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Review article

A Systematic Review of the Effect of Climate Change on Rice Farming in Nepal

Tulsi Ram Bhusal[1], Sutinee Sinutok[1,2]* and Saroj Gyawali[3]

[1]Faculty of Environmental Management, Prince of Songkla University, Hat Yai, Songkla 90110, Thailand
[2]Costal Oceanography and Climate Change Research Center, Prince of Songkla University, Hat Yai, Songkla 90110, Thailand
[3]Faculty of Technology and Environment, Prince of Songkla University, Phuket Campus, Phuket, Thailand

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Abstract

Exponential increments of CO_2 concentration and greenhouse gases in the atmosphere are causing climate change. Climate is an important factor in rainfall patterns and elevated air temperature and plays an important role in crop production. Rice is an important crop among Nepali farmers and adaptation is very crucial to cope with the climate change; however, due to lack of sufficient funds allocated in this sector, there is no intervention anymore from the government side in terms of policy. The climatic trends that are affecting the annual rice yield in Nepal are discussed thoroughly in this study. This study reviewed published studies from different indexing sources and sites and inferred some key points regarding the conditions of rice production in Nepal. Mainly due to increment of the average temperature, other physical conditions required for the proper cultivation of rice are changing. As a result, there has been a slight increment of annual rice production in the higher altitudes of Nepal where initially it was not possible to cultivate rice due to the colder climate. Moreover, the production of rice in lower altitudes has reduced. Although some farmers in the country have practiced different methods of cultivation to reduce the effect of climate change, a lack of available technology and financial support from government level has made it difficult for many of them to make necessary changes in rice production on their own. Therefore, with extensive research and an extension program, government officials and policy makers should concentrate on developing climate resilient adaptation measures for rice farming. This systematic study effectively presents the magnitude of the impact on rice farming due to changes in the climatic conditions in Nepal.

Keywords: effect; climate change; rice farming; rice production; agriculture

*Corresponding author: E-mail: ssutinee@gmail.com
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1. Introduction

Nepal is a landlocked country of rectangular shape, with an altitude ranging from 100 m to 8,848 m in the Himalayas. It is a developing nation and agriculture plays a basis socio economic role in the whole country (Thakur & Gyanendra, 2018). The nation is considered an agricultural country where around two-third of the population is directly involved in the agriculture sector, and this sector is responsible for up to 28.8% of the country's total GDP (Khanal et al., 2020). More than 80 % of the people in the nation reside in rural areas, and their main source of income is from natural resources (Agarwal et al., 2014; Bocchiola et al., 2019). Cultivated land is primarily rain-fed and over 50% of farmers in Nepal are small land holders cultivate less than 0.5 hectares (Mandal & Singh, 2020).

Climate is one of the basic factors impacting any crop production (Ghimire et al., 2015). Climatic changes occurs for several reasons, for example, human interference can play a significant role in affecting agriculture in both positive and negative ways. Climate change occurs continuously due to continental drift and volcanic eruption events that release a lot of gases and particles into the atmosphere, having detrimental effects on plants, animals and humans (Joshi et al., 2011). The negative outcomes are reinforced by human influences related to industrialization, urbanization, increasing emissions from vehicles and factories, over usage of groundwater resources, and deforestation on a large scale. Due to increasing heat and other stresses, cereal yield has been affected significantly (Poudel, 2021). These changes in the atmosphere, including soil quality and water availability, have already affected rice cultivation and production in Nepal.

According to the new Climate Change Vulnerability Index (CCVI), Nepal is the fourth most vulnerable in the world and the most vulnerable in South Asia to climate change. The records on climate monitoring reveal an annual rise in temperature of 0.06°C, and it is projected to increase somewhere between 1.5°C to 3.7°C by 2060, and annual precipitation is also predicted based on evidence to decrease by 10% to 20% across the nation (Amponin & Evans, 2016). The threats due to climatic changes are alarming and it is estimated that there will be an increase in temperature from 0.5°C to 2°C and precipitation may range from -34% to +22% by the year 2030 (Karki & Gurung, 2012). This shows there is a threat of a drought as well as heavy rainfall, both of which would harm cultivation. It is also predicted that instead of snow, there may be heavy rainfall during the winter season, which may ultimately lead to more than the rainfall required for cultivation. Predictions of increased natural disasters like droughts and flash floods due to melting of ice are also present (Ministry of Environment, 2010).

