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Weather station and annual temperature dynamics in the elevation gradient (spatial and temporal analysis of Chitwan-Annapurna, Nepal)

Abstract

This research was objectively done to assess gaps in distribution of weather stations, show temperature status and dynamics. Hence, primary data specifically minimum and maximum temperature from 1970 to 2015 was collected from 35 functional weather stations in Chitwan Annapurna Landscape (CHAL) of nineteen districts, Nepal. The map of the weather station was prepared. Moreover, linear regression, ANOVA and Duncan test were applied for statistical analysis. The result revealed that there was only one weather station above 3800 m elevation. The annual average, maximum and minimum temperatures below 200 m were 24.84±0.06, 31.07±0.10 and 18.61±0.73⁰C and the difference between these records was 12.46⁰C. The highest differences in the temperature was recorded 14.56⁰C above 3800 m though the maximum and minimum temperatures were very low only 14.94±0.28 and 0.38±0.20⁰C respectively. There was high correlation r^2 with 0.955, 0.922 and 0.911 of average, maximum and minimum temperature against the elevation gradient. The annual increase in average temperature ranges between 0.02-0.06⁰C. There was significance difference in annual increase in temperature according to elevation gradient. Moreover, there were eight statistically significant clusters of increasing temperature according to elevation gradient. The study guides the need of more weather stations.

Keywords: climate, weather, temperature, meteorological station, distribution, increase, altitude

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Introduction

The weather predictions are very important for various purposes like agriculture, tourism and travel, energy, irrigation, drinking water supply, fishery, biodiversity conservation and other purposes[1] particularly in mountainous country like Nepal. Climate Change is too fast in Nepal and disturbing the livelihood of the citizens in Nepal.[2] The touristic activities specifically mountaineering, trekking and travel gets affected by weather in any country. The world is warming and it is not stop soon.[3,4] The global surface temperature is projected to exceed by 1.5°C for RCP 4.5, RCP6.0 and RCP8.5 (high confidence) by the end of the 21st century (2081–2100) relative to 1850–1900.[5–7] The projection in temperature rise is alarming and it is expected to rise between 2.7 and 4.7 °C by 2100 in Asia.[8] The South Asian countries are projected to warm by 1°C (least scenario) by the end of the century.[9] The mean annual temperature during the last 25 years period has increased by 1.5⁰C with an average annual increase of 0.06⁰C between 1982 and 2006.[10]

It is not easy to forecast accurate weather and climate, which suddenly invite huge human, social, physical and economical loss.[11,12] There are several causes and risks associated to the prediction of weather and climate.[13] Most important reason is unavailability of sufficient records of metrological data due to limit number of weather stations.[14] On the other hand, the climate dynamic is the key issue which directly and indirectly relate to professions.[15,16] A few scientists have explored the temperature dynamics of Nepal but the research associated with distribution of weather stations and temperature dynamics together particularly in Chitwan Annapurna Landscape (CHAL) area was not studied before. Hence, this research was objectively carried out to find the distribution gaps in weather station; assess the increase in mean temperature and reveal the relationship between temperature and altitude.

Material and methods

Site selection

Weather stations in Chitwan Annapurna Landscape (CHAL) area were selected for the study site which covers Manang, Mustang, Myagdi, Baglung, Gulmi, Arghakhanchi, Palpa, Syangja, Parbat, Kaski, Tanahu, Lamjung, Gorkha, Dhading, Nawalparasi, Chitwan, Makwanpur, Nuwakot and Rasuwa districts. Geographically, records of temperature of these districts represent Tarai (lowlands) to Himalayan regions. Altogether there were seventy five weather stations in CHAL area. However only 34 weather stations are regular and functional. The detail of these districts specifically altitude range, latitude; longitude and area are presented in Table 1.

