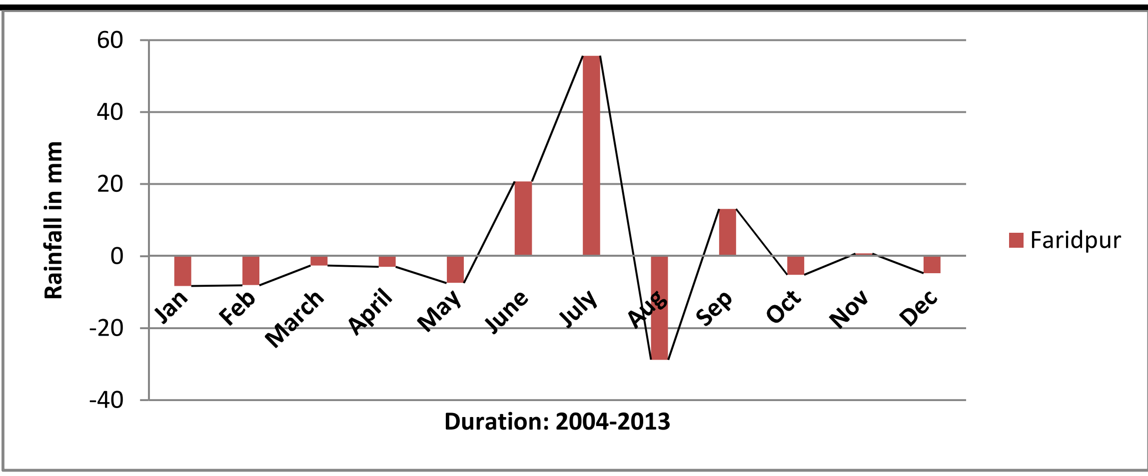

Fig.3(e): Monthly variation of rainfall from its long term monthly average at Faridpur rain gauge station

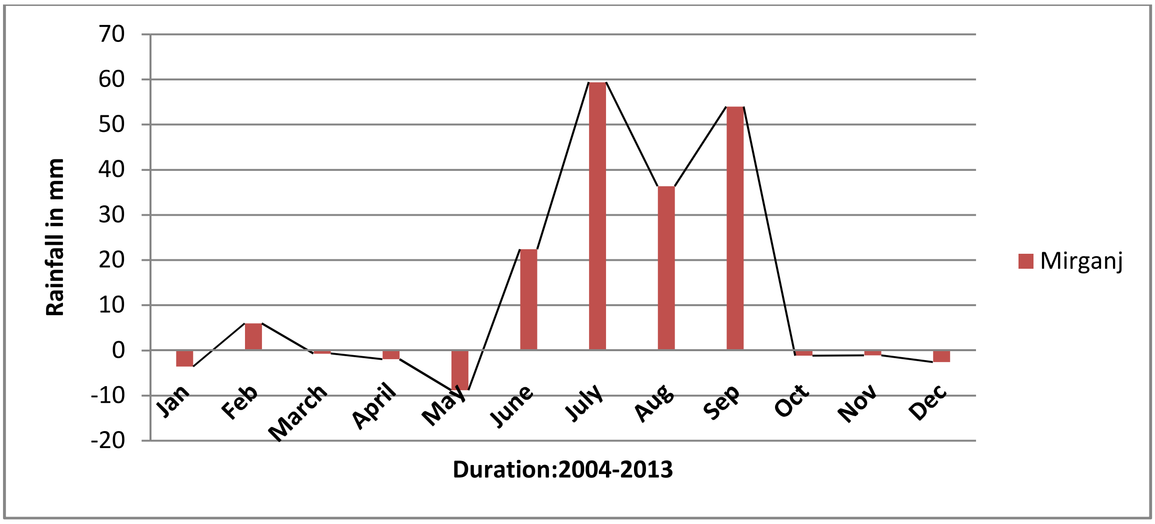

Fig.3(f): Monthly variation of rainfall from its long term monthly average at Mirgang rain gauge station

4.1.3Ground water table analysis:

