Research Article

Trends of Climate Change in Some Selected Districts of Western Nepal

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Abstract

Climate change is a global threat that has particularly strong impacts on countries whose economies are highly dependent on agriculture and still developing--like Nepal. The main objective of this study is to assess the trend of climate change in Gandaki Province, Nepal. This study is based on secondary data. It utilizes the data from the Department of Hydrology and Meteorology between 1970- 2018 based on eight districts with 10 different stations ranging from 110m. to 2680m. in Gandaki Province. Mann-Kendall test and Sen's slope is used to find the trend. The analyses reveal that trend of maximum temperature is increasing and significant. The maximum temperature trend is 0.08°C/year in monsoon and post-monsoon which is greater than the global rate. The minimum temperature trend is positive and significant and is highest in the monsoon season (0.04°C/year). The trend of the average rainfall sum is insignificant and is positive only in pre-monsoon and negative in other seasons, which indicates erratic rainfall that causes floods and droughts.

Keywords: Climate change, district, trend, western Nepal

Introduction

Global climate is changing naturally (CEH, 2007; Dhakal, 2010), but the changes in the last 50 years are dramatic, and scientists attribute the changes to human-induced factors (IPCC, 2001, 2007). The observed global mean surface temperature (GMST) for the decade 2006–2015 was 0.87°C higher than the average over the 1850–1900 periods. The global mean temperature shows warming of 0.85°C over the period 1880 to 2012(IPCC, 2014). The continuous increase in greenhouse gas emission due to anthropogenic pressure would further amplify the rate of increase in temperature and intensify the frequency of extreme weather events including floods, droughts, changing rainfall patterns, water resources depletion, and severe heat/cold waves. It has posed the global communities especially the poorest households more vulnerable to climate change. Climate change has a wide range of impacts on natural resources and biodiversity causing threats to forest conservation, species extinction, and the occurrence of pests and Disease (IPCC, 2007; IPCC, 2014).

One of the visible impacts is observed in the glaciers and glacial lakes in the Himalayas which are changing at an unprecedented rate. Himalayan glaciers are retreating faster as a result vanishing of small glaciers thereby leading to a shortage of water supply for power generation and irrigation in winter, particularly in highly glaciated basins. (Sun et al.,2017; Shrestha et al.,1999; Gautam et al., 2013). Climate change impacts water resources and energy, health, agriculture sector, disaster, tourism, gender, and urban sector (NCCIS, 2016; MoPE, 2019; Karki et al., 2020). Climatic variables have caused the increased frequency of disasters including flash floods posing many people to high vulnerability and exposing them to the risks of climate-induced disasters (MoPE, 2012). There was a significant decrease in the number of extreme cold events but a significant increase in the number of extreme warm events over the entire Hindu Kush Himalaya. The increasing trend of average temperature in the Terai region increasing heat stress (Pradhan et al., 2013).

Climate change has amplified extreme weather events which are more recurrent and intense in certain places around the globe. The temperature extreme is increasing in most South Asian countries. Heatwaves and rainfall intensity has increased that contributed to accelerating drought and extreme flood events. The number of wet days is reduced. The temperature trends are spatially less coherent than rainfall trends. (Naveendrakumar et al., 2019; Agarwal et al., 2016).

Nepal is a very fragile country with elevation ranges from 68 meters' low land (Terai) in the south to 8848 meters, the highest peak of the world, Mount Everest in the north. This large north-south variation of topography gives rise to different climatic regions; just within a span of about 193 km are very sensitive to climate change and variability (NAST, 2013). It has climate ranges from subtropical to tundra with different varieties of species which are rarely found in the rest parts of the world. The plant species native to any bioclimatic region of the world can adapt to the Nepalese climate (Shrestha et al., 2017a). It is rich in a diverse ecosystem. Nepal is the most vulnerable country to climate change due to rough and highly unstable geography, inadequate institutional capacity, underdeveloped infrastructures, increasing temperature, changing precipitation patterns, the threat from biological invasion, and limited adaptive capacity(CBS, 2017; Paini et al., 2016).

