North American Academic Research

Contents lists available at : www.twasp.info
Journal homepage: http://twasp.info/journal/home

Research

Tectonics Influence The Climate Change In The Himalayan Orogenic Belt

Bhupati Neupane[1,2,*], Junmeng Zhao[1,2], Sanjev Dhakal[1,2]
[1]*Key Laboratory of Continental Collision and Plateau Uplift, Institute of Tibetan Plateau Research, and Centre for Excellence in Tibetan Plateau Earth Sciences, Chinese Academy of Sciences, Beijing 100101, China*
[2]*University of Chinese Academy of Science, Beijing, China*

Corresponding Author :
B Neupane
Email: bhupati@itpcas.ac.cn *; Phone : +86 15501263702*

Published online : **24 Dec 2018**

Abstract*: This research presents a number of facts dealing with tectonic influences to climatic change and its impacts on mountain environments. Asian climates are affected significantly by the extent and height of the Himalayan mountains and the Tibetan plateau Uplift, which began after 55–50 Ma, and further significant uplifement occurred on the Tibetan plateau about 7–8 Myr ago or more recently. However, it is more challenging to estimate the significant impact of climate during the mountain building process (Himalayan tectonics).Intense precipitation (or glaciations) has been largely affected by zones of rapid rock-uplift in the numerous mountain ranges. The Greater Himalayan region holds the largest mass of ice outside Polar Regions, which are the major source of the 10 largest rivers in Asia. Triggered by climate changes, increase in erosion rate, which expected the glacier avalanches, landslides, and slope instability and outburst floods (GLOF) from moraine- and glacier-dammed lakes. A common understanding of climate change influences by the tectonics in the Himalayan regions needs to be developed through regional and local-scale research, increased regional collaboration in scientific research and policy making so that the mitigation and adaptation strategies can be identified and implemented.*

Keywords*: Climate change; Greater Himalaya; Tectonics; Global warming; Mitigation and adaptation strategies*

Introduction

The high altitude mountain system (i.e., Himalaya) and the Tibetan Plateau region formed after the intracontinental collision of the Indian and Eurasian plates during 55–50 Ma (Neupane et al., 2017 and reference therein). The Himalayan range, separating the plains of the Indian subcontinent from the Tibetan Plateau, extends 2,400 km-long from east - Namcha Barwa and west Nanga Parbat south of the northernmost bend of Indus river. The entire

Himalayan region divided into four tectonostratigraphic zones from south to north;the Tethys Himalaya, Higher Himalaya, Lesser Himalaya, and Sub Himalayan which are bounded and separated by several south propagating,north-dipping thrust/fault systems in different time spans (Neupane et al., 2018 and reference therein). The significant climate change occurred in Tibetan Plateau after rapidly uplifted at 7-8 Ma (Kappa et al., 2008; Murphy et al., 1997). The mechanics of the fold-and-thrust belts that flank many collisional mountain ranges, where the role of erosion in the tectonic evolution of mountain ranges was well known in the mid-1980s (Whipple, 2009). Dahlen et al. (1984), Davis et al. (1983) Stockmal (1983) described tapering wedges theory, a combination of sandbox experiments, analytical treatments of stress state and field observations which explained that fold-and-thrust belts form tapering wedges. After the advancement of critical-taper theory, researchers applied the rate and pattern of erosion of critical-taper orogenic wedges effectively dictates many aspects of the tectonic and structural evolution of mountain belts.Erosional efficiency determines the rate of erosion for a particulartopography and depends on rock type, debris size, and climate(Whipple, 2009). The deformational and exhumation response to induced by enhanced precipitation on windward slopes and rainshadow development on leeward slopes, which is well matched by near-surface rock-uplift patterns and the metamorphic grade of exposed rocks in several active mountain ranges.

Recently, Mountainous Region suffers several climatic impacts on several sectors like water availability, biodiversity, high-elevation ecosystem changes, monsoonal shifts, and loss of soil carbon (Xu et al., 2008). Mountainous region is sensitive indicators of climate change (Nijssen et al., 2001). These are also vulnerable to soil erosion, landslides, GLOF, and the rapid loss of habitat and genetic diversity. In several developing countries, in part because of the degradation of the natural environment, there is widespread unemployment, poverty, poor health and bad sanitation (Price et al., 2000).

