

Water Level Fluctuation in Nainital Lake and its Correlation with Rainfall and LULC Change

Rishabh Singh¹, Chiranjeev Pant²

¹B. Tech, College of Technology, GBPUAT

²B. Tech, College of Technology, GBPUAT

Abstract - The Nainital lake is an important source of water for the local population and is also of importance due to its tourist attraction. Over the years the water level in the Nainital lake has fluctuated and stayed below its ideal level. In this study linear regression and coefficient of correlation were used to establish a relationship between rainfall and lake water level, and built-up area and lake water level for a period of 7 years from 2010 to 2016. It was observed that both decreasing rainfall and increasing built-up area trends matched the trend of the decreasing lake water levels. Rainfall had a very weak correlation with the lake water levels ($R = -0.35482$), whereas built-up area showed a stronger correlation ($R = 0.8917$). This implied that though both factors may play a role in the decreasing water levels in the lake, increase in built-up area was far more influential as compared to rainfall.

Key Words: Nainital lake, built-up area, rainfall, lake water levels

1. INTRODUCTION

Lakes and small water bodies are important sources of water for local populations. The Nainital lake in addition to being a valuable resource is also of high aesthetic value due to the town being a tourist attraction. Situated at an altitude of 1937 m above mean sea level (Pant *et al.*, 1980; Singh and Gopal 1999; Gupta *et al.*, 1999), the lake is 1432 m long, 457 m wide and covers an area of 0.46 km² (Singh *et al.*, 2001). The maximum depth of the lake reaches up to 27.3 m. Over the last few years, the water level of the lake has been fluctuating frequently and has stayed below its ideal level of 5ft above the zero mark. In the present study, rainfall data and the LULC change for a period of 7 years was studied from 2010 to 2016 and an effort was made to determine their effect on the lake water levels.

1.1 Study Area

Nainital is a district town in the Kumaon region of the state of Uttarakhand. It has a population of around 41,377 and is situated at an altitude of 2048 m from mean sea level. The city covers an area of 11.73 km².

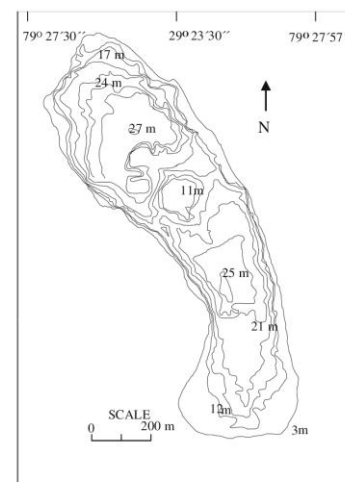
The Nainital lake (latitude 29°24' N, longitude 79°28' E) is situated in the centre of the town. The average temperature ranges from 25° C to close to 0° C (Gupta *et al.*, 2016). It was formed due to the rotational movement along

the Nainital Fault Line (Valdiya, 1988) approximately 40-50 thousand years ago (Singhvi *et al.*, 1994).

The lake is a major source of water supply for the population of Nainital (Singh and Gopal 1999). The lake depth varies from 27.3 m at the deepest point to close to 3 m at the most shallow point (Choudhary *et al.*, 2012).



Fig1- Satellite View of Nainital



Source: (Choudhary *et al.*, 2012).

Fig2- Bathymetric Map of Lake Nainital

2. METHODOLOGY

To study the respective effects of rainfall and LULC change on the lake water levels in Nainital, the mean rainfall data for the time period of 7 years from 2010 to 2016 was obtained (indiawris.gov.in). Furthermore the water levels of the Nainital lake for the said time period were obtained from news articles of local and national news. The reference for

the ideal water level in the lake was taken as 60 inches above the zero mark.

In the LULC data, the main factor that was taken into account was the change in built-up area over the given time period (Chakraborty *et al.*, 2016).

The available LULC data for four years 1990, 1999, 2009 and 2014 was converted to a linear regression line and an equation was determined to determine the approximate built up area in the required years. The built up area was taken for the extreme end values of years, i.e. 2010 and 2106 and the median year 2013.

Linear regression lines were then drawn for the three data sets and the correlation factor between water level change and rainfall, and the correlation factor between water level change and built up area were determined to determine which of the two factors had a bigger impact.

