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Economic impact of climate change on agriculture: Present, past and future

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Abstract
Agriculture is plausibly the most important sector of the economy that is highly dependent on climate. Climate change has been causing wide range of effects in agriculture directly or indirectly which is reflected by a low growth rate for a long time. Climate system warming is now undeniable, as is evident from increasing global average air and ocean temperatures, widespread melting of snow and ice, and rising global sea levels. This body of research addresses possible physical effects of climatic change on agriculture, such as changes in crop and livestock yields, as well as the economic consequences of these potential yield changes. This paper reviews the extant literature on these physical and economic effects and interprets this research in terms of common themes or findings of particular interest concerning the role of human adaptations in responding to climate change, possible regional impacts to agricultural systems and potential changes in patterns of food production and prices. Impacts on regional and local food supplies in some low latitude regions could amount to large percentage changes in current production. The adverse effect of such phenomenal global warming has already manifested itself in the form of increasing sea levels, growing extreme weather events such as heavy rainfall and drought, disturbed regional precipitation patterns, declining snowfall events, falling cold days and nights, melting glaciers. Finally, some speculations regarding issues of potential importance in interpreting and using information on climate change and agriculture are presented.

Keywords: Climate change, agriculture, economic consequences, regional effects, adaptations, uncertainty

1. Introduction

India is truly an agricultural economy, as agriculture and the allied sector play an influential role in the country's development by providing rural livelihood opportunities to more than half of its population, and agriculture contributes around 16.50 percent to the country's total Gross Domestic Product (GDP) at current prices (Indian economic survey, 2019-20). Development in agriculture and the allied sector is facing a continuous period of deep recession and is not able to reach its target of 4% growth over the last couple of decades. The average annual growth rate in real terms in agriculture and its allied sectors has remained persistent over the last six years, affecting income of farmers. According to the Economic Survey 2019-20, annual growth in real and allied agriculture is 2.90 percent. The Economic Survey Report 2020 emphasized the significance of sustainable agricultural practices to help small and marginal farmers, who make up 87 percent of peasant’s population. A combination of resource-saving approaches like adaptive crop patterns, judiciary use of fertilizers, effective irrigation systems, reliable adaptation, and climate change mitigation strategies are also pursued. The agricultural sector faced high volatility and steady decline in the growth rate at the same time during the seventh (1985-90), eighth (1992-97), ninth (1997-2002) and tenth (2002-07) five-year plan, which was 3.2, 4.7, 2.1 and 2.3 percent respectively. While many efforts has been made by the central government to boost the agriculture sector but after recognition of this volatility, satisfactory rate of growth was prompted in the eleventh five-year plan (2007-12) that is 3.3 percent respectively. But yet again, during the twelfth five-year plan (2012-17), the recession reoccurred as the growth rate was less than 2 percent which presents a frightening situation for policy makers nowadays (Sharma 2012 and Anonymous 2016) [70, 7].

The current crisis which have continued to prevail for a long period of time are decline or stagnation in the production and productivity of most crops say food grains, decline in the sector's performance over the last two decades, decline in the size of land holdings and subsequently a rise in marginal land holdings (about two thirds of total land holdings), lack of agricultural spending, reduction of public investment in agriculture, weak returns to farmers due to increased farm costs, lack of adequate infrastructure for all agricultural commodities except food grains, problems related to credit flow, increased rural unemployment in the agricultural sector etc.

The ever-growing urbanization, which has led to a rapid expansion of infrastructure, is causing farmers to lose their land and as a result, the decline in cultivated land is also a problem that favours the country's agricultural crisis (Sharma 2012 and Das 2015) [70, 26]. Moreover, when the agro-climate favours the farmers during the boom years of production, they do not earn remunerative prices equal to their cultivation costs. And during the years of production, it becomes very difficult for farming families to survive and a real crisis situation arises. Thus, it can be said that agriculture and the allied sector, which is the primary sector of the economy, have been faced with obstacles all around and thus reflected by a low growth rate for a long time.

