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EFFECT OF RAINFALL ON GROUNDWATER LEVEL FLUCTUATION OF SUNSARI DISTRICT, NEPAL

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ABSTRACT

Water is an essential natural resource on earth which cater for all the human endeavor. Groundwater is the most essential and reliable source of fresh water in every part of the world including an area with an excessive amount of rainfall and plentiful surface water. The study analyzed the effect of rainfall in groundwater fluctuation of Sunsari district from 2001 A.D to 2017 A.D. The groundwater level data were collected from the **GWRDB**, Biratnagar and rainfall data from **Department of Hydrology and Meteorology, Hattisar, Kathmandu** and it was analyzed using statistical tools, correlation. In this study, we examined 8 wells from the district. The result of the study showed that the annual rainfall is decreasing in the Sunsari district from 2001 to 2017, but the decreases are not linearly. Also, when we studied the groundwater of 17 years, we found that the groundwater level of **Amahibelha** and **Bhutaha** has no such relationship with time (i.e. we concluded that there was no any such variation in groudwater level till 2017 in these two-study area). Similarly, we found that the groundwater level of **Simariya** and **Holaiya** was depleting during the 17 years interval. Also, we found the groundwater level of **Kalabanjar**, **Dewanganj**, **Inaruwa** and **Bhokraha** was not started to depleted till 2017 (i.e. these study areas showed recharge was dominating the depletion till 2017).

KEYWORD: Groundwater table, rainfall, fluctuation.

Chapter 1 INTRODUCTION

Background

Groundwater is a precious and the most widely distributed resource of the earth and unlike any other mineral resource, it gets its annual replenishment from the meteoric precipitation. The world's total water resources are estimated at 1.37×10^8 M-ha-m. Of these global water resources, about 97.2% is salt water mainly in oceans, and only 2.8% is available as fresh water at any time on the planet earth. Out of this 2.8%, about 2.2% is available as surface water and 0.6% as groundwater. Out of this 0.6% of stored groundwater, only 0.3% (41.1×10^4 M-ha-m) can be economically extracted with the present drilling technology, the remaining being unavailable as it is situated below a depth of 800m. (Raghunath, 2007)

From a utilization perspective, agriculture, irrigation is the greatest user of water accounting for 80% of all consumptions. Beside agricultural consumptions, groundwater is a significant source of drinking, domestic and industrial water worldwide. In order to make an effective water resource management system, it is necessary to predict groundwater level variations with acceptable accuracies. Groundwater levels are subjected to variations due to differences between the supply and release of groundwater, gaining/losing stream flow variations, tidal effects, urbanization, earthquake, land subsidence, and meteorological phenomena as well as global climatic changes (Shiri, Kisi, Yoon, Lee, & Hossein Nazemi, 2013).

Precipitated water that reaches at the surface ground maybe partially discharge into streams as surface runoff or partially infiltrate into the ground. The latter further percolates into groundwater aquifers, eventually emerging in springs, seeping into streams to form surface runoff, or storing in the subsurface. The soil stores infiltrated water to become soil moisture, and then it recharges to groundwater level if the soil is saturated. Nevertheless, it releases slowly as subsurface flow to enter the stream as base flow during the rainless period. This may also result in deeper percolation, evapotranspiration, or artificial discharge. If no water supplies are continually provided from either rainfall or other sources of recharge, groundwater level would gradually decrease due to deeper percolation or evapotranspiration (Jan, Chen, & Lo, 2007)

The potential for groundwater irrigation in Nepal is tremendous. Of the Terai's total land area of 1.36 million ha, 65% is considered irrigated. However, only 41% of the irrigated area is irrigated year-round. This amounts to only 27.5% of the potentially irrigable land. It is well recognized by irrigation experts in Nepal that, despite considerable investments in infrastructure development and a well-trained cadre of technicians for their design, operation, and maintenance, public sector irrigation schemes (largely surface irrigation) have performed below expectations. The efficiency of surface irrigation is estimated to be around 30%, and, hence, a significant portion of irrigation goes to waste. Furthermore, crop productivity is stagnant or marginally increasing but much below potential. This leaves a tremendous opportunity to fill the gap by sustainably using groundwater resources for irrigation because irrigation water is utilized in a better way (Bardhan, 2012).

However, with the increase in demand this resource is being over exploited in many areas, so groundwater study is must. It is necessary that groundwater potential of the aquifers must be estimated to limit the exploitation of groundwater to safe yield. In years of abundant water, the water table rises and in years of draught, the water table declines. But rate of recharge and discharge tend to remain in approximate balance. When a well is put in a operation, a new set of condition is created.