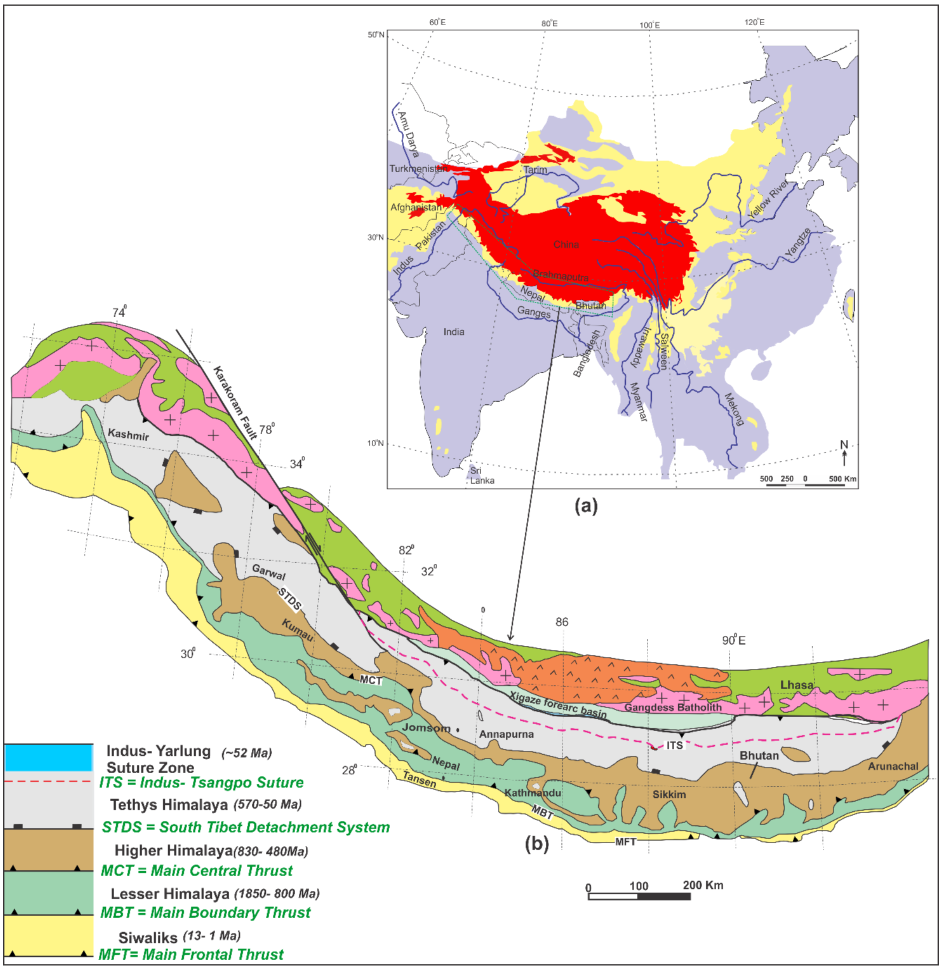

Fig.1: a) Location map of the Greater Himalayan region showing all areas with alpine (red), montane (yellow) zones, major river system and has impacts on lowland areas (light green) (adapted from (Qiu, 2008; Xu, 2008). b) General geological map of Himalaya (modified after Neupane et al., 2018)

There are several researchers studies in the Himalayas and found that glaciers in the region have retreated significantly in the last two decades (Owen et al., 2002; Parmesan, 2006; Price et al., 2000; Qiu, 2008). Recently, some researchers identified the formation and growth of a number of glacial lakes, possibility to retreat of glaciers, which could lead to the catastrophic outburst,floods (Owen et al., 2005). Some of the researchers believed that the main cause of Glacier retreat is global warming. Fluctuations in air temperature and precipitation also affect the glacier fluctuation over the last decade (Owen et al., 1998). The climatic impact caused the Himalayan glaciers have been retreating since 1850 A.D. It is possible that the cooling in 1940 observed in the global record caused reformed of these glaciers, and the warming after the mid-1970s resulted in accelerated shrinking in the past two decades (Owen et al., 2000). The Himalaya and Tibetan Plateau play a significant role in regional climate, which affect the monsoon circulation. Associations of the monsoon and other global-scale phenomena extend the implications of climatic variations in the Himalaya and in the Tibetan Plateau beyond the regional scale (Bolch et al., 2012; Immerzeel et al., 2010). The analysis of climatic variables showed a considerable increase in minimum and maximum temperature during the last century (i.e. 1901–2017) coupled with a continuous increase in solid precipitation (Taloor et al., 2018).