1.1 Climate change

Climate change is a major and permanent change in the statistical distribution of weather patterns over time scales from decades to millions of years. It may be a change in average weather conditions, or in the weather distribution around the average conditions. Climate change is no longer a vague theoretical possibility or academic rhetoric, but it is now visible and a fact worth calling attention to. Over the past two decades, the discourse on global climate change has moved from science circles to policy circles, with world nations now more seriously than ever considering a variety of response strategies to counter this dynamic problem that is threatening to have major and far-reaching impacts on human society. In its fourth assessment report, the Inter-governmental Panel on Climate Change (IPCC) noted that climate system warming is now undeniable, as is evident from increasing global average air and ocean temperatures, widespread melting of snow and ice, and rising global sea levels. The twenty-first session of the Conference of the Parties (COP) and the eleventh session of the Conference of the Parties to the Kyoto Protocol (CMP) were held from 30 November to 11 December 2015 in Paris, France. 196 countries in Paris have agreed on a landmark deal to tackle climate change and initiate action and investment to a low-carbon, resilient and prosperous future. The Paris Agreement gathers all nations to a common cause for the first time on the basis of their past, present and future obligations. Climate change can no longer be ignored, as its consequences have become increasingly visible across the world. Almost every year since 1992, the hottest years have been included and, according to the National Aeronautics and Space Administration (NASA) and the National Oceanic and Atmospheric Administration (NOAA), 2014 was the warmest. Record rises in temperature are expected to have significant impacts on the global hydrological system, habitats, sea level, crop production and related products (Sathaye *et al.*, 2006) [68]. The impacts will be especially extreme in the tropical regions, mainly developing countries, including India (IPCC). Climate change can have a major impact on the way the community lives, especially in the underdeveloped community (IPCC, 2007) [35]. Every community, agricultural or non-agricultural community evolves different ways of survival time to time depending on the climate and changes in the biotic and abiotic components of the environment. These modifications are adapted over the long term by changing their livelihoods and socio-economic components. This circumspect transition over a long period of time eventually forms the nature of society as a whole (Cline, 2007) [22]. Environment is a crucial element that regulates the current stage of development of every society and nation in the world.

1.2 Direct and indirect effects of climate change on Agriculture

Global warming has been an issue lately in many aspects because it has been in increasing trend since 1980s. Climate change might be a major concern to humanity since it affects many economic sectors as well as different aspects of human life. Negative impacts of climate change on agricultural sector will be especially dangerous since agriculture is directly related to food security and human life. The results show that higher temperatures and more precipitations in summer increase agricultural production while higher fall temperature is harmful in South and Southeast Asia. On the other hand, overall increase in annual temperature decreases agricultural production in Asian countries (Lee *et al*. 2012) [46]. Iglesias *et al*. (1996) [34] found from crop simulation study that climate change will be harmful on crop production in South and Southeastern Asian countries. Mathew *et al*. (1997) [52] also found from their simulation models that rice production will be declined under warming scenarios. The impact of climate change is much direct to the agriculture sector, especially through the change in cropping pattern due to rise in temperature and rainfall pattern in the country, use of pesticides in crops and some others. Notwithstanding agro-based economy, Nepal is a net importer of many agro-products and the trend of being so is rising every year. Furthermore, rise in temperature may largely affect the AGDP, which could not be inferred statistically, at least in this empirical measurement, as the relationship is insignificant. Nevertheless, seeds and chemical fertilizer could not impact on AGDP, as the statistical relation is insignificant (Acharya and Bhatta 2013) [1]. On a global scale, the regional increases and decreases associated with climate change are not expected to result in large changes in food production over the next century. Nevertheless, impacts on regional and local food supplies in some low latitude regions could amount to large percentage changes in current production. Climate change may therefore impose significant costs on these areas. In addition, warming beyond that reflected in current studies may impose greater costs in terms of aggregate food supply (Admas *et al.* 1998) [2]. The productivity of apple crop during 1985-2009 showed a cyclic pattern with an overall decreasing trend of 0.4 tonnes/ha. The productivity sensitivity analysis with maximum temperature showed a negative rate of 3.89 every year. The farmers' perception revealed adverse effects on apple biodiversity due to change in climatic conditions. The farmers reported that change in the snowfall pattern led to depletion and shifting of ecological niche of traditionally and commercially important apple varieties and an increase in low chill cultivars. Apple growers specifically in lower Kullu valley switched over to alternate crops and some preferred shifting their orchards to higher altitudes. Cumulative chill units showed a decrease of 9.52 in negative and 6.5 chill units every year in Positive chill units hours of Utah model in Kullu district due to increase in temperature (Sen *et al.* 2015) [69]. As agriculture represent the core sector of the Indian economy and is the main source of livelihood for majority of Indian population, it becomes further necessary to make an assessment of impact of climate change on the productivity of Indian agriculture. The predicted medium term impact of climate change on agricultural productivity is negative as it is estimated the yield of majority of the crops would decrease by 4.5% to 9% for period ranging from 2010-2039. The long term (2070-2099) impacts of changing climate are more severe as it shows that the yield could decrease by 25% if no adaptation measures are taken (Javeed and Manuhaar, 2013) [37].