Most of the major agricultural places of Nepal are experiencing very rapid decline in water tables. And this declination can threaten the future food security in the country. Water demand is increasing rapidly due to population growth and socioeconomic development in the recent times and needed to take a holistic approach in this sector. Research on groundwater level fluctuations in Sunsari district so far have not been reported. Therefore, the potentiality of groundwater attracted the attention of agricultural engineers, civil engineers, geologist, geophysicists and scientists from various disciplines (Abdullahi & Garba, 2016a)

Chapter 2 LITERATURE REVIEW

Groundwater is basically a dynamic resource that may be expressed as the quantity of water measured by the difference between optimum and minimum water table within the aquifer, which is principally recharged from monsoon rainwater for the rest of the year. Groundwater fluctuation is influenced not only by climate variability but also human intervention including, unsustainable withdrawal and groundwater abstraction (Abdullahi & Garba, 2016b)

Since Nepal receives a considerable amount of rainfall, therefore it has an abundant amount of water for groundwater recharge. About 80% of the total flow occurs during five months (June - October) and the rest during the remaining months. Therefore, it can be generalized that the total annual flows influence groundwater during this period (Secretariat & Durbar, 2011). Water resources in any part of the world are subject change due to meteorological and climatological impacts all the yearlong. Increased temperature, plant water requirements, demand for human and animal drinking water and industrial usage, limited rainfall on one hand and artificial groundwater recharge, on the other hand, requires more water resource development and planning activities in the future. Dealing with variations of groundwater resources in relation to the effect of rainfall and temperature on water table fluctuations is an important factor that plays a media role in sustainable groundwater development. The data obtained from metrological stations, yearly fluctuations, changes due to temperature can be used to predict the groundwater status in the coming future (Aflatooni & Mardaneh, 2011). This study relates to the changes seen in the groundwater level on the basis of changing time series. So far as groundwater resources of Nepal are concerned, systematic evaluation has not been carried out. In many places observation wells provide information only on static water levels (Aflatooni & Mardaneh, 2011)

Groundwater Table Fluctuations

Any phenomenon, which produces pressure change within an aquifer, results into the change of ground water level is groundwater level fluctuation. These changes in ground water level can be a result of changes in storage, amount of discharge and recharge, variation of stream stages and evaporation. External loads such as tides, trains, atmospheric pressure and earthquake are born in part by the ground water of confined aquifers. Hence, they affect piezometric levels. The general consideration is that due to any reason if the aquifer pressure rises above the atmospheric pressure an up leveling in ground water level results and vice-versa. Fluctuation of groundwater-level is associated with both anthropogenic activities such as over pumping, and natural processes, primarily through reduction in recharge. It is difficult to identify the causes of fluctuations only by observing short-term water-level records. Therefore, the long-term groundwater-level records were thoroughly analyzed along with the results from different method in order to understand the causes for the groundwater-level fluctuations indifferent areas. There are two broad kinds of level variation (Level, n.d.).

Secular variation: These are variations in ground water level extending over a period of years. Alternating seasons of wet and dry years is which the rainfall in above and below the mean respectively, produce long period fluctuation of level. Recharge is the governing factor, which depends upon the rainfall intensity and distribution and amount of surface run off. In over developed basins where draft exceeds recharge, a downward trend of ground water level may continue for many years (Level, n.d.).

Seasonal variation: These results from influence such as recharge from rainfall and irrigation and discharge by pumping which follow well defined seasonal cycles. Highest levels occur about April and lowest about September marking the beginning and end of the irrigation seasons (Level, n.d.).

Short-term variation: Groundwater level often display characteristics short-term fluctuations governed by the primary use of groundwater in a locality. Clearly defined diurnal variation may be associated with municipal water supply wells. Similarly, weekly patterns occur with pumping for industrial and municipal purposes (Level, n.d.).

Jan, Chen, & Lo, 2007, studied "Effect of rainfall intensity and distribution on groundwater level fluctuations." The study was carried out by Department of Hydraulic and Ocean Engineering, Disaster Prevention Research Center, National Cheng Kung University, Tainan 70101, Taiwan. A mathematical equation describing the relationship between the groundwater level increment and the effective accumulated rainfall amount was proposed in this study. To analyze the relationship, they first employed the BAYTAP-G program to filter out the response of the groundwater level to non-rainfall effects, such as barometric pressure and earth tide. Because both the present and antecedent rainfall events give an impact on the groundwater level increment, an effective accumulated rainfall amount was defined to account for their influences using the exponential-decay weighting method. They concluded that resulting groundwater level, conventionally termed the residual groundwater level, was found to linearly depend on the effective accumulated rainfall amount. It was also shown that the effective accumulated rainfall amount calculated from the exponential-decay weighting method with a decay parameter of 0.25 reveals a highly-correlated relation to the residual groundwater level increment (Jan et al., 2007)

Aflatooni and Mardaneh, 2011, "studied to forecast future groundwater fluctuations as affected by long term temperature and rainfall data", the study carried out by IAU (Department of water resources and Department of Agriculture). Box-Jenkings time series model was used to predict ground water table fluctuations in Shiraz plain. The study resulted in the yearly and monthly variations in the level of groundwater. Along with monthly and yearly variations, seasonal variations were calculated. They concluded that as far as the ground water level is concerned, when the air temperature increases, the ground water table level declines with a delayed time interval. Also, when it rains the ground water table increases after a time interval which may be called delay time (Aflatooni & Mardaneh, 2011)

Hasan, Mostafa, & Matin, 2013, studied "Effect of Rainfall on Groundwater Level Fluctuations in Chapai Nawabgonj District." The study was conducted in five Upazilas under