Table -1: Mean rainfall in Nainital from 2010 to 2016

Year	Mean Rainfall (mm)
2010	2225.32
2011	1602.85
2012	1014.09
2013	1694.08
2014	1450.18
2015	1397.53
2016	1470.21

Table -2: Mean water level in Nainital lake from 2010 to 2016

Year	Water level from reference point (feet)
2010	2.00
2011	3.33
2012	6.00
2013	2.45
2014	3.58
2015	0.33
2016	10.50

Table -3: Built-up area in Nainital (Available data)

Year	Built-up area (km ²)
1990	1.1
1999	2.9
2009	7.1
2014	9.0

3. RESULTS

The trend line for the water level in the lake in Nainital has an increasing trend, which indicates the water level going

further away from the reference mark and hence decreasing. The water level also didn't continuously keep on decreasing but fluctuated over the years with an overall trend that indicate falling levels.

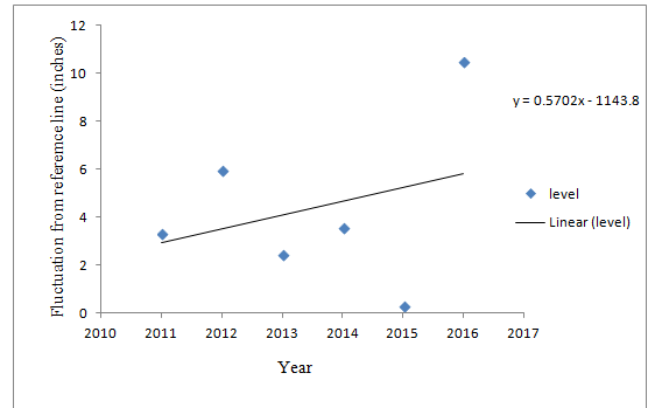


Chart -1: Water level fluctuation trend line

The trend line for rainfall in Nainital has a downward trend which indicates a subsequent decrease in the mean rainfall.

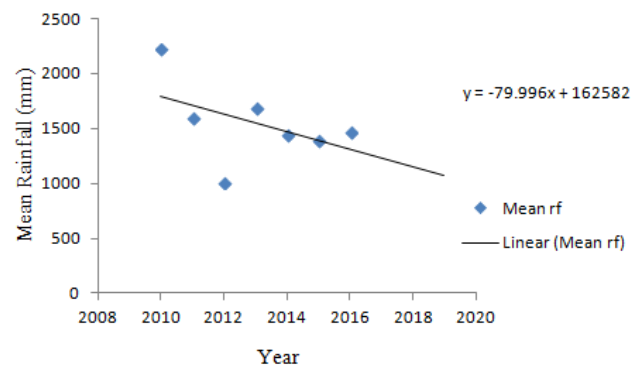


Chart -2: Average Rainfall Over the Period of Study

This decrease in the rainfall matches up with the trend of higher fluctuation of the lake water level. But to determine the extent of effect of only rainfall on water levels the coefficient of correlation (R) was calculated for the two sets of data.

$$R = \frac{Cov(\text{rainfall}, \text{water level})}{(\sigma_{\text{rainfall}} * \sigma_{\text{WaterLevel}})}$$

$$R = -0.35482$$

The low value of R implied a weak correlation between the mean rainfall and fluctuation of water levels.

The values of built-up area in Nainital were obtained for the years 1990, 1999, 2009, 2014. On the basis of these values the linear relationship was defined and the equation for built-up area was determined.

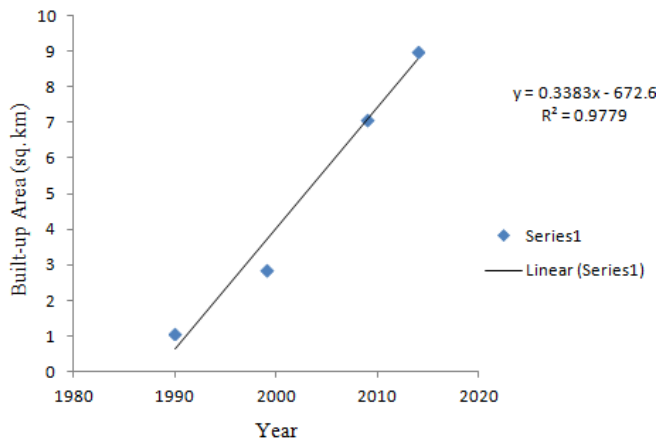


Chart -3: Built-up Area v/s Year

The equation for built up area was determined as

$$Y(\text{Built-up Area}) = 0.3383x - 672.6$$

On the basis of this equation the Built-up Area for 2010, 2013 and 2016 was calculated.

