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Research Paper

Macro-level study on Climate Change effects on agriculture and human health in Western Himalayas: A Review

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ABSTRACT

The current study reveals that the western Himalayas has a fragile ecosystem, highly susceptible to rapid changes in land morphology due to the consequences of climate change. Land-use and climatic change in this region has negative impacts on agriculture and human health. Increasing temperature, erratic precipitation, and rising CO_2 concentrations are the main drivers which show adverse effects on agriculture and human health. The impacts trends in this region can be categorised into exacerbated pathogenicity are pathogens, and hence disease outbreaks, changes in the traditional agriculture techniques, and people's migration that directly changes in ecological and leading to social inequalities. In the last few decades, there have been changes in vector species distribution in agriculture and increases of forest pest species attacks by climate change in agriculture and forest pest increases, and parasites are emerging during periods of these last few decades. Enhancement of seasonal transmission and distribution of pests pushes food insecurity and vector-borne infections deteriorate human health. This review article tries to analyse different literature on the effects of climate change on agriculture and human health in the Western Himalayas and suggest agroforestry and agroecology is some of the strategies to overcome climate change impact.

Keywords: Western Himalayas; Climate change; Human health; Agriculture; Temperature; Precipitation; CO_2 concentration.

INTRODUCTION

Climate change has been described as the biggest global threat in the 21st century (Costello et al., 2009). The Himalayan mountain environment is very delicate to environmental change that led to cause risk in socio-economic development employments for the individuals to progress in mountain biological systems for their endurance and improvement (Negi et al., 2017). Environmental components such as water resources, agriculture, and biodiversity and food security are highly affected directly and indirectly due to climate change (Field and Christopher, 2014). The entire Himalayas have been categorized and isolated into three regions namely: (I) Western Himalayan Region (WHR), (ii) Central Himalayan Region (CHR) and (iii) Eastern Himalayan Region (HER). The WHR is the largest region of the Indian Himalayas comprising of Jammu and Kashmir, Ladakh, Himachal Pradesh, and Uttarakhand. (Das and Meher et al., 2019). Climate change can be easily and early identified in mountains (Singh et al., 2010). The trend of warming in the Himalayas seems to be greater than the average rate based on preliminary studies (Liu and Chen, 2000; Shrestha et al., 1999), Winter and autumn the temperatures were as recorded higher and it increases with the elevation gradient altitudes (Liu and Chen 2000). Due to changes in the trend of temperature and precipitation worldwide, agricultural production is adversely affected (Turral et al., 2011). A trend analysis of vegetation index time series has shown that lower and middle elevations of the Himalayas have a higher extent of the greening region while higher elevations have registered a modest part of browning at elevation (N 3800 m), comparatively browning in western high Himalayas is less than eastern high Himalayas due to cropped area and driven by increasing agricultural fertilization and anthropogenic land change could be possible human drivers for climate change in Himalayas (Mishra and Mainali, 2017). Climate change has already warmed the planet; from the preindustrial period (1850–1900) to the present (1998–2018), our planet has the significant trend of warming by gradualness of climate change which leads to an increasing in global average temperature by 1.41^{o}C (Anderson et al., 2020) and changes in the frequency and severity of weather events such as drought (Gamble et al., 2010; Spinoni et al., 2019; Stringer et al., 2009) and precipitation trends (Lehmann et al., 2015; Mearns et al., 1997). Climate change will put further pressure on the environment. There have been reports of less snow, receding glaciers, increasing temperature and decreasing precipitation throughout the globe (Dar et al., 2014).

Agricultural yield is influenced by a range of factors, including climate conditions, crop and land management practices, pathogens and pests, and the occurrence of extreme weather events (Bhattacharya et al., 2016; Joshi et al., 1996; Zhao et al., 2017; Pathak et al., 2018). Due to climate change, the rainfall pattern changes in a shorter period, and the temperature is fluctuating, these consequences have significantly resulted in significant reductions in reduced productivity in the Himalayan region (Moore and Lobell, 2015). Long term trends such as drought occurrence, heat stress, and floods variation on the Himalayan region on agriculture by the impact of climate change has been documented (Dahal et al., 2020; Rashid and Romshoo, 2020). Climate change makes the innovation in agricultural practices, replacement of traditional staple crop by cash crop, declining undesirable changes in of phenological character of various fruits and early flowering in wheat and mustard (Negi et al., 2012). Climate change can reduce the quantity of harvested food reduced by climate change which could lead to higher food prices and reduced consumption (Nelson et al., 2010). Climate changes have also increased pests, diseases and invasive plant species (such as Eupatorium, sp. Lantana sp. and Parthenium sp.) which has directly affected crop productivity and food security (Lamsal et al., 2018). Climate change shifts the distribution of plant pathogens and pests (Neupane and Ghimire, 2020; Bebberet al., 2013; Hunjan and Lore, 2020) and the climatic changes occurring in the Himalayan region is expected to alter plant pathogen virulence and infection rates (Srivastava et al., 2020; Velasquez et al., 2018) which could be exacerbating aggravate yield losses (Neupane and Ghimire, 2020).