The Greater Himalayan region is also known as the Water Tower of Asia, covers approximately 7 million km^2(Xu et al., 2008) (Fig. 1). They are the source of 10 of the largest rivers in Asia (Fig. 1). Therefore, these basins provide water for about 1.3 billion people who stay near this area (Paul A and Jeschke, 1979). All over the world the mountains area like Andes Himalayas, from Southeast Asia to East and Central Africa, there is serious ecological deterioration. Mainly the mountain areas are experiencing environmental degradation. About 40% of the global population lives in the watersheds of rivers originating in the planet's different mountain ranges (Benn and Owen, 1998). Mountains also symbolize the unique areas for the detection of climatic change and the assessment of climate-related impacts.

The great climatic impact on the climate of the Himalayan regions caused the effects on glacier mountains, cascading effects on river flows, groundwater recharge, natural hazards, and biodiversity; ecosystem composition, structure, and function; and human livelihoods (Nijssen et al., 2001; Parmesan, 2006).

2. Overview of recent climate change study in the greater Himalaya region

There are several researchers involved to explain the problem and they applied different methods to acquire some concept about climate change and its impact on Greater Himalayan region.Owen et al. (2002) reconstructed the different numerical data and Barnard and Owen et al. (2000) reviewed the glacial geology of other Himalayan regions and for a selective bibliography for Late Quaternary glaciations in Tibet and the bordering mountains. They also used the optically stimulated luminescence (OSL) and cosmogenic radionuclide (CRN) surface exposure dating of moraines and their associated landforms.For the similar purposed Paul and Jeschke, (1979)studied on the topic of the Himalaya and trans- Himalaya glacier fluctuation since AD 1812. They update previous summaries and introduce an additional 27 glaciers for a total of 112 records of glacier fluctuations in the Himalayan and Trans – Himalayan area. Data used in this synthesis are presented in the form of frequency diagrams of glacier activity in which glacier activity is plotted for 10-yr periods.