1.3 Regional pattern of global warming

The geographical pattern of observed temperature parameters also underpins the undeniable warming. The annual average temperature in Canada rose by about 1.5˚C in the 1950-2010 period, accentuated more by the minimum temperature than by the maximum temperature; seasonally, the highest temperature in winter. (Vincent *et al.*, 2012) [76]. On the other hand, Mexico's warming has become more common at high temperatures than at minimum temperatures and in summer than in other seasons (Pavia *et al*., 2009; Peralta-Hernandez *et al*., 2009) [58, 59]. On the other hand, both the minimum and the maximum temperatures are increasing at a similar rate across the United States (Brown *et al.*, 2010) [13]. Considering the spatial and temporal fluctuations in the minimum and maximum temperature changes, the pattern in the diurnal temperature range is not consistent across North America. South America as a continent has been substantially warmed by the start of the 21st century. Annual mean temperatures rose by 0.08˚C per decade (Choi *et al.*, 2009) [20], largely explained by higher positive trends in night time temperatures in Uruguay. (Rusticucci and Renom, 2008) [66], winter minimum temperature over Southern Brazil (Marengo and Camargo, 2008) [51] and summer minimum temperature over Argentina (Rusticucci and Barrucand, 2004) [65] which have profoundly increased the frequency of warm days and nights (Vincent *et al.*, 2005; Augilar *et al.*, 2005) [75, 79]. While the mean annual temperature has significantly increased across Rwanda (Safari, 2012) [67], a general minimum temperature warming is quite evident at several locations over Eastern Africa (King'uyu *et al.*, 2000; Christy *et al.*, 2009) [40, 21]. West, Western Central and Southern Africa are clearly warming due to the significantly increasing trend of maximum and minimum temperatures, which is further accentuated by the increasing frequency of warm days and nights, and the declining frequency of cold days and nights. (Kruger and Shongwe, 2004; New *et al.*, 2006; Aguilar *et al.*, 2009) [44, 54, 3]. Overall, the annual average near-surface air temperature on the African continent has risen considerably (Collins, 2011) [25]. Similarly, average warming across Europe is observed, but with little to no difference whatsoever between average daily minimum patterns and maximum temperatures (Klein Tank and Konnen, 2003; Moberg *et al.*, 2006) [41, 53]. While having three distinct climatic regions. East Monsoon Zone, Northwest Arid and Semi-Arid Zones and the Qinghai-Tibet Alpine Zone (Zizhi and Degang, 2006) [81], The minimum temperature for China as a whole has risen at a rate exceeding the maximum temperature, resulting in a narrowing of the diurnal temperature range. (Qian and Lin, 2004; Liu *et al.*, 2004; Su *et al.*, 2006) [61, 48, 73]. This differential heating improved the duration of warm days and warm nights at the expense of cold days and cold nights (You *et al.*, 2010; Zhou and Ren, 2011) [78, 80]. The same trend has been observed throughout Asia and Australia (Kadioglu, 1997; Collins *et al.*, 2000; Manton *et al.*, 2001; Zhang *et al.*, 2005; Klein Tank *et al.*, 2006; Chambers and Griffiths, 2008; Rahimzadeh *et al.*, 2009; Choi *et al.*, 2009; Wang *et al.*, 2013) [38, 23, 50, 79, 42, 18, 62, 20, 77]. But for India, the increase in the maximum temperature exceeded that of the minimum temperature, resulting in an increase in the diurnal temperature range in all seven contrasting temperature zones. Western Himalayas, North East, North Central, North East, Inland Peninsula, West Coast and East Coast (Arora *et al.*, 2005; Fowler and Archer, 2006; Dash *et al.*, 2007; Bhutiyani *et al.*, 2007; Singh *et al.*, 2008; Jain *et al.*, 2012) [9, 28, 27, 11, 71, 36]. Eventually the Indian subcontinent has warmed by 0.56ºC during the last century (Attri and Tyagi, 2010) [10]. The adverse effect of such phenomenal global warming has already manifested itself in the form of increasing sea levels, growing extreme weather events such as heavy rainfall and drought, disturbed regional precipitation patterns, declining snowfall events, falling cold days and nights, melting glaciers, etc. Moreover, oceans are being acidified by elevated CO_2 concentrations, both of which pose a possible threat to both terrestrial and marine habitats.

