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An Overview of Climate Change And Its Impact on Agriculture: a Review From Least Developing Country, Nepal

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Abstract Climate is an important factor for agricultural production. However, in recent years consistent warming and rise in global temperature has resulted in visible impacts on the agriculture across the world. Nepal is not an exceptional case, where rising temperature has already affected the country's agricultural production thereby affecting the food security and agrarian communities. It is expected that the level of vulnerability will be higher in high altitude as compared to the lower altitude. In addition, majority of the population are subsistence farmer in rural parts of Nepal and has low land holding capacity. Nepal is one of the least developed countries in the world with low per capita income, and thus the country's ability to adapt to the extreme climatic events has direct implications in its strategies on agriculture sector development. However, Nepal still lack strong scientific data about the cases of climate change and due to varied geographical setting, sufficient meteorological data cannot be easily obtained from remote parts of the country. This review tries to explore the current status of vulnerability to the climate change in Nepal. In Nepal, more than 80% of the people heavily rely on agriculture for their subsistence and thus, climate change will bring expectedly negative response to the agricultural sector in the country.

Keywords Agriculture, adaptive capacity, climate change, developing countries, agrarian communities

1. Introduction

Climate is an essential factor that has direct effects on agricultural production[1-3]. The increased impacts of climate change put the agricultural sector at the central point of discussion globally since the sector contributes to global climate change as well as can be affected by the changing climate[2-5]. The impacts of climate change on agriculture production are both positive as well as negative, however, the impacts will differ globally[2, 5].

Developing countries are more vulnerable to climate change since majority of the populations depend on agriculture and lacks technical and financial capability to respond to increased variability[1,6,7]. In addition, the agricultural sector is not only vulnerable to climate change but also has been stressed with the chronic problems of low returns from agricultural exports in developing countries [4,8,9]. In recent years, climate change has been a topic of discussion in Nepal due to its increasing stress on water resources and other climate-sensitive resources thereby

affecting agricultural production, food security and livelihood[3,5,7,10].

Although Nepal is potentially much vulnerable to the impacts of climate change, there is limited data pertaining to climate change and agriculture. It is understood that the climate change and climate policy will have significant impacts on agriculture productions and livelihood of agrarian communities[1,11]. Table 1 shows the ecological zones of Nepal.

Table 1. Geographical features of Nepal [12-14]

Parameters	Mountains	Hills	Terai
Climate	Tundra	Temperate	Sub-tropical
Temperature*	<3°C-10°C	10°C-20°C	20°C-25°C
Precipitation**	Snow/150-200	275-2,300	1,100-3,000
% of total area	35	42	23
Cultivated area	0.3	46.1	51.6

*Mean annual temperature, **Average annual precipitation (mm)

Nepal is one of the least developed countries in the world with rich ethnic diversity and has varied geographical setting where agriculture has played fundamental role in maintaining fiscal and socio-economic stability[7,11,15]. Climate change is expected to affect the agricultural production, thereby affecting the livelihood and food security in poor rural parts of developing countries[1,2,4]. Thus, this review

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was carried out to know about the ongoing climate change and to predict possible changes that are likely to affect the agrarian communities of Nepal. This review also discusses about the adaptation and mitigation of climate change in relation to agriculture sector in Nepal.

2. Climate Change in Nepal

Nepal is a small landlocked country with a total area of 147,181 km² and located in the heart of Himalayas[16]. The geographical structure of Nepal resembles a rectangular shape with three main ecological zones running horizontally as continuous belts, namely, plains, hills and mountains [7,17,18]. The elevation of the country varies from 100 m in plain to 8,850 m in the Himalayas[19]. Due to such sharp altitudinal variation, Nepal is vulnerable to various types of natural disasters such as landslide, slope failure, soil erosion, landmass movement, and flood[3,7,17]. Table 2 summarizes information about the likely changes to the temperature, precipitation and runoff for Nepal due to climate change.