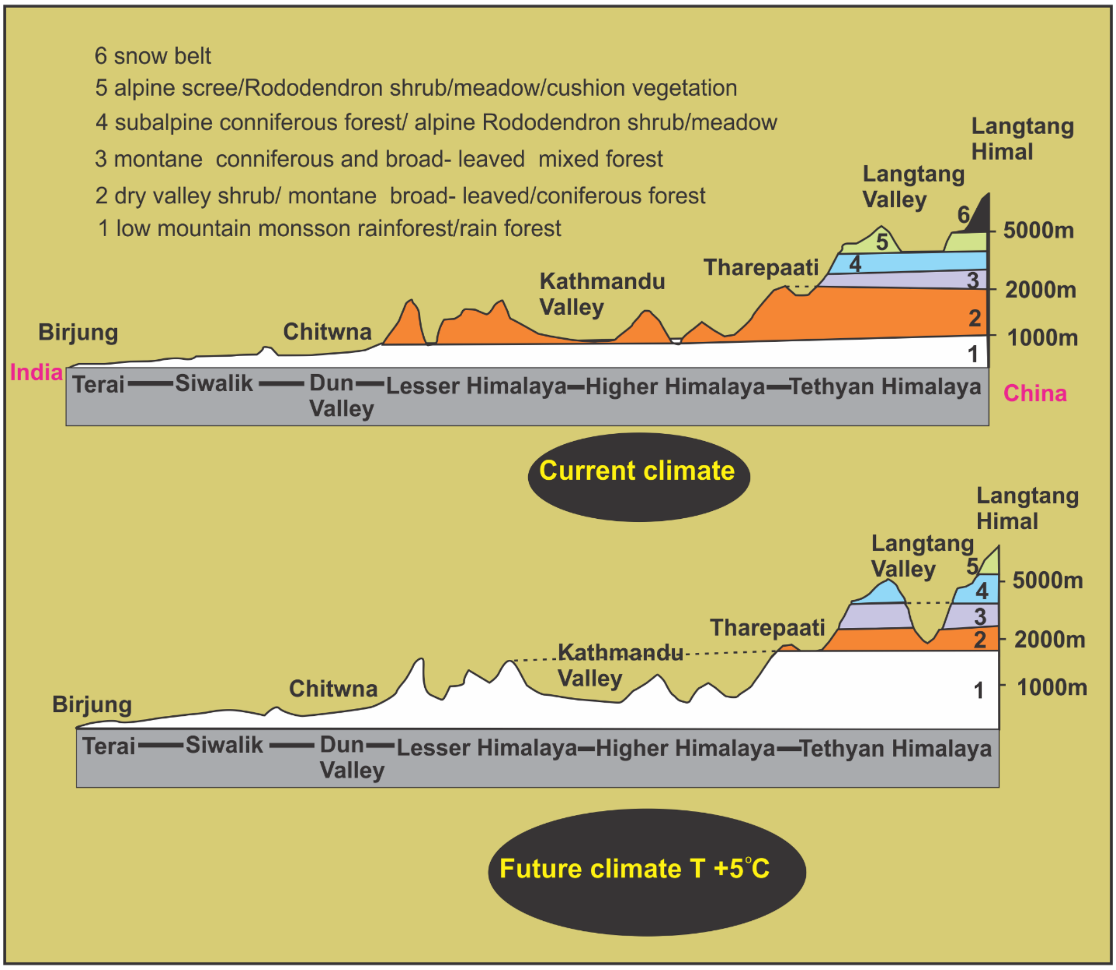

Fig. 2: The current elevational distribution of life zones in the central Himalayas (top) showing the future climate distribution (bottom) with a 5 ◦C temperature rise (Xu et al., 2008).

Similarly, Xu et al. (2008)described the issue of Melting Himalayas; cascading Effects of Climate Change on Water, Biodiversity, and Livelihoods. They compiled data on temperature and Precipitation, Glacial Response, Runoff and River Responses, Water-Related Hazards, Phenology, Pollination, and Predator-Prey Interactions, Endemism, and Extinction, Shifting Tree Lines, Ecosystem Composition and Dynamics, Cascading Effects, Effects on Ecosystems and Livelihoods, Downstream and Global Effects (Fig. 2).

Bolch et al. (2012) worked on the Himalayan Glaciers trend to used mainly historic data; vary between 43,178 km^2 and 49,650 km^2. The researcher used the recent satellite images and remote sensing for mapping purposed. They described some model for the glacier, which discusses projections of possible future changes, summarize important implications for water resources and natural hazards, and close by sketching a framework for integrated cryosphere research needed to fill the most critical gaps.Impact of warmer climate on melt and evaporation for the rainfed, snowfield and glacier-fed basins in the Himalayan region, Singh and Bengtsson (2005) used the different method for this research. Researchers mention the different parameters during the research, projected climatic changes over Indian sub-continent and India, hydrological models and structure of snowmelt model.

Zhisheng et al. (2001) proposed climate-model simulations, which show that continued uplift andexpansion of the plateau along its northern and eastern margins increases both summer and winter monsoons in the region of the Loess plateau/East Asia and continues the drying trend in central Asia. Where a little change in the general Asian summer monsoon circulation or the Indian monsoon precipitation. In the central Himalaya (Nepal), Blythe et al. (2007) and Huntington et al. (2006), have documented an acceleration of long-term rock cooling rates starting between 0.9 and 2.5 Myr, roughly coincident with the onset of Quaternary glaciations. Due to the absence of evidence for far-field tectonic change and for a change in structural geometry over this time interval, Huntington et al. (2006)suggested that this change in cooling rate represents a climatically triggered acceleration of exhumation rate. Taloor et al. (2018) studied in the Tectono-climatic response to landscape changes in the glaciated Durung Drung basin, Zanskar Himalaya, India, and they analyzed through quantitative morphometric analysis emphasizing on topography and landscape changes in glaciated that basin.

3. Discussion and interpretation

From the above results of Owen at al. (2002), obtained results indicate that the similar pattern of glaciation occurred in each study area and local LGM occurred early in the last glacial cycle. Similar hypothesis purposed by (Gillespie and Molnar, 1995) and (Benn and Owen, 1998), the maximum extent of glaciation in the Himalaya occurred before then the LGM spaced along the length of the Himalaya. It suggests that restricted glacier advance during the LGM is characteristic of the entire Himalaya. The nature of glaciations of the Himalaya controls the dominant climatic system of South Asian summer monsoon (Benn and Owen, 1998). (Benn and Lehmkuhl, 2000), have warned of the difficulties of determining ELAs on the steep debris-covered glaciers in the high-altitude Himalaya where the relationship between glacier mass-balance characteristics and climatic variables such as precipitation and air temperature is very complex in these situations.

The fluctuation records of glaciers in the Himalayas differ from those of glaciers in the Trans-Himalayas (Paul A and Jeschke, 1979). Most of the glaciers in the Himalayas have been in a general state of retreat since AD 1850. In the same task, sampling a much smaller number of glaciers than the number sampled, (Tewari, 1971), found the similar result of that the Himalayan glaciers were in a general state of retreat while the Trans-Himalayan glaciers have a more complicated record.