1.4 Regional pattern of rainfall

In that, the response of rainfall shows very high spatial and temporal incoherence. Even as annual average precipitation rose, the rise in heavy and very heavy precipitation in the USA was higher. Regionally and seasonally, the severity of patterns is most evident in the Central Great Plains, northern Midwest and eastern two-thirds of the nation, as opposed to rising dryness in the western and southwestern interiors; and especially in the warm seasons. (Groisman *et al*., 2004; Pryor *et al*., 2009) [31, 60]. Although South America has generally become wetter as overall precipitation, average rainfall duration, extreme rainfall events and the duration of consecutive wet days are all on the rise, Southern Peru, Southern Chile and Southwest Argentina display signs of drying (Haylock *et al*., 2006) [33]. While total precipitation decreased across the African continent with a rising period of consecutive dry days and a declining period of consecutive rainy days, average rainfall intensity and extreme rainfall events decreased in western Central Africa (Aguilar *et al*., 2009) [3] while they have increased in Southern Africa (New *et al*., 2006) [54]. While winter precipitation has increased in Central and Western Europe due to both increased intensity of precipitation events and average rainfall per rainy day, summer precipitation has increased significantly in Eastern Europe (Moberg *et al.*, 2006) [53]. Although complete and extreme precipitation patterns are on the rise in south-east, south-west and north-western China, they are on the decline in north-east and middle China (You *et al*., 2010) [78]. For Asia and Australia as a whole, there have been no spatially consistent changes in the number, frequency, severity and length of extreme precipitation events (Manton *et al.*, 2001; Zhang *et al.*, 2005; Klein Tank *et al.*, 2006; Choi *et al.*, 2009) [50, 79, 42, 20]. Even within India, the declining frequency of light to moderate rainfall has more than offset the rising frequency of heavy and very heavy rainfall to minimise the overall summer monsoonal rainfall in Central India (Goswami *et al.*, 2006; Rajeevan *et al.*, 2008; Pal and Al-Tabbaa, 2011) [30, 63, 57] while North West, North East and Peninsular regions did not show any homogenous pattern (Kumar *et al.*, 2010; Jain *et al.*, 2012) [45, 36].

1.5 Vulnerability to climate change

It is very likely that such extreme events will continue to become more common, posing a potential threat to ecosystems, especially agricultural production and productivity worldwide. The effect of such unprecedented climate change would be especially serious in tropical regions, primarily developing countries such as India, as they are at risk of numerous non-climatic stresses such as growing population, poverty, unequal access to services, food insecurity, disease incidences etc. (Rao *et al*. 2010) [64]. This shows that the vulnerability of the system is determined not only by the magnitude of the climate change to which it is exposed, but also by its resilience and adaptive capacity to cope with new climate conditions.