Table 2. Anticipated climate change impacts in Nepal [20-23]

Parameter	Remarks
	Significant and persistent rise in temperature
Temperature	0.5 to 2.0°C by 2030
	1.3 to 3.8°C by 2060
	1.8 to 5.8°C by 2090
	Changes in mean annual rainfall
Precipitation	-34 to +22% by the year 2030
	-36 to +67% by the year 2060
	-43 to +89% by the year 2090
	Changes in monsoon rainfall
	-14 to 40% by the year 2030
	-40 to +143% by the year 2060
	-52 to +135% by the year 2090
Runoff	Higher downstream flows in the short term, but lower downstream flows in the long term due to retreating glaciers and snowmelt
	Shift from snow to rain in winter season
	Increased natural disasters such as flash floods, mass movement, droughts and GLOF

In recent years, climate change has further amplified the situation by affecting the water resources, which ultimately add stress to the agricultural production[3,5,10,17]. A review of literature revealed that Nepal's climate continued to rise in maximum temperature at an annual rate between 0.04°C and 0.08°C[10,21,24]. The continued rise in temperature and increase in rainfall have significant impacts on agricultural production and livelihood of agrarian communities, especially in subsistence farming[10,17,25]. The changes in the climatic conditions have brought potentially significant new challenges, most critical are likely to be impact on local natural resources, biodiversity and environment, and leads to changes in biological, geophysical and socioeconomic elements[1,3,26].

For Nepal, it is predicted that there will be a significant and consistent increase in temperature and annual precipitation in the coming years-2030, 2060 and 2090[20-23]. Ap-

proximately 80% of the territory is occupied by hills and mountains, and consistent rise in temperature will accelerate the process of avalanche and glacier retreat in such regions [16]. Therefore, the ongoing climatic change and changes those are anticipated to occur in the coming years are likely to affect water resources including glacial fluctuation, hydrological regime, Glacier Lake Outburst Flood (GLOF), decline in agricultural production and food security, and biodiversity[3,16,17].

In Nepal, the warming rate is significantly higher than the global average warming rate, and the warming rate is found to be more pronounced in the Himalayas[16]. This poses direct impact on the plains during monsoon season when heavy rainfall coincides with the glacier and snowmelt from the mountains[7,16,17,21]. In addition, the impact of climate change is increasing steadily by resulting uncertainties and climate-induced extreme events[7,21]. However, Nepal has low adaptive capacity to respond to the variability occurs due to climate change[7]. Moreover, the assessment and predictions of climate change are mostly based on literature review and some scattered information, which were not so reliable [27]. Nevertheless, the country is severely threatened by the expected impacts of climate change especially affecting agricultural production, biodiversity and livelihood of agrarian communities[3,5,11].

3. Impacts of Climate Change on Agriculture in Nepal

Nepal is one of the least developed country in the world with low GDP of US\$562[28]. It is estimated that approximately 25% of the populations live below the poverty line as of US\$ 1.25 a day[19]. Agriculture is the dominant sector in Nepal[7,15]. It accounts more than 75% of human resource involvement and contributes to 35% of GDP (2011) [15,18, 29,30]. Agriculture sector has played fundamental role in human welfare especially in rural Nepal, where people heavily depend on agricultural exports for their fiscal and socio-political stability[4,9,15,19].

However, the contribution of agricultural sector to the national economy is challenged by its vulnerability to climate change[5,11]. In recent years, extreme climatic conditions such as persistent rise in mean annual temperature and increase in precipitation have almost adverse impacts of various elements of agricultural production system[10,11]. In addition, Nepal is experiencing various natural disasters such as flash floods, hailstones, landslides, mass movement, soil erosion, and avalanche, there by affecting the agriculture systems[3,7,10,16]. The level of vulnerability, however, will be dependent on both socioeconomic and environmental factors[2,5]. In Nepal, approximately 85% of the population live in rural areas, and thus, concern has been expressed by many researchers and organizations that climate change will undermine the rural economy who typically depend on climate-sensitive natural resources[7,29,31].