Climate change is observed in the form of rising temperatures, change in rainfall patterns, unfavorable weather phenomena, and an increase in the frequency of natural disasters. (K.C., 2018). The temperature is rising at a higher rate in Nepal and the Chinese regions of the Himalayas compared with the rest of the Himalayas (Gautam et al., 2013). Chaulagain (2006) has pointed out that the climate in the Nepal Himalaya is changing faster than the global average. The mean annual temperature has been increasing by 0.06 °C per year (MoPE, 2016). The maximum temperature trend is higher in a mountain and Himalayan region ranging from 0.06°C to 0.12°C per year and less than 0.03°C in Terai (Shrestha, Wake, Mayewski & Dibb, 1999); Karki et al., 2020). According to the Observed Climate Trend Analysis report (2017) the maximum temperature trend is significantly positive (0.056 ^{0}C /yr) and the minimum temperature trend is also positive (0.02 ^{0}C/yr) and insignificant. It is warming in general with maximum temperature (0.04°C per year) increasing faster than minimum temperature (0.02°C per year) on countrywide average which is contrary to the changes in the Tibetan Plateau and its surroundings and the global average(Kattel & Yao, 2013; Karki et al., 2020)). The maximum and minimum temperatures show increasing trends, while frost days and the diurnal temperature range (DTR) show significant decreasing trends(Sun et al., 2017; Joshi et al., 2019; Pradhan et al., 2013).

Nepal's nighttime land surface temperature is increased more prominently warming in the pre-monsoon and monsoon seasons, while the daytime land surface temperature change was statistically insignificant (Luitel et al., 2019). The magnitude of spatial warming is higher for maximum temperatures, while minimum temperatures exhibit larger variability such as positive, negative, or no change which is consistent with the Indian subcontinent and Upper Indus Basin, but different from conditions on the Tibetan Plateau (China), where the warming of minimum temperatures is more prominent than that of the maximum temperatures(Kattel & Yao, 2013). The changes in extreme temperatures are spatiotemporally heterogeneous and unique. There are strong correlations between the trends of maximum temperature-related variables and elevation ie. warming faster and greater in higher elevation. It also reveals that December and January tend to have colder days in the Terai but summer months are getting hotter in each region across the country(Poudel et al., 2020). The trend of average, maximum, and minimum temperature indicate that the temperature has increased significantly (Devkota, 2014).

The increases in precipitation have been accompanied by an increasing frequency of extremes over the southern central Himalaya. However, no relation could be established between the precipitation extreme indices and circulation indices for higher altitudes. (Sigdel & Ma, 2017).

Most literature predicts increases in monsoon precipitations and decreases in winter precipitations in the future thereby leading to monsoon flooding and increased sediments in streamflow (Gautam et al., 2013; Devkota, 2014). The mean rainfall has been decreasing by 0.37 mm (-3.2%) per month per year (MoPE, 2016).

Climate change is the biggest environmental challenge that plays out through changing intensity, duration, and frequency of extreme events in the Gandaki basin. The lowlands regions bringing about rainfall related hazards like floods and soil degradation due to intense rainfall and in hill region possible cause of landslides. In the eastern part of the basin due to the significant decreasing trend of annual total wet days precipitation impacts agriculture facilities, food security, and water scarcity. (Lamichhane et al. , 2020). At the district level for the maximum temperature, the highest significant positive trend (0.12 ^{0}C/yr) is observed in the Manang district in the winter season. The significantly highest positive rainfall trend is observed in Syangja and Parbat districts in the monsoon season. (DHM, 2017).

Data and Methods

The climatic stations were chosen so that it represents all the climatic zones of the Gandaki province as far as possible. Ten stations are considered in this study to look at the trend pattern in temperature. Out of these, Lumle, Pokhara Airport, Khairine Tar, Baglung, Beni Bazar, and Khudi Bazar, lie in the hilly region, whereas Dumkauli and Semari lie in the southern low lying Terai belt with an altitude less than 300 m and Thakmarpha, and Chame from the high mountain region. Out of ten stations, only two stations used in this study are located at an altitude of about 2500m or above. These two stations are Chame (2680m) in Manang District and Thakmarpha (2655m) in the Mustang district.

For climatic data, long-term temperature and rainfall data were obtained from the department of hydrology and meteorology. Data has a monthly temporal resolution and spans 49 year period from 1970 to 2018. The seasonal mean rainfall and temperature for four prominent seasons (pre-monsoon, monsoon, post-monsoon, and winter) were calculated.