Climate change is a critical big issue not only in the Himalayan region but overall, in the world. There are mainly three components that affect the environment due to climate change shows the climate change in a region i.) Temperature, ii.) Precipitation and iii.) CO_2 concentration. Taking into consideration the sensitive nature of the Himalayas to climatic changes. The current review depend basses upon the western part of the Himalayas shows what are the factors and effects of climate change on the people of this region? Western Himalayas, the prime main area of focusing is the impact of climate change on agriculture and people health of the people in this region.

The area studied for the review is the western part of the Himalayas. Several research articles and reviews which were already published for reviewing the cause and effect of climate change were perused. The research articles were searched using Google Scholar, Science Direct, Google, EBSCO with the main keyword's climate change, western Himalayas, Himalayas, temperature, precipitation, CO_2 concentration, agriculture, glaciers, pests, diseases.

CHANGES IN TEMPERATURE

In the last few decades, the temperatures trend of the last few decades has shown an increasing trend at a significant rate in the upland regions of countries like Nepal and India (Thakur et al., 2020). The global mean temperature is expected to increase by between 1.1°C and 6. 4°C as a result, with a good approximate range of 1. 8–4°C (Hodnebrog et al., 2020). Wiltshire (2014) observed a warming trend in the Hindu Kush, Karakoram and Himalayan region from 1971-2000 was observed with an increase in temperature of by 4- 5.5°C and highlighted that North Bhutan and Himachal Pradesh Himalayas are most vulnerable for environmental change as compared to the Karakoram and Hindu Kush (Wiltshire, 2014). In the 2010–2018 period, the Himalayan region experienced higher temperatures and less precipitation than decadal averages and reported an average 40% decline in yield of several crop species, including barley, wheat, and apple (Budhathoki and Zander, 2020; Sahu et al., 2020). Variation in temperature and snowfall trend using data at different ranges of western Himalayas whereas the change in the number of snowfall days due to climate change. Shekhar et al. (2010) have reported a significant increase in seasonal maximum and minimum temperatures in the Western Himalayas (Shekhar and Chand et al., 2010).

The scenario of agricultural product trends indicates an overall decline in wheat and barley yields of more than 5 and 8%, respectively (Chhogyel et al., 2020). The impacts are not evenly distributed, somewhere up to 8-10% or greater decline have been observed in the high-altitude Himalayan crops (Paudel et al., 2020). The increase of heat has impacted cereal production by 15% in the Himalayan regions while reducing global 10% during the last five decades only, and droughts on this same duration caused a higher reduction than the heat loss caused in the western Himalayan region and globally due to climate change (Gupta et al., 2017; Lesk et al., 2016). Wheat yield is expected to reduce by 4-6% for each degree of global temperature increase (Asseng et al., 2015; Das et al., 2020). Maize productivity has shown similar effects, with an expected reduction in yield in more than 50% of the world's area will experience the declined yield (Pandey and Arunachalam, 2020; Pugh et al., 2016). Temperature increases directly enhance the plant pathogen growth and developmental responses like that of Phytophthora infesting populations affects the field of potato (Mariette et al., 2016; Shakya et al., 2015) and temperature fluctuations also make bacterial communities more susceptible to invasion of novel taxa (Inaotombi and Sarma, 2020).

Health can be affected by climate change in various ways: both directly, due to changes in temperature, precipitation, and the occurrence of heatwaves, floods, droughts, and fires; or indirectly, due to ecological and social disruptions, such as crop failures, shifting patterns of disease vectors, and displacement of people (Smith et al. 2014). The pattern of vector-borne diseases in human populations are inherently sensitive to changes in environmental conditions that influence the life cycle dynamics of the pathogen, its vector, and its host. Malaria is already a problem in most countries in the Hindu Kush–Himalayas (Bhattacharya et al., 2016). Globally and regionally, many institutions and research groups have been running different statistical and biological models of a chance to predict the potential spread of malaria as the drawback result of climate change in poor, developing countries (Bhandari et al., 2020; Ebi et al., 2007; Hanafi-Bojd et al., 2020).