Table 1 Description of districts of CHAL area

Districts	Altitude m	No. of weather stations	Latitude (N) in degree	Longitude (E) in degree
Manang	1000-6400	2(1)	28.633	84
Mustang	2000-6400	10(4)	29.083	83.74
Myagdi	300-6400	8(2)	28.45	83.48

Table continue

Districts	Altitude m	No. of weather stations	Latitude (N) in degree	Longitude (E) in degree
Baglung	300-5000	4(1)	28.27	83.59
Gulmi	300-3000	3(1)	28.09	83.29
Arghakhanchi	300-3000	2(1)	27.925	82.067
Palpa	300-2000	3(2)	27.868	83.55
Syangja	300-2000	3(1)	28.02	83.8
Parbat	300-4000	3(1)	28.01	80.693
Kaski	300-6400	9(4)	28.212	83.947
Tanahu	300-2000	3(3)	27.918	84.25
Lamjung	300-6400	3(1)	28.555	84.22
Gorkha	300-6401	4(1)	28.038	84.465
Dhading	300-5000	2(1)	27.975	84.433
Nawalparasi	200-2000	5(3)	27.533	83.668
Chitwan	200-2000	3(2)	27.583	84.5
Makwanpur	200-3000	3(2)	27.429	85.03
Nuwakot	300-5000	3(2)	28.17	83.917
Rasuwa	300-5500	2(1)	27.99	85.2

Note Figure in parenthesis shows the number of weather stations having complete and regular temperature data

Sampling and experimental design

Temperature data were obtained from the Department of Hydrology and Meteorology, Government of Nepal (GoN) from 1970 to 2015 all 46 years of 34 weather stations. These weather stations were grouped based upon their distribution at interval of 200 m elevation. The graph of distribution of weather stations was prepared using Microsoft excel. The maps of weather stations were also prepared using geographical coordinates (X and Y) of location applying ArcGIS to show the spatial distribution. The text file of temperature data was converted into excel format to calculate the mean annual temperature of minimum, maximum and average temperature.

Statistical comparison

The Shapiro- Wilk normality test was done in R statistical software to examine the normality of the data. The data of average, minimum and maximum temperature showed the normal distribution (Kothari, 2004). Thus the parametric test specifically One-way ANOVA and multiple post hoc Duncan test were used to examine whether there was significant difference in mean temperature at 5% level of significance according to altitude. The summary statistics, linear regression model[17,18] between altitude and temperature as well as increase in temperature between different periods were also calculated.

Results and discussion

Distribution gaps in weather stations

The regular and complete sets of temperature data are available only from 34 weather stations in Chitwan Annapurna Landscape area. Among them more than 55.88% i.e. 19 weather stations occur below 1200 m altitude; 14 (41.17%) weather stations at the elevation range of 1200 to 3600m and only one station i.e. 2.95% above 3600m altitude (Figure 1&Table 1). Some of the weather stations are not functioning well so the complete set of data is not available. The reason of incomplete set of metrological data may be due to irregularity in charging the solar batteries. The solar power system needs at least five hours sunlight each day.[19] Another reason may be weather station is not regularly maintained[20] due to lack of local technical experts.

The analysis reveals that a huge gap in distribution of weather stations in CHAL area according to the elevation band. The weather stations were nil in the elevation range of 600-800m, 2800-3600m and even only one weather station was at above 3800m. Moreover, the available record of temperature at elevation range of 1200-1400 m was not consistent. There are not any standard criteria and policies to maintain the distance between two weather stations. Generally weather stations are installed where there are easy accessibility and transportation to maintain the equipment and monitor the stations. Another reason is, the establishment of weather stations depends up on the objective of the institutions or project. However, the aspects, slope and hilly terrain have high influence on the climatic data.[21] There are several weather stations in different parts of hilly region of India. There are 21 weather stations in Assam, 7 in Meghalaya, 1 in Sikkim and 7 in Arunachal Pradesh,[22] though these numbers are also inadequate to understand the weather. The Himalayan Environmental Rhythms Observation and Evaluation System (HEROES) Project in Bhutan has been supporting a network of 23 weather stations out of that 20 stations were installed in schools, and 3 in remote mountain locations to relate the records of climate variable with the climate change issue.[23] These are some examples of weather stations. However, it is realized that there are inadequate numbers of weather station in hilly areas in Nepal too to forecast the weather precisely (Figures 1&2).