Mann–Kendall Test is a statistical method that is mostly used to check the null hypothesis of no trend versus the alternative hypothesis of the existence of monotonic increasing or decreasing trend of hydro-climatic time series data. The non-parametric Mann Kendall test is fit for those data series where the trend may be assumed to be monotonic (i.e. mathematically the trend consistently increasing and never decreasing or consistently decreasing and never increasing) and no seasonal or other cycle is present. Sen's slope Estimator has been used for predicting the magnitude (true slope) of hydro-metrological time series data. It uses a linear model for the trend analysis.

Result and Discussion

Pattern of Temperature and Rainfall Trend

Table 1

Spatial Distribution of Temperature and Rainfall

Station	District	Minimum Temperature				Maximum temperature				Rainfall sum			
		Min	Max.	Mean	S.D	Min	Max	Mean	S.D	Min.	Max	Mean	S.D.
604	Mustang	-4.6	14.4	5.41	5.49	6.0	24.8	17.16	4.01	0	209.2	33.41	33.05
605	Baglung	4.5	23.0	14.99	5.64	18.8	35.0	27.89	4.02	0	978.1	158.33	199.34
609	Myagdi	2.6	24.6	15.52	5.37	18.3	35.04	28.32	4.09	0	871.1	135.7	159.4
706	Nawalparasi	7.3	26.5	18.80	6.12	19.0	39.8	30.84	4.56	0	1225.8	196.45	245.26
728	Nawalparasi	2.5	30.3	18.15	6.80	10.8	44.9	31.56	6.02	0	1350.5	159.15	228.53
802	Lamjung	-1.9	22.5	14.89	5.36	17.5	38.4	26.87	4.07	0	1427.5	277.17	323.69
804	Kaski	5.0	23.1	15.44	5.44	17.5	33.6	26.64	4.04	0	1815.1	320.55	366.02
814	Kaski	2.5	18.5	12.01	4.50	11.2	27.4	20.05	3.90	0	2149.6	449.04	548.44
815	Tanahun	1.2	25.2	16.88	5.79	11.5	36.7	29.05	4.60	0	1130.8	189.87	213.88
816	Manang	-5.3	13.1	4.82	4.79	5.5	24.5	16.94	4.20	0	439.2	79.91	79.81

The spatial distribution of minimum temperature, maximum temperature, and rainfall sum of ten stations in eight districts indicates that the minimum temperature is least in Manang district (-5.3°C) and highest in Nawalparasi (7.3°C) whereas maximum temperature is least in Manang (5.5°C) and highest in Nawalparasi (44.9°C) and the maximum rainfall in Kaski district(2149.6mm) in Lumle station. The data indicate that maximum variation in minimum temperature is in Nawalparasi (6.80°C) and maximum temperature also in Nawalparasi (6.02°C).

Trend of Maximum Temperature

The maximum temperature trend is highest in monsoon and post-monsoon season (0.08°C/

year) followed by pre-monsoon season (0.079°C/year) and lowest in the winter season (0.072°C/year). The highest value of the maximum temperature is 26.7°C in 2016 and the lowest value is 23.7°C in 1980. The average maximum temperature since1970 to 2018 is 25.4°C with the utmost variation in maximum temperature in that period is in 1992(S.D.=7.95° C). On observing the record of the maximum temperature of the Gandaki province the trend is found to be positive (0.078^{0}C/year) which is greater than the maximum temperature trend of 0.056^{0}C/year for Nepal (DHM, 2017). The graph and trend line of maximum temperature is given in figure 1 and its Kendall test and Sen's slope value are presented in table 3 which indicate that the maximum temperature trend is positive in all seasons and is highly significant.