Chapai Nawabgonj district from 2007 to 2011 to evaluate the effect of rainfall on groundwater level fluctuation. The data were analyzed to show the rainfall variations, runoff, infiltration and groundwater fluctuation levels in different years. The results illustrate that rain started usually in May and ended in September and little or no rainfall occurred during the rest of the year. The study results show that the maximum rainfall occurred throughout June -August and at the same time the estimated runoff and infiltration showed the maximum as expected. The maximum water table was found during July- September due to rainwater infiltration. The results also observe that the minimum water table was shown throughout March – May, during irrigation period of the area. This study illustrates that there were no significant change in rainfall and infiltration patterns during the study period, but the overall ground water table was declining day by day due to over withdrawal of groundwater for irrigation purpose (Abdullahi & Garba, 2016a)

Ahmeduzzaman, Kar, & Asad, 2016, carried to Study on Ground Water Fluctuation at Barind Area, Rajshahi. For this study groundwater level of Barind area of Rajshahi have been analyzed. All available data of Paba of Barind area of Rajshahi have been considered for preparing hydrographs. He concluded that, Ground water level shows a seasonal pattern of fluctuation. The magnitude of fluctuation depends upon the qualities of water recharge and discharge. The ground water level in Barind area rise and falls continuously with the advance of wet and dry season. Analysis the records of ground water level in observation well of Paba have indicated the level rises to its peak in the month of August to September even to October in some place. During October, November and December when the intensity of rainfall decreases ground water level starts depleting rapidly. In the Barind area it is seen that the amount of ground water extraction is caused by irrigation. There is no rainfall occur equally all the month in a year of our country. In the Barind area rainfall is so little. But that are only rainy season. In the Barind area soil is normally hard clay or clay type which is less permeable to infiltration. As a result, a little amount of rain water is infiltrated into the ground (Ahmeduzzaman, Kar, & Asad, 2012)

Abdullahi & Garba, 2016, studied "Effect of Rainfall on Groundwater Level Fluctuation in Terengganu, Malaysia." This study evaluated the effect of rainfall on groundwater level fluctuation using the rainfall, Evapotranspiration, and groundwater level fluctuation data from 2001 to 2013 in Terengganu Malaysia. These data were analyzed to show the rainfall variations, runoff, infiltration and groundwater fluctuation levels in different years. The analysis also illustrated that, the rainfall is influencing the groundwater level of the study area as the rain usually started in September and ended in December. However, there are little occurrences of rain in the rest of the months throughout the year. The maximum water level also was found during January to February due to the recharge by rainfall, runoff, and infiltration. The water table starts to decline from June to August and reaches its lowest level usually from August to September. The result also illustrates that, groundwater level decreased day by day due to mismanagement and unnecessary withdrawal from irrigation sectors and domestic uses (Abdullahi & Garba, 2016a)

Based upon the reference studies done by the researchers, this study is being conducted in Sunsari district of Nepal to relate the change in the level of groundwater over the changing course of time. This study will be illustrating the course of change of water level over the data of rainfall recharging the groundwater of changing years.

Chapter 3 RESULT AND DISCUSSION

Rainfall Variation

The monthly rainfall variations of three meteorological stations Chatara, Tarahara and Dharan of Sunsari district, the study area during 2001-2017 are shown in Fig *6.1.1*, *6.1.2* and *6.1.3*. The maximum rainfall was found throughout June to September during the rainy season of the area. The minimum or average rainfall was found between March to May and in October and very little or no rainfall occurred during November- February in the study area. The study results also illustrate that the maximum rainfall was recorded at Chatara station in July 2003, Tarahara station in July 2002, and Dharan station in July 2010.

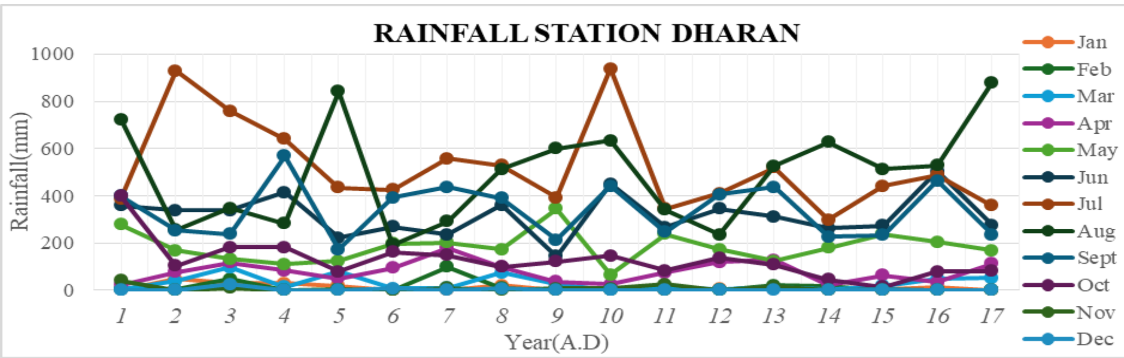

Figure 6.1. 1 Rainfall Variation of Meteorological Station Dharan.