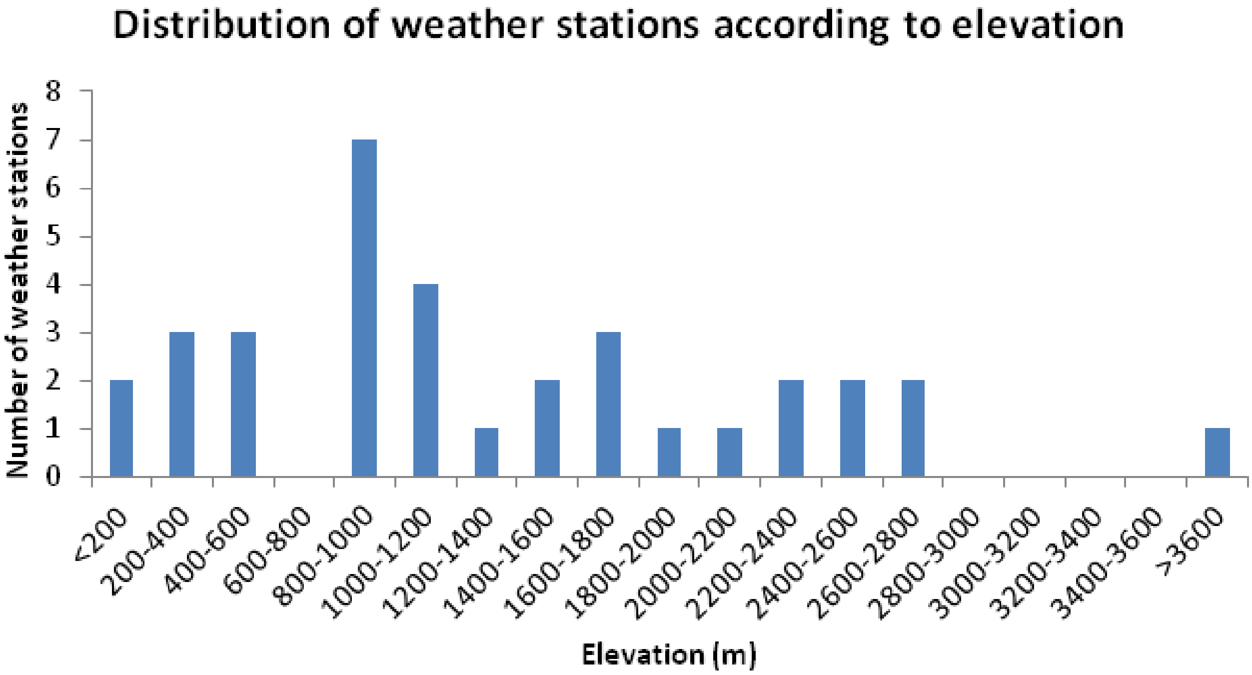

Figure 1 Number of weather stations according to elevation gradient altitude and distribution of weather stations.