The obtained results in (Fig. 2), the current elevation distribution of life zones in the Himalayas and their distribution with a 5^{0}C temperature rise (Xu et al., 2009), indicated that elevational distribution of life zones would shift significantly. An additional effect on alpine vegetation shrank, evergreen forest decreased significantly, and tropical lowland forest increased. The effect of warm climate is the region of temperature increases, shifts in ecosystems, and increased frequency and duration of extreme events. This research deals three types of adaptation occurred in Himalayan regions; local community, urban and rural, and regional and transboundary.

(Bolch et al., 2012) observed the change of length more than 100 glaciers in Himalaya and Karakoram(H-K), suggest that most Himalayan glaciers have been retreating since the mid-19th century, except for 1920 to 1940. In the eastern Hindu Kush, west of the Karakoram, 25% of the glaciers were stable or advancing from 1976 to 2007. North of the Karakoram, in the Wakhan Pamir, glaciers were retreating during a similar period.

Thousands of glaciers in H-K were changed the original position due to the warm climate. Therefore, the area change data shows that the Yarkant basin north of the main ridge, loss rate was ~0.1% year−1 between 1962 and 1999. Similarly, high-altitude glaciers in the Transhimalaya of Ladakh had a shrinkage rate of ~0.4% year−1 from 1969 to 2010 and the Indian Himalaya, shrinkage rates are regionally variable: ~0.2 to ~0.7% year−1, the 1960s to 2001– 2004. Likewise, (von Cvitković et al., 1935)and (Mayewski and Jeschke, 1979) deals the same trend of results. The above result indicates that the warm and diverse climate directly affect the Glacier.

(Singh and Bengtsson, 2005) explained the current effect in Himalayan regions which shows a comparison of the annual evaporation occurred in different types of basins under current temperature (T + 2^{0}C) condition and warmer climate (T + 2 ^{0}C) scenario.