Furthermore, climate change projections from the Nepal Climate Vulnerability Study Team (NCVST 2009) and the Organization for Economic Cooperation and Development (OECD 2003) estimate that the mean annual temperature will increase to 1.2°C by 2030, 1.7°C by 2050, and 3°C by 2100 and precipitation may range from -34% to +22% by the year 2030 (Thapa et al., 2015). Apart from this, since the fertility of the soil has been destroyed due to the uncontrolled use of pesticides by farmers, it has become necessary to adopt bio-friendly scientific methods in farming (Gauchan & Pandey, 2011).

Nepal's geography can be divided into three main categories, namely terai, hills and mountains (Baruwal, 2014). The average temperature of the terai region ranges from 20 to 25°C, the hills range from 10 to 20°C, while the mountains range from less than 3°C to 10°C. The climate in the terai region is sub-tropical, temperate in hilly regions, and tundra type in the mountains where snow occurs annually. In the sub-tropical terai, the average annual precipitation varies from 100 to 2,000 mm. The hilly region is the largest covering with 42% of the total land area, followed by mountains (35%) and terai (23%). However,

the cultivated area is mainly located in the terai region, for 51.6%, whereas hilly region is 46.1% and mountain is only 0.3%. A summary of Nepal's geography is presented in Table 1.

Table 1. Geographical features of Nepal (Karki & Gurung, 2012)

Feature	Terai	Hilly Region	Mountain
Temperature (°C)*	20 – 25	10 – 20	3 - 10
Precipitation (mm)**	100 – 2,000	275 – 2,300	1,100 – 3,000
Climate type	Sub-tropical	Temperate	Tundra
Total area (%)	23	42	35
Cultivated area (%)	51.6	46.1	0.3

*Annual average temperature
** Total annual precipitation

Nepal has a variety of ecological settings where rice is cultivated, including the lowlands of the terai region (50-300 m asl), the hills (>300-1500 m asl), and the mountains (>1500-3000 m asl). With a rice production share of 73%, the terai leads the way. Similarly, the hills region comes in second rank with 24% of rice production, whereas the mountain region makes up only 3% of the total rice production in the country. Additionally, the terai region has a larger yield (2.8 t/ha) than the hills (2.6 t/ha) and mountains (2.0 t/ha) (Gauchan & Pandey, 2011).

Rice is the most important and largest grown cereal crop in Nepal, covering 1,491,744 hectares overall and producing 5,610,011 metric tons in 2019 (Dhakal et al., 2020). It is considered a primary staple food because more than 90% of Nepalese people consume it (Sapkota & Sapkota, 2019). Moreover, it accounts for more than half of the calories consumed in Nepal (Kharel et al., 2018; Gadal et al., 2019). Therefore, finding solutions to boost rice production while improving food security has emerged as a critical challenge.

In this systematic review, the trends in rice production in Nepal and the extent to which it is affected by global and local climatic changes are presented. Rice production is affected by the changing status of the climate via air quality, air composition, soil quality, availability of water for irrigation, and soil chemistry. Due to the changing climatic status, as compared to the required production, the yield of the annual rice crop is significantly lacking given the needs of the population in Nepal. In this study, possible adaptation practices by the farmers by using technologies and other available farming techniques to normalize the production capacity is also considered.

In Nepal, rice is considered as a main staple food. Since most of the Nepalese use rice for their food, increasing the production of paddy has become the main task today (Gadal et al., 2019). On the one hand, due to climate change challenges are facing in its production, the production of rice needs to be increased. In this environment, better knowledge of the impact of climate change on rice cultivation and production can help to solve the problems. Due to changes in global temperature, the climate will change and its

effects can be seen. As the geography of Nepal varies, the climate also does. The climate has had an impact on agriculture and cultivation. The farmers of Nepal have already faced many problems, such as various types of insects in the planted rice, the decrease of crop quality, and resistance to disease decrease. Finding ways to increase rice production and improve food security has become a major task at present. Efforts should be made for this, and the problems should be solved immediately. Apart from this, since the fertility of the soil has been destroyed due to the uncontrolled use of pesticides by farmers, it has become necessary to adopt bio-friendly scientific methods in farming (Gauchan & Pandey, 2011). The research questions of the paper are: “What are the effects of climate change on rice cultivation in Nepal?” and “What are the gaps in essential knowledge?”