From the table 5 and figure (4) it is observed that the pre monsoon water table of the study area ranges from 2.981m (shallowest) at Baheri station to 11.477m (Deepest) at Aonla station. Similarly post monsoon water table ranges from 1.619m at Baheri station to 10.689m at Aonla station. It is also evident from table 5 and figure (4) that minimum fluctuations of 0.581m is at Bareilly sadar station followed by Aonla (0.788m), Faridpur (0.985m), Baheri (1.299m) and Mirganj station (1.38m). Highest fluctuations of ground water table (2.023m) have been recorded at Nawabganj station followed by Mirganj and Baheri station. The all above three stations represent the areas which are not dominated by settlements but by water intensive cropped area. The crops grown are Paddy, Sugarcane Mentha and wheat. To meet out the water requirements of these crops the ground water draft is very high causing lowering of water table particularly in the non monsoon period. Also recharging of water table is very high as these areas receive very high amount of rainfall over negligible built up area and maximum crop cultivated area which are favourable for better infiltration and ground water recharge. The lower fluctuation in the water table observed at Bareilly sadar station indicates the higher drafts with lesser recharge as this area is mainly dominated by city settlements forcing higher draft with lower recharge conditions. The water table depth at Aonla station is highest because of very less groundwater recharge as this area receives very less rainfall. The regular pattern of receiving lesser rainfall have compelled the farmers to grow less water consuming crops thus avoiding over pumping of groundwater , which is evident from the table 6 and figure(5) that in spite of very less rainfall the fluctuation of water level is still less than other stations except Bareilly Sadar station. From table 7 and figure (7) the entire study area shows positive fluctuations in the ground water table. It is clear from the Figure (8) that for more rainfall during monsoon season there is more groundwater recharge as reflected through more rise in Groundwater table. From figure (7) it is also evident that the ground water table in the entire study area is depleting though moderately but steadily.

Table 5 Observation well-wise groundwater level status in the study area.

Observation well station name	Pre-Monsoon Water level (Meter)	Post-Monsoon Water level (Meter)	Fluctuation (Pre-Post) (Meter)
Bareilly Sadar	5.781	5.2	0.581
Baheri	2.918	1.619	1.299
Aonla	11.477	10.689	0.788
Nawabganj	4.378	2.355	2.023
Faridpur	5.848	4.863	0.985
Mirganj	6.099	4.719	1.38

(Source: Senior Hydro geologist's office, Bareilly, and Groundwater information system, NIC, GOI.)

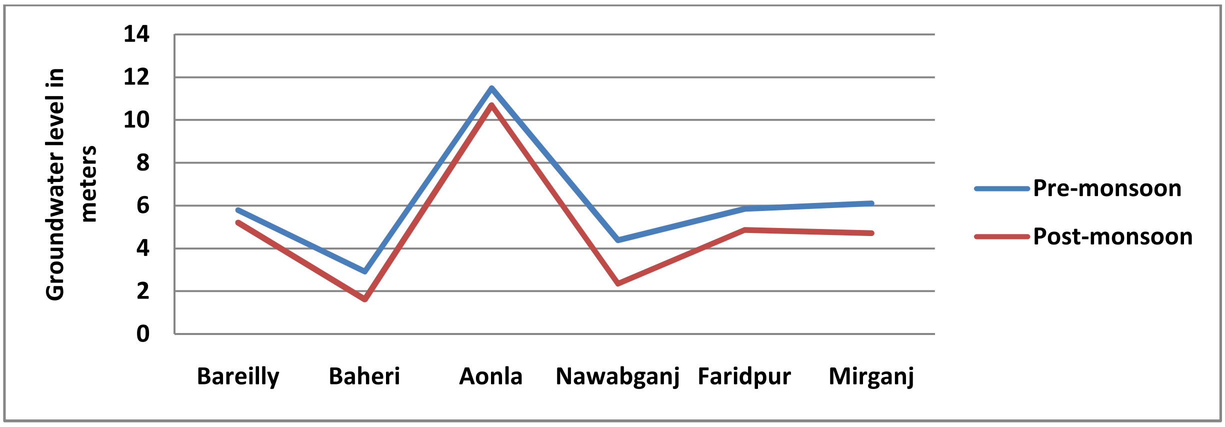

Fig.4: Observation well-wise groundwater table (Pre & Post-monsoon) status in the study area

Table 6: Observation well-wise groundwater level fluctuation in the study period (2004-2013)

Station Name	Groundwater level Fluctuation in meters
Bareilly	+ 0.581
Baheri	+ 1.299
Aonla	+ 0.788
Nawabganj	+ 2.023
Faridpur	+ 0.985
Mirganj	+ 1.38