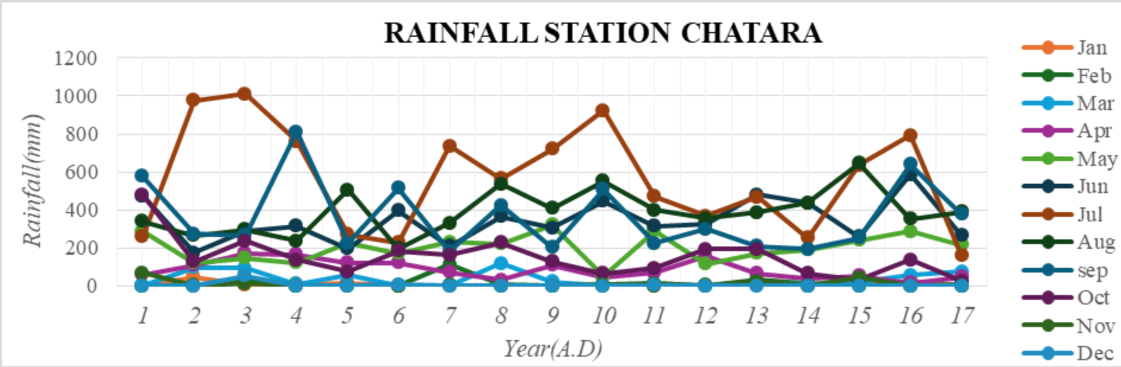

Figure 6.1. 2 Rainfall Variation of Meteorological Station Chatara.

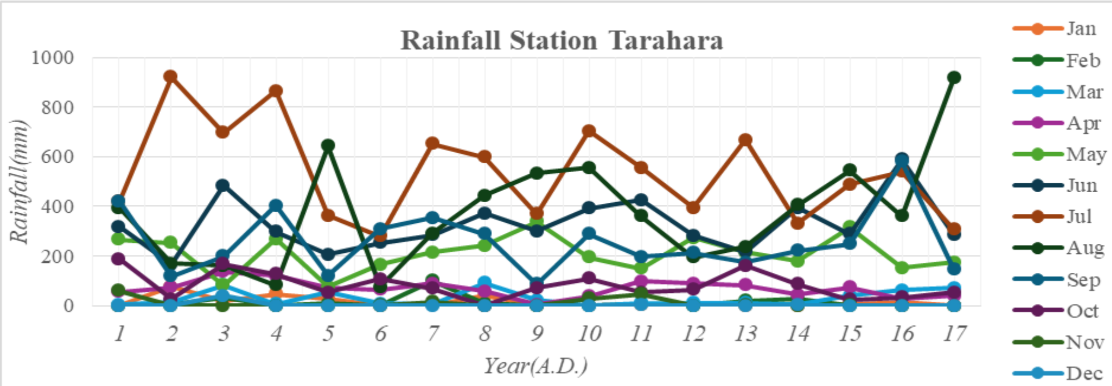

Figure 6.1. 3 Rainfall Variation of Meteorological Station Tarahara.

RESULT

The results show that Chatara station recorded the highest annual rainfall of 2894 mm in 2016 and Tarahara station recorded the lowest annual rainfall of 1264.1 mm in 2006 during the study period of the area.

The average annual rainfall received in Sunsari district was 2070.476 mm during 2001-2017. When we calculated the correlation coefficient, we found the value to be negative and equals to -0.2245. The overall study result entailed that the rainfall is decreasing in the Sunsari district from 2001 to 2017, but the decreases are not linearly. The rainfall data of the study also show a wide variation of rainfall depending on area and year.

Relationship Between Rainfall and Water Level Fluctuation

The average annual rainfall received in Sunsari district was 2070.476 mm during 2001-2017. The overall study result entailed that the rainfall is decreasing in the area from 2001 to 2017, but the decreases are not linearly.

Amahibelha

The below Fig. *6.3.1.1* illustrates the trends in the water table of the Amahibelha during 2001 to 2017.

The results illustrate that the overall water table level showed a minimum in 2004 and a maximum in 2017. The graphs show wave-like fluctuation curves, where the highest depletion occurred during April-May and then the water table decreased slowly in the graph and reached a minimum during August-October (i.e. groundwater started to recharge again) and again slowly increase (i.e. depletion occurred) until the rain started in May in most years. The study results reveal that a good relationship between rainfall and water table fluctuations were observed where the groundwater table was recharged by the rainfall.