The aim of this paper is to systematically review the published papers on the effects of climate change on rice production in Nepal. This review would bring forward the current insights into rice farming in Nepal and the effects on its farming from changing climatic conditions. The review discusses and analyzes the published papers that show different aspects of rice cultivation in Nepal, and its vulnerability to recent adverse changes in the climatic patterns. The purpose of this study is to identify the problems and to propose measures to address them.

2. Materials and Methods

This study was based on secondary sources of information. All the data were collected from various indexing sources and sites. The related published papers were selected by using the Google search engine. For the purposes of this study, extensive research was done. Published papers were searched in Google Scholar, Scopus, Bing Academic and Web of Science. Research published over the years 2010-2020 was selected. The main search keywords that were used were "rice", "Nepal", and "climatic changes". The search term "climatic changes" was replaced by "changing climate" or "changing climatic pattern" or "climate changes" or "weather pattern changing". The search term "rice" was replaced with "rice cultivation" or "rice farming" or "paddy cultivation". Inclusion criteria were used and the included studies should be conducted in Nepal, showing the effects of climate change on rice cultivation (from 2010 to 2020). Papers that were excluded from this study were those which discussed the effects of climatic changes on crops other than rice, those that discussed climatic change effects on other areas like the human population, and those done before 2010. The studies conducted by government institutions and non-governmental institutions were all included in the study.

The method of this systematic study is now presented in detail. The PRISMA diagram reveals the number of papers obtained and screened in each stage of this study. The PRISMA flow diagram is given in Figure 1. Screening was made by going through the abstract and conclusion parts of each paper. Primarily, 402 studies were obtained during the identification stage. Some duplication was found during the search and 140 studies were excluded and finally 262 studies were selected at this stage. Similarly, titles and keywords were used to exclude ineligible research work, where 148 studies were excluded and 114 studies were selected. Based on the abstract of each study, 32 works were excluded and only 82 literary works were selected. Then, the discussion part of the selected studies was considered, where 37 studies were excluded. Based on the conclusion of the pre- literature review, only 45 studies were made up of the eligible ones that finally reviewed.