3.1. Pattern of Agriculture in Nepal

The most vulnerable groups are the poor, marginalized and underprivileged population in rural parts of Nepal, whose livelihoods primarily depend on agriculture[7,31]. Although Nepal is predominantly an agricultural country, approximately 78% of the farmers are harvesting agricultural products mainly for household consumption[32]. In addition, nearly 60% of farmers cannot meet their own food needs, especially in higher mountainous areas, where household can meet their food requirements for 3- 8 months per year[30,32]. In such areas, the majority of farmers rely on rain fed crops and follow labour intensive traditional methods for farming[9,10].

Table 3. Categorization of households based on the size of land ownership as of 2001 [33]

Household category	Total household number	Size of land ownership (ha)
Landless farmers	287100	0-0.1
Marginal farmers	670000	0.1-0.3
Small farmers	648000	0.3-0.5
Medium farmers	1131560	0.5-3.0
Large farmers	93700	3.0-10.0
Extra large farmers	3800	>10.0

Approximately 17% of the total land area of Nepal is agricultural land[14,15,33,34]. Due to continuous fragmentation of land, the land holding capacity per household across Nepal is found to be relatively low; estimated average size of parcel is to be less than 1.0 ha[14]. According to the estimation carried out by Agricultural Census 2001, there were a total of 4,253,222 households in Nepal in which 3,364,100 were farming households (Table 3)[14,33].

Although agriculture sector remains the major source of income and employment opportunities in Nepal, agriculture is mainly based on low-value cereals and subsistence production[9,15,32]. Despite of getting special attention from government and other donor agencies in term of formulation and implementation of appropriate policies, the development of agriculture sector is still implausible in the country[15]. Furthermore, due to lack of investment capacity and infrastructure as well as lack of market opportunities for agricultural products, majority of the poor peasants are still adopting traditional technology in their production system [9,35]. It is estimated that hardly 13% of the agricultural products are traded in the market[32].

On the other hand, regional variation in the distribution of agricultural land is substantial in Nepal[33,34]. Although the plain covers only 17% of the total land area, it comprises 49% of the total agricultural land[13,18,19,36]. Similarly, the hills and the mountains cover 63 and 20% of the total land area accounting for 40 and 11% of agricultural land, respectively [13,36]. In other words, the highest availability of agriculture land in plain is 0.944 ha, followed by 0.655 and 0.633 ha, respectively in hills and mountains[14,33,34,36]. There is a great variation in the land ownership among rural populations and majority of the populations do not have enough land to live on[37]. Overall, approximately 2.3 Nepalese are

landless, and primarily rely on shared cropping and tenancy for their livelihood[37].

3.2. Impact of Climate Change on Cereal Production

Agriculture sector plays fundamental role in the Nepalese economy and contributes about 80% of the exports and one-third of the country's GDP[15]. Cereal crops including rice, wheat, maize, millet, barely and buckwheat are the mainstay of Nepal's agriculture[15]. However, Nepal is much vulnerable to climate change due to weather variability associated with rising temperature and changing pattern of precipitation[11,24]. Rice is the prime food crop of the country which could face risk due to changes in the reliability of stream flows, a more intense and potentially erratic monsoon rainfall and the impacts of flooding[15,24,38]. Approximately 64% of the cultivated areas are heavily dependent on monsoon rainfall and changes in the time and duration of this monsoon rainfall could affect the agricultural production significantly, especially rice yields[10,24].

The level of vulnerability will differ across the regional setting[5]. The impacts of climate change is expected to be severe in the mountain and Himalayas as compared to plain areas[11]. In the higher altitude, population entirely rely on agriculture for their subsistence and the extreme climatic conditions will put these areas in economic stress by affecting the agricultural production and food security[11,17, 24,38]. Table 4 shows the agricultural production affected by the water-induced disaster such as floods, landslide, inundation and land cutting.