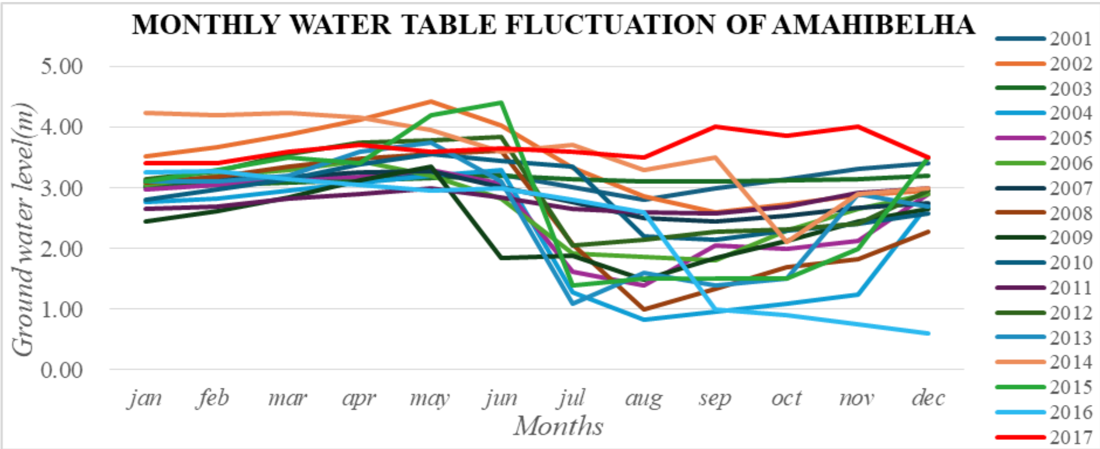

Figure 6.3.1. 1 Monthly Water Table Fluctuation of Amahibelha, Sunsari

However, when we calculated the correlation coefficient, we found the value to be positive but very nearly equals to zero (i.e. $r = 0.0599$). Thus, our results concluded that there was no any such variation in groundwater level till 2017.

Simariya

The below Fig. *6.3.2.1* illustrates the trends in the water table of the Simariya during 2001 to 2017. The results illustrate that the overall water table level showed a minimum in 2004 and a maximum in 2013. The graphs show, however (but not exact) wave-like fluctuation curves, where the highest depletion occurred during April-May and then the water table decreased slowly and reached a minimum during August-October and again slowly increase until the rain started in May in most years. While in the year 2017, it was seen the groundwater depletion occurred during February-May at very high rate.

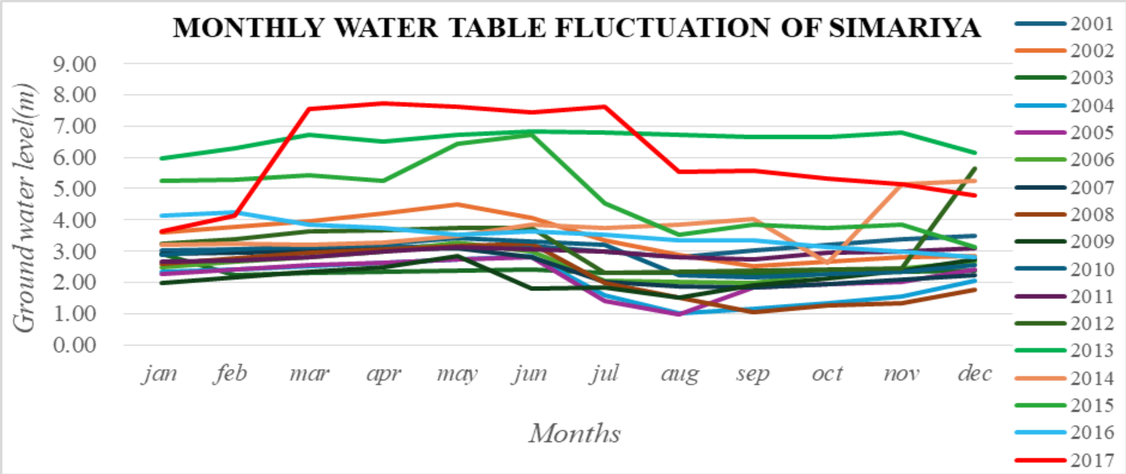

Figure 6.3.2. 1 Monthly Water Table Fluctuation of Simariya, Sunsari.

However, when we calculated the correlation coefficient, we found the value to be positive and equals to 0.631. Thus, our results show that groundwater depletion is at a high rate in Simariya. The overall yearly water table declining trend indicates that unsustainable withdrawal of groundwater for irrigation and domestic purposes were played a vital role in water table fluctuations in the study area.

Bhutaha

The below Fig. *6.3.3.1* illustrates the trends in the water table of the Bhutaha during 2001 to 2017. The results illustrate that the overall water table level showed a minimum in 2016 and a maximum in 2017. The graphs show however (but not exact) wave-like fluctuation curves, where the highest depletion occurred during March-May and then the water table decreased slowly and reached a minimum during July-October and again slowly increase until the rain started in May in most years. In the year 2016, it was seen that groundwater was recharged till December while in the year 2017 after February, it was seen the groundwater depletion occurred in very huge rate.