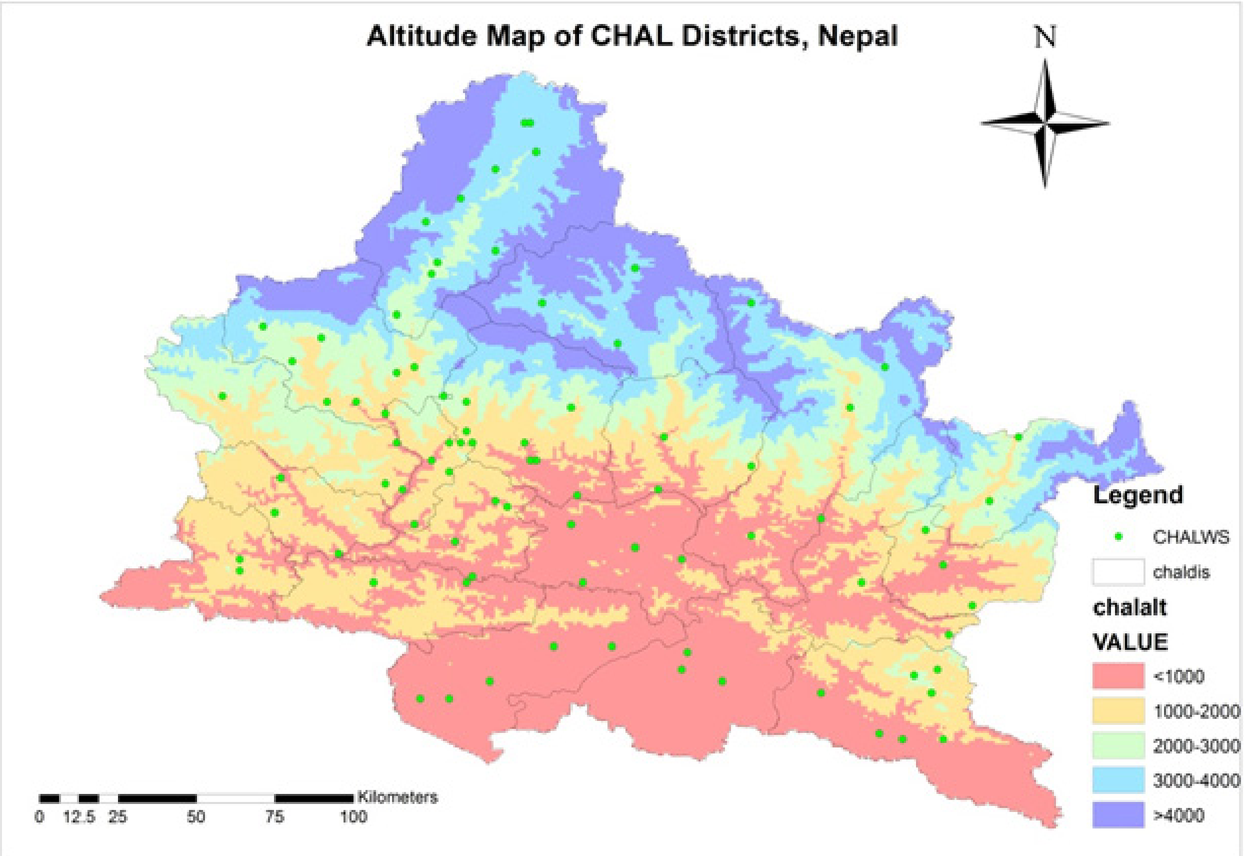

Figure 2 Altitudinal variation in CHAL.

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The altitude below 1000 m in CHAL covers about 11858.79 sq km which is nearly 33.07% but the total number of weather station is 15. The area of slope >4000 m in CHAL cover nearly 8282.33 sq km (23.10 %) but there is no any weather station. Thus, the gaps are clearly indicated in weather station which is the problem of weather prediction in Nepal (Table 2).

Table 2 Altitude and area coverage

Altitude	Area Sq Km	Percentage	Remarks
<1000	11858.79	33.07	
1000-2000	8277.78	23.08	
2000-3000	3802.65	10.6	
3000-4000	3639.46	10.15	
>4000	8282.33	23.1	

Temperature dynamics according to elevation

The mean annual average, maximum and minimum temperatures were 24.84±0.06, 31.07±0.10 and 18.61±0.73°C below 200 m and the difference between mean maximum and minimum temperature was 12.46°C. The highest differences in temperature was recorded 14.56°C above the 3800 m though the maximum and minimum temperatures were very low only 14.94±0.28 and 0.38±0.20°C respectively. The lower minimum temperature below 6°C was recorded above 2400 m altitude. This research showed that the altitude has high influence on regional temperature which was supported by Jain and Kumar.[24] The higher variation in minimum and maximum temperature, the higher influence is on climate change (Table 3).[25,26]

Spatial distribution of weather stations

The spatial distribution of weather station showed that there was greater number of weather stations in western parts of CHAL in comparison to eastern area. Though altitudinal variation was very high in Gorkha district, there were only four weather stations. In case of Rasuwa district, there were only two weather stations which cannot represent the climate of western part. Air temperature observations at ground stations are essential but many high-altitude areas (greater than 4.000 m) are still heavily under sampled (Figures 3−5) (Tables 4−6).[27] The percentage coverage of aspect in CHAL area is varied. There are 31.81% SW aspect in CHAL and it was followed by 26.81% SE aspect. The distribution of climatic variables of CHAL is also affected due to theses aspects. Obviously the temperature and rainfall are affected because of the hilly aspects.