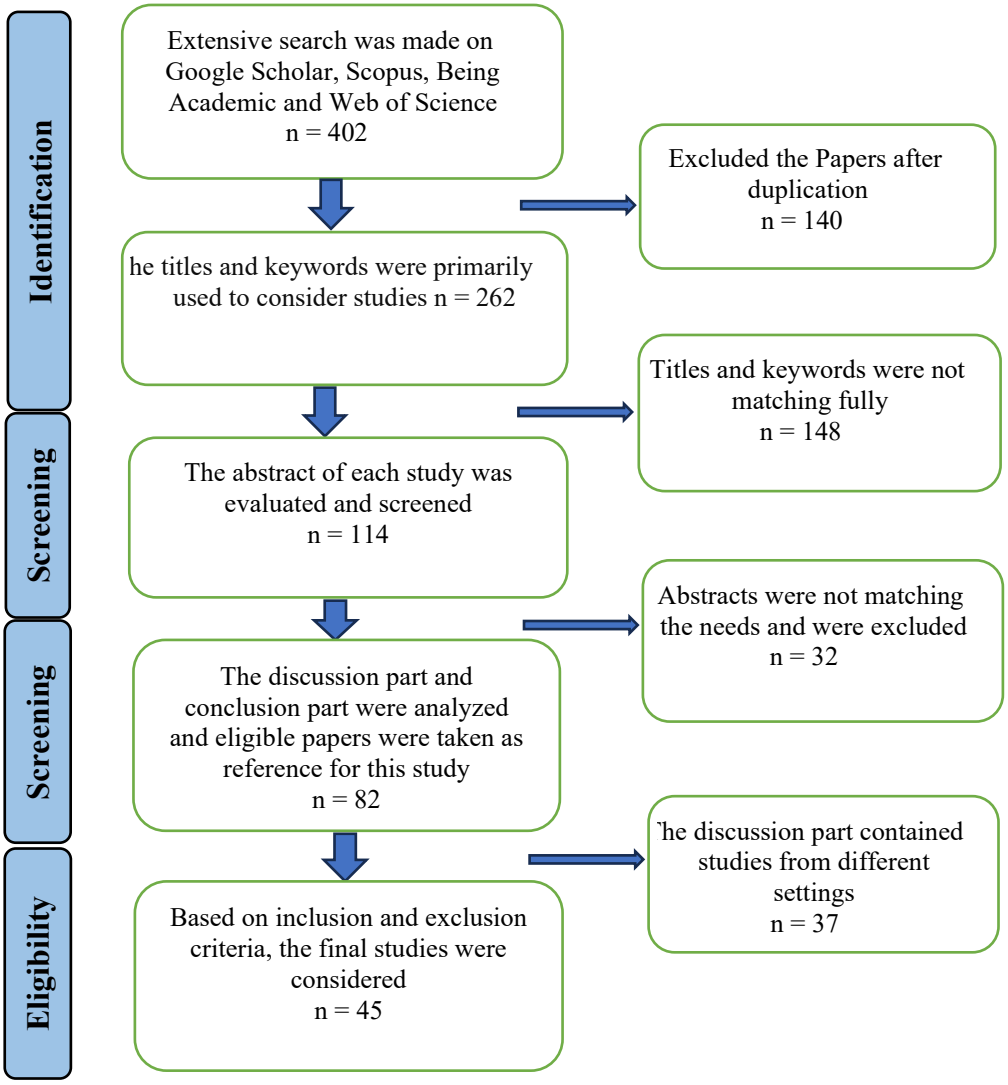

Figure 1. PRISMA flow diagram of this review article

3. Results and Discussion

3.1 Results

3.1.1 Effect of climate change on crop production

Climatic factors like precipitation, carbon dioxide emissions, solar radiation, and average temperature are all important in rice production. Extreme environmental conditions like drought events or flood events have affected rice cultivation and its production (Neenu et al., 2013). Our study drew attention to rice, one of the main staple foods in Asian countries,

including Nepal. Reduction in the quantity and quality of rice production can affect the population's nutrition significantly. It was suggested that there was an urgent need to perform climate research and to adopt mitigation strategies such as crop management technologies to counter these negative conditions (Gauchan & Pandey, 2011).

Paudyal et al. (2015) found that the temperature in Dhading district of Nepal was rising at the rate of 0.03°C annually. Statistically, this was a significant increase when compared to the trend of 0.009°C annual increase. Furthermore, it was also revealed that the average temperature before the monsoon season was following an increasing trend, which was significant. While the temperature was increasing, data showed there was a decreasing trend in precipitation at the rate of 1.85 mm annually, which was again statistically significant. These data were subjected to the Mann-Kendall test, where the long-standing drought conditions had led to a reduction of rice productivity, especially for the upland rice variety locally known as Ghaiyadhan (*Oryza sativa*). In fact, it was found that upland varieties were the worst hit by climate change. Apart from productivity, the authors also stated that the farmers had experienced increased pest infestations, including those by *Nephotettix* spp. and *Phyllophaga* spp.

The public resource allocation for rice farming research was analyzed by Shrestha et al. (2013), who used a congruence model. The study revealed inadequate research on rice cultivation, especially in the Terai region of Nepal. The investment into developing stress-tolerant strains of rice should be encouraged, however, the current investment was not adequate, being less than 0.1% of the total national agricultural research budget. This study revealed that the meager investment into research on rice cultivation was one of the contributing reasons behind the high impact on rice production of changing climatic conditions.