1.6 Adaptation to climate change

Policy approaches to climate change include the mitigation of GHGs that lead to adverse climate change and adaptation to future climate change impacts (Kavi Kumar, 2010) [39]. Ambitious mitigation measures will minimise, but not eliminate, potential climate change. Although substantial emission reductions could stabilise ambient GHG concentrations at lower levels than "business as usual," they would still be far above present, let alone pre-industrial levels (Burton *et al*., 2006) [16]. Given that developed and developing countries are only on the verge of being responsible for reducing GHGs, there is an urgent need to explore effective adaptation strategies that render the environment more able to withstand major climate change shocks (Boomiraj *et al*., 2010) [12]. In doing so, the perception of climate change by local people must be taken into account, and while climate change is a global phenomenon, adaptation is primarily site-specific (Lema and Majula, 2009) [47]. In addition, indigenous knowledge is based on constant exploration, invention and adaptation, integrating multiple knowledge systems to solve local problems (UNFCCC, 2003) [74]. A better understanding of farmers' perceptions of climate change, its impacts on agriculture, ongoing adaptation initiatives and the factors that affect their adoption is therefore required in order to establish policies and programmes aimed at promoting effective adaptation of the agricultural sector (Hassan and Nhemachena, 2008; Apata *et al.*, 2009; Bryan *et al*, 2009; Chaudhary *et al*., 2011; and Komba and Muchapondwa, 2012) [32, 8, 14, 14, 43].

1.7 Adaptation strategies

Indigenous farmers follow a myriad of adaptation methods to tackle the detrimental effects of climate change. They alter crop and livestock combinations by substituting higher drought or heat tolerance for plant varieties, cultivars and hybrids and animal breeds; manipulate the strength of chemical, capital and labour inputs to reduce environmental and economic risks; Pursue alternative fallow and tillage practises for the conservation of moisture and nutrients; transform land topography by contouring and terracing, construction of diversions, reservoirs and water storage and recharging areas to minimise runoff and erosion; implement creative irrigation practises including centre pivot irrigation, dormant season irrigation, drip irrigation, gravity irrigation, pipe irrigation; Adjust the timing of operations such as planting, spraying and harvesting to take advantage of the varying length of growing seasons and related changes in temperature and humidity to prevent heat stress and moisture deficiency (Smit and Skinner, 2002; Butt *et al*., 2005; Osman-Elasha *et al*., 2006; Nhemachena and Hassan, 2007; Hassan and Nhemachena, 2008; Gbetibouo, 2009; Bryan *et al.*, 2009; Bryan *et al.*, 2011; Angles *et al*., 2011) [72, 17, 56, 55, 32, 29, 14, 15, 5].

