Spatial and Temporal Variations of Surface Air Temperature (1962–2022) across Physiographic Regions in the Koshi Basin, Nepal

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Abstract

This study analyzed the seasonal and annual trends of maximum temperature (Tmax), minimum temperature (Tmin), and mean temperature (Tavg) across the physiographic regions of the Koshi Basin (Himalaya, High Mountain, Middle Mountain, Siwalik, and Tarai) using observed data from 23 stations between 1962 and 2022. Missing temperature data were filled using the lapse rate method. The Mann-Kendall (M-K) test was employed to assess the consistency of the temperature dataset. The analysis revealed distinct regional and seasonal temperature trends in the Koshi Basin. In the Middle Mountain and High Mountain regions, Tmax increased significantly during the Pre-monsoon season, while Tmin decreased significantly during Monsoon and Winter. Conversely, the Siwalik and Tarai regions experienced more pronounced cooling trends, especially during Monsoon and Winter. Overall, the Himalaya and High Mountain regions exhibited a cooling trend until the late 1990s, followed by a warming trend. The Middle Mountain region demonstrated similar patterns, with a significant temperature increase after the 1990s. The Siwalik and Tarai regions experienced a general cooling trend, although the Siwalik region exhibited some fluctuations. The key findings are the significant regional variations in temperature trends were observed. The Tmax was increased in the Pre-monsoon season, while Tmin decreased in Monsoon and Winter in the Middle Mountain and High Mountain regions. The Siwalik and Tarai regions experienced cooling trends, particularly in Monsoon and Winter. Similarly, the Himalaya and High Mountains showed a cooling-warming shift in the late 1990s. The seasonal variations were prominent, especially in Monsoon and Winter. All these findings are underscoring the importance of considering both regional and seasonal factors when studying temperature trends in the Koshi Basin.

Keywords: Koshi Basin, temperature trends, spatial variation, physiographic regions, seasonal changes.

1 Introduction

Climate change (CC) contributes to increased greenhouse gas emissions, which will cause a global temperature rise of 1.40 to 5.8°C by the year 2100 compared to 1990 levels (McCarthy et al., 2001). The ongoing warming process is expected to significantly affect atmospheric and ecological processes, with wide-reaching consequences for ecosystems and human communities. The threat posed by climate change to mankind is growing, yet many of the most vulnerable individuals are still ignorant of the full effects of global warming (Maharjan et al., 2010). Globally, there has been an increase in the frequency and intensity of severe weather and climate events associated with human-induced climate change since the 1950s. These occurrences are predicted to get worse as long as global warming continues (IPCC, 2023) (IPCC, 2021). The effects of climate change can particularly threaten small, developing nations whose economies and means of subsistence mostly rely on natural resources. One of these nations is Nepal, which is distinguished by its landlocked location, diverse physiographic features within a small region, and difficult hilly terrain (Shrestha and Aryal, 2011). Nepal, recognized as the fourth most climate-vulnerable nation, exemplifies the challenges posed by climate change (Manandhar et al., 2011; Reilly et al., 2001). Notably, the warming rate in Nepal's Himalayan regions is expected to be greater than the global average, particularly in high-altitude areas (Leduc and Bhattarai, 2008; Yao et al., 2019; Shrestha et al., 1999).

Seasonal shifts, such as heavy rainfall during the monsoon season and accelerated glacier melt, contribute to a range of climate-induced hazards, including landslides, floods, and droughts. The effects of these changes are becoming more apparent, and they present a significant challenge to the country's infrastructure and future development (Pokhrel & Pandey, 2011). Climate-related disasters are now the primary cause of natural disaster deaths in Nepal, with their frequency increasing in recent years. Because of its sensitivity and lack of preparation, Nepal is regarded as one of the country's most susceptible to catastrophic weather occurrences (Aksha et al., 2018) and (Eckstein et al., 2021). Environmental changes in the Koshi Basin, one of the significant subbasins of the Ganges River, have led to multiple challenges. Rising temperatures and changing precipitation patterns have increased the frequency and intensity of floods and droughts, leading to increased vulnerability in this region (Bastakoti et al., 2017). The Koshi Basin spans a wide geographical area, ranging from elevations near 100 meters to over 8,000 meters, including the highest point on Earth, Mount Everest. This varied topography results in significant temperature differences within the basin (Bhatt et al., 2014). Multiple studies have demonstrated that the Himalayan region is warming at a faster rate than the global average, with temperature trends showing significant variability across altitudes and seasons. Hingane et al., (1985), Shrestha et al., (2017), Sabin et al. (2020) highlighted that while warming rates are generally consistent, they vary depending on altitude, commonly referred to as the elevation dependency of climate warming. Their studies revealed an increase in mean annual temperatures, with some areas experiencing a rise of 0.4 degrees Celsius over the past century. Shrestha et al. (1999) investigated maximum temperature trends in Nepal from 1971 to 1994, reporting an average annual temperature increase of 0.06 °C/year. This finding underscores the persistent warming trend in Nepal, particularly in higher-altitude regions. Recent studies further emphasize that the warming rates in the Himalayas are not uniform. Some regions, particularly in the western and central parts of Nepal, have experienced more rapid warming than others. The seasonal patterns also vary, with significant temperature increases noted during winter, followed by spring, autumn, and summer (Agarwal et al., 2016). In the Koshi Basin, Shrestha et al., (2017) found that hill and mountain areas experienced warming between 1975 and 2010, while the plains showed minimal warming or even declines. Bastakoti et al., (2017) observed an increasing variability in minimum temperatures and a narrowing of the range of maximum temperatures. These findings highlight the critical importance of understanding the specific temperature trends in regions like the Koshi Basin to assess their impact on ecosystems and communities. Additionally, studies such as those by Poudel et al., (2020) emphasize the growing complexity of climate impacts, particularly in regions with varying elevations and climatic conditions. Nepal's climate ranges from subtropical in the Tarai to arctic in the high Himalayas due to its unique physiographic and topographic diversity within a short north-south span. The mean maximum temperature in the Tarai exceeds 30°C, gradually decreasing with altitude to below 22°C in the high mountains. Similarly, the mean minimum temperature ranges from above 18°C in the Tarai to below 6°C in the northwest, reflecting a distinct temperature gradient across the country's varied altitudes (Marahatta et al., 2009). Study of temperature is integral part of climate change studies, those changes can vary based on space and time (Bajracharya et al., 2023), temperature varies largely with altitude (Chand et al., 2019). Research in Nepal demonstrates the urgency of addressing climate change, as the country faces heightened vulnerability to extreme weather events and significant challenges in preparedness (Chapagain et al., 2021). This research aims to contribute to the growing body of knowledge on climate trends in the Himalayas and their implications for environmental and social resilience in vulnerable regions like the Koshi Basin.

2 Materials and Methodology

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3 Results and Discussion

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4 Conclusion

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