CHANGING PRECIPITATION PATTERNS

Widespread deforestation in the Himalayas in the period from 2008 to 2018 have around decreased forest areas by 4732.71 km^2 forest area and about 56% of protected areas had a decreasing trend from 1998 to 2018 (over only the latest few decades) in the Himalaya region (Gu et al., 2020). Future scenarios (RCP 4.5 and RCP 8.5) reveal an increase in precipitation trend during summer and a decrease in the number of rainy days (Palazzi et al., 2013). The concentration of black carbon significantly increase due to anthropogenic activities and biomass burning due to forest fire and its concentration is negatively correlated with rainfall and humidity (Kant and Patel, 2012). The concentration of PM2.5 was maximum due to biomass combustion (Kumar and Attri, 2015). Climate change effect over the Hindu Kush increased snowfall and decreased precipitation (Wiltshire, 2014). A concern in the Himalayas region is whether climate change will affect the monsoon season (Gautam et al., 2009). Partial rainfall in the Himalayan region as well as increases in the magnitude of extreme rainfall events has been projected with climate change and is expected to increase the frequency and intensity of flooding in the region (Elalem and Pal, 2015). Weather and seasonal rain impact the agriculture of mountainous regions, and any change in climate changes the crop yield and food supply in the Himalayan region (Negi et al., 2012). The temperature and rainfall increase in Himalayan areas are expected to creating stress on the indigenous local communities by affecting agro-biodiversity, crop yield, cropping patterns and the species composition of forests (Pandey et al., 2017). The Hindu-Kush Himalayan region has experienced more due to an increase in extreme conditions over the last decade, with both droughts and increasing floods negatively affecting agricultural yields, and similar effects are expected for the western Himalayas (Chauhan et al., 2020; Manzoor et al., 2013). Mountainous parts of the Kashmir valley have shown a drastic decrease in precipitation while flood plains have shown a relatively less rate of decrease (Shafiq et al., 2019). In contrast, in the especially central part of the Himalayan in the last decades, high rainfall and cooler temperatures resulted in almost doubled flooding downstream (Kumar et al., 2020; Posthumus et al., 2009). About 70% of the summer flow in the Ganga comes from melting glaciers that act to regulate water runoff from the mountains to the plains between dry and wet periods, thus glaciers are instrumental in securing agricultural productivity and livelihoods for millions of people of this region (Ruane et al., 2013). Some shreds of evidence suggest that there have been alterations of snowmelt phenology with earlier commencement of snowmelt and faster melting in the spring leading to shifts in the total time of distribution of runoff and runoff related projects in low land people and livelihood (Bhandari et al. 2020; Guntukula and Goyari, 2020; Panwar, 2020). These changes could affect the availability of freshwater for natural systems and human use (Cristea et al., 2014).

Glacial lake outburst events have caused catastrophic downstream flooding and loss of life due to climate change frequently in the Himalayan region (Harrison et al., 2018). Human well-being, as well as mortality, is greatly affected by glacial lake floods, which wash out agricultural land and bridges and sever communication networks for substantial periods between people living on either side of the rivers or ravines in the Himalayan region for substantial periods (Bajracharya and Mool, 2009). Rain, high humidity, and high soil moisture favour many plant diseases by increasing fungal infection rates (Hunjan and Lore, 2020). A close trend of irregularity is present in the plant immunity process, where plant species and communities exhibit contrasting reactions or responses to increasing temperature and humidity (Lamaoui et al., 2018; Sundriyal et al., 2020). This may affect agricultural production severely in the future. Many diarrheal diseases have more than one means of transmission, and all modes are possible in mountainous regions (Ebi et al., 2007). Diarrheal diseases are already a major cause of morbidity and mortality in the Himalayas developing countries (Moors et al., 2013). There is highly enough evidence to suggest that water-related diseases are directly and indirectly influences the occurrences and prevalence of diseases by the change in the pattern, quantity, and timing of runoff from snowmelt and glaciers (Ebi et al., 2007). During the wet season, floods flush into water sources, while during the dry season, lack of water increases the risk of water-washed diseases that might chance increase the risk of waterborne and water-based infections. (Sharma et al., 2018).

EFFECTS OF RISING CO_2 CONCENTRATIONS

Continuous rise in the concentration of greenhouse gases (GHGs) like carbon dioxide, methane, nitrous oxide, water vapour, CFCs, etc in the environment is the reason for climate change and the rise in CO_2 concentration mainly led to global warming (World Climate News, 2006). By 2100, global atmospheric concentrations of CO_2 are anticipated to ranges into being between 490 and 1260 ppm (75% – 350% above the concentration of 280 ppm in the year 1750) (Hodnebrog et al., 2020). The burning of fossil fuels after industrialization has increased CO_2 concentrations by 90% mainly in latitudes between 200 - 600 N (Marland et al., 1985). The concentration of atmospheric CO_2 was about 280 ppm during the pre-industrial period exceeded 400 ppm in recent times, the average growth rate has been estimated at 2.11 ppm per year during the last decade, and a value of 410 ppm was observed in 2018 (Chakraborty et al., 2020) Increases in global population (Kintigh and Peeples, 2020) have contributed to continued deforestation and increased demands for land, leading to continued elevated Green House Gases (GHG) emissions (Ray et al., 2015).