Table 4. Cereals affected by natural disaster (in ha) [15]

Cereals	FY 2007	FY 2008	FY 2009	FY 2010
Paddy	88800	30873	92000	567
Maize	4271	549	1700	563
Millet	1451	3.2	0	13
Total	94522	31425.2	93700	1143

FY=fiscal year

Nepal receives more than 80% of precipitation in the monsoon during June to September[17]. In most parts of the country, peasants rely on this form of precipitation for farming[30,32]. This implies that small peasants in Nepal are likely to suffer more since the poor farmers rely on rain fed cultivation for subsistence farming[10,38]. Based on the severity of the impacts, vulnerability index of climate change for Nepal is categorized as depicted in Table 5. In addition, local farmers do not have scientific knowledge about climate change and its impact on their crops[37,39,40]. Moreover, actions on climate change adaptation and mitigation are challenged by country's low financial capacity and in cooperation among the governmental sectors working on climate change[41]. There is lack of understanding between the environment ministry and ministry of forestry working in this regard[41]. Such pessimistic actions of actors working on climate change make the agricultural sector more vulnerable as compared to other livelihood options in Nepal [9,17,41].

Table 5. Nepal's districts ranking according to overall climate change vulnerability index [24]

Vulnerability index	Districts
Very high (0.787-1.000)	Kathmandu, Ramechhap, Udayapur, Lamjung, Mugu, Bhaktapur, Dolakha, Saptari, Jajarkot
High (0.61-0.786)	Mahottarari, Dhading, Taplejung, Siraha, Gorkha, Solukhumbu, Chitwan, Okhaldhunga, Achham, Manang, Dolpa, Kalikot, Khotang, Danusha, Dailekh, Parsa, Salyan
Moderate (0.356-0.600)	Sankhuwasabha, Baglung, Sindhuli, Bhojpur, Jumla, Mustang, Rolpa, Bajhang, Rukum, Rauthat, Panchthar, Parbat, Dadeldhura, Sunsari, Doti, Tanahu, Makawanpur, Myagdi, Humla, Bajura, Baitadi, Rasuwa, Nawalparasi, Sarlahi, Sindhupalchok, Darchula, Kaski
Low (0.181-0.355)	Nuwakot, Dhankuta, Kanchanpur, Bardiya, Kapilbastu, Terathum, Gulmi, Pyuthan, Surkhet, Argakhachi, Morang, Dang, Lalitpur, Kailali, Syanja, Kaverpalanchok
Very low (0.000-0.180)	Ilam, Jhapa, Banke, Palpa, Rupendehi

Analysis and the estimation of the current visible alterations and changes which are predicted to occur in the future suggests that approximately 1.9 million populations are highly vulnerable to climate change, while 10 million populations are increasingly at risk[21,24,38]. Up to some extent, rise in the temperature can bring positive response to crop production, for example, cereals can be cultivated in higher altitude areas like Manang, Mustang[5,10]. In higher altitude, rise in temperature extend the length of the potential growing season thereby allowing earlier planting and harvesting[5]. In addition, farming in those areas can be benefitted by summer monsoon and availability of water due to snow, ice and glacial melt[3]. Moreover, consistent warming conditions support the process of natural decomposition of organic material and contribution to the nutrient uptake mechanisms[3,5,17]. However, at the same time such areas can become susceptible to natural disasters such as GLOFs that completely wash out crops along with destruction of physical infrastructures and resulting in mass casualties [3,27].

However, rise in temperature can worsen the agricultural production in lower altitude (plain) where temperature is already high[5]. Consistent rise in temperature can affect both the physical and chemical properties in the soil and thus altering the yields of different crops and geographic limits may be altered by changes in soil moisture and other environmental factors[2,5]. It is expected that in drier regions, higher temperature may result in salinization and desertification of agricultural land mainly due to changes in the soil properties such as the loss of organic matter and leaching of soil nutrients[2,10]. Rise in temperature may accelerate unfavourable conditions such as developing a conducive-environment for weeds, insects, pests and diseases[2,5,10]. Moreover, rise in temperature will lead to increase evaporation from soil and accelerate transpiration in the plants themselves will result in moisture stress, and thus crop production will be affected significantly[2,5].