The vulnerability index shows the areas that are probably strongly affected their rice production by changing climate. For instance, the vulnerability index is highest in places like Kathmandu, Udayapur, Dolakha, and Saptari districts. Similarly, it is moderate in Bhojpur, Rolpa, Bajhang, Rauthat, Doti, Humla, Parbat, and Tanahu districts. However, the vulnerability index is low to very low in Dhankuta, Gulmi, Lalitpur, Morang, Jhapa, Palpa, and Ilam districts. Therefore, temperature rise annually may result in reduced production in lower altitudes of Nepal; while there can be a slight increase in production in the higher altitudes of Nepal where it was initially not possible due to the colder climate. Also, a rise in average annual temperature led to increased evaporation from soil and plant transpiration, leading to moisture stress. Moreover, increased temperatures in the terai region may also increase insects, pests and the growth of unwanted weeds, resulting in diseases in crop plants. A combination of all these factors could lead to reduced yield of annual rice production (Karn, 2014).

According to a UNICEF survey, the impact of climate change on agriculture in Nepal had a broader sense. Food insecurity in Nepal was increased due to the economic and agricultural slowdown and it was determined that 10% of the population was below the poverty line (Shrestha et al., 2013). The status of rice production is depicted in Figure 2 (MoALD, 2022).

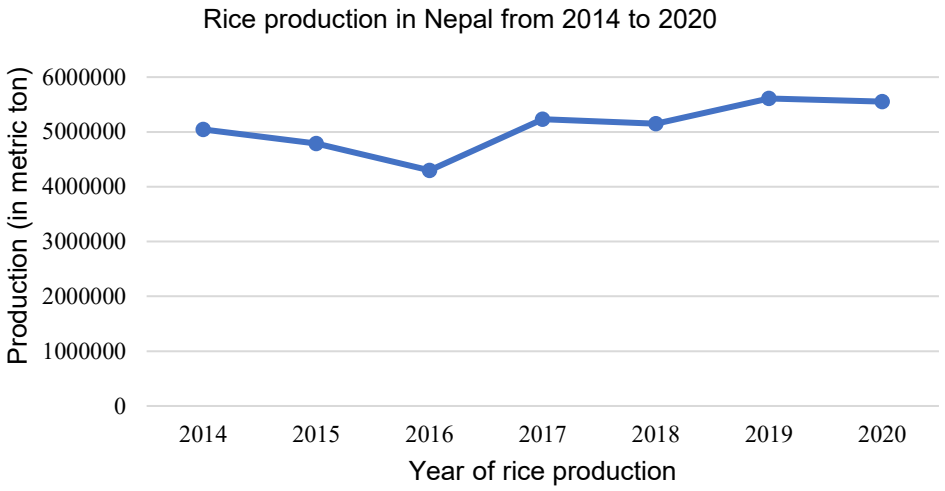

Figure 2. The production of rice crop in Nepal during 2014 -2020

3.1.2 Adaptation and mitigation to climate change in rice production

The negative impact on rice production throughout the nation was contributed by lack of irrigation facilities at that time, which was during the absence of timely precipitation and lack of an adequate amount of rainfall. The regions with higher vulnerability were the most affected. Unfavorable climatic conditions have severely affected the country's agriculture sector (Timsina, 2011). A study was focused on the adaptation to changing climate to suit the needs of agriculture at the level of policymaking. Although Nepal has joined the United Nations Framework Convention on Climate Change (UNFCCC), the lack of funds is one of the main reasons due to which climatic change related agricultural adaptation has not been implemented (Karki & Gurung, 2012). Other factors that play a role in the failure of adaptation are lack of technical ability, mismanaged coordination of the government at all levels, and lack of awareness among the farmers about the methods needed to adapt to climatic changes when cultivating rice (Charmakar, 2010).

Manandhar et al. (2011) brought forward their findings. The authors concluded that the farmers used techniques at their own level to adapt to the changing climate. Some farmers changed the pattern of rice cropping to suit the new climatic conditions. Many farmers changed rice cropping to cultivation of other crops like maize and green vegetables due to increasing temperatures. A few financially able farmers also brought new improved seeds for growing that were more tolerant of the changing climatic conditions like increased average temperature and less rainfall.

Khanal et al. (2018) conducted a study under the topic of impact of adaptation on rice yields among rice farmers in Nepal. They interviewed 422 rice farmers of two types (adaptors and non-adaptors) in the country. The results revealed that those farmers who adapted to climate change exhibited an enormous increase in rice yield. The factors that influenced the adaptors included their education, their access to credit and extension services, their early encounters with situations of famine and flood, their exposure to information on climate change, their belief in the happening of climate change, and their personal desire to actually adapt.

