Assessing the Impact of Climate Change in Tawang River Basin, Eastern Himalayas

A Thesis

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by

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Abstract

Climate change in the Himalayan region has been adversely affecting various systems- physical as well as socio-economic which the mountain people depend on. Snow plays a crucial role in the hydrological cycle, in these high-elevation regions. The Eastern Himalayas is not an exception in facing the changes. The region holds uneven topography and harsh terrain and has limited ground-based data, and thus needs a better comprehension of the hydrological cycle and water resource management. The changes in climate variables (temperature and precipitation), snow cover, and/or glacier, resulting streamflow highly influence the mountain people's lifestyle as well as livelihood. Mountain tourism is one of the socio-economic sectors that has seen the climate change impact directly. These changes are elevating in nature and are projected to be increased in the future. Taking all these facts into consideration, a framework is developed to study and assess the climate change impact on the Tawang river basin, a tributary to the Brahmaputra river in the Eastern Himalayas, in this research work. Thus, this study aims to assess the changes in snow cover area, climate change (temperature and precipitation) trends, its impact on snowmelt runoff in snow cover areas of the Mago Chu sub-basin in the Arunachal Himalayas and corresponding streamflow under different projected climatic scenarios. This thesis also study the impact of climate change on the tourism sector and livelihood that depends on the tourism sector which can be a help to the water resources management of the region and other agencies.

The precipitation and temperature trends analysis in historical and futuristic time series is done using statistical trend analysis techniques- Mann-Kendall test (MK) and Sen's slope estimator (S) and the homogeneity test using Pettitt's test. The long-term historical and future (1950-2099) trends for the NEX-GDDP data RCP4.5 and RCP8.5 on approximately 30-year timescale at annual and seasonal for precipitation and at annual, seasonal, monthly, and diurnal temperature range (DTR) for temperature maximum (T_max), temperature minimum (T_min) variations is chosen. The study is carried out in three spatial points across the Tawang Chu of Tawang district , Arunachal Pradesh. The summer means precipitation for RCP4.5 (2006-2065) shows a positive trend for point 1, point 2, and point 3, with a rise in precipitation in all the study points. The mean annual precipitation statistics for all the points show an increase for RCP4.5 in the 2006-2052 and 2053-2099 timescale. During the study, all points in both RCP4.5 and RCP8.5 display a uniform rise in mean annual T_min and T_max. Still, the inter-decadal temperature statistical analysis shows that the increase in mean annual T_min is greater than the increase in T_max, indicating a decreasing trend in DTR.

After the trend analysis, the selected dataset for the precipitation, T_max, and T_min are used for the simulation of snowmelt in the Mago Chu basin (842.294 km^2), a small

tributary to the Tawang river basin using Snowmelt Runoff Model (SRM). For the simulation of future projection of the basin discharge, the selected General Circulation Models (GCM) are used. The SRM is a degree-day-based deterministic model that uses the Snow Cover Area (SCA) and meteorological variables such as rainfall and temperature. The SCA as a critical variable for SRM is calculated using images of the SCA collected from the MODIS satellite-based product, MOD10A2. A total of 8 sub-basins are demarcated within the basin. The model performance is evaluated using the coefficient of determination (R^2), Pearson correlation coefficient (r), Nash-Sutcliff Efficiency (NSE), and Volume difference (D_v) for three different years - 2007, 2009, and 2013. The results of the SRM model in simulating daily runoff for both the calibration and validation periods were satisfactory. It is found that for the snow-dominated regions, SRM is a suitable hydrological model as it considers more snow-related parameters for modeling (such as lapse rate, recession coefficient, critical temperature, etc.). Further, runoff projections were studied using the SRM model for NEX-GDDP under two different representative concentration pathways (RCP4.5 and RCP8.5) scenarios for the years 2040, 2060, and 2090. The projections indicate an increase in the flow under RCP4.5 and RCP8.5 for the years 2040, 2060, and 2090, respectively.

The change analysis and impact assessment of the climate variables and streamflow showed that the study elements would be affected by global warming. The impact of the same may affect the mountain's livelihood, especially in the tourism sector. This part of study has been carried out in the Tawang district of Arunachal Pradesh, Eastern Himalayas, and examines the perception of climate change and its consequences in tourist industry facilities including the owners and management (hotels, restaurants, souvenir shops and transportation) in Tawang and the investigation is done using questionnaire-based survey and interviews. The purposive sampling approach is used since the study is focused on climate change perception, its influence on tourism, resilience, and adaptation to climate change. The study population is divided into four groups based on their reliance on tourism-related occupations and tourism service providers: travel/tour operators, permanent workers: hotel/restaurant/resorts, seasonal workers: hotels/restaurants/resorts, and tourism-dependent livelihoods. A total of 15 respondents have been interviewed for each of the classes with a total of 60 numbers of population samples engaged in the tourism sector. The historical meteorological data is also used to validate the perception of the respondents and the homogeneity test analysis for the period 1991-2020 - average maximum temperature (T_max), average minimum temperature (T_min), average temperature (T_average) and total precipitation (TP) from the NASA POWER. The historical meteorological data used in the study are classified into three decades from- 1991-2000, 2001-2010, and 2011-2020, for a better understanding of inter-decadal changes. The results highlight that people have a clear perception of climate change and its impact which coincides with the climate data.

It is anticipated that outcomes of this study will contribute to a better understanding of the relationship between change in climate and regional hydrological behavior. It can benefit society to develop a regional strategy for water resource management and can serve

as a resource for climate impact research scope such as assessments, adaptation, mitigation, and disaster management strategies for India's north-eastern region. The study can be used in planning a tourism-economic development nexus and in sustainable tourism initiatives.

Keywords: Climate Change Perception; Climate Change; Climate Scenarios; Eastern Himalayas; Mountain Tourism; Precipitation; Snow; Snowmelt Runoff; Sustainable Tourism; Temperature.