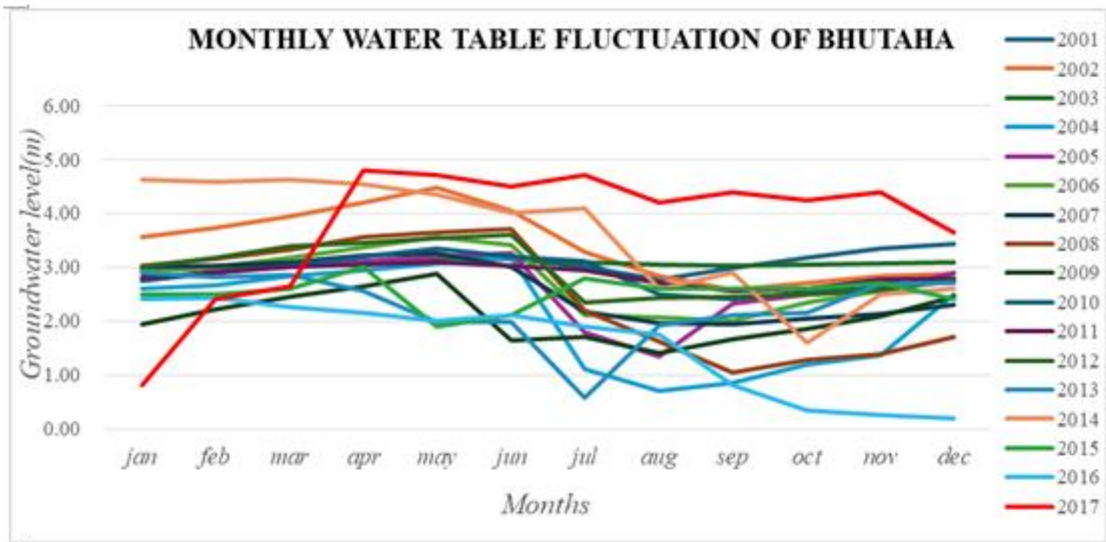

Figure 6.3.3. 1 Monthly Water Table Fluctuation of Bhutaha, Sunsari.

However, when we calculated the correlation coefficient, we found the value to be negative and nearly equals to zero (i.e.-0.0725). Thus, our results concluded that there was no any such variation in groundwater level till 2017. But also, by only analyzing the 2017 result it was seen that the depletion of groundwater was increasing suddenly.

Holaiya

The below Fig. *6.3.4.1* illustrates the trends in the water table of the Holiya during 2001 to 2017. The results illustrate that the overall water table level showed a minimum in 2004 and a maximum in 2003. The graphs show fluctuation curves, where the highest depletion occurred during April-May and then the water table decreased slowly in the graph and reached a minimum during August-October (i.e. groundwater started to recharge again) and again slowly increased (i.e. depletion occurred) until the rain started in May in most years. The study results reveal that a good relationship between rainfall and water table fluctuations were observed where the groundwater table was recharged by the rainfall.

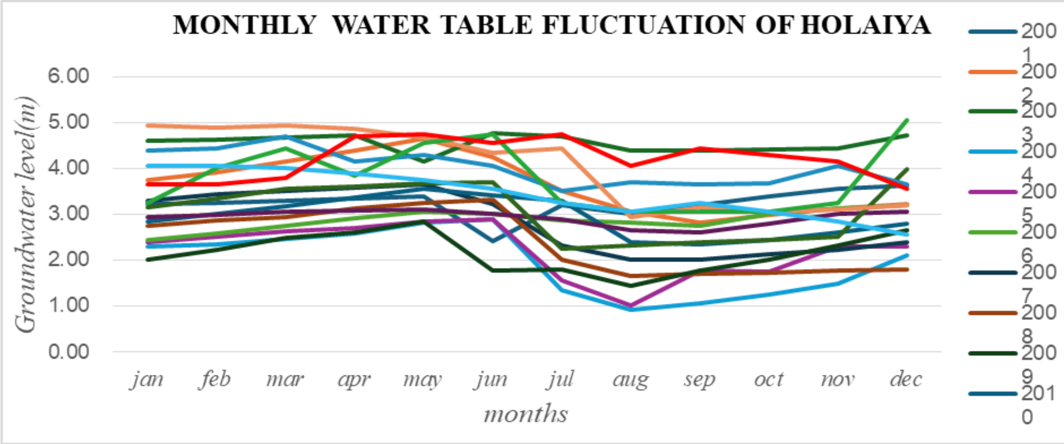

Figure 6.3.4. 1 Monthly Water Level Fluctuation of Holaiya, Sunsari.

However, when we calculated the correlation coefficient, we found the value to be positive and equals to 0.332. Thus, our results show that groundwater depletion is at an increasing rate in Holiya. The overall yearly water table declining trend indicates that unsustainable withdrawal of groundwater for irrigation and domestic purposes were played a vital role in water table fluctuations in the study area.

Kalabanjar

The below Fig. *6.3.5.1* illustrates the trends in the water table of the Kalabanjar during 2001 to 2017. The results illustrate that the overall water table level showed a minimum in 2009 and a maximum in 2002. The graphs show fluctuation curves, where the highest depletion occurred during April-May and then the water table decreased slowly and reached a minimum during August-October (i.e. groundwater started to recharge again) and again slowly increased (i.e. depletion occurred) until the rain started in May in most years.

It was seen that from mid of the year 2004 (i.e. from July), the groundwater level was seen to be recharged drastically as compared to previous years and the level was within the same range till November 2012 and again depletion started to occurred at high range until 2017.