Another study was conducted on 773 households in Nepal from both the hills and the plains, and the results revealed that most of the farmers agreed that changes in temperature and rainfall were the major hurdles to changes in rice production, followed by production decrease. The authors found 12 adaptation measures opted for by those farmers. The important ones were the use of climate-resistant rice varieties, enhancement of the concentration of chemical fertilizers used, and changing the period of the year when planting the rice crop in the paddy field. Major barriers faced were lack of capital, expensive agricultural equipment, dearth of credit availability, and lack of awareness about adaptation strategies, accompanied with inadequate information available (Devkota et al., 2018).

Evidence of the farmers' adaptation to the changing climate while maintaining the same production of rice cultivation is in a study conducted on 773 Nepalese rice farmers, attempting to understand the role of ICT (Information and Communication Technologies) in their lives. The results revealed that more than 50% of the farmers had various ICT devices and they used them for updating themselves about temperature, amount of precipitation, and other related information. More than 80% of the farmers reported that they were religious users of the ICT devices owned by them, and about 90% of them reported that they receive information in their own dialect and thus they were totally able to understand what was being conveyed to them. Radio was found to be the most popular device, followed by television and mobile phones. All the devices were reported to be user-friendly and easily accessible (Devkota & Phuyal, 2018).

Another study in Bhaktapur district of Nepal revealed that the major soil type found in this area was silt- loam. The study employed a yield simulation model named Aqua Crop, which was able to simulate the crop yield with satisfactory accuracy. The study reported an increased yield of monsoon rice (under a particular scenario), and a satisfactorily stable yield of winter wheat. The results also revealed that crop yields would decrease because of the shortage of water and inappropriate fertilizer use. It was also found that augmented dosages of fertilizers gave better results under full irrigation situations rather than in rain-dependent cropping regions (Shrestha & Shrestha, 2017).

Bhatt et al. (2014) carried out a study in the Koshi basin of Nepal. The results revealed that the altitude at which rice was being cropped had a major impact on yield, and the rice crop also suffered if the temperatures were higher during flowering and grain forming stages. However, one result which was very clear was that warmer temperatures during growing seasons had negative impact on the yield of rice. In contrast, positive effects of warming were observed in rice and maize crops at some high altitudes. Ultimately, the authors concluded that such kind of continuous rise in temperature would surely have a negative effect on rice production in this specific area, but this same rise in temperature would be beneficial at higher altitudes if other conditions of water availability and soil fertility were fulfilled.

Another study by Khanal et al. (2018) pointed out that all those farmers who had moved and accepted the adaptation strategies benefited from their actions and were able to increase their food production. The major strategies, which were mostly adopted, included proper management of soil and water, followed by a change in sowing time of the rice crop, and the choice of a rice variety to be planted. Major factors responsible for acceptance and use of adaptation measures were age and educational qualifications of the head of the family (who was supposed to decide about the adaptation strategies), size of the family, the distance of the house from the market and the farm, and availability of information about the rapidly changing climate. The adoption of changes in managing the soil and proper water usage allowed farmers to thrive and survive economically. The study also pointed out that the educational qualifications for young members in farmers' families were primarily responsible for this.

The chosen area of another study was “Paklihawa Campus, IAAS, Rupandehi, Nepal”. The study was aimed at understanding how organic and inorganic nitrogen sources in different combinations had the impact on rice crops. The results showcased that “a mixture of 75% of an appropriate dose of nitrogen (90 kg ha-1), farmyard manure (5 tons’ ha-1) and blue-green algae (9 kg ha-1)” enhanced plant height, grain numbers, and gave better tiller and straw yield (Karki et al., 2018).

One study aimed to disseminate information regarding climate change happening in South Asia (including Nepal). The results revealed that the use of stress-tolerant seeds at plantations, appropriate use of available water (with techniques like micro-irrigation), restoring and enriching the depleted soil and water reservoirs, promoting carbon sequestration, and conserving the native biodiversity, could help reach better yields of rice cultivars (Jat et al., 2016).