1.8 Climate Change in Context of Himachal Pradesh

Himachal Pradesh, laterally meaning "land Snowy Mountains," is located in the heart of the Himalayas in the northwestern part of India. Himachal Pradesh is mainly mountainous, with the exception of small pockets bordering Punjab and Haryana. The state comprises hilly topography, perennial rivers and extensive forest cover. The state provides great opportunities, given its ample water supplies, hydropower, mineral resources, horticulture, agriculture and tourism potential. However, it faces major challenges resulting from its elevation, topography and ecological vulnerability. Covering an area of 55,673 km (34,594 miles), Himachal Pradesh is a mountainous state with an elevation of approximately 350 metres (1,148 ft.) to 6,000 metres (19,685 ft.) above mean sea level. Region-wise, Hamirpur is the smallest district of the Pradesh, covering an area of 1,118 square kilometres (2.01%) and Lahaul & Spiti has the largest area of 13,835 square kilometres (24.85%). The population of Himachal Pradesh is 68,56,509 as per the Indian Census, 2011. It constitutes just 0.57% of the total population of the country. The population of the State rose by 17.53% between 1991 and 2001 and decreased by 12.81% in 2011. The sex ratio (i.e. the number of females per thousand miles) of the population was 968 to 974. The urban population increased by 10.04 percent in 2011 compared to 9.80 percent in 2001, but the rural population decreased by 0.30 percent in the state and the number of cities also grew in the state. It is noted from the census data that while the urban population is growing at a faster rate in the state, the majority of the population still lives in rural areas of the state and is dependent on agriculture-horticulture and state natural resources. Most agricultural and horticultural practises are of a subsistence nature and rely on prevailing climatic conditions for yield. The regional drainage system is well developed and forms part of the Indian Indus and Ganges River Basins. The main rivers which either originate or pass through Himachal are the Satluj, Ravi, Beas, Chenab and Yamuna. Apart from these, there are a number of small rivers such as Baspa, Parvati, and Spiti, etc. which contributes to the major river systems of Himachal Pradesh. These rivers are perennial and are fed by snow and rain. They are covered by a large canopy of natural vegetation. The land cover pattern available in Himachal Pradesh. Based on the satellite data study, the predominant land use / land cover categories available in the State are primarily forest which is ever-green or semi-green in nature, forest planting, agriculture, land with/without scrub, etc. (Fig.1). The soils of Himachal Pradesh can be classified into nine classes on the basis of their development and physio-chemical properties. These classes are alluvial soils, brown hill soils, brown soils, brown porous soils, grey wooded or podozolic soils, grey brown podzolic soils, planolic soils, humus and iron podzolic soils and alpine humus skeletal soils (Anonymous, 2012a) [7].