The impact of climate change is already felt in a number ways in the plain areas of Nepal; there was rain deficit in the eastern part of Terai during the year 2005/06, and the crop production reduced by 12.5 % on national basis[17]. On the other hand, there was torrential rain in the mid western Terai and the crop production reduced by 30% in the year 2005/06 [17,25]. Mass movement and edge cutting are another impact of heavy rainfall that carry away fertile soil and deposit sediments on agricultural land[38]. Due to lack of proper irrigation facilities, agriculture production is heavily dependent on favourable weather conditions, especially during monsoon and availability of rain water, however, variation in monsoon rain highly negate the crop production in Nepal [17,38]. Thus, Nepal is more vulnerable to climate change with respect to its agricultural production. The ongoing alterations and changes that are likely to occur in the future will negate the water resources thereby affecting agricultural production and food security, and put poor rural agrarian communities under economic stress[3,5,11]. Extreme climatic conditions will worsen the country's agricultural sector by reducing the yield and production, reduce marginal GDP from agriculture and induce migration and civil unrest in the country[5].

4. Adaptation to Climate Change in Nepal

Although developed countries have organized policy and regulations to respond to extreme climatic conditions, developing countries do not have such regulations and lack adaptive capacity to tackle with it[7]. The Intergovernmental Panel on Climate Change (IPCC) 2007 defined adaptation as "adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities"[42]. However, adapting agriculture to climate change is equally problematic in developing countries due to lack of fiscal and technical capacity to respond to the extreme climatic events[1,6,7,43]. In general, adaptation options in agriculture are influenced by number of parameters such as climate, biophysical, socio-political and environmental factors[2-4, 43].

In order to respond to climate change, the government of Nepal created a National Adaptation Programme of Action (NAPA)-a multidisciplinary platform on information, data and studies on climate change to identify priority activities [24,41]. In 1994, Nepal signed the United Nations Framework Convention on Climate Change (UNFCCC) and also a National Climate Change Policy is in the process of elaboration[16,41]. Since the country does not have enough funds to invest on activities focused on reducing the impacts of climate change, Nepal heavily relies on donor support to cope with climate change[41]. However, the NAPA programme is not effective as expected due to lack of technical capacity and weak coordination across the government sectors, and also low awareness of climate change among the

farmers at local levels[11,41].

Lack of funding on implementation of adaptive activities on climate change is considered as one of the bottlenecks for agriculture sector in Nepal[24,41,43]. It is estimated that the annual adaptation cost on agriculture will be in the order of US\$20,000 (about US\$70 per target household) at grass-roots (village) scale in Nepal[43]. However, this amount will not be adequate in order to carry out adaptation in full scale in the country[43]. In recent years, farmers are concerned about the climatic change and are trying to adapt through technological innovations in response to climate change at their disposal[44]. Farmers have changed their cropping pattern as per the climatic adjustments and prioritized the use of organic manure rather than chemical fertilizers[39,40]. Warming and rising of temperature in the higher altitude has benefitted some households such as growing maize, and green vegetables[40]. Improved varieties of seeds are also being introduced in their farming[39, 40,44].

5. Conclusions

Nepal is much vulnerable to climate change. Nepal has already started to experience impacts of climate change in a number of ways, in which most critical one being the agriculture sector since more than 80% of the population heavily relies on this sector. Torrential rain, flash floods, mass movement, landslide, GLOFs are some of the major disasters occurring as a result of changing climatic patterns in Nepal, thereby affecting the agricultural production and food security in the country. The level of vulnerability will be more pronounced in higher altitude; in the mountains and hills, where majority of the people rely on subsistence farming. Despite receiving continuous financial and technical assistance from foreign donors, the process of adaptation to climate change is slow and discouraging.

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