Pandey et al. (2010) conducted a study in Nepal on the utilization of urea, green manure and blue algae on rice seedlings in the nursery to increase yield. They found significant improvements in the yield of rice, in terms of the height of the rice plant and yield per square meter, for both grain and straw yield. They pointed out the development or breeding of seeds that could tolerate environmental stresses like those from changing climatic conditions. The nature of farmer adaptations and their ways of coping with the changing patterns of climate, which included changing the techniques of farming to suit the changing environmental conditions among other, were some of the factors that this study brought forward. The farmers also needed seeds and financial support, which could enforce their chances of keeping their farming practice going.

Another study reviewed that better adaptation policies were framed and handled by developed nations, while developing nations had a hard time framing and maintaining the policies due to financial inadequacy. Lack of technological advancement was another significant disadvantage which contributed to the failure of adaptation to climate change in the agriculture sector. However, adaptation of agricultural methods to the continuous change of climate also depended on many other factors like socio-political and environmental conditions (Kumar et al., 2020).

Another study emphasized the impact on glaciers from climatic changes. Observations in the last few decades showed the melting of large snow reservoirs and glaciers in the highlands of the Himalaya. This is expected to affect the livelihoods of the Nepali farmers, and their crop cultures (Shrestha & Aryal, 2011).A field experiment revealed that managing the nitrogen content effectively and culturing hybrid rice crop like Aries 6444, could lead to sufficient improvement in the number of tillers, the height of rice plants, and dry matter accumulation, yielding more grains and ultimately increasing crop productivity.

Some of the conclusions and impressions made by the important studies regarding the effects on rice farming due to climatic changes are listed in Table 2.

3.2 Discussion

The phenomena of climate change is worldwide and impacts farmers globally. This study has drawn attention to rice, which is one of the main staple food crop in Nepal and its cultivation is particularly vulnerable to climate change. Therefore, this study attempted to systematically examine the literature on the effects of climate change on rice farming in Nepal. The review revealed that 45 published papers addressed the impact of climate change on rice cultivation, adaptation to changing climate conditions, and how much rice

Table 2. Summary of selected key studies in analyzing rice farming impacted by climatic changes

Factor	Issues or Summary of the Findings	Authors	Gap in Knowledge
Climate change impact	Several varieties were introduced but climatic changes have impacted rice cultivation significantly.	(Sharma et al., 2020)	This study did not point out the impact on socio-economic status of the country and how the country can deal with this.
	Increasing trend of temperature was found and it will reach alarming level by 2060 while rainfall may reduce significantly.	(Pant, 2011)	This study did not provide the mitigation techniques or the ways of adaptation clearly. The study mainly focused on the temperature and rainfall.
	Heavy rainfall along with the melting snow badly impacted the land as the presence of excessive water hindered social setup to cultivation. There was a threat of drought as well as of heavy rainfall. Both are harmful for the cultivation. It is also predicted that there may be heavy rainfall during the winter season and more than required rainfall for the cultivation.	(Dixit, 2011)	The impacts on human lives and policies were not discussed.
	Plant phenology and breeding behavior of several animals significant affected by changes in climatic conditions over the years. This affected productivity of livestock and rice farming due to several reasons like pest infestations and land degradation.	(Paudyal et al., 2015)	Specific climatic change over the time was not presented clearly.

Table 2. Summary of selected key studies in analyzing rice farming impacted by climatic changes (continued)

Factor	Issues or Summary of the Findings	Authors	Gap in Knowledge
Adaptation and mitigation	This study concluded that the regions of higher altitude were more vulnerable; the people of these regions depended on subsistence farming. The movement towards sustainability was slower in these places and some of the reasons may be the low availability of technical assistance and financial adequacy.	(Karki & Gurung, 2012)	Although the points regarding adaptation were discussed, but still more specific points were needed with respect to the country of Nepal.
	This study mentioned about an awareness and Capacity Building program in local level community to reduce the impact of climate change in agriculture sector.	(Nepal, 2020)	This study discussed some important point but did not point out any specific program that could build farmer aware and capacity in regards to the climate change at the local level.
	This study revealed that there was insufficient investment in the research on rice farming, especially in terai regions of Nepal.	(Gauchan & Pandey, 2011)	Although the paper discussed very important aspects, there was a lack of suggestions for policies in terms of adaptation and mitigation on a national level.
Policy or Impact	This paper examined the coherence of Nepal's climate and forest policies using concepts from policy coherence for development frameworks and policy content analysis. It also explored the obstacles to effective implementation.	(Ranabhat et al., 2018)	The policies were exhibited in greater consistency when it came to motivation levels and adaptability metrics. However, their implementation was not clearly mentioned.
	This study concluded that there was a significant effect on economy of Nepal.	(Regmi et al., 2016)	Policies or preventive suggestions were not devised.