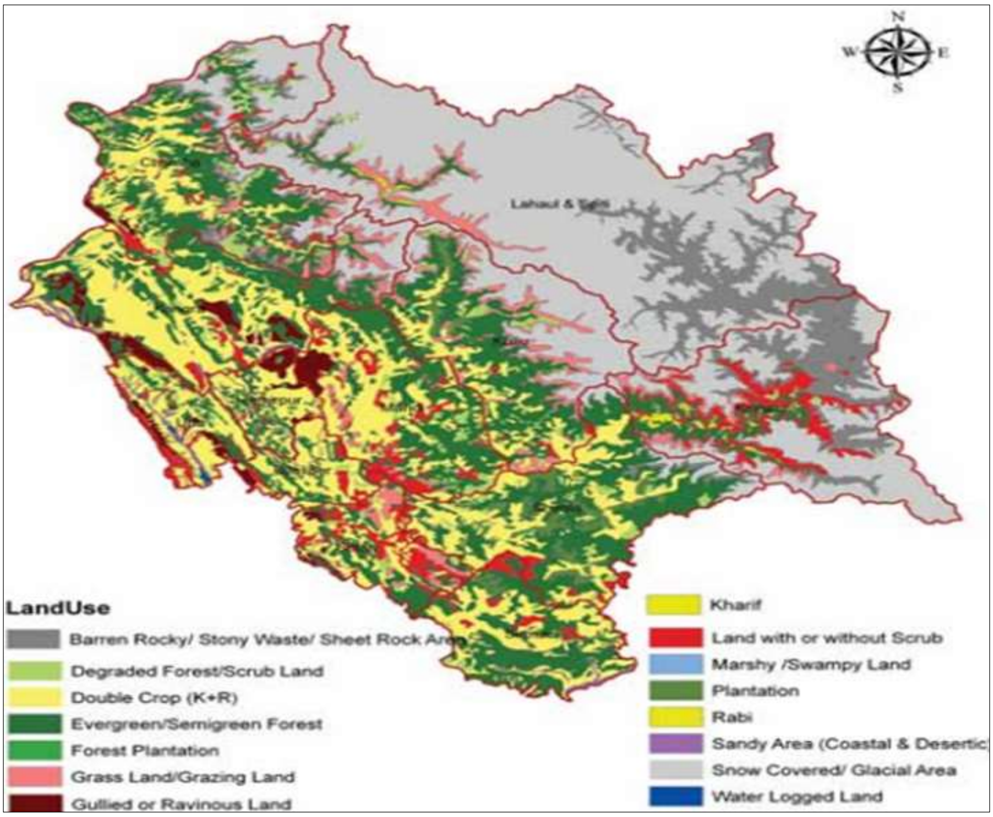

Fig 1: Land cover in Himachal Pradesh

The term climate is primarily determined by two variables *viz*. Temperature and rainfall. Himachal Pradesh has the benefit of diverse climates, ranging from dry temperate to subtropical areas, and its climate is preferable to agricultural conditions. The land use system in the state is undergoing transformation due to rapid changes in the socio-economic status of farmers, industrialization and climate change, as well as government policies. Land use options that improve the protection of livelihoods and reduce vulnerability to climate change and environmental change are therefore important. It varies from hot and sub-humid tropical (450-900 m) in the southern lowlands, warm and temperate (900-1,800 m), cool and temperate (1,900-2,400 m) and cold alpine and glacial (2,400-4,800 m) in the northern and eastern high mountain ranges. Climate Trends of Temperature and Rainfall in Himachal Pradesh.

In the context of understanding climate trends in Himachal Pradesh, both precipitation (Rainfall & Snowfall) and temperature are considered to be important indicators. Based on detailed studies carried out by NW Himalayas on long-term trends in maximum, minimum and average annual air temperatures (Bhutiyani, *et al*. 2007) [11], included observation from Shimla, HP for a period 1901-2002, at 95 percent confidence level indicates that there is a significant increase in air temperature in the NW Himalayan region by about 1.6ºC with winter warming at a faster pace. According to Bhutiyani *et al.* 2007 [11] based on short term analysis observed that in different altitudinal zones in Himachal Pradesh, the rate of increase in maximum temperature at higher altitudes was higher than at lower altitudes and warmed significantly higher than the global average in the north-west Himalayan region of the last century. There is a notable increase in winter temperature in Himachal and across the North-West Himalayan region. The study of the data base from 1866-2006 w.r.t. climate change and precipitation variability in the north western Himalayas (Bhutiyani *et al.* 2007) [11] has shown that increases in winter precipitation are minor, but there is a substantial decrease in monsoon precipitation. Trend analysis of annual rainfall data (Ranbir, 2010) of last 25 years in different districts in Himachal Pradesh revels that increasing trend of about 33.5 percent, 54.3 percent and 51.5 percent has been observed in the State in district Kinnaur, Chamba and Lahul & Spiti respectively on one hand and decrease of about 8.7 percent, 13.3 percent and 26.6 percent in District Solan, Shimla and Sirmour respectively. Approximately 0.5˚ C increase in maximum temperature is observed in Palampur, Kangra District. It has also been noted that there has been a 40% drop in rainfall over the last 25 years, as it was 948 mm in 1987, which has decreased to around 470 mm in 2009. Another climate study of Shimla shows that overall precipitation and snowfall has a declining trend over the season. The analysis of twenty years data by (Bhan & Manmohan, 2011, IMD) reveals that the season tends to end by about 10-12 days earlier per decade leaving long term impacts on agriculture and horticulture production of the State. Kangra district receives a maximum amount of rainfall (185 cm) per year, while Una receives a minimum amount of rainfall (121 cm) per year. Figures showing the pattern of rainfall during the winter season (December to February) and the pre-monsoon season (March to May) have been plotted. During the winter and pre-monsoon periods, rainfall over the state increases towards the northeast zone. The pattern of spatial distribution of rainfall over the state during the southwest monsoon season usually resembles that of the spatial distribution of annual rainfall. Of the overall annual rainfall, about 73 percent is received during the southwest monsoon season (June to September), about 9 percent is received in the winter season (December, January and February), about 11 percent is received in the pre-monsoon season (March to May) and about 6 percent is received in the post-monsoon season (October to November). The proportion of rainy days in season with respect to the annual number of rainy days is 63% for the southwest monsoon season, 16% for the pre-monsoon season, 7% for the post-monsoon season and 13% for the winter season. During the southwest monsoon season, rainfall is mainly attributed to low-pressure areas and monsoon depressions originating from the Bay of Bengal. Climate change induces annual temperature increases between 1.5-2.8 ˚C and average annual precipitation is expected to range between 1250 ± 225.2 and 1550 ± 175.20 mm (Anonymous 2012). Increased rainfall variability leading to drought as well as flash floods, reduced glacier area, change in tree line and increased disease incidence and evolving seasonal patterns, snowfall, vegetation (Anonymous, 2012) [7].