Figure 1

Trend of Maximum Temperature of Different Seasons

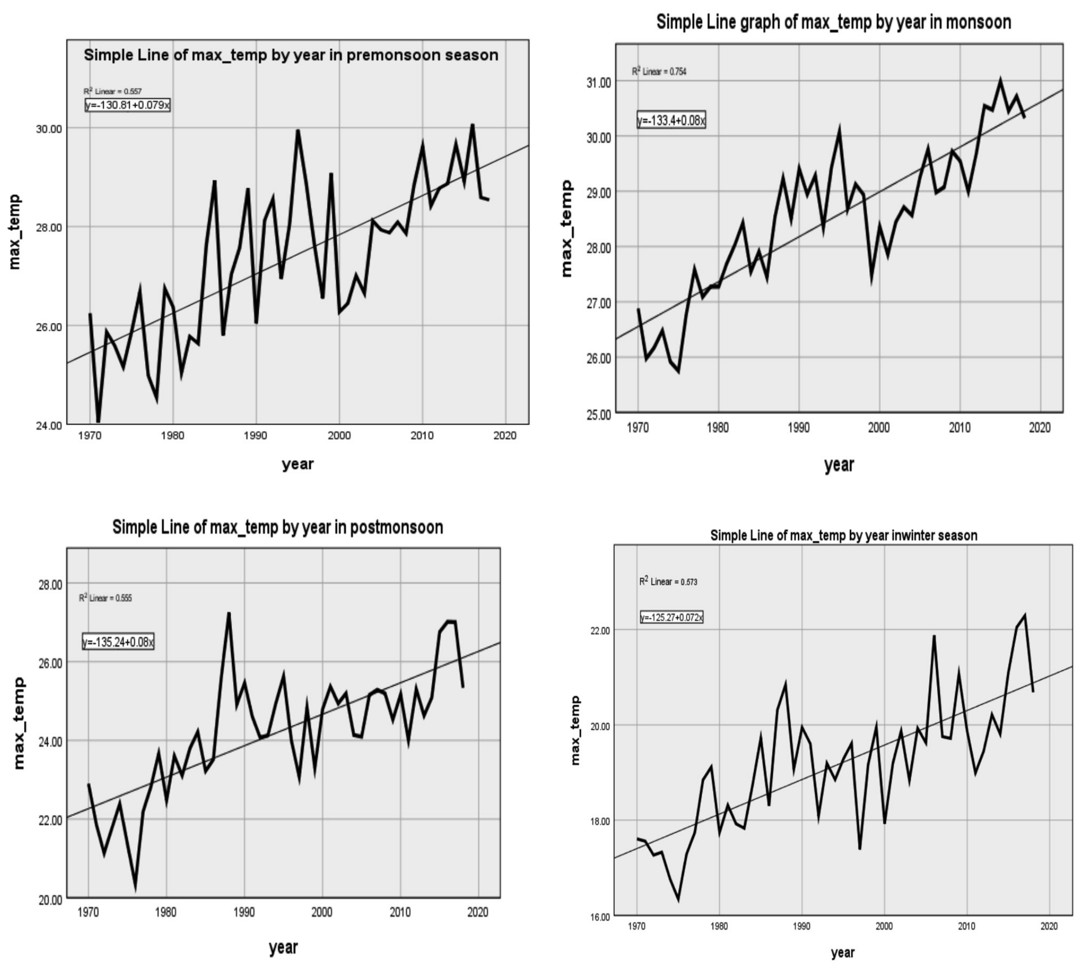


Table 2

Mann-Kendall Test and Sen's Slope of Maximum Temperature

Season	Mann Kendall value	Sen's slope	Trend
Pre-monsoon	0.542***	0.080**	positive
Monsoon	0.689***	0.083***	positive
Post-monsoon	0.554***	0. 079***	positive
Winter	0.576***	0.072***	positive