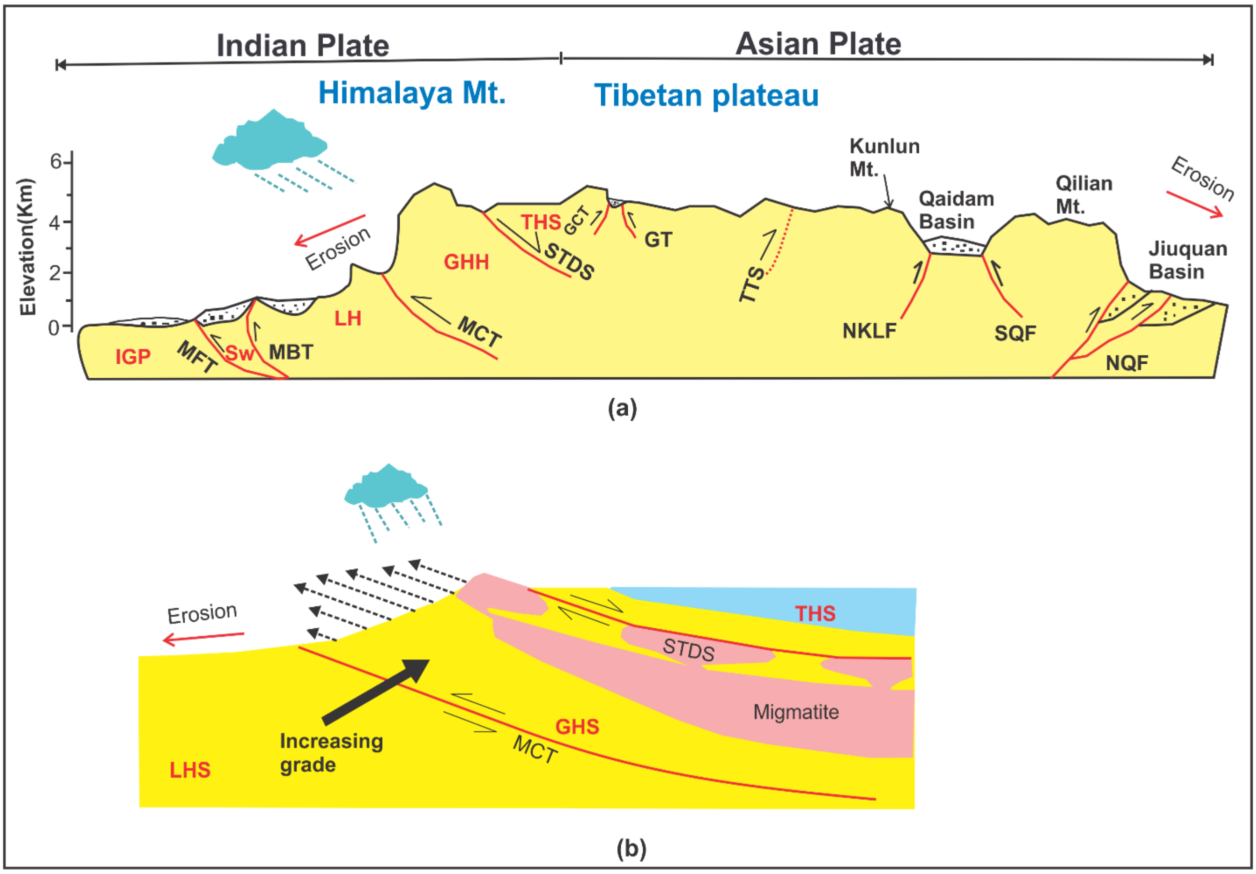

Fig. 3:Uplifted tectonic of the Himalaya – Tibetan Plateau influence by erosion. a, Schematic paleogeographic cross-sections of the Himalaya and Tibetan Plateau modified from Neupane et al. (2017); MCT, Main Central Thrust; GT, Gangdese thrust; STDS, South Tibetan Detachment System; GCB, Gangrinboche Conglomerates; TTS, Tanggula Thrust System; NKLF, North Kunlun Fault; SQF, South Qilian Mountain Fault; NQF, North Qilian Mountain Fault; MBT, Main Boundary Thrust; GCT, Great Counter-Thrust; MFT, Main Frontal Thrust. IGP, Sw, LH, GHS, THS refer to Indo Gangetic Plain, Siwalik, Lesser Himalaya, Grater Himalaya sequences, Tethyan Himalayan sequences. b, the uplifted grater Himalayan metamorphic rocks are experiences rapid erosion and removal of material at the southern margin of the Himalayan flank allows the movement of a channel of hot, weak ductile rock (pink regions).

Therefore, an increase in temperature from 1 to 3^0 C for the rainfed basin, the increase in annual evaporation was computed to be about 6–18% for the rainfed basin and 13–35% for the snowfield basin. The adverse effect on river runoff is likely to affect the watersheds within the mountains that create the problems in lowland regions, which are heavily dependent on this mountain resource (Singh and Bengtsson, 2005). Because these systems are sensitive to climatic factors and are likely to have different vulnerability thresholds according to the species, the amplitude, and the rate of climatic change (Dale et al., 2001).

The climatic model results (Zhisheng et la., 2001)suggested that the relatively large high-elevation area that we insert in the model in going from stage, presumably reflecting elevation changes that occurred no later than about 8 Myr ago, are sufficient to alter significantly the thermally forced circulation and establish strong continent-scale summer and winter monsoons and central Asian aridity.The channel-flow model (Whipple, 2009) suggest a number of key attributes of Himalayan geology; extrusion of the GHS by means of contemporaneous slip. Between the MCT and STD, the conditions and timing of metamorphism in the GHS and LHS and, the formation of the chain of gneiss domes north of the Himalaya (Fig. 3).

The monsoon in Himalaya was well established in the Miocene (Huntington et al., 2006; Kroon et al., 1991) which indicate that vigorous glacial erosion in the higher and drier mountain peaks to the north was important: consistent with the argument above that vigorous glacial erosion may counterbalance the northward decline in precipitation through the Himalaya. A large number of glaciers now terminate on such slopes in a state of gravitational disequilibrium.Similarly, recent climate change impact in the Greater Himalayan region affected by several sectors. Hydrological cycle will be affected by the absence of snow and ice. Therefore, the current distribution, seasonality, and the amount of precipitation may experience significant changes in various geographical regions.

The current evidence from the above review suggests that climate change affects the entire Himalayan region; temperature increases, shifts in ecosystems, and increased frequency and duration of extreme events. It will be significant changes in volumes and timing of river flows and freshwater sources.The complex geological structure, the rugged and steep topography, insufficient exposures, dense forests, and high altitude are a major problem in the Himalayas. There was not much research carried out the region and contains many research gap from East to west Himalaya.