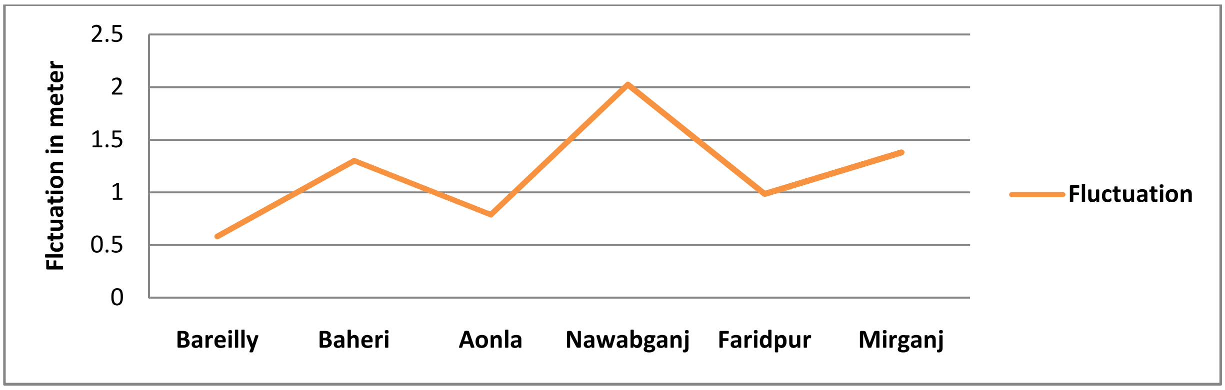

Fig.5: Observation well-wise groundwater level fluctuation in the study area during 2004-2013

Table 7: Average Pre & Post Monsoon groundwater table and average groundwater table fluctuation (2004-13)

Year	Average Pre-Monsoon groundwater table (Meter)	Average Post-Monsoon groundwater table (Meter)	Average Groundwater table fluctuation (Meter)
2004	5.36	4.59	+0.77
2005	5.75	4.76	+0.99
2006	5.65	5.18	+0.47

2007	5.9	4.92	+0.98
2008	6.74	4.81	+1.93
2009	6.26	5.19	+1.07
2010	6.44	4.69	+1.75
2011	5.85	4.23	+1.62
2012	6.48	5.67	+0.81
2013	6.39	5.01	+1.38

(Source: Senior Hydro-geologist's office, Bareilly, and Groundwater information system, NIC, GOI.)

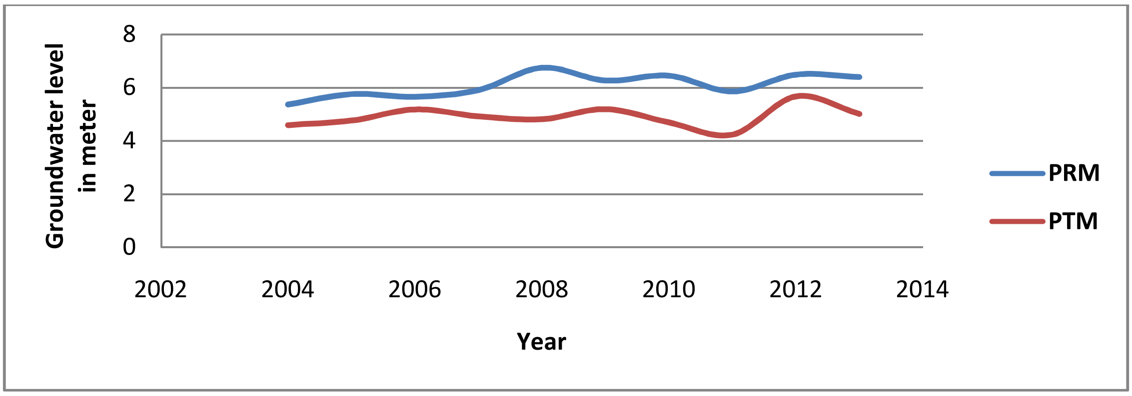

Fig.6: Year-wise variation in Pre & Post-monsoon groundwater level in the study area (2004-2013)