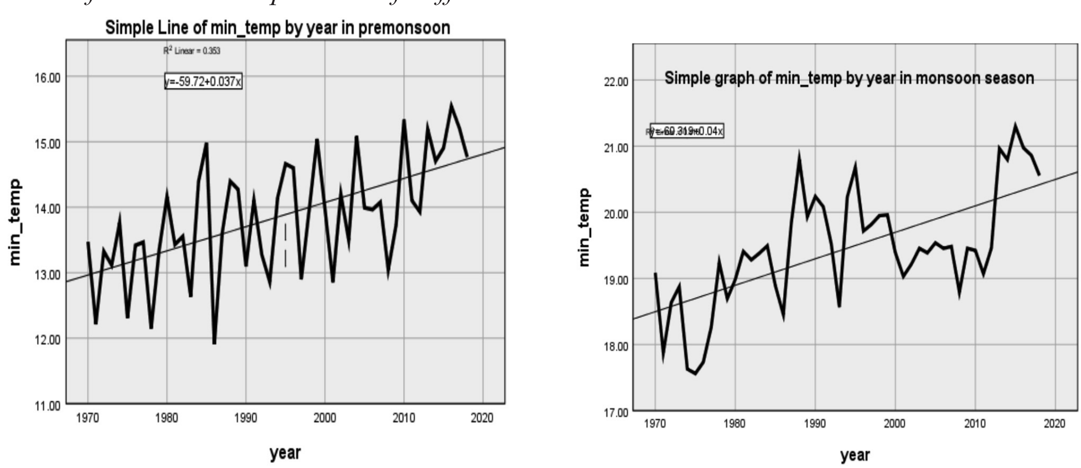
Note: ***=p<0.001

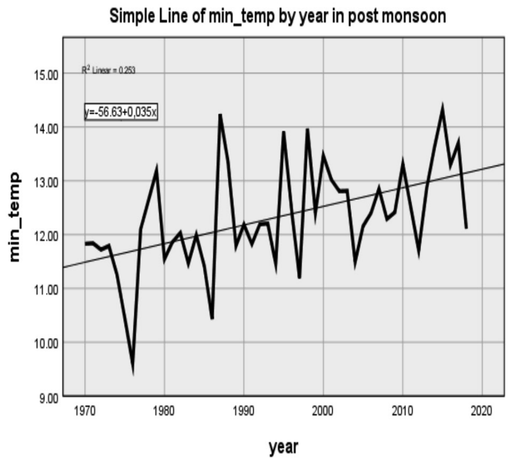
Trend of Minimum Temperature

The minimum temperature trend is highest in monsoon season (0.04°C/year) followed by pre-monsoon season (0.037°C /year), post-monsoon (0.035°C /year), and lowest in the winter season (0.03°C /year). On observing the record of the minimum temperature of the selected district, the trend is found to be positive (0.036^0C /year) which is slightly greater than the minimum temperature trend (0.02^0C /year) for Nepal (DHM, 2017). The graph indicates (Fig.2) that the highest value of the minimum temperature is 15.32°C in 2015 and the lowest value is 11.96°C in 1986. The average minimum temperature since1970 to 2018 is 13.7°c with the maximum variation in minimum temperature in that period is in 2007(S.D.=7.7°C). The graph and trend line is given in Figure 2. The Mann-Kendall test and Sen's slope value are presented in table 4 which indicate that the minimum temperature trend is positive in all seasons and significant.

Figure 2

Trend of Minimum Temperature of Different Seasons





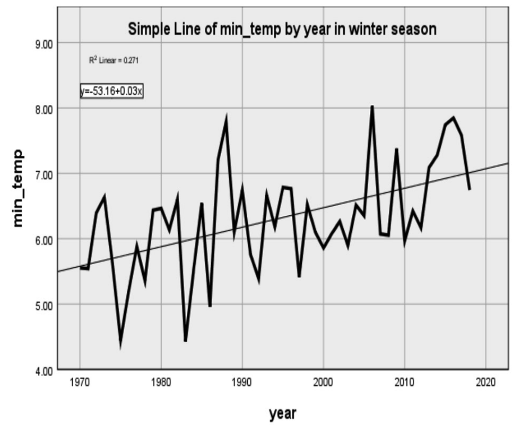


Table 3

Mann-Kendall Test and Sen's Slope for Minimum Temperature of Different Seasons

Season	Mann Kendall value	Sen's slope	Trend
Pre-monsoon	0.399***	0.037***	positive
Monsoon	0.433***	0. 039***	positive
Post-monsoon	0.366***	0.032***	positive
Winter	0.329***	0.028***	positive

Note: ***= p<0.001

Trend of Rainfall

The rainfall-sum is 0.19mm/year in pre-monsoon season, -0.042mm/year in winter season, -0.32mm/year in monsoon season and -0.54mm/year in post-monsoon. The average rainfall_ sum is found to be a slightly negative trend (-0.165mm/year). The average rainfall is maximum in 1995(262.42 mm) and minimum in1990 (163.113 mm) and the average rainfall from 1970-2018 is 206.152mm. The graph and trend line is given in figure 4. The Mann-Kendall test and Sen's slope estimator are presented in table 6 which indicate that precipitation trend is positive only in pre-monsoon and negative in all other seasons but the trend is insignificant in all seasons; showing the extreme pattern of rainfall-sum causes floods and droughts .