4. Conclusions and future works

Although many field observation, experiments, and hypothesis (erosion-induced channel-flow hypothesis) existed, it is quite complicated to make arguments that erosional control of deformation rates and patterns is shown in the topography, geology and thermal history of the Himalayan regions. Erosion and deformation rate in the mountain system have arisen in the scope of studies aiming to test the hypothesis that climate can significantly influence the tectonic and structural evolution of mountain ranges.The measurable climate parameters and erosional efficiency relation should be studied well. The above results and models related to tectonic–surface process predict that the tectonic and structural evolution of a mountain belt is sensitive to spatial and temporal variations in erosional efficiency. The erosional efficiency is directly linked with precipitation, whenever this link has been quantitatively established can the assessment of spatial correlations between climate and deformation rates and patterns move beyond speculation.There are several basins located tectonically active mountain fronts which are overfilled by sediments detritus, where precipitation and erosion play the major role for sedimentation in the regions where erosion controls the tectonics.Different drainage basin asymmetry of the Himalaya suggests tilting, active upliftment, and dynamic incision.

Glacier is the most important part of the Greater Himalayan regions. Recently, the global warming effect shown in the period of glaciations, affect the nature of environmental change and the landscape evolution in the mountains of Central Asia. It shows the essential relations between climate change and glaciation in the Himalaya. The rate of accumulation of glaciers is less than the rate of retreat, effects on the South Asian summer monsoon system. The historical records of glacier fluctuations in the Himalayas and Trans-Himalayas extend back over 150 years. Recent deglaciation triggered the Catastrophic events consist of ice avalanches, landslides and slope instability caused by debuttressing, and outburst floods from moraine- and glacier-dammed lakes.

To addressing the research gaps, we recommend, more widespread and long-term tracking of glacial ice volumes, studying the paleoclimate for greater Himalayan regions, further work is required to synthesize a set of testable hypotheses to guide field evaluation of the potential role of climate and erosion in shaping the evolution of such systems.

Acknowledgments

We would like to thanks a number of scientists whose work we have referenced here. This study was funded by the National Natural Science Foundation of China (Grant No.41661144026), and the major program of the National Natural Science Foundation of China (Grant No. 41490611).

References

Benn, D., Owen, L., 1998. The role of the Indian summer monsoon and the mid-latitude westerlies in Himalayan glaciation: review and speculative discussion. Journal of the Geological Society 155, 353-363.

Benn, D.I., Lehmkuhl, F., 2000. Mass balance and equilibrium-line altitudes of glaciers in high-mountain environments. Quaternary International 65, 15-29.

Blythe, A. E., Burbank, D. W., Carter, A., Schmidt, K. & Putkonen, J.,2007. Plio-Quaternary exhumation history of the central Nepalese Himalaya: 1. Apatite and zircon fission track and apatite [U-Th]/He analyses. Tectonics 26, doi:10.1029/2006TC001990

Bolch, T., et al., 2012. The state and fate of Himalayan glaciers. Science 336, 310-314.

Dale, V.H., et al., 2001. Climate Change and Forest Disturbances: Climate change can affect forests by altering the frequency, intensity, duration, and timing of fire, drought, introduced species, insect and pathogen outbreaks, hurricanes, windstorms, ice storms, or landslides. Bioscience 51, 723-734.

Dahlen, F. A., Suppe, J. & Davis, D 1984. Mechanics of fold-and-thrust belts and accretionary wedges: Cohesive Coulomb theory. J. Geophys. Res. 89, 10087–10101.

Davis, D., Suppe, J. & Dahlen, F. A. 1983. Mechanics of fold-and-thrust belts andaccretionary wedges. J. Geophys. Res. 88, 1153–1172

Gillespie, A., Molnar, P., 1995. Asynchronism of mountain and continental glaciations. Reviews of Geophysics 33, 311–364.

Huntington, K. W., Blythe, A. E. & Hodges, K. V., 2006. Climate change and Late Pliocene acceleration of erosion in the Himalaya. Earth Planet. Sci. Lett. 252, 107–118

Immerzeel, W.W., van Beek, L.P., Bierkens, M.F., 2010. Climate change will affect the Asian water towers. Science 328, 1382-1385.

Kapp, P., Taylor, M., Stockli, D., Ding, L. 2008. Development of active low-angle normal fault systems during orogenic collapse: Insight from Tibet. Geology 36, 7-10.