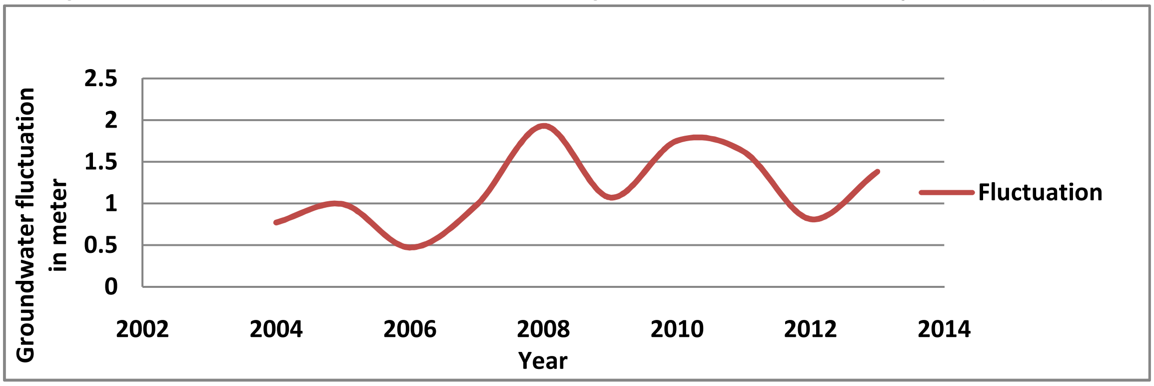

Fig.7: Year-wise average groundwater fluctuation in meters in the study area during 2004-2013

Table 8: Average annual rainfall and Post-monsoon water table during 2004-2013

Year	Annual Rainfall (mm)	Post-monsoon groundwater level (mm)
2004	767.4	4596.67
2005	895	4765
2006	696.3	5181.67
2007	1040.1	4918.33
2008	1356.2	4815
2009	894.2	5195
2010	1430.2	4690
2011	1196.1	4235
2012	617.5	5668.33
2013	1288.5	5010

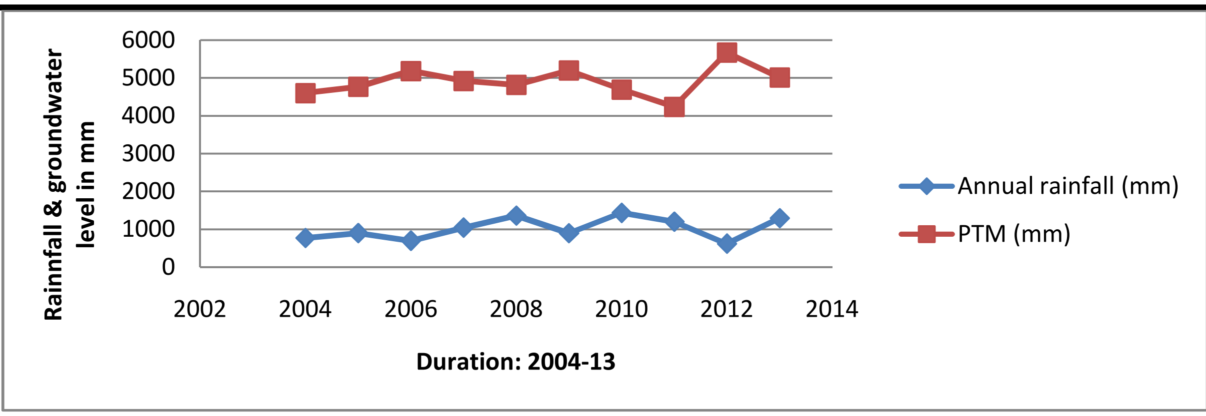

Fig.8: Rainfall and groundwater table variation at the study area during 2004-2013.

V. CONCLUSION

Rainfall is the main sources of water in the study area. The average rainfall over the study area is 949.76 mm and monsoon rainfall contributes to a large extent of about 93.17%. The annual minimum rainfall of 216.27 mm is received at Aonla rain gauge station and maximum rainfall of 1734.21 mm at Baheri rain gauge station. It is also evident that the rainfall is maximum on the northern side of the study area with a decreasing trend from north to south reaching minimum at Aonla. The main source of ground water occurring in the district is through rainfall and return flow from applied irrigation. Ground water level shows a seasonal pattern of fluctuation. The magnitude of fluctuation depends upon the amount of water recharge and draft. The Aonla area receives very little rainfall due to which groundwater table is lowest. The agronomic and engineering practices like agro-forestry, animal husbandry and water harvesting structures should be encouraged with crop cultivation. The entire area shows a declining trend of groundwater table though the other five areas (Tehsils) receive adequate amount of rain fall. In order to check the decline of groundwater table, cropping pattern should be moderated and area under crops having high water demand is to be reduced in favour of less water intensive crops besides other water conservation practices in tje entire area.

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