Increased CO_2 concentration in the atmosphere through climate change directly affect the function process of open stomata for gas exchange (lower numbers open) due to higher concentrations of CO_2 (Sharma et al., 2020) that directly affect respiration evapotranspiration, photosynthesis rates means all biological function pressurized mostly drought stress resilience plants that mainly found in the Himalayan region of narrow niche environment which leads to support the plants for extinction. IPCC short-term predictions indicate that under several climate change scenarios, yield gains are positively expected in the Himalayan region due to warmer conditions that extend the growing season at high latitudes (Nanditha et al., 2020) due to elevated CO_2 fertilization, but in the long-term climate change will alter all ecological functions (Chettri et al., 2020) and there might be extinction of local or native crops or domination ted of by invasive species (Pramanik et al., 2020). Moreover, many researchers have found that the nutritional quality of some C3 crop species was reduced in terms of protein, zinc, and iron, due to increased CO_2 concentrations (Myers et al., 2014; Uddling et al., 2018). GHG emissions have led to major changes in agriculture ecosystems (Anyamba et al., 2014) of the Himalayan regions (Martin et al., 2010). Increases in atmospheric CO_2 concentrations can aggravate pathogenicity virulence is influenced by increases in atmospheric CO_2 concentrations (Corredor et al., 2020; Shaw and Osborne, 2011) virulence of Fusarium gramine arum on wheat, and potato (Váry et al., 2015; Neupane and Ghimire, 2020).

SYNTHESIS

Nowadays a lot of research is focused on response modelling to control the outbreaks of pests minimize the impacts on food security in the western Himalayan region (Sekhri et al., 2020). Many research suggested and approved that due to climate change in the Himalayan region where finds fragile ecosystem could affect more human population health due that In the Himalayan region most of the poor people are with low health facilities accessibility, therefore there are high chances of the creation of favourable conditions for disease vectors, malnutrition, rodent-borne diseases, forest fires, avalanches, heavy snowfalls, major storms, floods, and droughts, changes in intensity and frequency of snowfall cover and length of the snow-free season, changes in daylight temperature pattern, range between daylight duration of sunlight (Ebi et al., 2007). Climate zones are expected to shift at high altitudes due to climate change and this will change the distribution of highly productive agricultural areas (Bagaria et al., 2020; Hunter et al., 2017; Scheben and Edwards, 2018). The plant pathogen may spread, attack and distribution trend changes easily if also new cultivars are introduced expose by local people in the Himalayan region due to the increase of precipitation irregularity, temperature, and CO_2 trend in high land that faces more vulnerability (Sekhri et al., 2020) or more virulent strains (Saarinen et al., 2019). Variations from the mean temperature and precipitation, or in vegetation, can alter the geographic distribution and abundance of vectors and the rate of pathogen replication within vectors. Natural vegetation and crops which require longer growth periods (such as forestry and orchard crops) may be at a higher risk of plant-pathogen infection, as management procedures and cultivars are less flexible. (Maqbool et al., 2020; Sahu et al., 2020). The complexity of pathogen infection and plant susceptibility, together with the ability of pathogen populations (Patle et al., 2020) to rapidly respond to their environment predicts pests and disease outbreaks incredibly complicated (Bhusal, 2020).

CONCLUSIONS AND RECOMMENDATIONS

The western Himalayan region is facing major challenges of climate change. People are depending upon the agriculture-related system, so agriculture and human health are closely bonded. Human health is directly and indirectly affected depending on the changing climate. The fifth assessment report is concerned with the rise in global temperature due to human activities (Russill, 2016), it is strange human activities are responsible for climate change, changing climate affects the day to day life of humans directly. Issues like extreme climate events and natural impacts are extremely complex and costly ventures, and to addresses, such issues global level policies are required. Understanding the issues and linking research on environmental processes, ecosystems, and human health requires an interdisciplinary approach. Increasing temperature, precipitation and CO_2 concentration are the main criteria as which impacts agriculture, local vegetation, and human health by increasing plant pathogens attack, pests attack and increasing vector-borne diseases.

People of western Himalaya's area adopt certain changes to overcome the climate change impact like innovating agricultural techniques and, replacement of traditional crops. Decreasing the source of earning males of these areas have started rural-urban migration. Climate change increases the flourishing of invasive species cause local vegetation damage and low regeneration. Agroforestry and agroecological intensification reduce the vulnerability of climate change, it provides a wide variety of agricultural and forest products, fruit, fodder and thereby facilitate environmental amelioration helps in benefiting farmers directly (Pandey et al., 2016).

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