Kroon, D., Steens, T. & Troelstra, S. R., 1991. Onset of monsoon related upwelling in the western Arabian Sea as revealed by planktonic foraminifers. Proc. Ocean Drilling Program Scientific Results 117, 257–263

Mayewski, P.A., Jeschke, P.A., 1979. Himalayan and Trans-Himalayan glacier fluctuations since AD 1812. Arctic and Alpine Research, 267-287.

Murphy, M., Yin, A., Harrison, T., Dürr, S., Chen, Z., Ryerson, F., Kidd, W., Wang, X., Zhou, X. 1997. Did the Indo-Asian collision alone create the Tibetan plateau? Geology 25, 719-722.

Neupane B, Ju Y, Tan F, Baral U, Ulak PD (2017). Cenozoic tectonic evolution of the Tibetan Plateau-the Nepal Himalaya and the provenance of their foreland basins. Geological Journal 52(4): 646-666.

Neupane, B., Ju, Y., Allen, C.M., Ulak, P.D. and Han, K., 2018. Petrography and provenance of Upper Cretaceous–Palaeogene sandstones in the foreland basin system of Central Nepal. International Geology Review, 60(2), 135-156.

Nijssen, B., O'Donnell, G.M., Hamlet, A.F., Lettenmaier, D.P., 2001. Hydrologic sensitivity of global rivers to climate change. Climatic change 50, 143-175.

Owen, L., Scott, C.H., Derbyshire, E., 2000. The quaternary glacial history of Nanga Parbat. Quaternary International 65, 63-79.

Owen, L.A., Derbyshire, E., Fort, M., 1998. The Quaternary glacial history of the Himalaya. Journal of Quaternary Science 13, 91-120.

Owen, L.A., et al., 2005. Climatic and topographic controls on the style and timing of late Quaternary glaciation throughout Tibet and the Himalaya defined by 10 Be cosmogenic radionuclide surface exposure dating. Quaternary Science Reviews 24, 1391-1411.

Owen, L.A., Finkel, R.C., Caffee, M.W., 2002. A note on the extent of glaciation throughout the Himalaya during the global Last Glacial Maximum. Quaternary Science Reviews 21, 147-157.

Parmesan, C., 2006. Ecological and evolutionary responses to recent climate change. Annual Review of Ecology, Evolution, and Systematics, 637-669.

Paul A, M., Jeschke, P.A., 1979. Himalayan and Trans-Himalayan glacier fluctuations since AD 1812. Arctic and Alpine Research, 267-287.

Price, M., Kohler, T., Wachs, T., Mountain Agenda, B., 2000. Mountains of the world. Mountain forests and sustainable development.
Qiu, J., 2008. China: The third pole. Nature News 454, 393-396.
Singh, P., Arora, M., Goel, N., 2006. Effect of climate change on runoff of a glacierized Himalayan basin. Hydrological Processes 20, 1979-1992.
Singh, P., Bengtsson, L., 2005. Impact of warmer climate on melt and evaporation for the rainfed, snowfed and glacierfed basins in the Himalayan region. Journal of Hydrology 300, 140-154.
Stockmal, G. S. 1983. Modeling of large-scale accretionary wedge deformation. J. Geophys. Res. 88, 8271–8287 (1983).
Taloor, A.K., Kotlia, B.S., Jasrotia, A.S., Kumar, A., Alam, A., Ali, S., Kouser, B., Garg, P.K., Kumar, R., Singh, A.K. and Singh, B., 2018. Tectono-climatic influence on landscape changes in the glaciated Durung Drung basin, Zanskar Himalaya, India: A geospatial approach. Quaternary International.
Tewari, A.P., 1971. A short report on glacierstudies in the Himalayan Mountains by theGeological Survey of India. Carpatho-Balcancia, 5, 173-181.
von Cvitković, J., Visser, P.C., Visser, J.H., 1935. Wissenschaftliche Ergebnisse der niederländischen Expeditionen in den Karakorum und die angrenzenden Gebiete in den Jahren 1922, 1925 und 1929/30. In kommission bei FA Brockhaus.
Whipple, K. X., 2009. The influence of climate on the tectonic evolution of mountain belts. Nature geoscience, 2(2), 97.
Xu, J., 2008. The highlands: a shared water tower In a changing climate and changing Asia.
Zhisheng, A., Kutzbach, J.E., Prell, W.L. and Porter, S.C., 2001. Evolution of Asian monsoons and phased uplift of the Himalaya–Tibetan plateau since Late Miocene times. nature, 411(6833), p.62.