1.9 Glaciers & snow fields in Himanchal Himalaya

According to the investigations conducted in the Himachal Himalayas, there are nearly 334 glaciers in the entire Satluj basin, including the glaciers in Beas, Sainj, Spiti, Baspa and 457 glaciers in the Chenab basin in Himachal Himalaya. Out of 334 glaciers in the Satluj basin, 202 glaciers are situated in Himachal Pradesh. The total area occupied by these glaciers in the Satluj and Chenab basins is approximately 2,175 square kilometres. In addition, there are about 1,826 permanent snow fields in these basins with a total area of 1,101,737 square kilometer. In the case of the flow of the Himachal Pradesh Rivers, the main contribution is from the snow and the glacier melt, which greatly affects the flow of the streams. In order to understand the impact of global warming on the hydrological balance, snow removal studies have been performed in the Himalayas. Initially, studies were conducted in the Beas and Baspa basins in Himachal Pradesh. The analysis of the available data therefore indicates that the effects of climate change are likely to become more severe by the next 2-3 decades, when the temperature may rise by 2-4 ˚C. There will be a strong shift in the pattern of monsoon precipitation, which could increase by 20-25%. The frequency of severe events will double. Resultantly there will be snow and glacier field loss, which will affect the flow in river system, the flow in lower elevation would reduce maximum. Glacier fields can decline by more than 50% due to temperature rise, increased melting rate, monsoon, extreme events can further rise the problems of sedimentation, significant erosion, destabilization of slopes and an increase in GOLF events, etc.

1.10 Problem Statement

Rural communities in developing countries are projected to be more affected by their extensive reliance on climate-sensitive livelihood options and limited adaptive capacity to adapt to change (UNFCCC, 2009) [79]. In India, climate change impacts are most acutely felt in the Himalayan region because they are among the most fragile habitats, and most of the population is dependent on agriculture and horticulture to maintain their livelihoods. With its fragile geography, mainly natural resource-based livelihoods and low adaptive ability, Himachal Pradesh ranks among vulnerable states to climate change and natural disasters, especially floods and landslides. With increased monsoon risk intensity, the risk of flash floods, erosion and landslides may increase in the coming years. The adverse effects of climate change and severe events would certainly worsen insecurity, existing poverty and inequality in the state.

2. Conclusion

Agriculture is plausibly the most important sector of the economy that is highly dependent on climate. Climate change has been causing wide range of effects in agriculture directly or indirectly which is reflected by a low growth rate for a long time. Climate system warming is now undeniable, as is evident from increasing global average air and ocean temperatures, widespread melting of snow and ice, and rising global sea levels according to IPCC assessment reports. The adverse effect of such extreme events has already manifested globally which pose a possible threat to both terrestrial and marine habitats and subsequently to agriculture production and productivity. The effect of such unprecedented climate change would be serious in tropical regions, primarily developing countries such as India, as they are at risk of numerous non-climatic stresses therefore it is a need of the hour to formulate and promote effective policies aiming to adapt agriculture sector in its best. For this, a better understanding of farmers' perceptions on climate change, its impacts on agriculture, the ongoing adaptation initiatives and the factors that affect their adoption are required to establish policies and programs effectively. General economic development programs can also play an important role in adaptation of policies in vulnerable areas by limiting the dependency on climate for sources of livelihood.

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