Figure 3

Trend of Rainfall-total in Different Seasons

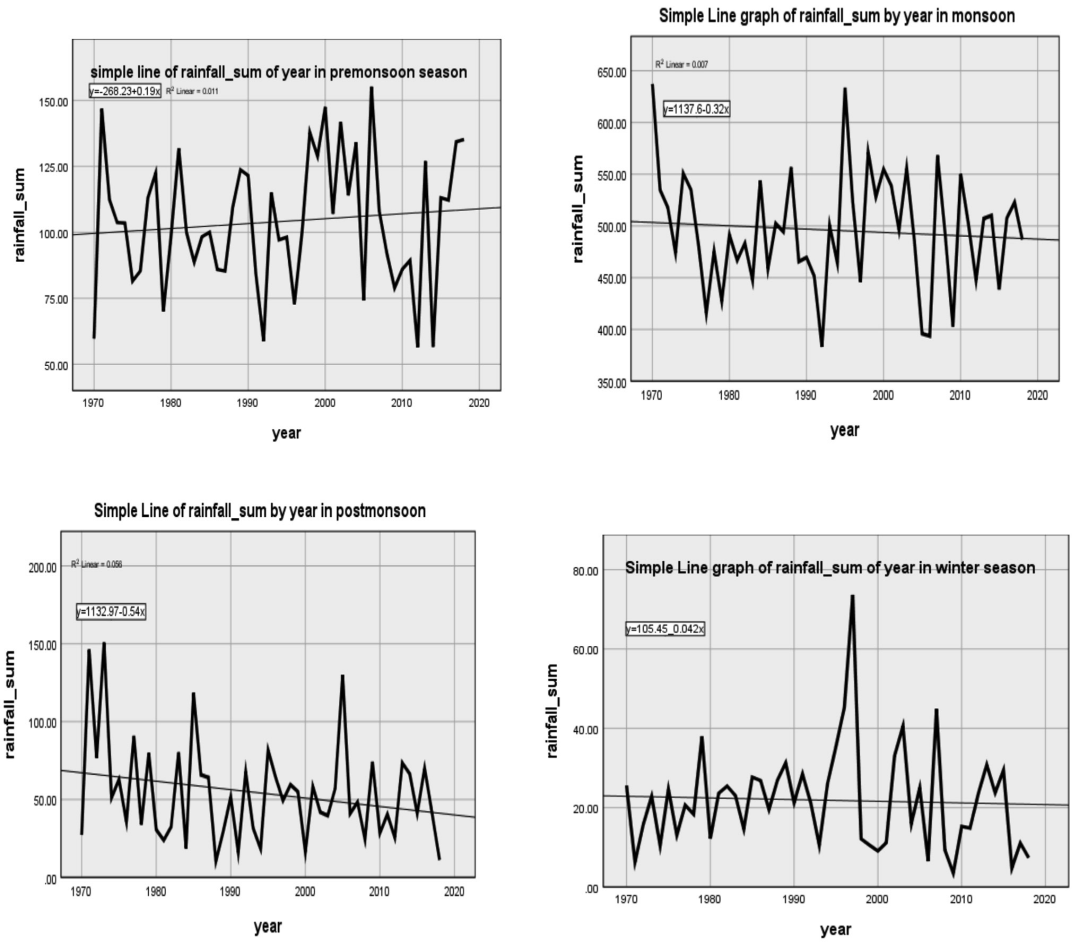


Table 4

Mann-Kendall Test and Sen's Slope of Rainfall_Totla of Different Seasons

Season	Mann-Kendall value	Sen's slope	Trend
pre-monsoon	0.082	0. 220	positive
monsoon	-0.012	-0.148	negative
post-monsoon	-0.119	-0.377	negative
winter	-0.039	-0.057	negative

Note: * All values are not significant (p>0.05)

Conclusion

This study highlights the current status of temperature and precipitations in Gandaki Province. The trend of maximum temperature is positive(0.078^{0}C/year) and significant which is greater than Nepal's maximum temperature trend(0.054^{0}C/year). The increase in temperature indicates an increase in extreme events. The precipitation trend is negative (-0.165mm/year). It indicates the increase in extreme events like floods and drought in this region.

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