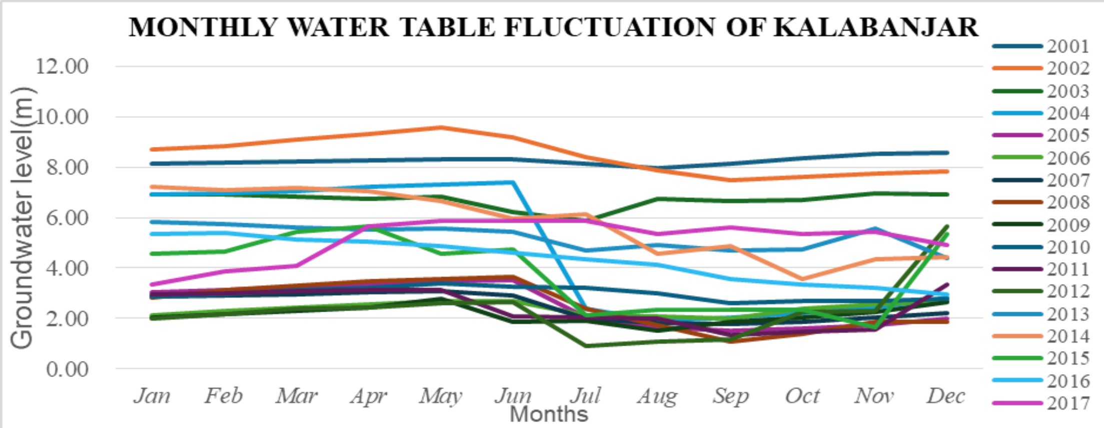

Figure 6.3.5. 1 Monthly Water Table Fluctuation of Kalabanjar, Sunsari.

However, when we calculated the correlation coefficient, we found the value to be negative and equals to -0.3278. Thus, our results show that overall the groundwater was not depleted till 2017 which may be due to the recharge at a high rate from mid-2004 to 2012. But from 2012, data showed depletion again started to increase at a high rate so we can conclude if the depletion continues at the same rate than in the near future there may be depletion in groundwater of Kalabanjar.

Dewanganj

The below Fig. *6.3.6.1* illustrates the trends in the water table of the Dewanganj during 2001 to 2017. The results illustrate that the overall water table level showed a minimum in 2004 and a maximum in 2003. The graphs show fluctuation curves, where the highest depletion occurred during April-May and then the water table decreased slowly in the graph and reached a minimum during August-October (i.e. groundwater started to recharge again) and again slowly increased (i.e. depletion occurred) until the rain started in May in most years. The study results reveal that a good relationship between rainfall and water table fluctuations were observed where the groundwater table was recharged by the rainfall.

In year 2004, it was seen that at the month of July the groundwater level was just 0.03m from the ground surface.

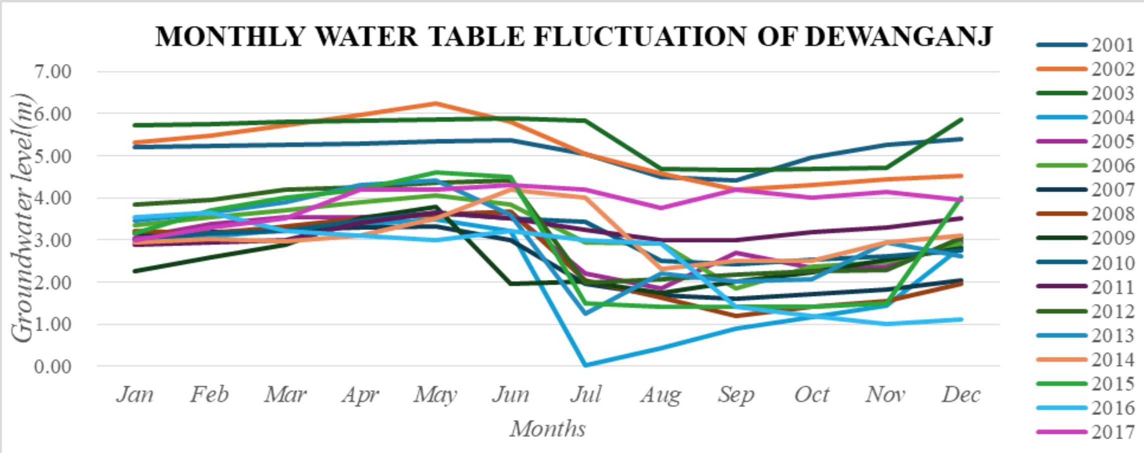

Figure 6.3.6. 1 Monthly Water Table Fluctuation of Dewanganj, Sunsari.

However, when we calculated the correlation coefficient, we found the value to be negative and nearly equals to -0.446. Thus, our results show that overall the groundwater depletion was not started to depleted till 2017. Also, when we analyzed through graph it was seen that groundwater was started to recharged sufficiently from 2004 as compared to the previous three years.

Inaruwa

The below Fig. *6.3.7.1* illustrates the trends in the water table of the Inaruwa during 2001 to 2017. The results illustrate that the overall water table level showed a minimum in 2009 and a maximum in 2002. The graphs show fluctuation curves, where the highest depletion occurred during April-May and then the water table decreased slowly in the graph and reached a minimum during August-October (i.e. groundwater started to recharge again) and again slowly increased (i.e. depletion occurred) until the rain started in May in most years.

Also, the graph shows that during the first three years groundwater level was at more height from the ground surface and again in mid-years, it was seen that groundwater recharged sufficiently as height decreases. And in the last four years, groundwater was again found to be increased on depletion.