Table -4: Built-up area in Nainital (Calculated data)

Year	Built-up Area (km ²)
2010	7.38
2013	8.39
2016	9.42

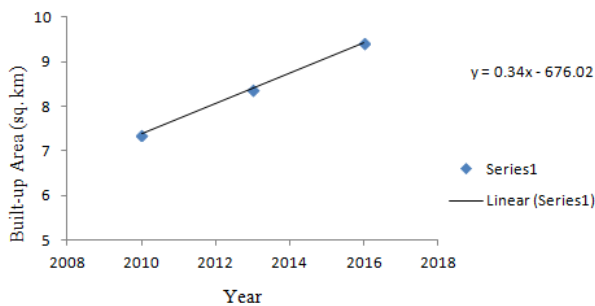


Chart -4: Calculated Built-up Area v/s Year

This increase in the built-up area matches up with the trend of higher fluctuation of the lake water level. But to determine the extent of effect of only built-up area on water levels the coefficient of correlation (R) was calculated for the two sets of data.

$$R = \frac{[\text{Cov}(\text{built-up area}, \text{water level})]}{(\sigma_{\text{built-upArea}} * \sigma_{\text{WaterLevel}})}$$

$$R = 0.8917$$

As the value of R for built up area is much higher than that of rainfall, we can see that increase in built up area has had a

much more profound effect on the water level fluctuations of the Nainital lake.

4. CONCLUSION

The water levels in the Nainital lake have fluctuated over the period of the study but show an overall trend of going further away from the reference line and decreasing. The highest and lowest deviation from the reference line was 10.5 m and 0.33 m respectively in 2016 and 2015 respectively. In the same time period rainfall also showed a net decreasing trend but a weak correlation with the water levels (R= -0.35482). The built-up area over the time period of the study has had a continuous increasing trend and also matches up with the decreasing water levels and has a comparatively stronger correlation than rainfall (R= 0.8917).

REFERENCES

- [1] Choudhary, Preetam & Routh, Joyanto & Chakrapani, Govind & Kumar, Bhishm. (2012). **Biogeochemical records of paleoenvironmental changes in Nainital Lake, Kumaun Himalayas, India.** Journal of Paleolimnology. 42. 571-586. 10.1007/s10933-009-9306-y.
- [2] Gupta PK, Nagdali SS, Singh SP (1999) Limnology of lakes. In: Singh SP, Gopal B (eds) Nainital and Kumaun Himalaya lakes. NIE Publication, New Delhi
- [3] Singh SP, Gopal B (1999) Nainital and Himalayan Lakes. NIE and WWF, New Delhi, p 62
- [4] Singh SP, Gopal B, Kathuria V (2001) Integrated management of water resources of Lake Nainital and its watershed: an environmental economics approach. EERC, Indira Gandhi Institute for Developmental Research, Mumbai
- [5] Singhvi, A.K. ; Banerjee, D; Pande, K; Gogte, V; Valdiya, K.S. **Luminescence studies on neotectonic events in south-central Kumaun Himalaya - a feasibility study,** Quaternary Science Reviews, 13 (5-7) (1994), pp. 595-600.
- [6] Valdiya, K.S. **Geology of Kumaun Lesser Himalaya**
- [7] Wadia Institute of Himalayan Geology, Dehradun (1980).
- [8] Upadhayay, V; Naini Lake Should Ideally be 5-7 ft Above Normal, Times of India, 2018.

BIOGRAPHIES



Rishabh Singh is a student of B. Tech (Agricultural Engineering) from GBPUAT, Pantagar



Chiranjeev Pant is a student of B. Tech (Agricultural Engineering) from GBPUAT, Pantagar