Table 3 Summary statistics of maximum and minimum temperature (^{0}C) of CHAL area

Altitude range (m)	Elevation range (m)	Temperature °C based on mean temperature				Remark
		Average	Maximum	Minimum	Difference (Max-Min)	
<200	154	24.84±0.06	31.07±0.10	18.61±0.73	12.46	
200-400	205-358	24.22±.08	30.67±.09	17.77±0.11	12.9	
400-600	460-500	23.01±.05	29.20±.07	16.83±.07	12.37	Stations missing in 600-800 &
800-1000	823-965	21.12±0.06	27.07±0.07	15.17±0.06	11.9	1200-1400
1000-1200	1003-1097	20.97±0.08	26.26±0.11	15.68±0.09	10.58	m altitude range
1400-1600	1432-1530	17.68±0.11	22.87±0.16	12.50±0.12	10.37	
1600-1800	1740-1760	15.87±0.07	19.67±0.12	12.07±0.06	7.6	
1800-2000	1900-1982	15.48±0.11	20.33±0.16	10.63±0.17	9.7	
2000-2200	2064	15.25±0.11	19.87±0.08	10.64±0.19	9.23	One station
2200-2400	2314-2384	12.82±0.16	18.02±0.14	7.95±0.28	10.07	
2400-2600	2530-2566	11.32±0.10	17.18±0.14	5.46±0.13	11.72	
2600-2800	2680-2744	10.62±0.25	16.68±0.23	4.56±0.31	12.12	
>3800	3870	7.80±0.28	14.94±0.28	0.38±0.20	14.56	One station

Note 1 There is inconsistency in weather station at 600-800, 1200-1400, 2800-3600 and higher than 3900 m altitudes

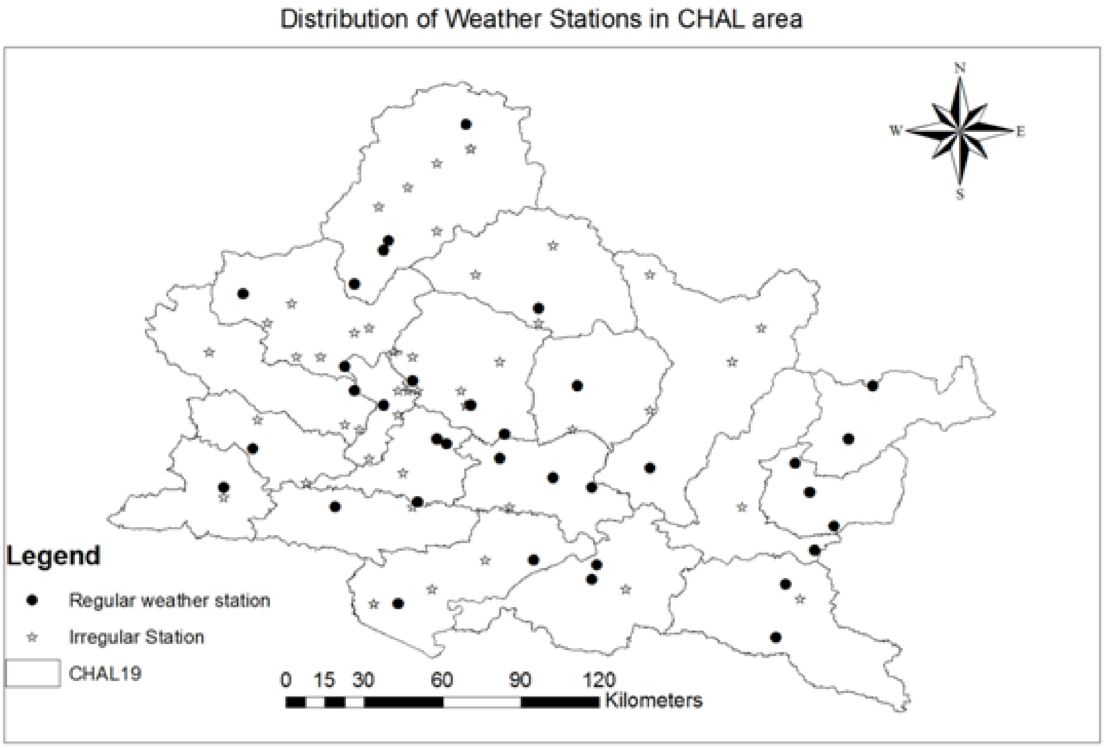

Figure 3 Spatial distribution of weather stations in CHAL area Nepal.