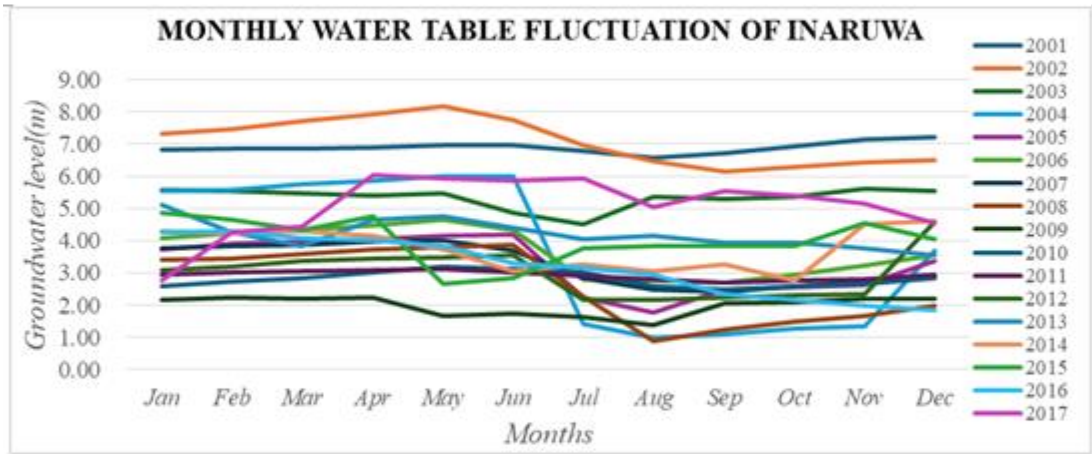

Figure 6.3.7. 1 Monthly Water Table Fluctuation of Inaruwa, Sunsari.

However, when we calculated the correlation coefficient, we found the value to be negative and nearly equals to -0.420. Thus, our results show that overall the groundwater depletion was not started to depleted till 2017.

Bhokraha

The below Fig. *6.3.8.1* illustrates the trends in the water table of the Bhokraha during 2001 to 2017. The results illustrate that the overall water table level showed a minimum in 2014 and the maximum in 2003. The graphs show fluctuation curves, where the highest depletion occurred during March-May and then the water table decreased slowly in the graph and reached a minimum during August-October (i.e. groundwater started to recharge again) and again slowly increased (i.e. depletion occurred) until the rain started in May in most years.

The first three years in graph showed the groundwater level was depleting but from mid-2004 it was seen that groundwater was recharged in large amounts with minimum extraction/depletion.

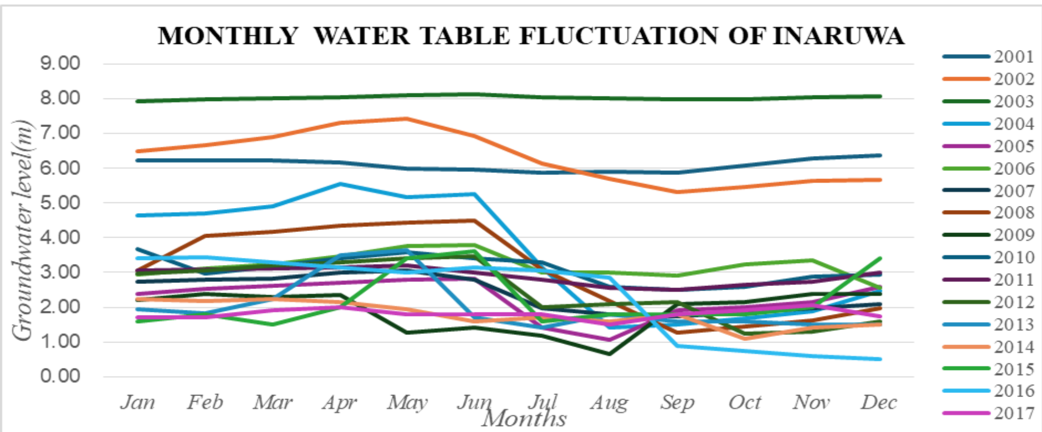

Figure 6.3.8. 1 Monthly Water Level Fluctuation of Bhokraha, Sunsari.

When we calculated the correlation coefficient, we found the value to be negative and nearly equals to -0.736. Thus, our results show that overall the groundwater depletion was not started to depleted till 2017 but has a huge scope of extraction.

Chapter 4 RECOMMENDATION AND DISCUSSION

CONCLUSION

The study results illustrate that the maximum rainfall was found throughout June to September during the rainy season of the area. The minimum or average rainfall was found between March to May and in October and very little or no rainfall occurred during November- February in the study area.

The monthly water table fluctuation data showed an elevated water table during August-October indicating groundwater recharged by rainwater infiltration, and then the water table declined continuously and reached the lowest level throughout March-May, the irrigation period of the study area in most years in all the study area. The study results illustrated that groundwater level fluctuations largely depended on rainfall patterns. The findings of this research may provide some information to the government for water management and for predicting future climatic events.

Recommendation

The pattern of rainfall may not be similar every time and the effect of that rainfall on the groundwater level may also change on the basis of intensity of rainfall. Therefore, people should not totally depend upon the groundwater for their needs, instead they should use several techniques like water harvesting for their needs.

It can be recommended that, we should not totally depend upon rainfall to recharge the groundwater level but use several methods for groundwater recharge like constructing pits in several clean places for the purpose of recharge. This may also lead to change the trend of decreasing groundwater level to increasing. Therefore, besides rainfall other methods should also be adopted that contributes to groundwater recharge.

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