could be produced in the country. From the results, there are a few key factors that influence rice cultivation due to the changes of climatic variables: precipitation and average temperature. These key factors were determined to influence the adaptation strategies and rice production in Nepal.

Nepal experiences an annual maximum temperature increase of 0.056°C whereas the minimum temperature rising trend of 0.002°C (DHM, 2017). Rising temperatures every year may cause production in Nepal's lower elevations to decline, but production in the higher elevations may slightly increase where it was previously impossible because of the colder climate. Monsoon precipitation is trending upward, whilst winter precipitation is trending downward (Karki et al., 2017). Therefore, flooding in the lowland terai region, and landslides in the hilly region in Nepal due to heavy rainfall during monsoon season, and mostly drought events during the winter are some of the climatic hurdles in the country for rice cultivation.

Additionally, Small-scale farmers in Nepal were disproportionately affected by the consequences of increased climate change because over 50% of them had less than 0.5 hectares of cultivated land (Mandal & Singh, 2020). As such, it would be beneficial to reinforce their climate change adaption strategies like use of improved seed varieties, knowledge sharing and capacity building, use of green manure, mulching, early warning systems, and policy support and access to resources as some of the farmers successfully used. These kinds of adaptation strategies illustrated the actions performed to support ecosystems and the environment by addressing the anticipated or existing effects of climate change. These strategies seemed to be methods which involved society teaching itself to manage risks more skilfully. Small-scale farmers must therefore improve their climate change adaptation strategies in order to reduce adverse effects, reduce risks and vulnerabilities, and seize any opportunities that may arise.

Some other regions especially in South Asian countries, i.e., India, Pakistan, Bangladesh, Bhutan, and Sri Lanka are also dealing with similar climatic stresses like rising temperatures, changing precipitation patterns, and extreme weather events. The findings of this study may help understand how these issues affect rice production in Nepal, which may be similar to circumstances in neighbouring nations. Additionally, the adaptation strategies and policies implications in Nepal found in this review can assist those in other regions to maintain and improve rice production, enhance food security and pursue sustainable farming practices.

4. Conclusions

The review presented Nepal's geography in a comprehensive manner, describing its terrain, climate, weather patterns, and other geographical parameters. Global climatic changes and their effects were also considered as they affected Nepal's agriculture significantly, similar to other countries. The agricultural economy of Nepal was introduced effectively and each of the changing climatic parameters were discussed with proper reference. Future perspectives were also discussed. This current review was focused on the conditions in Nepal. There is also a need to review studies that have been conducted in other highland regions, so that adaptations that are made in other highland areas can be analyzed. Climatic factors like precipitation, carbon dioxide status in the atmosphere, and the trends of average temperature, have all affected the annual yields of rice crop. It has been highlighted in the study that due to climatic changes, one of the staple foods of the Nepalese, rice, will be heavily affected, which can impact the nutritional status of the whole country. The rising temperature trend by 0.009^{o}C annually has been proven to

significantly affect rice production. Along with productivity, increases in pest infestations have recently affected the quality of rice crops. Investments in more biotechnologically advanced rice strains that can tolerate the increasing stresses from the environment are strongly recommended.

5. Acknowledgements

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6. Conflicts of Interest

The authors declared there are no conflicts of interest.

ORCID

Tulsi Ram Bhusal https://orcid.org/0009-0004-7172-6869

Sutinee Sinutok https://orcid.org/0000-0002-1428-8477

Saroj Gyawali https://orcid.org/ 0000-0002-8961-293X

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