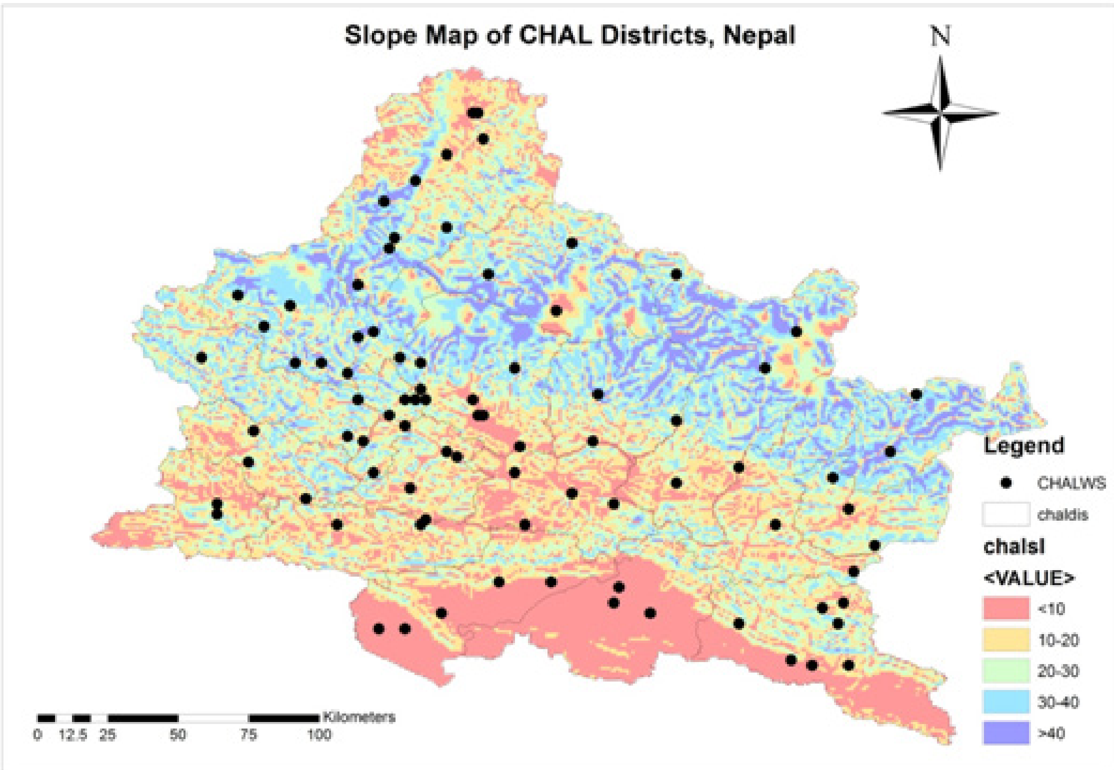

Figure 4 Slope dynamics in CHAL.

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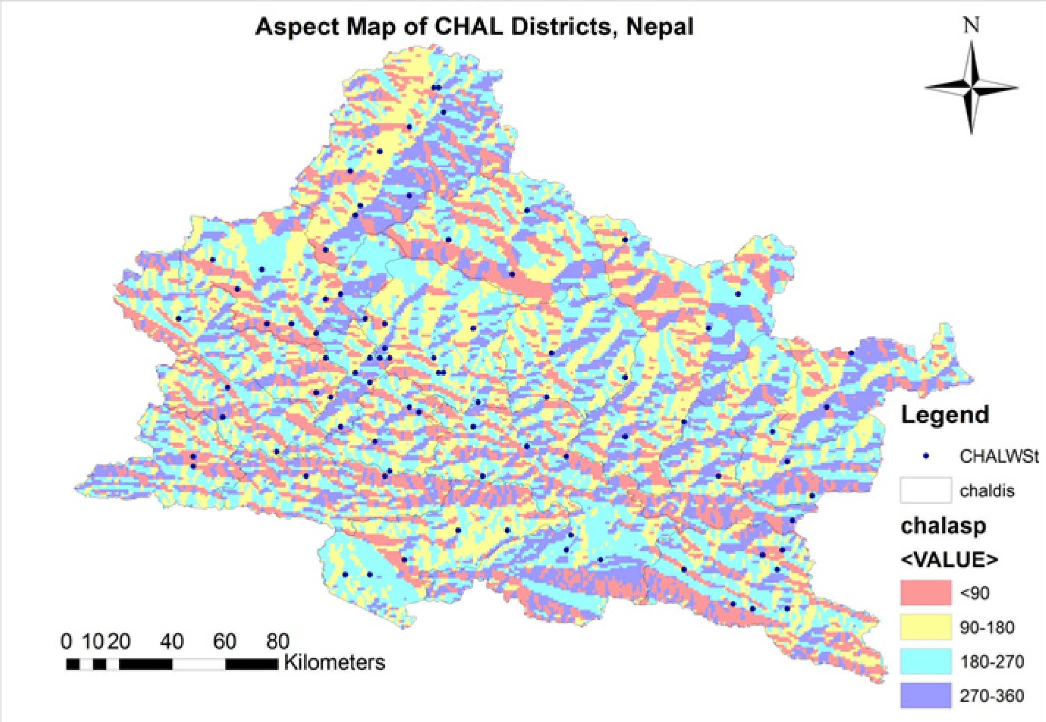

Figure 5 Aspect dynamics in CHAL area.

Table 4 The slope is another factor affecting the climatic variables in Nepal

Slope	Areas	Percentage	Remarks
0 to 10	16635.25	46.39	
10 to 20	13124.82	36.6	
20 to 30	5168.107	14.41	
30 to 40	878.9349	2.45	
>40	53.88979	0.15	

Table 5 Aspect dynamics in CHAL area

Slope	Areas	Percentage	Remarks
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10 to 20	13124.82	36.6	
20 to 30	5168.107	14.41	
30 to 40	878.9349	2.45	
>40	53.88979	0.15	

Table 6

Correlations	Regression equation	Coefficient of determination R^2	Remarks
Average Temperature VS Altitude	Y=0.005X+25.72	0.955	
Maximum Temperature VS Altitude	Y=0.005X+31.95	0.92	
Minimum Temperature VS Altitude	Y=0.005X+19.78	0.911	

Annual temperature dynamics and elevation gradient

There was a strong relation between altitude and average annual temperature. The linear regression showed that the R^2 value was 0.955. The finding depicted that there was decrease in average temperature according to the elevation gradient from Tarai to Himalaya. This was justified by several studies like research done by Pepin and Seidel[28] and Oyler et al.[29] Moreover, there is a rapid warming trend in high elevation zone[30,31] because of melting snow and ice result in lower surface albedo which contributes to further warming.[32] The cooling is another key characteristic of high mountainous region in comparison to plain due to circulation of cold air. In fact, cold air pooling and local heating are happened due to combination of topography and synoptic condition.[33,34] This may be one of the reliable reasons of rapid warming in high altitude. Similar results recorded for the relation between mean maximum annual temperature and elevation gradient having coefficient of determination (R^2) about 0.922. Available records showed that there was very good relationship between minimum temperature and elevation gradient. The linear

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regression showed that R^2 was 0.911 of these two variables. However, there was high variation in mean minimum temperature.

Conclusion

A big gap in occurrence of weather station at high elevations area especially above 2800-3600 m was noticed. The temperature rise was higher at high elevation and lower at low altitude. There was high correlation between temperature and elevation gradient. The present study reveals the need of weather stations above 2800 m and also emphasizes on the maintenance and monitoring weather stations regularly.[35,36]

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Conflicts of interest

Author declares that there is no conflict of interest.

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